GUIDELINE
Wood I-Joists

ASD
ALLOWABLE STRESS DESIGN

MANUAL FOR ENGINEERED WOOD CONSTRUCTION

Preface

This guideline to the ASD Manual for Engineered Wood Construction contains data and information on terms, design conditions, adjustment factors, reference design values and typical installation details for Wood I-Joists. This information represents currently available data for use in conjunction with ANSI/AF&PA NDS-1997 *National Design Specification® (NDS®) for Wood Construction.*

The wood I-joist is very efficient at utilizing wood fiber. The flanges (the top and bottom of the assembled member) are designed to resist bending forces and provide stiffness to the product. The web section, typically plywood or OSB, is designed to resist the shear forces in the joist. The connection between the two typically occurs in a rout in the flange where adhesive has been applied.

The efficiencies obtained through the use of an "I" cross section require additional considerations relative to solid rectangular sections. The intent of this document is to familiarize the user with the special requirements of designing and installing I-joist systems.

Design values are derived according to the principles of ASTM D5055-97, *Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists.*

The design values shall be adjusted by the product of applicable adjustment factors as defined in ANSI/AF&PA NDS-1997 and also provided in this guideline. For unusual end-use conditions, the designer should consult manufacturer's literature for possible further adjustments.

This document has been prepared by the Wood I-Joist Manufacturer's Association. Every attempt has been made to ensure that the data and information presented is as accurate and complete as possible and in a fashion representative of the industry at large. The user is cautioned that the data and information presented is indicative of I-joists in general. Consultation with the specific manufacturer regarding each proprietary joist is required prior to completing design and installation specifications on any specific project.

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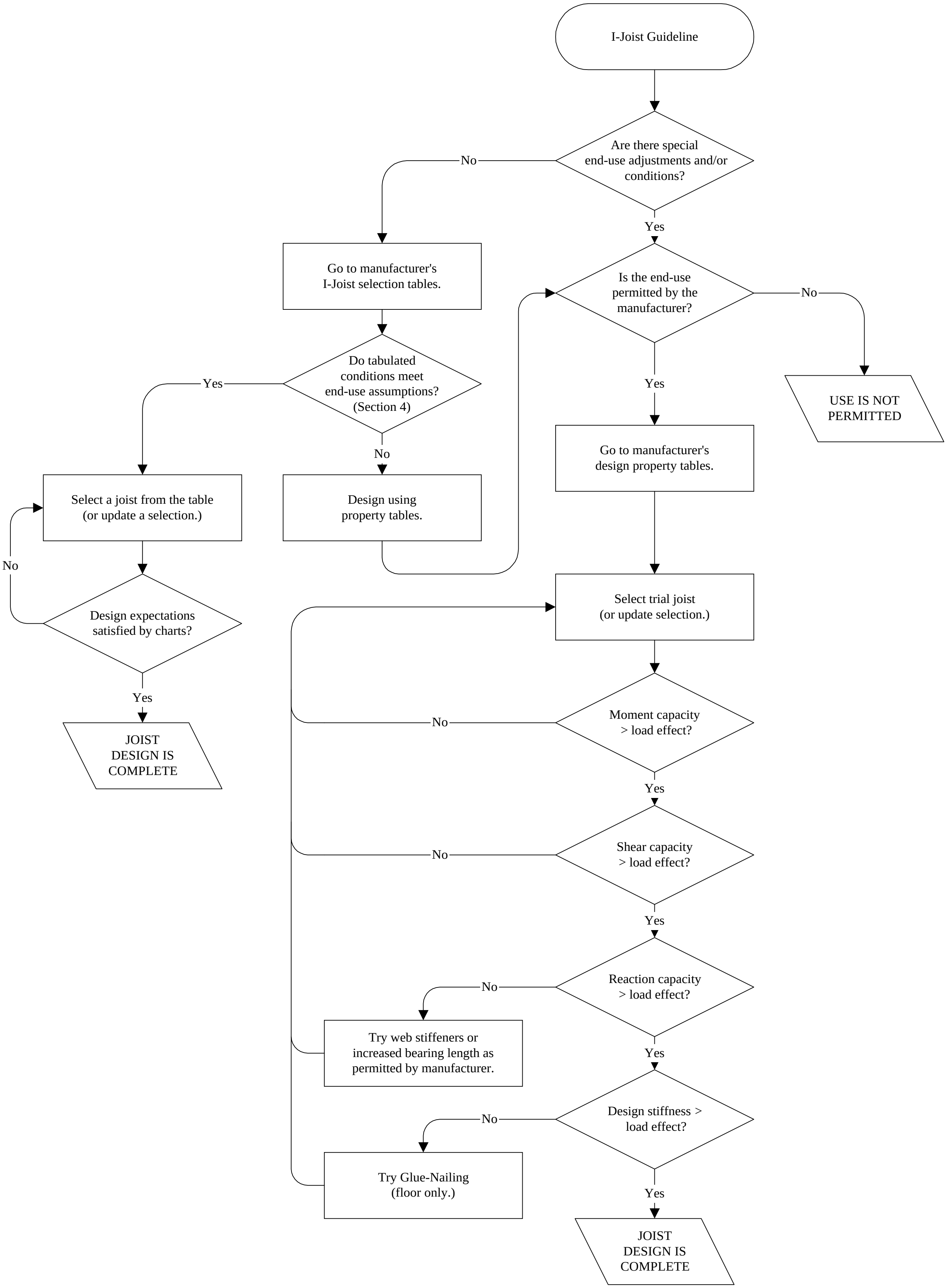
1.1 Flowchart



INTRODUCTION TO PREFABRICATED WOOD I-JOISTS

2.1 Product Information

Wood I-joists are well accepted throughout the construction industry. I-joists are a high strength, cost efficient alternative to conventional framing. They are exceptionally stiff, lightweight and capable of long spans. Holes may be easily cut in the web according to manufacturer's recommendations, allowing ducts and utilities to be run through the joist. I-joists are dimensionally stable and uniform in size, with no crown. This keeps floors quieter, reduces field modifications, and eliminates rejects in the field. I-joists may be field cut to proper length using conventional methods and tools.

Manufacturing of I-joists utilizes the geometry of the cross-section and high strength components to maximize the strength and stiffness of the wood fiber. Flanges are manufactured from solid sawn lumber or structural composite lumber, while webs typically consist of plywood or oriented strand board. The efficient utilization of raw materials, along with high quality exterior adhesives and state of the art quality control procedures, result in an extremely consistent product that maximizes environmental benefits as well (see inside cover of this guideline).

Wood I-joists are produced as proprietary products which are covered by code acceptance reports by one or all of the model building codes. Acceptance reports and product literature should be consulted for current design information.

2.2 Common Uses

Prefabricated wood I-joists are used throughout the world. They are widely used as a framing material for housing in North America. I-joists are made in different grades and with various processes and can be utilized in various applications. Proper design is required to optimize performance and economics.

In addition to use in housing, I-joists find increasing use in commercial and industrial construction. The high strength, stiffness, wide availability and cost saving attributes make them a viable alternative in most low-rise construction projects.

Prefabricated wood I-joists are typically used as floor and roof joists in conventional construction. In addition, I-joists are used as studs where long lengths and high strengths are required.

2.3 Availability

I-joists are widely regarded as a premium construction material and are available throughout the US. To efficiently specify I-joists for individual construction projects, consideration should be given to the size and the required strength of the I-joist. Sizes vary with each individual product. The best source of this information is your local lumber supplier, distribution center or I-joist manufacturer. Proper design is facilitated through the use of manufacturer's literature and specification software available from I-joist manufacturers.

DESIGN CAPACITY

3.1 Introduction to Design Values

Each wood I-joist producer develops its own proprietary design values. The derivation of these values is reviewed by the applicable building code authorities. Since materials, manufacturing processes, and product evaluations may differ between the various producers, selected design values are appropriate only for the specific product and application.

To generate the design capacity of a given product, the producer of that product evaluates test data. The design capacity is then determined per ASTM D5055-97.

The latest model building code agency evaluation reports are a reliable source for wood I-joist design values. These reports list accepted design values for shear, moment, stiffness, and reaction capacity based on minimum bearing. In addition, evaluation reports note the limitations on web holes, concentrated loads, and requirements for web stiffeners.

Tabulated design capacities reflect standard conditions and must be modified as discussed in Section 4 to obtain adjusted capacity values.

3.2 Shear Design

At end bearing locations, the critical shear is the vertical shear at the ends of the design span. The practice of neglecting all uniform loads within a distance from the end support equal to the joist depth, commonly used for other wood materials, is not applicable to wood I-joists. At locations of continuity, the critical shear location for several wood I-joist types is located a distance equal to the depth of the joist from the centerline of bearing (uniform loads only). A cantilevered portion of a wood I-joist is generally not considered a location of continuity (unless the cantilever length exceeds the joist depth) and vertical shear at the cantilever bearing is the critical shear. Individual producers, or the appropriate evaluation reports, should be consulted for reference to shear design at locations of continuity.

Often, the allowable shear value is based on other considerations such as bottom flange bearing length or the installation of web stiffeners or bearing blocks. (See Section 3.3)

$$V' > \text{Load conditions}$$

where

V' = adjusted shear design capacity value

3.3 Bearing/Reaction Design

Bearing lengths at supports often control the design capacity of an I-joist. Typically minimum bearing lengths are used to establish design parameters. In some cases additional bearing is available and can be verified in an installation. Increased bearing length means that the joist can support additional loading, up to the value limited by the shear capacity of the web material and web joint. Both interior and exterior reactions must be evaluated.

Use of web stiffeners may be required and typically increases the bearing capacity of the joist. Correct installation is required to obtain the specified capacities. Additional loading from walls above will load the joist in bearing, further limiting the capacity of the joist if proper end detailing is not followed. Additional information on bearing specifics can be found in the supplemental design information section (Section 6.5).

Allowable bearing capacities are determined in the same empirical fashion as is the allowable shear.

$$V_b' \geq \text{Load conditions}$$

where

V_b' = adjusted bearing design capacity value

3.4 Moment Design

Published moment capacities of I-joists are determined from empirical testing of a completely assembled joist or by engineering analysis supplemented by tension testing the flange component. If the flange contains end jointed material, the allowable tension value is the lesser of the joint capacity or the material capacity.

Because flanges of a wood I-joist can be highly stressed, field notching of the flanges is not allowed. Similarly, excessive nailing or the use of improper nail sizes can cause flange splitting that will also reduce capacity. The producer should be contacted when evaluating a damaged flange.

$M' \geq$ Load conditions

where

M' = adjusted bending moment capacity value

3.5 Deflection Design

Wood I-joists, due to their optimized web materials, are susceptible to the effects of shear deflection. This component of deflection can account for as much as 15% to 30% of the total deflection. For this reason, both bending and shear deflection should be considered in the deflection design. A typical deflection calculation for simple span wood I-joists under uniform load is shown below.

Deflection = Bending Component + Shear Component

$$\Delta = \frac{5w\ell^4}{384EI} + \frac{w\ell^2}{k}$$

Individual producers provide equations in a similar format. Values for use in the preceding equations can be found in the individual producer's evaluation reports. For other load and span conditions, an approximate answer can be found by using conventional bending deflection equations adjusted as follows:

$$\text{Deflection} = \text{Bending Deflection}\left(1 + \frac{384EI}{5\ell^2 k}\right)$$

w = Uniform load in pounds per lineal inch

ℓ = Design span in inches

EI = Joist moment of inertia times flange modulus of elasticity

k = Shear deflection coefficient

Since wood I-Joists have the inherent capability to span farther than conventional lumber, the model building code maximum live load deflection criteria may not be appropriate for many floor applications. Many wood I-joist producers recommend using stiffer criteria, such as L/480 for residential floor construction and L/600 for public access commercial applications like office floors. The minimum code required criteria for storage floors and roof applications is normally adequate.

DESIGN ADJUSTMENT FACTORS

4.1 General

Member design capacity is the product of reference design values and adjustment factors. Reference design values for I-Joists are discussed in Section 3 of this Guideline.

The design values listed in the evaluation reports are generally applicable to dry use conditions. Environmental effects, such as high moisture conditions, high temperatures, or pressure impregnated chemical treatments, typically result in strength and stiffness adjustments different from those used for sawn lumber. Individual wood I-joist producers should be consulted for appropriate adjustments.

The user is cautioned that producers may not permit the use of some applications and/or treatments. Unauthorized treatments can void a producer warranty, and may result in structural deficiencies.

4.2 Lateral Stability

The design values contained in the evaluation reports assume continuous lateral restraint of the joist's compression edge and lateral torsional restraint at the support locations. Lateral restraint is generally provided by diaphragm sheathing or bracing spaced at 16" on center or less (based on 1½" width joist flanges) nailed to the joist's compression flange.

Applications without continuous lateral bracing will generally have reduced moment design capacities. The reduced capacity results from the increased potential for lateral buckling of the joist's compression flange. Consultation with individual producers is recommended for all applications without continuous lateral bracing.

4.3 Special Loads or Applications

Wood I-joists are configured and optimized to act primarily as joists to resist bending loads supported at the bearing by the bottom flange. Applications that result in significant axial tension or compression loads, require web holes, special connections, or other unusual conditions should be evaluated only with the assistance of the individual wood I-joist producers.

4.4 Repetitive Members

Where joists are arranged in compliance with ASTM D5055 requirements for repetitive members (i.e., 3 or more adjacent members spaced 24" on center or less joined by a transverse load distributing decking capable of supporting the design loads), the allowable bending moments may be increased beyond single member design values. The moment design value increases are based on the statistical strength variability of the specific flange material selected for the wood I-joist.

Joists with flanges made from laminated veneer lumber (LVL) or parallel strand lumber (PSL) can be increased 4% when the repetitive member design criteria is met. Joists with MSR lumber flanges can use an increase of 7%, while joists with visually graded lumber flanges are allowed a repetitive member increase of 15%. Some manufacturers incorporate these increases into tabulated values so careful review of footnotes is required.

4.5 Bending (moment and shear)

The allowable bending and shear design values are computed by multiplying the reference design values by a series of adjustment factors. (Note that, while the following list of adjustment factors is somewhat intimidating, many of the factors equal unity for common applications.)

The reference values for *M* and *V* are discussed in Section 3 of this Guideline.

$$M' = M\, C_D\, C_M\, C_t\, C_L\, C_r$$

$$V' = V\, C_D\, C_M\, C_t$$

and

C_D per Section 2.3.2 of ANSI/AF&PA NDS-1997.

C_M is 1.0 up to 16% MC or as indicated in the manufacturer's literature and code acceptance report.

C_t is 1.0 for sustained temperatures up to 100 degrees and occasional temperatures up to 150 degrees F.

C_L is 1.0 for fully supported beams or as given in ANSI/AF&PA NDS-1997 Section 3.3.3 otherwise.

C_r is equal to values discussed in Section 4.4 for members used in a repetitive assembly as defined in ASTM D5055 or 1.00 otherwise.

4.6 Bearing (reactions)

The allowable bearing design value V_b' is computed by multiplying the tabulated design value by a series of adjustment factors.

$$V_b' = V_b\, C_D\, C_M\, C_t$$

and adjustments are as discussed in Section 4.5.

DESIGN EXAMPLES

5.1 General

The design of an I-joist system is straight-forward and similar to other framing materials. The unique considerations discussed below include:

- Shear deformations
- Web stiffener and bearing requirements
- Design for holes

Section 6 discusses these and other supplemental design considerations in detail.

Example:

Design a simple span I-Joist floor system for a multi-story apartment building. Assume joists spaced 16" o/c and design live and dead loads equal to 40 psf and 10 psf, respectively. The required clear span is 18'-8". Design span is assumed to be 18'-10" to accommodate a minimum 1¾" required bearing length specified by the joist manufacturer. The following reference conditions exist:

- "Dry" service conditions (C_M = 1.0)
- "Normal" temperature range (C_t = 1.0)
- Full lateral support provided by sheathing (C_L = 1.0)
- Duration of load factor based on "floor live" loads (C_D = 1.0)

Load equals (10 psf + 40 psf) x 1.33' = 67 plf. Live load for deflection calculations equals 40 psf x 1.33' = 53 plf. Select an 11⁷/₈" deep trial section with the following tabulated resistances from the manufacturer's literature:

- M′ = 3390 ft-pounds (including the load sharing factor (C_r) per ASTM D5055
- V′ = 1425 pounds
- V'_b = 975 pounds without web stiffeners (1.75" bearing)
  = 1425 pounds with web stiffeners (1.75" bearing)
- Bending stiffness coefficient (EI) = 350,000,000 lb-in^2
- Shear deflection coefficient (K) = 6,180,000 lb

5.2 Moment, Shear and Bearing Design

As this is a simple span joist, in the example above, the moment is

$$M = \frac{w\ell^2}{8} = 2970\ ft - pounds$$

and the shear computed at the joist end (not at a depth "d" from the support), is

$$V = \frac{w\ell}{2} = 630\ pounds$$

Note: *Multiple span joists would require consideration of alternate and adjacent span load cases to determine maximum moments and shears.*

The moment and shear design capacities exceed applied moments and shears. This joist is acceptable on a strength basis.

For this condition the end reaction equals the applied shear (630 pounds). Based on the manufacturer's minimum bearing requirements, provide a bearing detail with the minimum bearing distance (1.75"), and web stiffeners are not required.

5.3 Deflection Design

In addition to strength calculations, deflection must be checked relative to code-prescribed limits. Additionally most manufacturers publish recommended deflection limits that are more stringent than code minimums. Assume code prescribed minimums of $\ell/240$ for total load and $\ell/360$ for live load. The manufacturer recommends $\ell/480$ for live load. By inspection live load deflections control.

Shear deformations must be taken into account when deflections are checked. The live load deflection for this joist is:

$$w = 53 \text{ plf} = 4.42 \text{ lbs per inch}$$

$$\ell = 18.83' = 226 \text{ inches}$$

$$\text{Deflection} = \frac{5w\ell^4}{384EI} + \frac{w\ell^2}{k}$$

$$= 0.429" + .037"$$

$$= 0.465" = \ell/485$$

The joist is acceptable on a deflection basis. A stiffer floor system could be provided by specifying glued/nailed floor sheathing.

5.4 Concentrated Load Example

Consider the example above with the additional provision of a lightly loaded bearing wall perpendicular to the joists located 10" from the end of the joist. Although this load is within "d" from the joist end, it must be considered. Assume an applied load of 400 pounds. The first consideration is to meet the manufacturer's requirements for reinforcing the joist under the concentrated load.

The critical shear (V) and reaction (V_b) are now approximately equal to 630 pounds (see above) plus the concentrated load of 400 pounds, or 1030 pounds. The shear and bearing design capacities are greater than the applied shear and bearing, but web stiffeners are now required to attain the required bearing resistance. Moment and deflection performance should also be verified.

5.5 Considerations for Web Holes

I-Joists provide great flexibility for locating holes in the web. Manufacturers provide product specific charts that address particular ***uniform*** load cases. Additional consideration is required for other than specified uniform loads and concentrated loads. The joist manufacturer should be contacted to determine the joist capacity with the requested hole. The partial span load case shown in Figure 2 of Section 6.3 should be considered. This load case is critical when evaluating full web height rectangular holes.

SUPPLEMENTAL DESIGN CONSIDERATIONS

6.1 Introduction

The wood I-joist is similar to conventional lumber in that it is based on the same raw materials, but differs in how the material is composed. For this reason, conventional lumber design practices are not always compatible with the unique configuration and wood fiber orientation of the wood I-joist. Designers using wood I-joists should develop solutions in accordance with the following guidelines.

6.2 Design Span

The design span used for determining critical shears and moments is defined as the clear span between the faces of support plus one-half the minimum required bearing on each end (see Figure 1). For most wood I-joists, the minimum required end bearing length varies from 1½" to 3½" (adding 2" to the clear span dimension is a good estimate for most applications). At locations of continuity over intermediate bearings, the design span is measured from the centerline of the intermediate support to the face of the bearing at the end support, plus one half the minimum required bearing length. For interior spans of a continuous joist, the design span extends from centerline to centerline of the intermediate bearings.

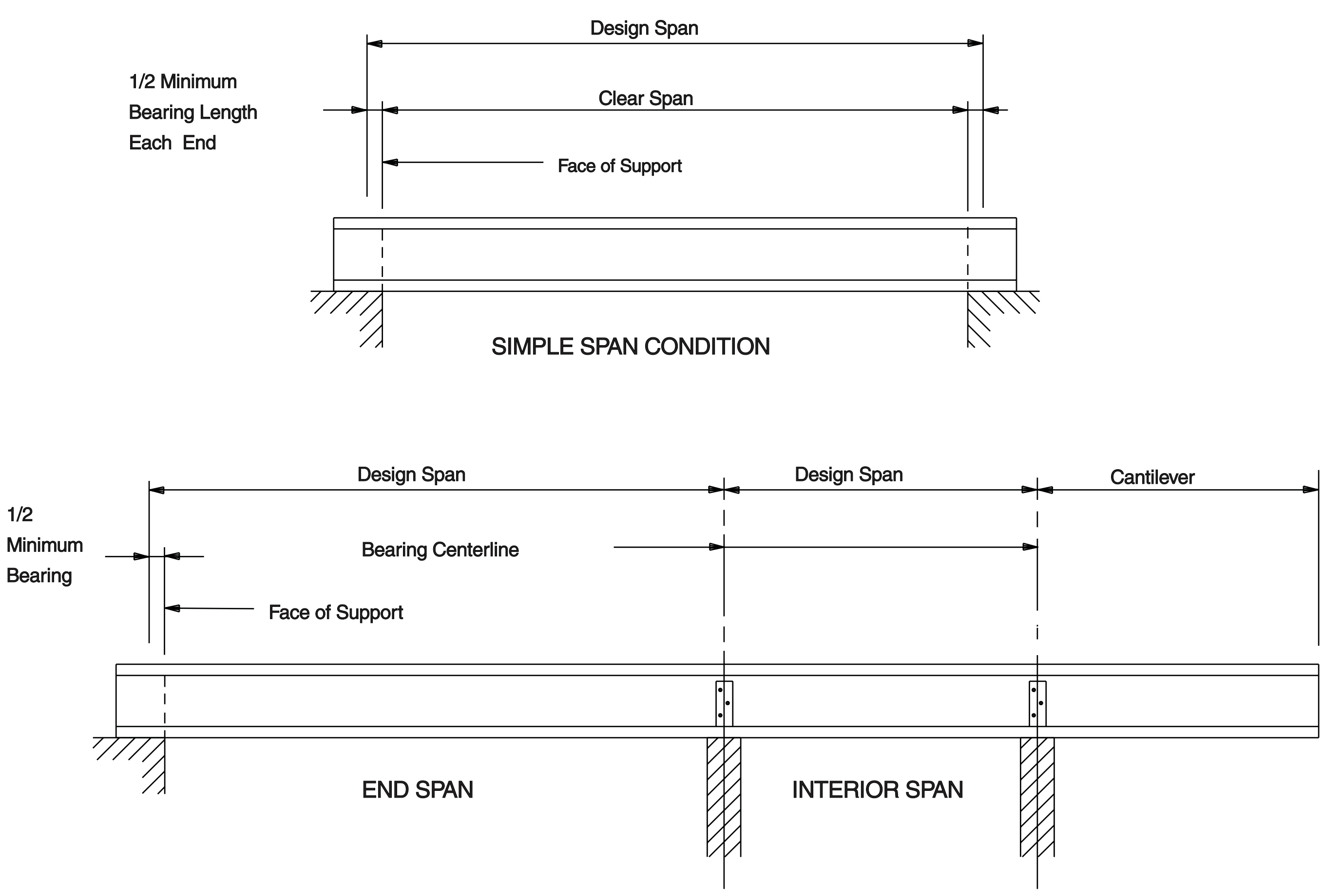


Figure 1 Design Span Determination

6.3 Load Cases

Most building codes require consideration of a critical distribution of loads. Due to the long length and continuous span capabilities of the wood I-joist, these code provisions have particular meaning. Considering a multiple span member, the following design load cases should be considered:

- All spans with total loads
- Alternate span loading
- Adjacent span loading
- Partial span loading (joists with holes)
- Concentrated load provisions (as occurs)

A basic description of each of these load cases follows:

Total loads on all spans - This load case involves placing all live and dead design loads on all spans simultaneously.

Alternate span loading - This load case places the L, L_R, S or R load portion of the design loads on every other span and can involve two loading patterns. The first pattern results in the removal of the live loads from all even numbered spans. The second pattern removes live loads from all odd numbered spans. For roof applications, some building codes require removal of only a portion of the live loads from odd or even numbered spans. The alternate span load case usually generates maximum end reactions, mid-span moments, and mid-span deflections. Illustrations of this type of loading are shown in Figure 2.

Adjacent span loading - This load case (see Figure 2) removes L, L_R, S or R loads from all but two adjoining spans. All other spans, if they exist, are loaded with dead loads only. Depending on the number of spans involved, this load case can lead to a number of load patterns. All combinations of adjacent spans become separate loadings. This load case is used to develop maximum shears and reactions at internal bearing locations.

Partial span loading - This load case involves applying L, L_R, S or R loads to less than the full length of a span (see Figure 2). For wood I-joists with web holes, this case is used to develop shear at hole locations. When this load case applies, uniform L, L_R, S, R load is applied only from an adjacent bearing to the opposite edge of a rectangular hole (centerline of a circular hole). For each hole within a given span, there are two corresponding load cases. Live loads other than the uniform application load, located within the span containing the hole, are also applied simultaneously. This includes all special loads such as point or tapered loads.

Concentrated load provisions - Most building codes have a concentrated load (live load) provision in addition to standard application design loads. This load case considers this concentrated load to act in combination with the system dead loads on an otherwise unloaded floor or roof. Usually, this provision applies to non-residential construction. An example is the "safe" load applied over a 2½ square foot area for office floors. This load case helps insure the product being evaluated has the required shear and moment capacity throughout it's entire length and should be considered when analyzing the effect of web holes.

A properly designed multiple span member requires numerous load case evaluations. Most wood I-joist producers have developed computer programs, load and span tables, or both that take these various load cases into account.

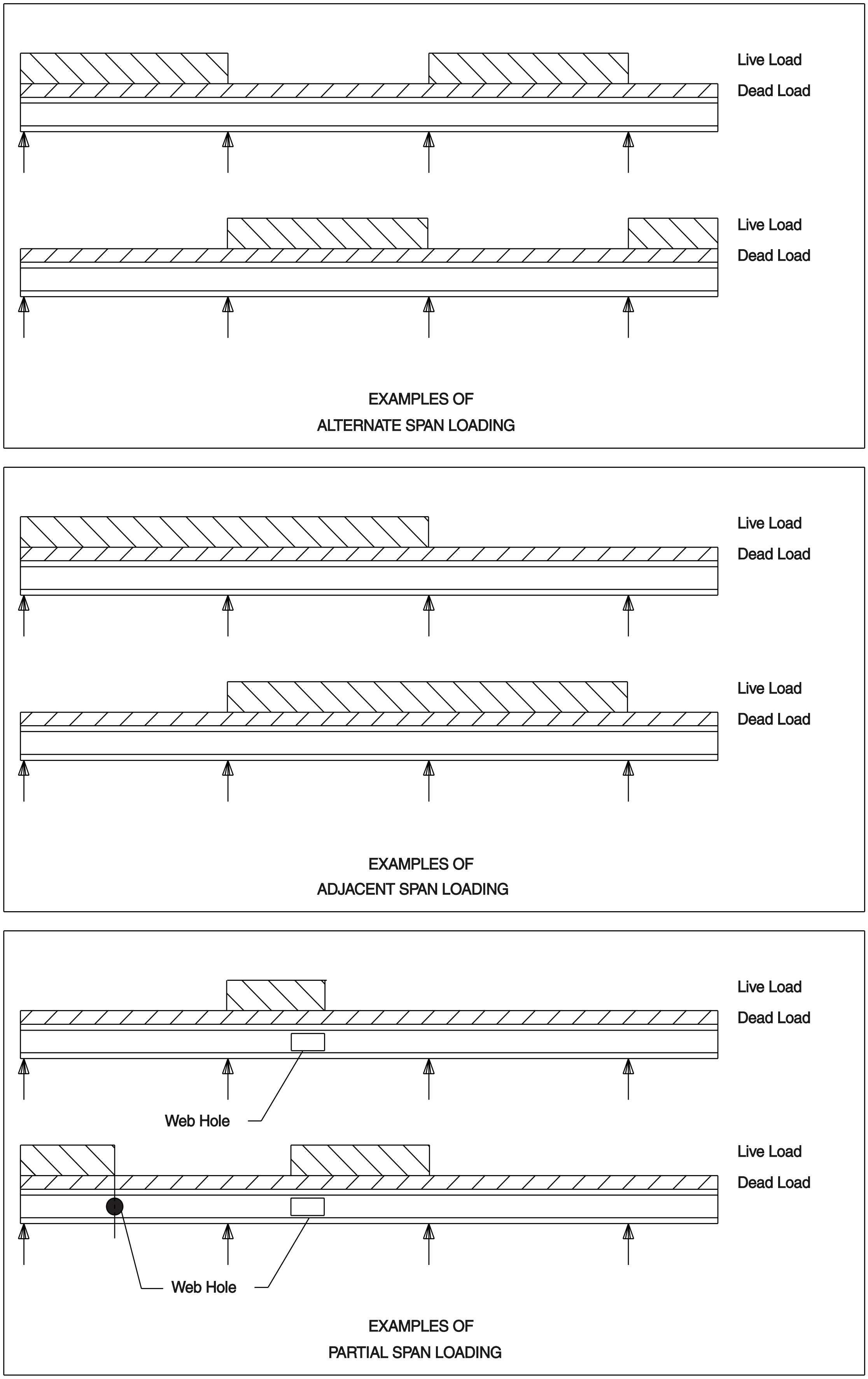


Figure 2 Load Case Evaluations

6.4 Floor Performance

Designing a floor system to meet the minimum requirements of a building code may not always provide acceptable performance to the end user. Although minimum criteria help assure a floor system can safely support the imposed loads, the system ultimately must perform to the satisfaction of the end user. Since expectancy levels may vary from one person to another, designing a floor system becomes a subjective issue requiring judgment as to the sensitivity of the intended occupant.

Joist deflection is often used as the primary means for designing in floor performance. Although deflection is a factor, there are other equally important variables that can influence the performance of a floor system. A glue-nailed floor system will generally have better deflection performance than a nailed only system. Selection of the decking material is also an important consideration. Deflection of the sheathing material between joists can be reduced by placing the joists at a closer on center spacing or increasing the sheathing thickness.

Proper installation and job site storage are important considerations. All building materials, including wood I-Joists, need to be kept dry and protected from exposure to the elements. Proper installation includes correct spacing of sheathing joints, care in fastening of the joists and sheathing, and providing adequate and level supports. All of these considerations are essential for proper system performance.

Vibration may be a design consideration for floor systems that are stiff and where very little dead load (i.e.: partition walls, ceilings, furniture, etc.) exists. Vibration can generally be damped with a ceiling system directly attached to the bottom flange of the wood I-joists. Effective bridging or continuous bottom flange nailers (i.e.: 2x4 nailed flat-wise and perpendicular to the joist and tied of to the end walls) can also help to minimize the potential for vibration in the absence of a direct applied ceiling. Limiting the span/depth ratio of the I-joist may also improve floor performance.

6.5 Joist Bearing

Bearing design for wood I-joists requires more than consideration of perpendicular to grain bearing values. Minimum required bearing lengths take into account a number of considerations. These include: cross grain bending and tensile forces in the flanges, web stiffener connection to the joist web, adhesive joint locations and strength, and perpendicular to grain bearing stresses. The model building code evaluation reports provide a source for bearing design information, usually in the form of minimum required bearing lengths.

Usually, published bearing lengths are based on the maximum allowable shear capacity of the particular product and depth or allowable reactions are related to specific bearing lengths. Bearing lengths for wood I-joists are most often based on empirical test results rather than a calculated approach. Each specific producer should be consulted for information where deviations from published criteria are desired.

To better understand the variables involved in a wood I-joist bearing, it's convenient to visualize the member as a composition of pieces, each serving a specific task. For a typical simple span joist, the top flange is a compression member, the bottom flange is a tension member, and the web resists the vertical shear forces. Using this concept, shear forces accumulate in the web member at the bearing locations and must be transferred through the flanges to the support structure. This transfer involves two critical interfaces: between the flange and support member and between the web and flange materials.

Starting with the support member, flange to support bearing involves perpendicular to grain stresses. The lowest design value for either the support member or flange material is usually used to develop the minimum required bearing area.

The second interface to be checked is between the lower joist flange and the bottom edge of the joist web, assuming a bottom flange bearing condition. This connection, usually a routed groove in the flange and a matching shaped profile on the web, is a glued joint secured with a waterproof structural adhesive. The contact surfaces include the sides and bottom of the routed flange.

In most cases, the adhesive line stresses at this joint control the bearing length design. The effective bearing length of the web into the flange is approximately the length of flange bearing onto the support plus an incremental length related to the thickness and stiffness of the flange material.

Since most wood I-joists have web shear capacity in excess of the flange to web joint strength, connection reinforcement is sometimes utilized. The most common method of reinforcement is the addition of web stiffeners (also commonly referred to as bearing blocks). Web stiffeners are vertically oriented wood blocks positioned on both sides of the web. Web stiffeners should be cut so that a gap of at least 1/8" is between the stiffener and the flange to avoid a force fit. Stiffeners are positioned tight to the bottom flange at bearing locations and snug to the bottom of the top flange beneath heavy point loads within a span. Figure 3 provides an illustration of a typical end bearing assembly.

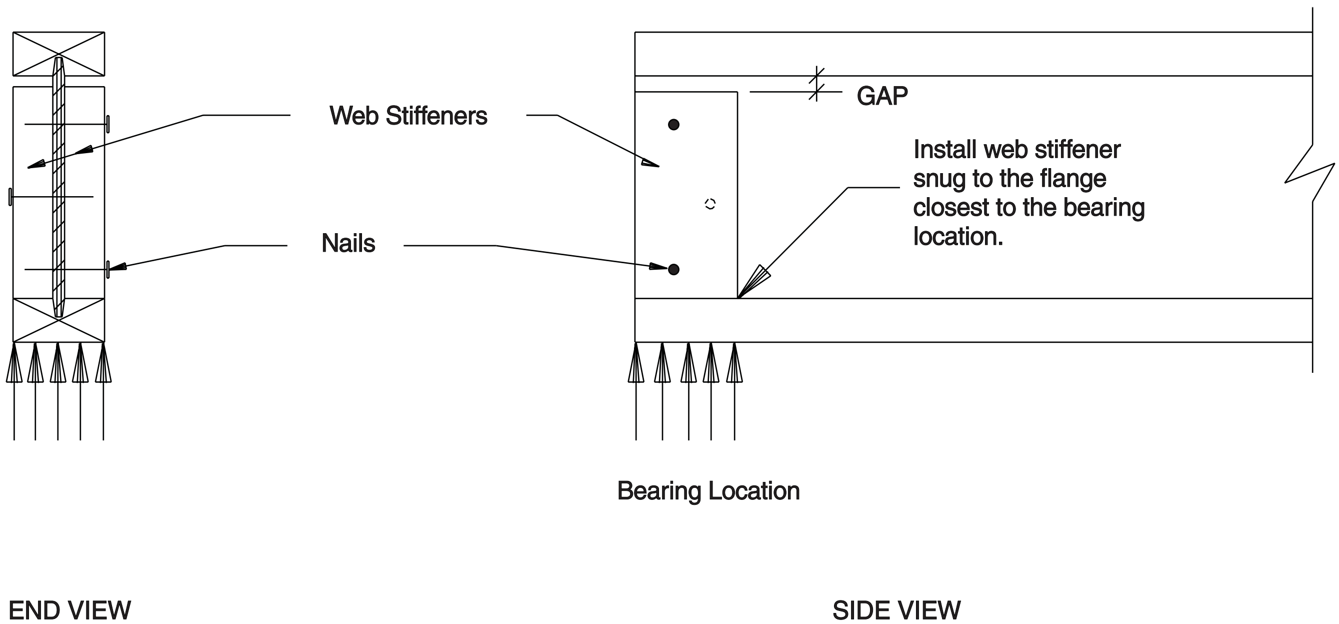


Figure 3 End Bearing Web Stiffeners (Bearing Block)

6.6 Web Stiffeners

When correctly fastened to the joist web, web stiffeners transfer some of the load from the web into the top of the bottom flange. This reduces the loads on the web to flange joint. A pair of web stiffeners (one on each side) is usually mechanically connected to the web with nails or staples loaded in double shear. For some of the higher capacity wood I-joists, nailing and supplemental gluing with a structural adhesive is required. The added bearing capacity achievable with web stiffeners is limited by the allowable bearing stresses where the stiffeners contact the bearing flange, and by their mechanical connection to the web.

Web stiffeners also serve the implied function of reinforcing the web against buckling. Since shear capacity usually increases proportionately with the depth, web stiffeners are very important for deep wood I-joists. For example, a 30" deep wood I-joist may only develop 20 to 30 percent of its shear and bearing capacity without properly attached web stiffeners at the bearing locations. This is especially important at continuous span bearing locations, where reaction magnitudes can exceed simple span reactions by an additional 25 percent.

Web stiffeners should be cut so that a gap of at least 1/8" is between the stiffener and the top or bottom of the flange to avoid a force fit. Web stiffeners should be installed snug to the bottom flange for bearing reinforcement or snug to the top flange if under concentrated load from above.

For shallow depth joists, where relatively low shear capacities are required, web stiffeners may not be needed. When larger reaction capacities are required, web stiffener reinforcement may be needed, especially where short bearing lengths are desired. Figure 4 illustrates the bearing interfaces.

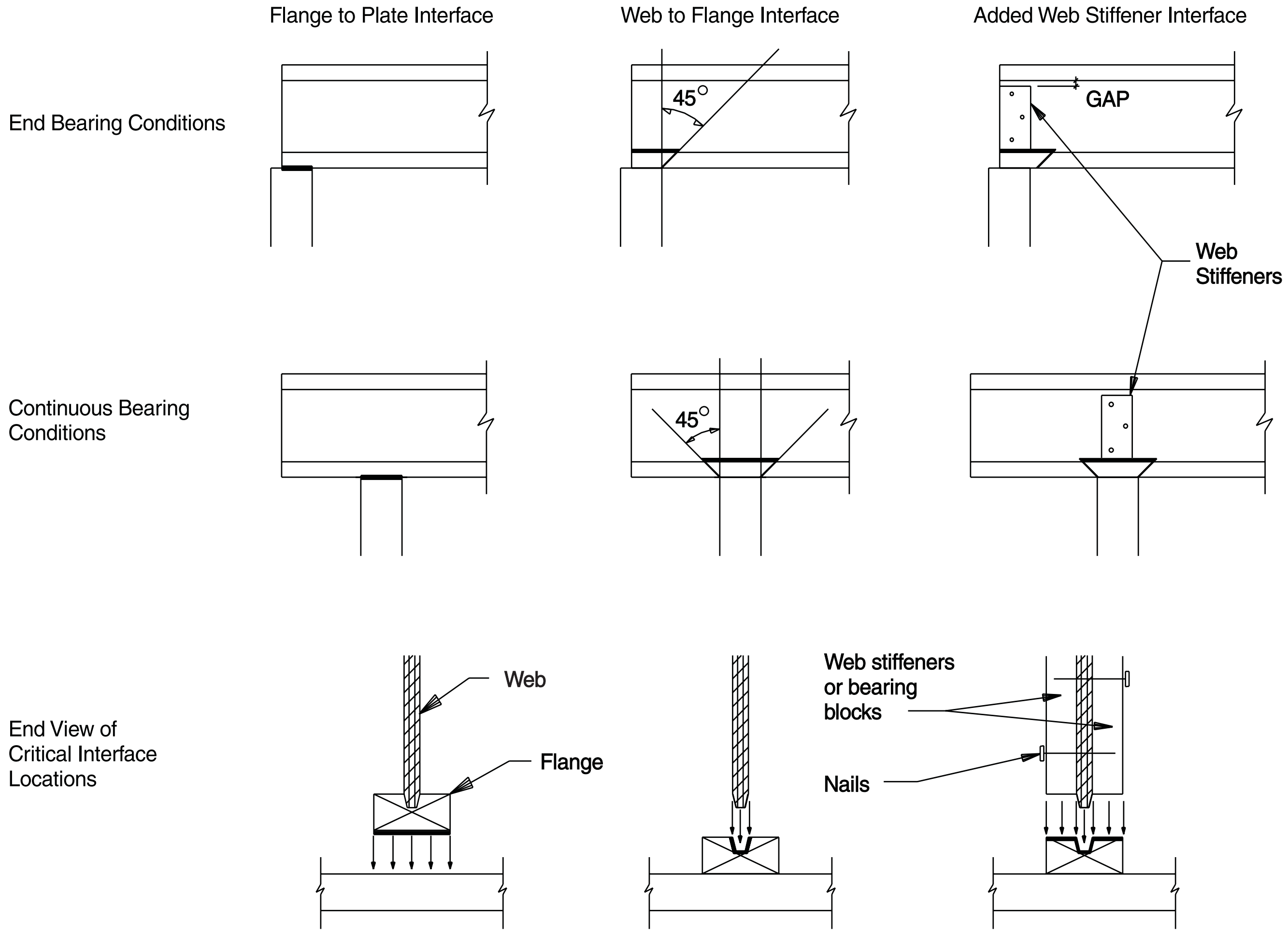


Figure 4 Web Stiffener Bearing Interface

6.7 Beveled End Cuts

Beveled end cuts, where the end of the joist is cut on an angle (top flange does not project over the bearing, much like a fire cut), also requires special design consideration. Again the severity of the angle, web material, location of web section joints, and web stiffener application criteria effect the performance of this type of bearing condition. The specific wood I-joist producers should be consulted for limits on this type of end cut.

It is generally accepted that if a wood I-joist has the minimum required bearing length, and the top flange of the joist is not cut beyond the face of bearing (measured from a line perpendicular to the joist's bottom flange), there is no reduction in shear or reaction capacity. This differs from the conventional lumber provision that suggests there is no decrease in shear strength for beveled cuts of up to an angle of 45°. The reason involves the composite nature of the wood I-joist and how the member fails in shear and or bearing. Figure 5 provides an illustration of the beveled end cut limitation.

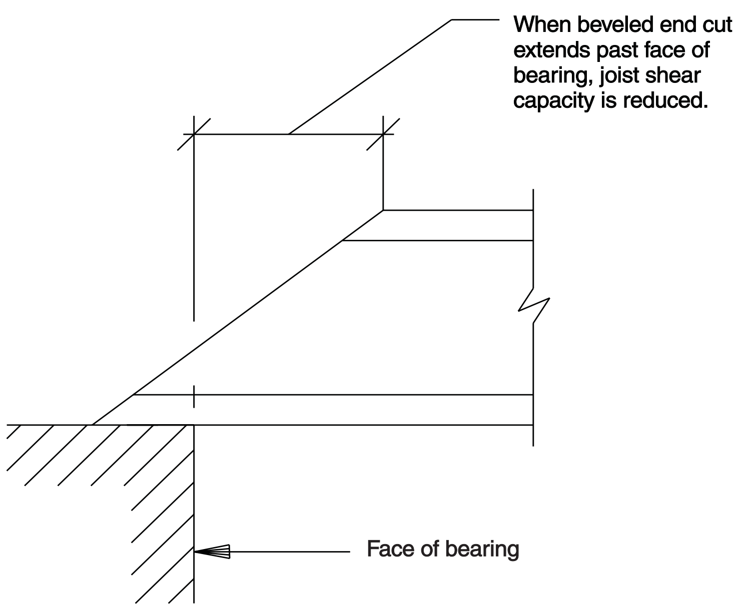


Figure 5 Beveled End Cut

6.8 Sloped Bearing Conditions

Sloped bearing conditions require design considerations different from conventional lumber. An example is a birdsmouth bearing cut (notches in the bottom flange - see Figure 6). This type of bearing should only be used on the low end bearing for wood I-joists. Another example is the use of metal joist support connectors that attach only to the web area of the joist and do not provide a bottom seat in which to bear. In general, this type of connector is not recommended for use with wood I-joists without consideration for the resulting reduced capacity.

The birdsmouth cut is a good solution for the low end bearing when the slope is steep and the tangential loads are high (loads along the axis of the joist member). This assumes the quality of construction is good and the cuts are made correctly and at the right locations. This type of bearing cut requires some skill and is not easy to make, particularly with the wider flange joists. The bearing capacity, especially with high shear capacity members, may be reduced as a result of the cut since the effective flange bearing area is reduced. The notched cut will also reduce the member's shear and moment capacity at a cantilever location.

An alternative to a birdsmouth cut is a beveled bearing plate matching the joist slope or special sloped seat bearing hardware manufactured by some metal connector suppliers. These alternatives also have special design considerations with steep slope applications. As the member slope increases, so does the tangential component of reaction, sometimes requiring additional flange to bearing nailing or straps to provide resistance. Figure 6 shows some examples of acceptable low end bearing conditions.

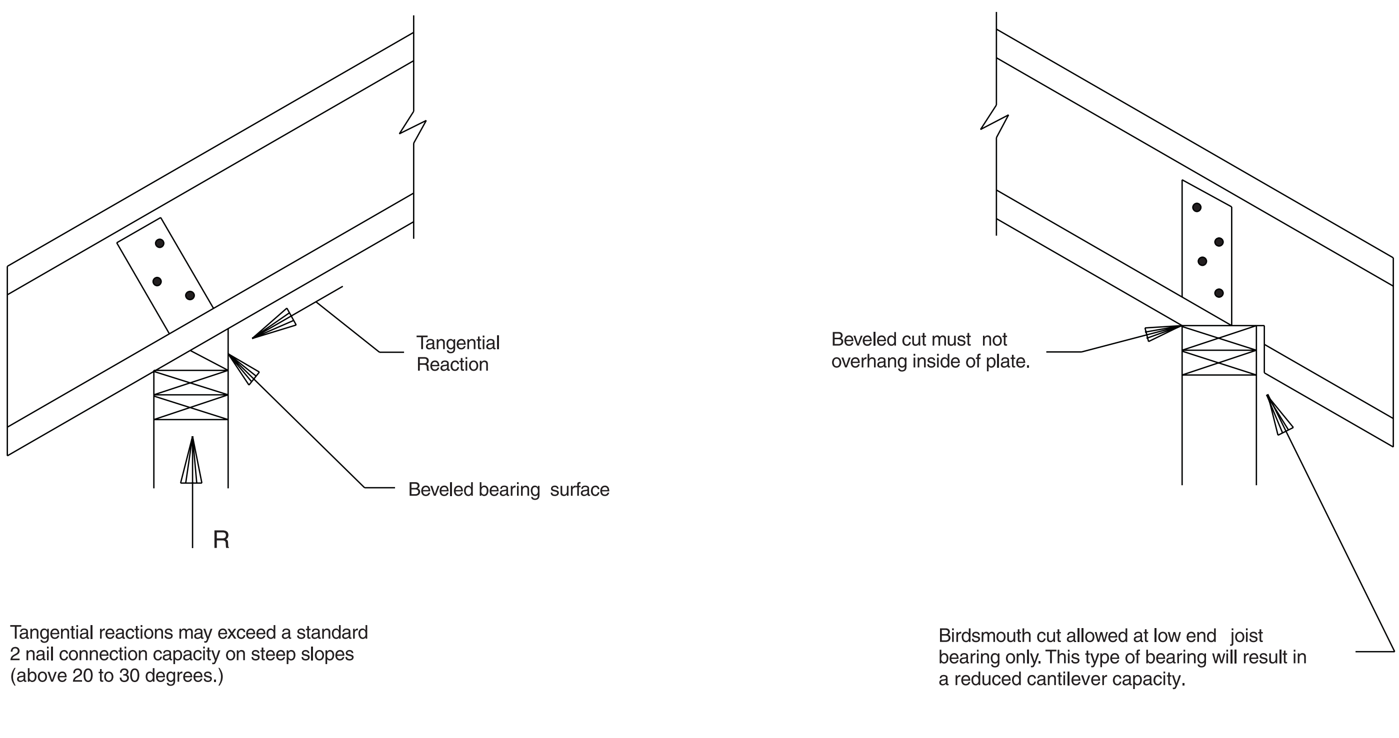


Figure 6 Sloped Bearing Conditions (Low End)

For the high end support, bottom flange bearing in a suitable connector or on a beveled plate is recommended. When slopes exceed 30°, straps or gussets may be needed to resist the tangential component of the reaction.

Support connections only to the web area of a wood I-joist, especially at the high end of a sloped application, are not generally recommended. Since a wood I-joist is made up of a number of pieces, joints between web sections occurring near the end of the member may reduce the joist's shear capacity when not supported from the bottom flange.

When a wood I-joist is supported from the web only, the closest web to web joint from the end may be stressed in tension. This could result in a joint failure with the web section pulling out of the bottom flange. Locating these internal joints away from the end of the member or applying joint reinforcements are potential remedies, but generally are not practical in the field.

The best bearing solution is to provide direct support to the joist's bottom flange to avoid reductions in capacity. Figure 7 shows typical high end bearing conditions.

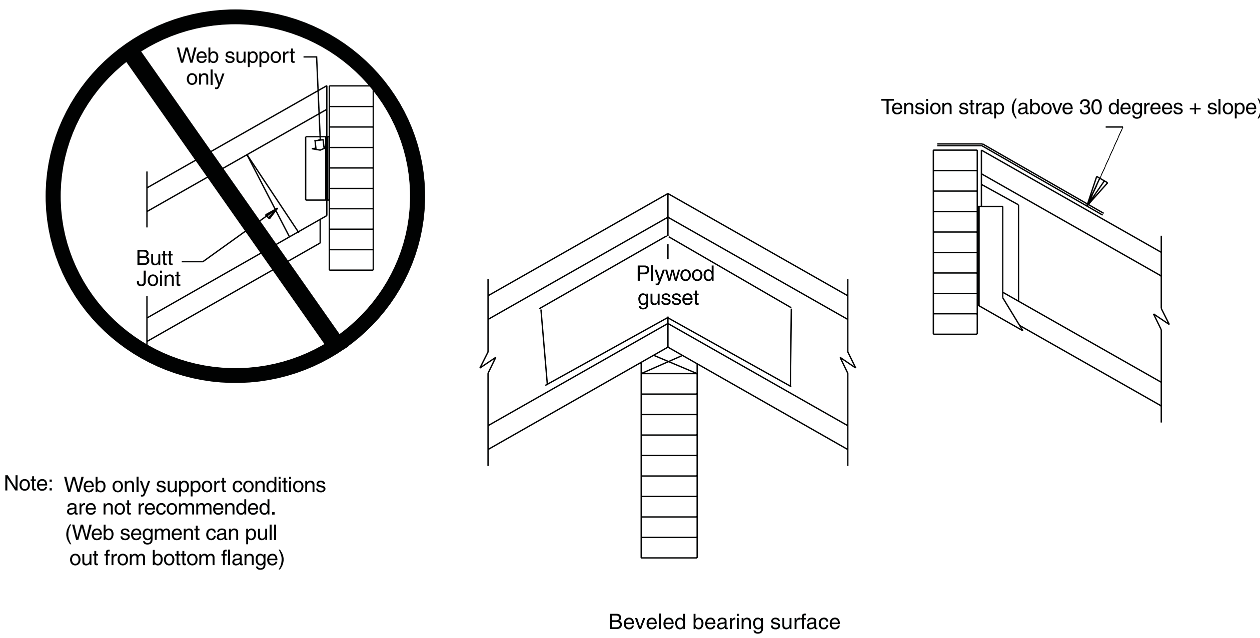


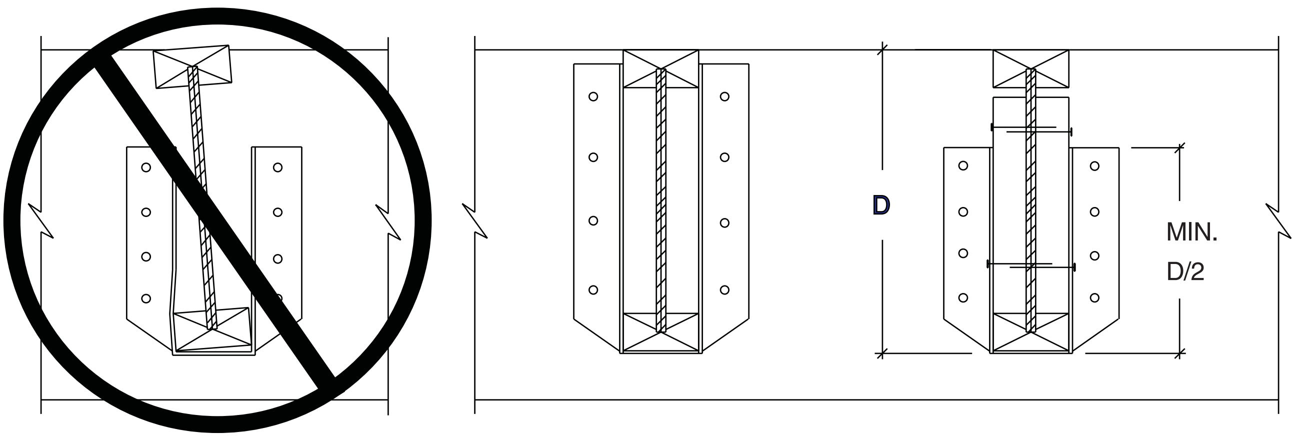
Figure 7 Sloped Bearing Conditions (High End)

6.9 Connector Design/Joist Hangers

Although there are numerous hangers and connectors available that are compatible with wood I-joists, many are not. Hangers developed for conventional lumber or glulam beams often use large nails and space them in a pattern that will split the joist flanges and web stiffeners. Hanger selection considerations for wood I-joists should include nail length and diameter, nail location, wood I-joist bearing capacity, composition of the supporting member, physical fit, and load capacity. For example, hangers appropriate for a wood I-joist to glulam beam support may not be compatible for an I-joist to I-joist connection.

In general, nails into the flanges should not exceed the diameter of a 10d common nail, with a recommended length no greater than 1½". Nails into web stiffeners should not exceed the diameter of a 16d common nail. Nails through the sides of the hanger, when used in combination with web stiffeners, can be used to reduce the joist's minimum required bearing length. Nails help transfer loads directly from the I-joist web into the hanger, reducing the load transferred through direct bearing in the bottom hanger seat.

Hangers should be capable of providing lateral support to the top flange of the joist. This is usually accomplished by a hanger flange that extends the full depth of the joist. As a minimum, hanger support should extend to at least mid-height of a joist used with web stiffeners. Some connector manufacturers have developed hangers specifically for use with wood I-joists that provide full lateral support without the use of web stiffeners. Figure 8 illustrates lateral joist support requirements for hangers.



Top and bottom joist flanges must be laterally restrained against rotation.

Figure 8 Lateral Support Requirements for Joists in Hangers

When top flange style hangers are used to support one I-joist from another, especially the wider flange I-joists, web stiffeners need to be installed tight to the bottom side of the support joist's top flanges. This prevents cross grain bending and rotation of the top flange (see Figure 9).

When face-nail hangers are used for joist to joist connections, nails into the support joist should extend through and beyond the web element. Filler blocks should also be attached sufficiently to provide support for the hanger. Again, nail diameter should be considered to avoid splitting the filler block material.

Multiple I-joists need to be adequately connected together to achieve desired performance. This requires proper selection of a nailing or bolting pattern and attention to web stiffener and blocking needs. Connections should be made through the webs of the I-joists, and never through the flanges.

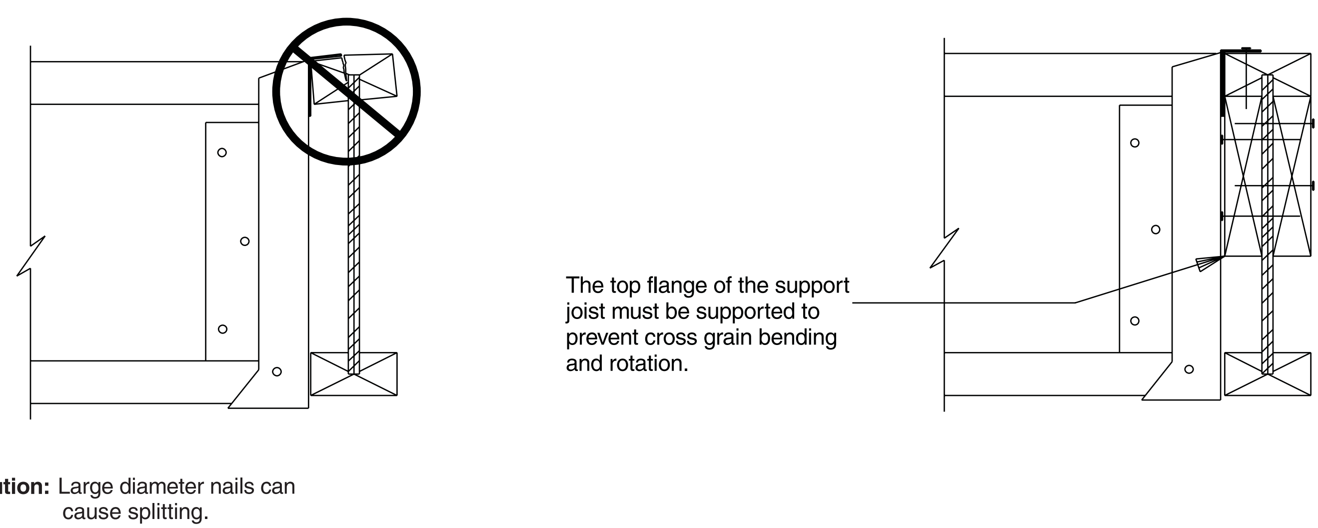


Figure 9 Top Flange Hanger Support

For a double I-joist member loaded from one side only, the minimum connection between members should be capable of transferring at least 50% of the applied load. Likewise, for a triple member loaded from one side only, the minimum connection between members must be capable of transferring at least 2/3 of the applied load. The actual connection design should consider the potential slip and differential member stiffness. Many producers recommend limiting multiple members to 3 joists. Multiple I-joists with 3½" wide flanges may be further limited to two members.

The low torsional resistance of most wood I-joists is also a design consideration for joist to joist connections. Eccentrically applied side loads, such as a top flange hanger hung from the side of a double joist, create the potential for joist rotation. Bottom flange restraining straps, blocking, or directly applied ceiling systems may be needed on heavily loaded eccentric connections to resist rotation. Figure 10 shows additional I-joist connection considerations for use with face nail hangers.

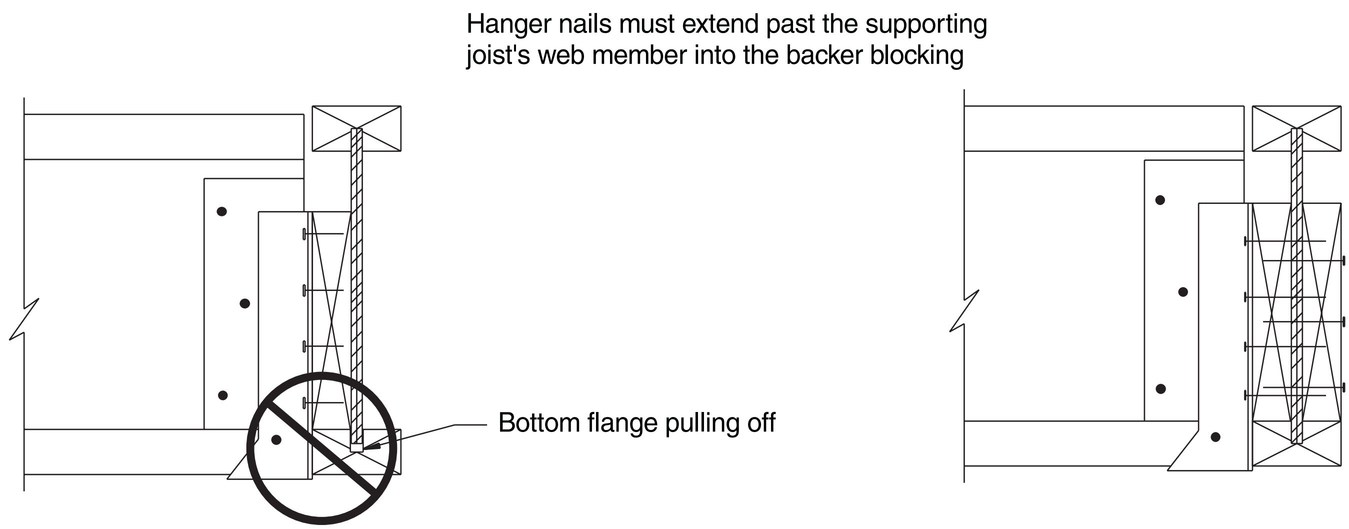


Figure 10 Connection Requirements for Face Nail Hangers

6.10 Vertical Load Transfer

Bearing loads originating above the joists at the bearing location require blocking to transfer these loads around the wood I-joist to the supporting wall or foundation. This is typically the case in a multi-story structure where bearing walls stack and platform framing is used. Usually, the available bearing capacity of the joist is needed to support its reaction, leaving little if any excess capacity to support additional bearing wall loads from above.

The most common type of blocking uses short pieces of wood I-joist, often referred to as blocking panels, positioned directly over the lower bearing and cut to fit in between the joists. These panels also provide lateral support for the joists and an easy means to transfer lateral diaphragm shears.

The ability to transfer lateral loads (due to wind, seismic, construction loads, etc.) to shear walls or foundations below is important to the integrity of the building design. Compared with dimension lumber blocking, which usually is toe-nailed to the bearing below, wood I-joist blocking can develop higher diaphragm transfer values because of a wider member width and better nail values.

Specialty products designed specifically for rim boards are pre-cut in strips equal to the joist depth, and provide support for the loads from above. This solution may also provide diaphragm boundary nailing for lateral loads.

A third method uses vertically oriented short studs, often called squash blocks or cripple blocks, on each side of the joist and cut to a length slightly longer than the depth of the joist. This method should be used in combination with some type of rim joist or blocking material when lateral stability or diaphragm transfer is required.

The use of horizontally oriented sawn lumber as a blocking material is unacceptable. Wood I-joists generally do not shrink in the vertical direction due to their panel type web, creating the potential for a mismatch in height as sawn lumber shrinks to achieve equilibrium. When conventional lumber is used in the vertical orientation, shrinkage problems are not a problem because changes in elongation due to moisture changes are minimal. Figure 11 shows a few common methods for developing vertical load transfer.

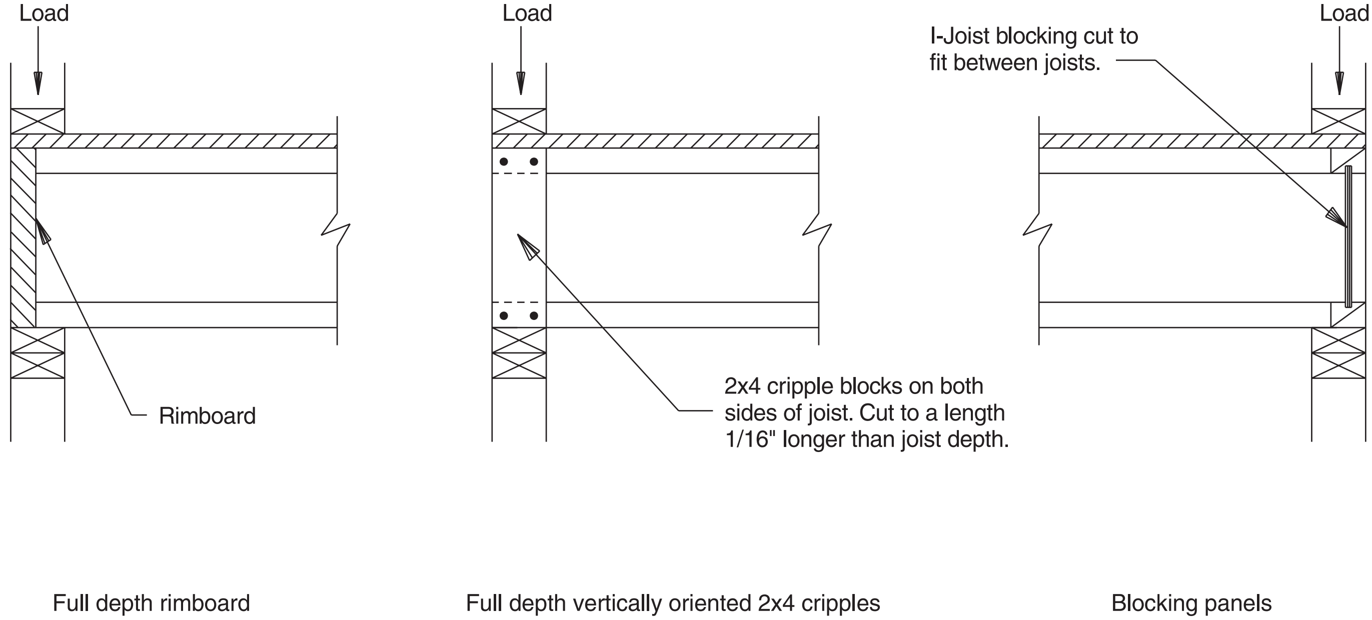


Figure 11 Details for Vertical Load Transfer

6.11 Web Holes

Holes cut in the web area of a wood I-joist affect the member's shear capacity. Usually, the larger the hole, the greater the reduction in shear capacity. For this reason, holes are generally located in areas where shear stresses are low. This explains why the largest holes are generally permitted near mid-span of a member. The required spacing between holes and from the end of the member is dependent upon the specific materials and processes used during manufacturing.

The allowable shear capacity of a wood I-joist at a hole location is influenced by a number of variables. These include: percentage of web removed; proximity to a vertical joint between web segments, the strength of the web to flange glue joint, flange stiffness, and the shear strength of the web material. Since wood I-joists are manufactured using different processes and materials, each producer should be consulted for the proper web hole design.

The methodology used to analyze the application loads is important in the evaluation of web holes. All load cases that will develop the highest shear at the hole location should be considered. Usually, for members resisting simple uniform design loads, the loading condition that develops the highest shear loads in the center area of a joist span involves partial span loading.

Web holes do contribute somewhat to increased deflection. The larger the hole the larger the contribution. Provided there are not too many holes involved, the contribution is negligible. In most cases, using a producer's recommended hole criteria and limiting the number of holes to three or less per span, the additional deflection does not warrant consideration.

6.12 Fire Assemblies

The Wood I-Joist Manufacturer's Association (WIJMA) has been active in support and development of the following projects to establish fire endurance performance of systems using I-Joist products:

- The Fire Resistance Design Manual, as published by the Gypsum Association, establishes a 1-hour system for I-Joist floor-ceiling assemblies using 2 layers of 5/8" type X gypsum wallboard (#FC 5406).
- Several ASTM E-119 fire tests have been conducted by wood I-Joist manufacturers to establish fire resistive properties of I-Joist systems. These systems are shown in each manufacturer's research report.
- National Fire Protection Research Foundation Report titled "National Engineered Lightweight Construction Fire Research Project." This report documents an extensive literature search of fire performance of engineered lightweight construction.
- A video has been produced by WIJMA: "I-JOISTS: FACTS ABOUT PROGRESS." This video describes some basic facts about changes taking place within the construction and fire service industries. Along with this video is a document that provides greater detail on fire performance issues for those that desire more in depth information.
- Industry research in fire endurance modeling for I-Joist systems.

INSTALLATION DETAILS

7.1 Introduction

Each jobsite utilizing I-joists should have specific details addressing handling, storage, bracing, web holes, web stiffeners (when required) and bearing details. Each manufacturer publishes this information in the form of installation guides available from retail distributors or jobsite specific detail packages for joists in commercial applications. The installation guidelines address framing methods recommended for common applications in residential construction, and the manufacturer should be contacted if special details are required.

7.2 Jobsite Handling and Storage

As with any structural material, jobsite handling and storage of I-Joists requires consideration to assure intended performance. I-Joists should be handled in the vertical orientation as they have been engineered to maximize stiffness in this direction. Additionally they should be handled to prevent prying on the flanges and forklift damage to the webs. Specific recommendations for jobsite handling are available from each supplier and the information typically included is shown in Figure 12.

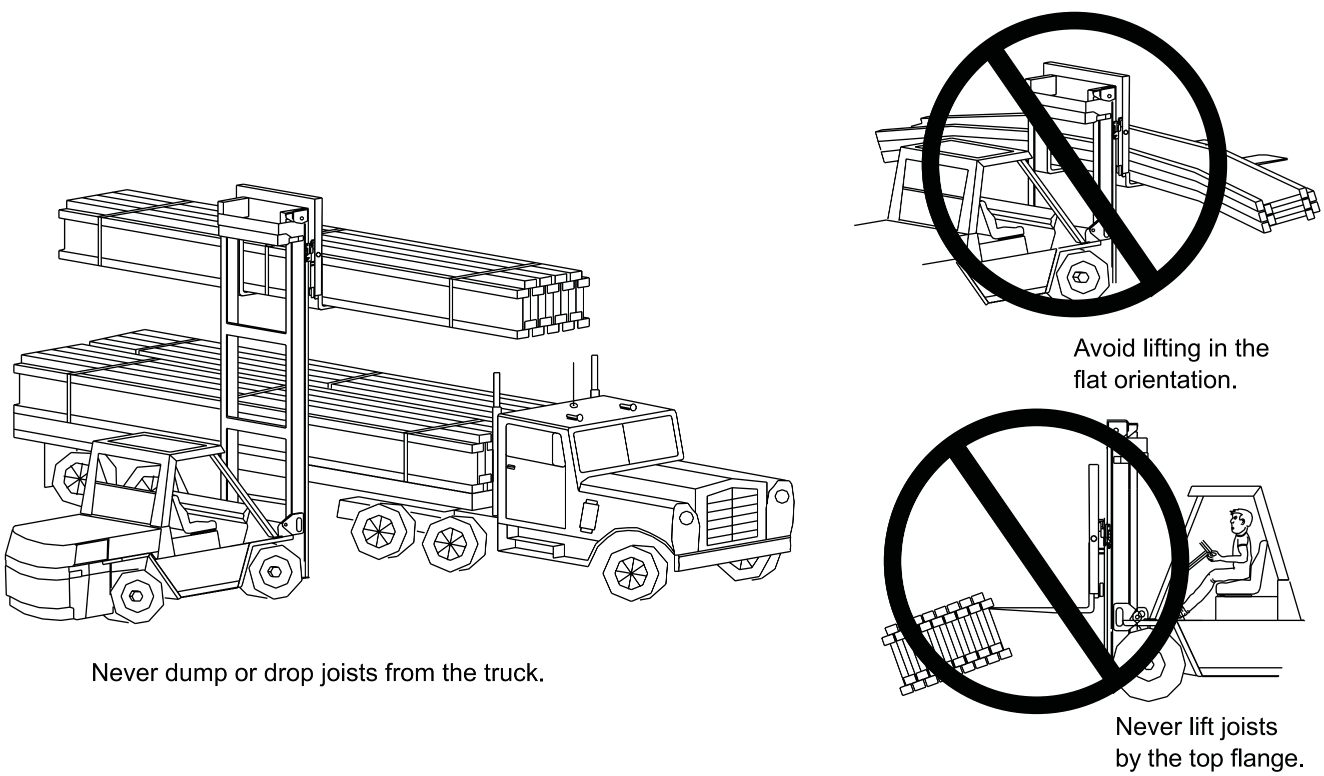


Figure 12 Jobsite Handling

Jobsite storage recommendations are similar to other dry engineered products. I-Joists should remain bundled and be stickered such that the joists are not in the mud or standing water. The joists should be protected from extended exposure to the elements. Additionally the I-Joists should be stored vertically to prevent ponding of water beteween the flanges. Specific recommendations for jobsite storage are available from each supplier and typical recommendations are shown in Figure 13.

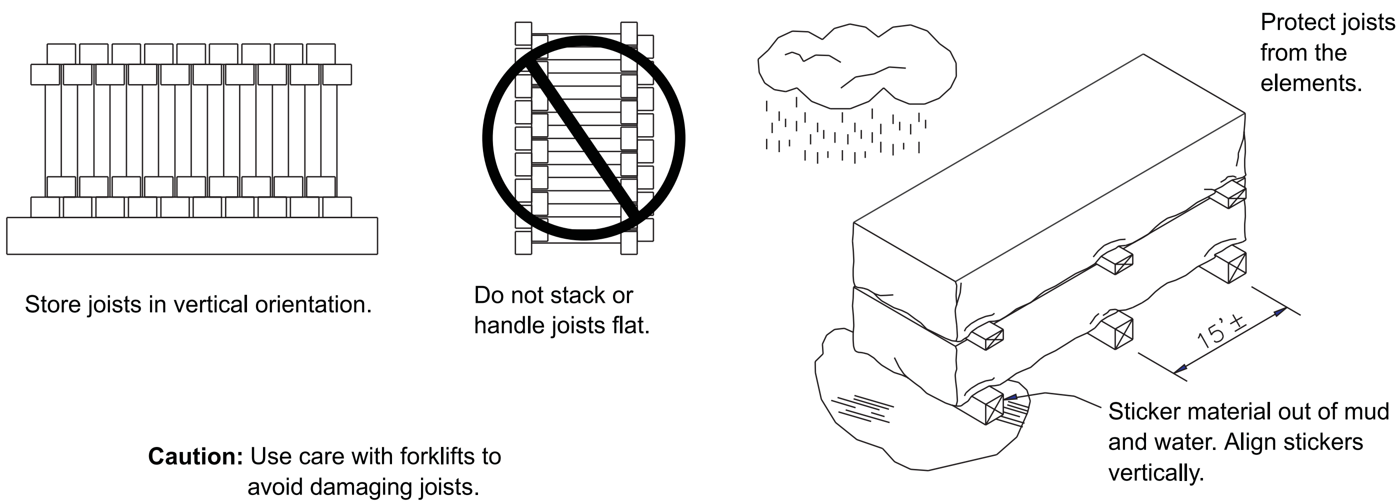


Figure 13 Jobsite Storage

7.3 Erection Bracing

The engineered profile of I-Joists requires additional consideration of erection bracing. Workers and building materials should not be permitted on joists prior to completion of the steps below. Web stiffeners (if required) should be installed prior to joist installation. Each joist should be fully installed at each support, with hangers, blocking or rimjoists completely nailed as specified by the manufacturer. The ends of cantilevers need careful attention and require bracing at the ends with blocking, X-bridging or temporary bracing. The final step is to provide lateral support of the I-Joist compression flange utilizing permanent sheathing or temporary strut bracing as detailed by the manufacturer. Recommendations for erection bracing are available from each supplier and information typically included is shown in Figure 14.

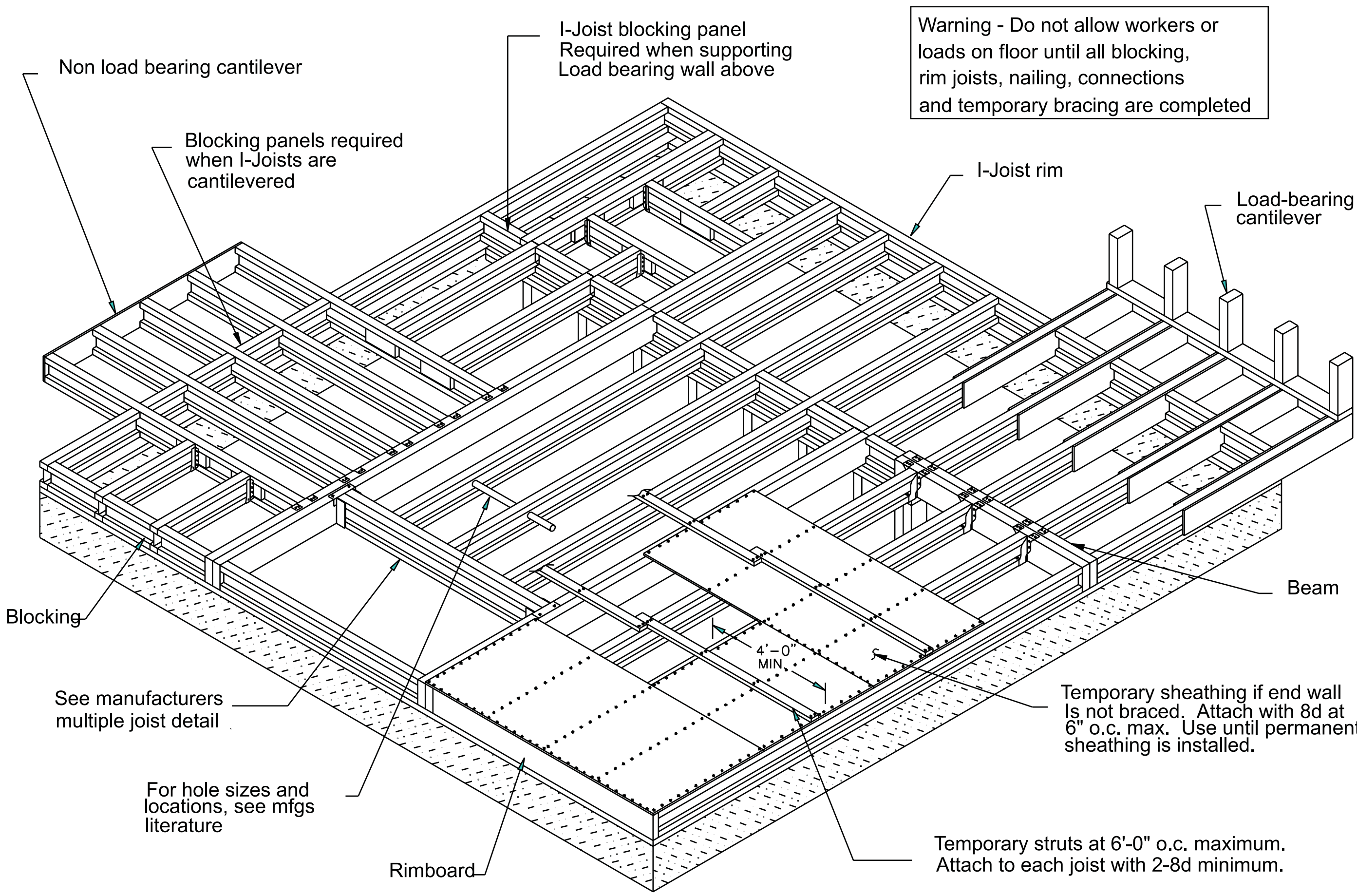


Figure 14 Typical Errection Bracing Recommendations

7.4 Typical Details

Web stiffeners are discussed extensively in Section 6.6 and typical attachment details are shown in Figure 15. Note that web stiffeners used to reinforce the I-Joist for concentrated loads need to be applied tight to the bottom of the top flange.

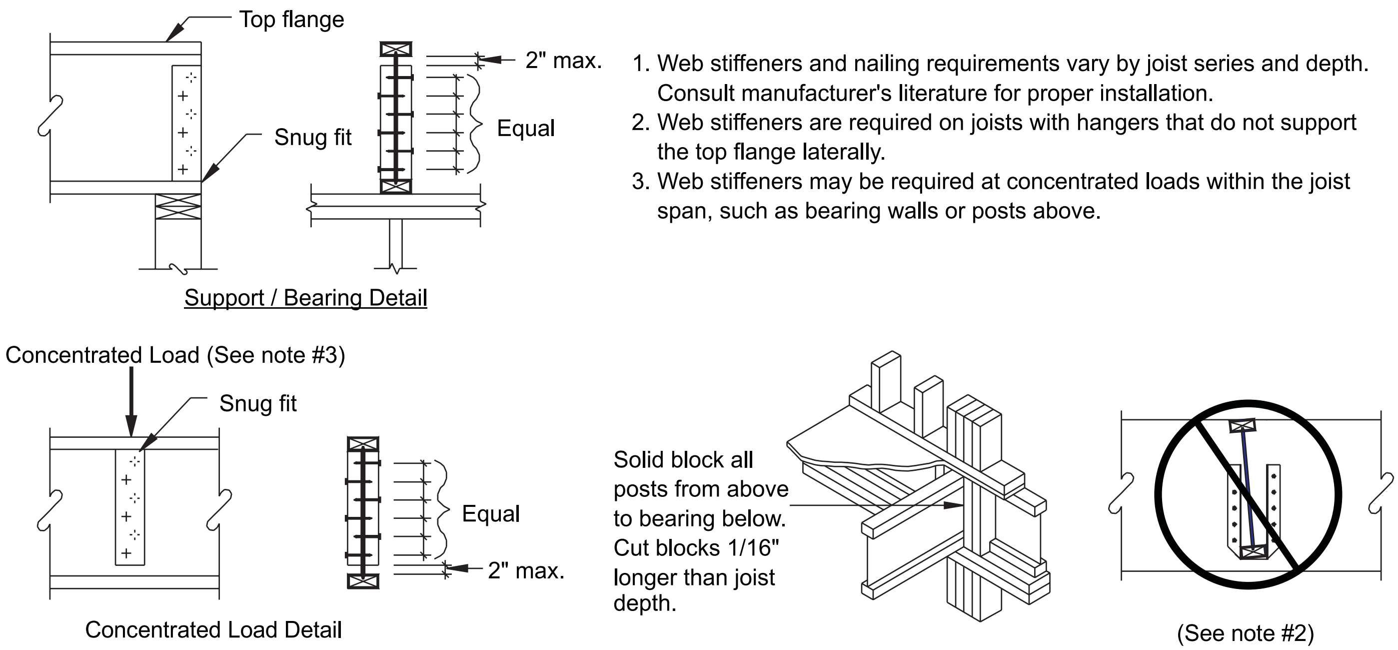
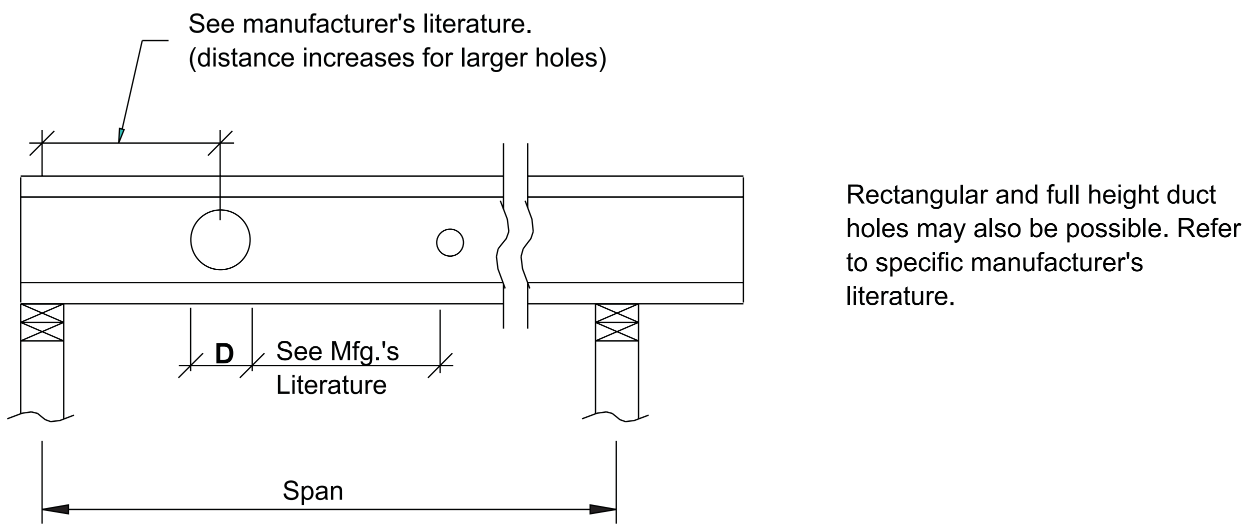


Figure 15 Web Stiffener Attachment

Each manufacturer publishes unique hole charts, and therefore hole charts cannot be used interchangeably between manufacturers. Key considerations are the size and shape of hole permitted, the location of the hole relative to the supports and the spacing between holes. Note hole charts are usually limited to expected span and load conditions. Figure 16 reflects information typically included by each manufacturer.



Important: Please read all instructions and notes before drilling holes and only cut in web area as specified.

Figure 16 Hole Chart

Bearing detail options are numerous and provide flexibility for virtually any condition typically encountered in the field. Each manufacturer publishes installation guides for common conditions, and provides assistance for specific requirements. Section 6 on Supplemental Design provides additional considerations for appropriate detailing. Representative details for typical conditions are shown in Figure 17.

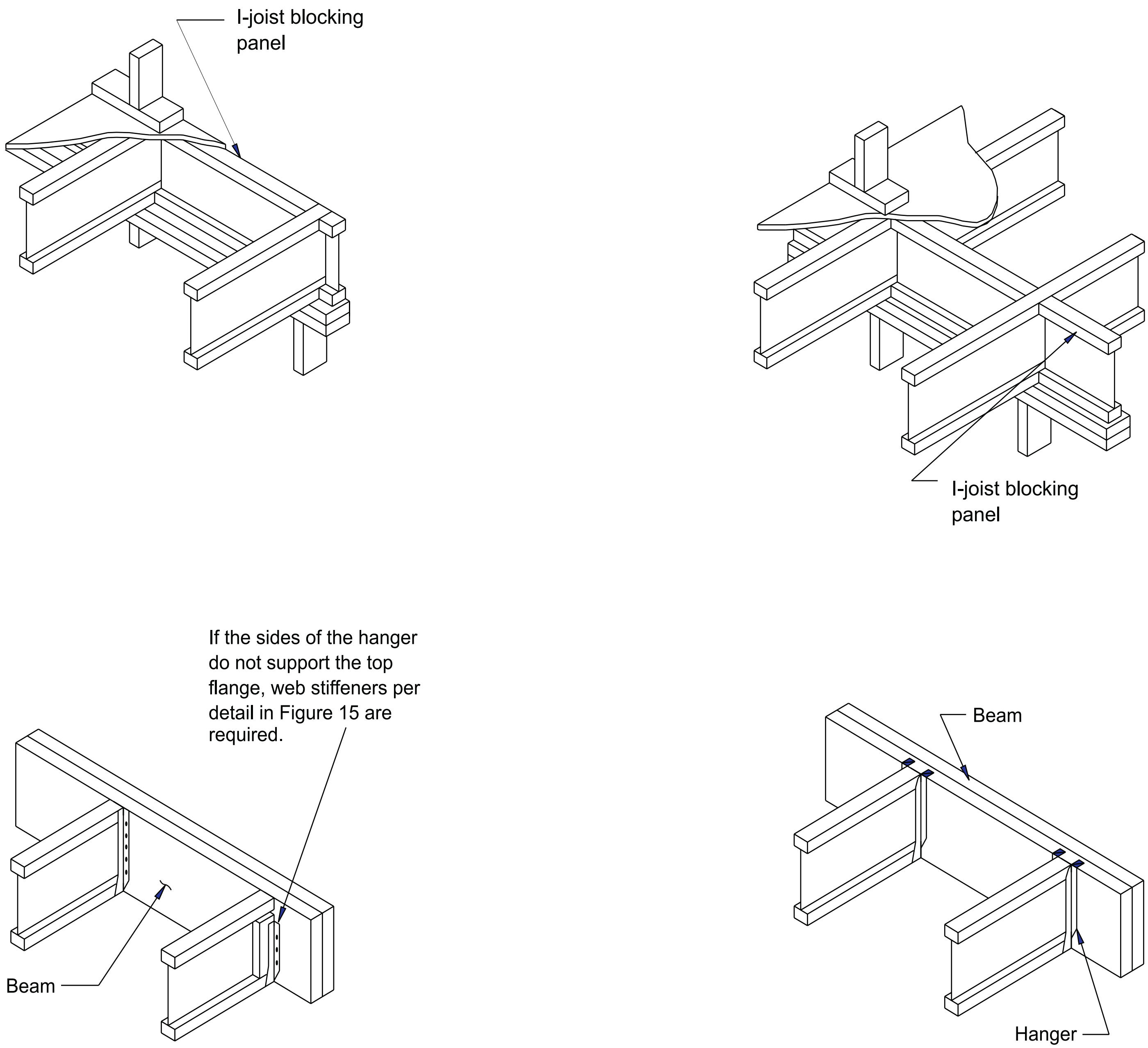


Figure 17 Representative Bearing Details