# AITC TECHNICAL NOTE 19

# GUIDELINES FOR EVALUATION OF DRILLED HOLES AND NOTCHES IN STRUCTURAL GLUED LAMINATED TIMBER BEAMS

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## AMERICAN INSTITUTE OF TIMBER CONSTRUCTION

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### SCOPE

This technical note has been developed to assist engineers, architects, building officials and others in evaluating the effects of notches and drilled holes in structural glued laminated timber beams. These guidelines are applicable to holes that are to be used to provide access ("open") holes and are not applicable to holes drilled for mechanical fasteners or connectors. Specifically, the guidelines are for simply supported single span beams carrying uniform gravity (vertical) loads perpendicular to the wide faces of the laminations. The evaluation of drilled holes and notches in other glued laminated members and beams with other support or load conditions is discussed briefly. Furthermore, these guidelines shall only apply to round holes and to the specific notch types described herein.

### INTRODUCTION

Glued laminated timbers are typically used in highly stressed engineering applications. The design of glued laminated timber beams is governed by the *Timber Construction Manual* (Reference 1). Since glued laminated timbers are typically used in highly stressed applications, it is very important that these members not be drilled or notched in any manner that would adversely affect their intended structural performance. Drilled holes and notches produce stress concentrations and tension stresses perpendicular to grain. As such, particular attention shall be given to holes and notches in portions of beams highly stressed in tension parallel to grain, and/or shear parallel to grain.

Approved engineered shop drawings should detail all drilled holes and notches. Prescriptive limitations for horizontal holes are included in this document. When such drawings do not exist or prescriptive limitations are exceeded, all drilled holes and notches must be approved by the Engineer of Record or an engineer or architect qualified in engineered timber design.

### EVALUATION GUIDELINES

Limited horizontal holes in glued laminated timbers are allowed in regions of the beam that typically experience relatively low tension and/or shear stress. Horizontal holes in any of the higher stress zones, and all vertical holes, require special consideration and shall be approved by the Engineer or Architect of Record or Engineer or Architect qualified in timber design. Notches of limited shape, size, and location are allowed only if the reduced member section is still adequate to carry design loads with particular consideration of the shear stresses modified by the notch.

In the structural evaluation of the effects of drilled holes and notches, the suitability of the member and existence of any excess capacity must first be verified. Particular evaluation considerations for holes and notches are described in more detail in the following sections.

## HOLES

The holes described herein are those drilled through glued laminated timbers to accommodate the passage of electrical conduit, sprinkler lines or small diameter plumbing or other lines. Holes for mechanical fasteners and holes that transfer significant loads to the beam must be evaluated separately

### *Horizontal Holes (Prescriptive Limitations)*

Drilled horizontal holes in uniformly loaded, simply supported beams are allowed in the zones NOT identified as Critical (Figure 1) with the following limitations:

1. Holes must be a minimum of 4 hole diameters from the top or bottom surface of the beam and a minimum of 8 hole diameters from the end of the beam. The distance is measured from the edge of the hole to the nearest edge of the beam.
2. Maximum hole size is 1-1/2" diameter or a hole diameter equal to 1/10 the beam depth, whichever is smaller.
3. Maximum Number of Holes: The number of holes (not including holes related to connections) shall not exceed one hole per each 5 feet length of the member (i.e. 4 holes in a 20 foot member). (This rule does not apply to spacing of holes.)
4. Spacing between holes shall be a minimum of 8 hole diameters (based on the largest diameter of any adjacent hole in the member) from any other hole in the member. The distance is measured between the nearest edges of adjacent holes.

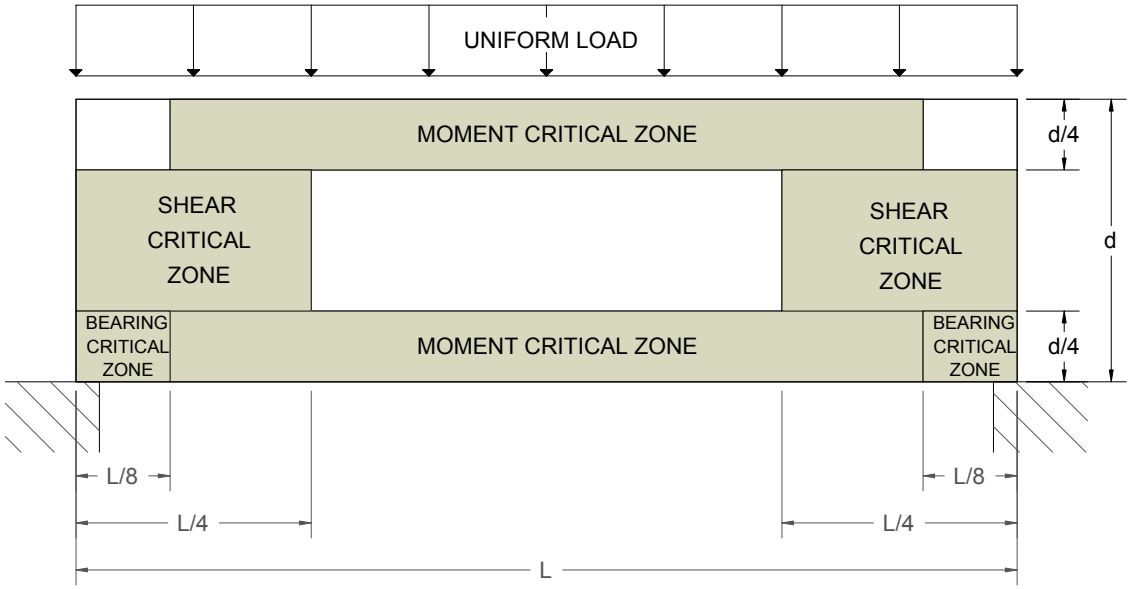


**Figure 1.** *Critical Zones in a Uniformly Loaded, Simply Supported Beam*

### *Horizontal Holes (Critical Zones)*

Horizontal holes in any of the Critical Zones must be approved by the Engineer of Record or Engineer or Architect qualified in Timber Design. The evaluation of the effects of the holes must consider of the effect of reduced member section, stress concentrations produced at the holes, as well as potential failure modes (splitting).

### *Vertical Holes*

A vertical hole reduces the net width of the beam at the location of the hole and may significantly reduce the beam's bending and shear strength. Prior to drilling any vertical holes, a qualified engineer or architect shall be consulted.

It is recommended that drilling vertical holes in glued laminated horizontal beams be avoided whenever possible. Not only is there a reduction in section properties at the vertical hole, there are also stress concentrations due to the discontinuity of the wood fibers at the hole. The following steps shall be taken in the evaluation of vertical holes:

1. The section modulus at the vertical hole shall be based on the width of the member minus 1.5 times the hole diameter.
2. The maximum extreme fiber stress in bending for the reduced section modulus (Step 1) shall not exceed the allowable extreme fiber stress in bending.
3. The area for the determination of shear parallel to grain (horizontal shear) at the vertical hole shall be the net section at the hole.
4. The minimum edge distance from either side of the member to the center of the vertical hole shall be 3 times the diameter of the hole.

## NOTCHES

These guidelines apply only to simply supported, single span, horizontal beams and not to sloped members such as roof rafters. AITC 104 *Typical Construction Details* (Reference 2) should be consulted for information regarding sloped beams or rafters.

### *Tension Face Notches*

A decrease in strength is caused by stress concentrations induced at the corner of the notch as well as a reduction of the section available to resist the design stresses. Notches also induce tension perpendicular to grain stresses that interact with the shear parallel to grain forces causing a tendency for the member to split along a line extended from the corner of the notch. **This type of notch should be avoided whenever possible. Under no circumstances should a simple span glued laminated timber beam be notched on the tension face other than at an end bearing.**

Where a notch on the tension face cannot be avoided, and recognizing that certain field conditions require notching the member on the tension face at end bearings as illustrated by Figure 2, the shear stress at the notch shall be calculated using Equation 1. The depth of a tension side notch is limited to a maximum of 1/10 the depth of the member, not to exceed 3 inches.

$$f_v = \frac{3R_v}{2bd_e}\left(\frac{d}{d_e}\right)^2 \le F_v' \qquad \textbf{Equation 1.}$$

where: $f_v$ = the calculated horizontal shear (psi) modified for the notch,
$R_V$ = the design vertical end reaction (lb),
$b$ = the width of beam (in),
$d$ = the depth of beam (in),
$d_e$ = the depth of the beam less the depth of the notch, and
$F_v'$ = the allowable horizontal shear stress.

Note: A gradual tapered notch configuration in lieu of a square cornered notch or mechanical reinforcing at square cornered notches may be used to reduce the effects of stress concentrations at the reentrant corner of notches. The notch should be cut from the face of the beam to a drilled hole as shown in Figure 2.

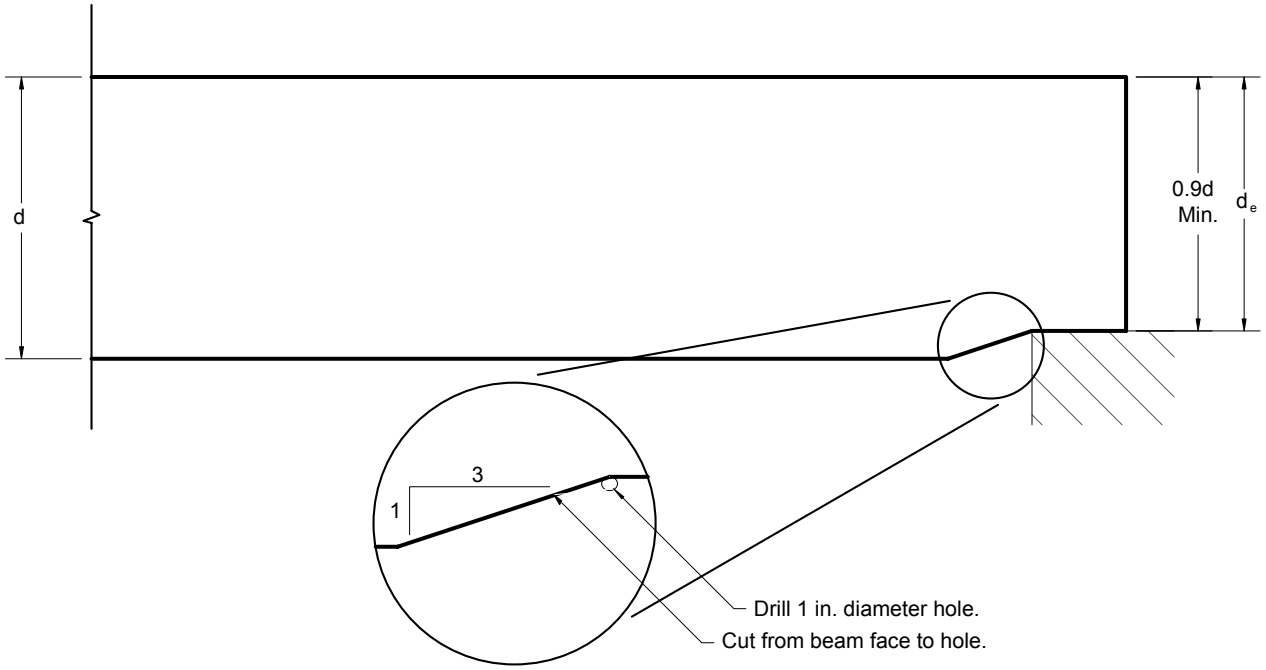


**Figure 2.** *End Bearing Notch Detail*

The bearing capacity of the exposed wood should be evaluated. Tabular design values for bearing (compression perpendicular to grain) for glued laminated timbers are based on the relatively higher grade bottom lamination(s). Where notches at end bearing have removed the higher grade bottom lamination(s), consideration should be made for the reduced bearing capacity of the remaining wood.

***Compression Face Notches at Ends***

In some instances, it may be necessary to notch a beam on its compression face at the end of the member. Limitations on such notches are shown in Figure 3. For the conditions shown, the shear stress parallel to grain shall be calculated using the appropriate equation below:

$$f_V = \frac{3R_V}{2b\left(d - \left(\frac{d-d_e}{d_e}\right)e\right)} \le F_v' \qquad \text{when: } e \le d_e \qquad \textbf{Equation 2}.$$

$$f_V = \frac{3R_V}{2bd_e} \le F_v' \qquad \text{when: } e > d_e \qquad \textbf{Equation 3.}$$

where: $f_v$, $R_v$, b , d, $d_e$, and $F_v'$ are defined with Equation 1, and
e = the distance from the inner edge of the closest support to the farthest edge of the notch (in).

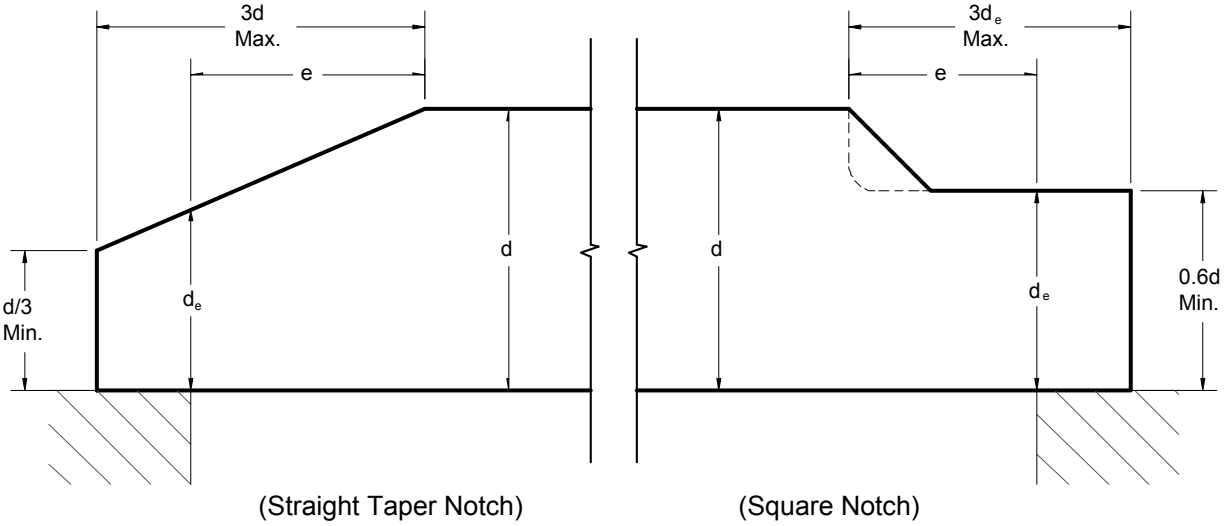


**Figure 3.** *Notch Restrictions on Compression Face at Ends*

***Compression Face Notches Away from Ends***

Occasionally, it is necessary to cut a notch across the width of the top of a glued laminated timber member to provide for passage of a small diameter plumbing or conduit run. Such notches shall only be cut in areas that are stressed to less than 50% of the allowable flexural stress. Member stresses shall be checked based on the reduced cross section resulting from the notch. Due to removal of high grade lumber at the surfaces, notching will also cause a reduction in allowable bending stresses. A preferred method for providing required passage for pipes, conduit, etc. is to mechanically attach additional (non-structural) laminations of depth equal to or greater than the desired notch. In this way the additional material is `notched' leaving the original structural member unaffected.

***Notches for Hangers***

**Cantilevered hinge connections** The necessity to provide for the flush fit of a cantilever hinge connector is a commonly encountered field situation that requires the cutting of a notch or dap. For cantilever hinge connectors, the notch is limited to the thickness of the steel plate.

**Top mount saddle type hangers** AITC recommends that glued laminated members not be dapped at top mounted hangers when the thickness of the metal is such that is does not interfere with the installation of the floor or roof sheathing or decking. If dapping is necessary, the dap shall only be cut in zones of compression stress and shall be limited to the thickness of the metal.

In all cases of dapping a glued laminated beam to accommodate a metal hanger, the designer must check the member stresses based on the reduced section modulus resulting from the dap.

## OTHER CONSIDERATIONS

**Pressure treatment** If it is necessary to notch or drill a glued laminated timber that has been pressure impregnated with a preservative treatment, all cut surfaces shall receive a field treatment of preservative. One commonly used field preservative treatment is copper naphthenate. AWPA M4 (Reference 3) contains information and requirements for field treating.

## OTHER STRUCTURAL APPLICATIONS

This Technical Note addresses the drilling and notching of glued laminated timber beams. However, similar considerations and limitations should be applied with respect to drilled holes and notches in any glued laminated timber member such as columns, arches, and truss members

## OTHER LOADING AND SUPPORT CONDITIONS

### *Non-Uniformly Distributed Loads*

For non-uniform loading conditions, a qualified engineer shall be consulted for evaluation and approval of holes and notches.

### *Continuous and Cantilevered Spans*

All holes and notches in glued laminated timber for continuous or cantilevered spans, subject to any loading conditions, shall be evaluated and approved by a qualified engineer. The engineer may choose to designate critical zones (dimensioned as appropriate) where field drilling is not allowed with a drawing similar to Figure 4.

Generally, continuous span or cantilever span beams should not be notched in the top of the member over the support where negative moments exist nor on the bottom side of the member in the mid span area of positive moments . Holes shall not be drilled in any zone designated as a critical zone in Figure 4 unless specifically evaluated and approved by the Engineer of Record or qualified Engineer or Architect.

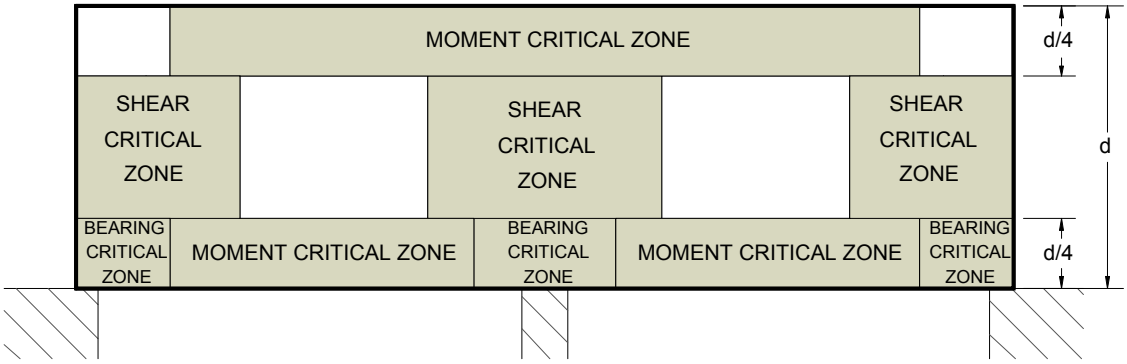


**Figure 4.** *Critical Zones in Multi-Span Beam*

## HOLES FOR MECHANICAL FASTENERS AND CONNECTORS

For the installation of glued laminated timber, it is often necessary to drill holes in the member to attach connection hardware. *AITC Standard 104, Typical Construction Details* (Reference 2) illustrates and describes various connections commonly used. AITC 104 also indicates certain connection details that should be avoided. Two specific types of connection details to be avoided are:

1. those which will induce tension perpendicular to grain stress in the member.
2. connections that will restrain the member from its natural tendency to change dimension (shrinking or swelling) when subjected to changes in moisture content. In most applications, dimensional changes are relatively small for glued laminated members, but must be considered in a proper design.

The design, fabrication, and installation of mechanical fasteners and connector hardware is governed by the *National Design Specification for Wood Construction* and the *Manual of Steel Construction* (References 4 and 5).

## SUSPENDED EQUIPMENT SUPPORT

The necessity to provide support for building elements such as for suspended conduit, plumbing lines, mechanical units or ceiling fans is frequently encountered in the field. Such imposed loads should be suspended in such a manner that the load is applied to the top of the member (Figure 5) to avoid introducing tension perpendicular to grain stresses (load transferred through horizontal holes drilled in beam).

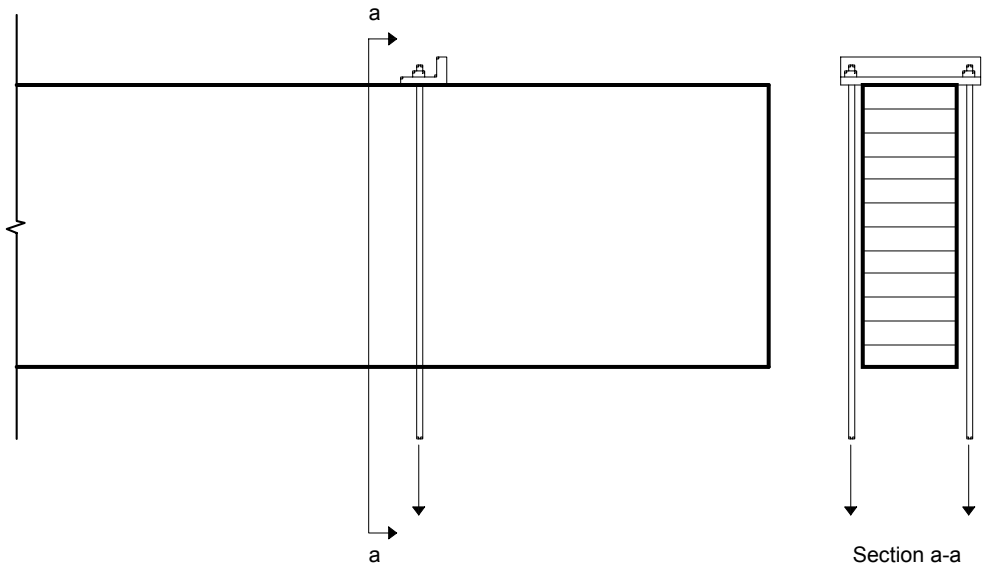


**Figure 5.** *Connection Detail for Suspending Heavy Loads*

For horizontal holes carrying light loads such as small plumbing lines or electrical conduit, fasteners shall be positioned at least 25% of the depth or 4 laminations, whichever is greater, away from the tension face of the member. If it is necessary to drill horizontal holes for the support heavier loads, such as plumbing lines, mechanical units or other suspended loads, the holes should be located in the compression zone of the member and in a zone stressed to not greater than 50% of the design flexural stress. All effects of these added loads shall be considered in the design verification of the member.

## REFERENCES

1. *Timber Construction Manual*, American Institute of Timber Construction, 7012 S. Revere Parkway, Suite 140, Englewood, CO 80112.

2. AITC 104-84, *Typical Construction Details*, American Institute of Timber Construction, 7012 S. Revere Parkway, Suite 140, Englewood, CO 80112.

3. AWPA M4-95 *Standard for the Care of Preservative-Treated Wood Products*, American Wood-Preservers Association, P.O. Box 286, Woodstock, MD 21163-0286.

4. *The National Design Specification for Wood Construction*, American Forest & Paper Association, 1111 19th Street, N.W., Suite 800, Washington, D.C. 20036.

5. *Manual of Steel Construction*, American Institute of Steel Construction, 1 East Wacker Drive, Suite 3100, Chicago, Illinois 60601.

## RECOMMENDED READING

AITC Technical Note No. 11, *Checking in Glued Laminated Timber*, American Institute of Timber Construction 7012 S. Revere Parkway, Suite 140, Englewood, CO 80112.

AITC Technical Note No. 18*, Evaluation of Checking in Glued Laminated Timbers*, American Institute of Timber Construction. 7012 S. Revere Parkway, Suite 140, Englewood, CO 80112.

*"Design Criteria for Notched Wood Beams",* Greg C. Foliente, Thomas E. McLain, and Frederick C. Pneuman, Journal of Structural Engineering, September 1992, ASCE, New York, NY.