AITC TECHNICAL NOTE 18

EVALUATION OF CHECKING IN GLUED LAMINATED TIMBERS

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INTRODUCTION

As discussed in detail in AITC Technical Note No. 11, *Checking in Glued Laminated Timber*, checks in wood are separations along the fibers occurring across the annual growth rings resulting from stresses developed during reductions in moisture content, with the effect being most prevalent if drying is rapid. Wood adjusts to an equilibrium moisture content in balance with the humidity of the surrounding atmosphere. The equilibrium moisture content (EMC) varies with the temperature and relative humidity of the surrounding air with relative humidity having the greatest effect. The EMC of wood at varying relative humidities and temperatures is given in **Table 1**.

In glued laminated timber, the individual laminations are dried prior to gluing so that the finished member more closely approximates the equilibrium moisture content expected to exist in service. This reduces checking in glued laminated timber.

STRUCTURAL SIGNIFICANCE

Seasoning checks have limited effect on the strength of glued laminated timbers. In bending members, checks affect only the horizontal shear strength and are not of structural importance unless the checks are significant in depth or occur near mid-height of the member near its support. In compression members, checks are not of structural importance unless they develop into a split that increases the slenderness ratio of the member. If a preliminary inspection indicates that checks appear to fit either of these structural situations, a detailed evaluation should be performed by a qualified design professional.

FIELD INSPECTION

Using a feeler gauge or other similar probe, the depth of all checks thought to be significant should be measured. A sketch should be prepared locating each check indicating its length, depth and width. Carefully mark the ends of the checks on the members and record the date of observation to allow monitoring of subsequent changes.

Measure the moisture content of the member at the time of inspection to determine the magnitude of drying which has occurred in relationship to the original "as installed" moisture content (if known) and to the expected equilibrium moisture content. These measurements should be taken at the surface and at some depth of the member using a resistance type moisture meter to establish a moisture gradient. An assessment of surrounding conditions such as location of heat ducts or unit heaters, or exposure to direct wetting and drying by the elements, or other environmental conditions which might lead to moisture cycling in the member should be made to determine if additional checking may be expected.

Table 1. *Equilibrium moisture content (%) for various temperature and relative humidity conditions.*

Temperature		Relative Humidity																		
^{0}C	^{0}F	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
-1.1	**30**	1.5	2.5	3.5	4.5	5.5	6.5	7.0	8.0	8.5	9.5	10.5	11.5	12.5	13.5	15.0	16.5	18.5	21.0	24.5
4.4	**40**	1.5	2.5	3.5	4.5	5.5	6.5	7.0	8.0	8.5	9.5	10.5	11.5	12.5	13.5	15.0	16.5	18.5	21.0	24.5
10.0	**50**	1.5	2.5	3.5	4.5	5.5	6.5	7.0	8.0	8.5	9.5	10.5	11.0	12.5	13.5	15.0	16.5	18.5	21.0	24.5
15.6	**60**	1.5	2.5	3.5	4.5	5.5	6.5	7.0	8.0	8.5	9.5	10.0	11.0	12.0	13.5	14.5	16.0	18.0	20.5	24.0
21.1	**70**	1.5	2.5	3.5	4.5	5.5	6.0	7.0	7.5	8.5	9.0	10.0	11.0	12.0	13.0	14.5	16.0	18.0	20.5	24.0
26.7	**80**	1.5	2.5	3.5	4.5	5.5	6.0	7.0	7.5	8.5	9.0	10.0	11.0	12.0	13.0	14.0	15.5	17.5	20.0	23.5
32.2	**90**	1.0	2.5	3.5	4.5	5.0	6.0	6.5	7.5	8.0	9.0	9.5	10.5	11.5	12.5	14.0	15.5	17.5	20.0	23.5
37.8	**100**	1.0	2.5	3.5	4.0	5.0	6.0	6.5	7.0	8.0	8.5	9.5	10.5	11.0	12.5	13.5	15.0	17.0	19.5	23.0
43.3	**110**	1.0	2.0	3.0	4.0	5.0	5.5	6.5	7.0	7.5	8.5	9.0	10.0	11.0	12.0	13.0	14.5	16.5	19.0	22.5
48.9	**120**	1.0	2.0	3.0	4.0	4.5	5.5	6.0	7.0	7.5	8.0	9.0	10.0	10.5	11.5	13.0	14.5	16.0	18.5	22.0
54.4	**130**	1.0	2.0	3.0	3.5	4.5	5.0	6.0	6.5	7.5	8.0	8.5	9.5	10.5	11.5	12.5	14.0	16.0	18.0	21.5
60.0	**140**	1.0	2.0	3.0	3.5	4.5	5.0	5.5	6.5	7.0	7.5	8.5	9.0	10.0	11.0	12.0	13.5	15.5	17.5	21.0
65.6	**150**	1.0	2.0	2.5	3.5	4.0	5.0	5.5	6.0	6.5	7.5	8.0	9.0	9.5	10.5	12.0	13.0	15.0	17.0	20.5

Values were calculated using Equation 3-3, Wood Handbook: Wood as an Engineering Material, 1999, FPL-GTR-113.[4]
See Chapter 3, Wood Handbook for further information. Values have been rounded to nearest 0.5%.

STRUCTURAL ADEQUACY EVALUATION

Compression Members

If an inspection verifies that a check has become a split, the structural integrity of the member should be re-evaluated based on the new slenderness ratio (ℓ/d) resulting from the split. A split is a lengthwise separation of the wood extending from one surface of the piece through to the opposite surface or through to the adjacent surface. It is noted that it is unlikely that a split would occur over the full length of a compression member such as a column. Typically, the split will only develop over a partial length of the member. For example, assume that a split approximately 7 ft long develops across the narrow width of a 6-3/4 in. x 9 in. column such that the least dimension of the member along the split is 3 inches (**Figure 1**). For the original section, with an assumed effective length of 12 ft, the ℓ/d ratio is 21.33 (i.e. 144 in./6.75 in.). However, after the split has occurred, the ℓ/d ratio for the split length is 28.0 (i.e. 84in./3in.). Therefore, the load carrying capacity of this member has been reduced. The resultant load capacity, taking the split into account, should be determined and compared to the actual load carrying requirements of the member to determine if reinforcement or other remedial repairs are needed.

Bending Members

Checking can affect the shear strength of bending members by reducing the effective shear resistance area. However, a minor amount of checking will not reduce the beam capacity. Based on experience, judgment, and research, the laminated timber industry recommends no reduction in shear capacity for beams with checks up to 15% of the beam width. In most cases, the effect of seasoning checks in glued laminated timbers can be ignored. The steps to determine the impact of checking on a glued laminated beam are:

1. Determine the effective size of the check.

2. Compare the effective size of the check to the allowed check size at the check location.

3. If effective check size is greater than the allowed check size, calculate a shear stress reduction factor.

4. Determine adequacy of beam under design loads.

Determine Effective Check Size

The size of a side check is defined as its average depth (d_1). No guidelines are given for the determination of the average depth of a check. This is left to the judgment of the inspector or designer after consideration of the discussion under the FIELD INSPECTION section of this document.

The effective size of an end check is defined as one third of its average length and can be calculated with the following formula (see **Figure 2**):

$$\ell_0 = \frac{1}{3}\left(\frac{\ell_{01} + \ell_{02}}{2}\right)$$

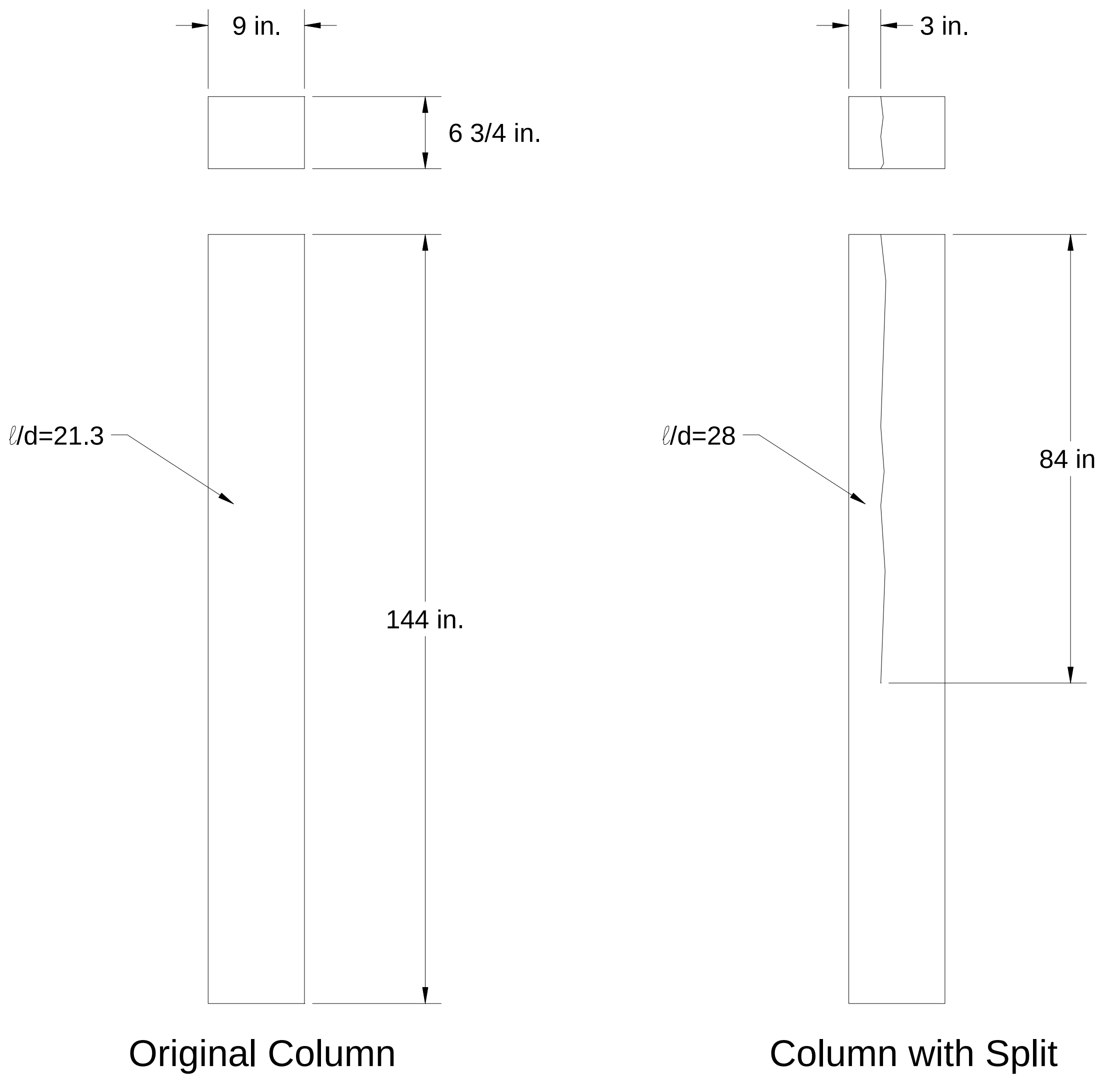

Figure 1. *Effect of split on column slenderness ratio.*

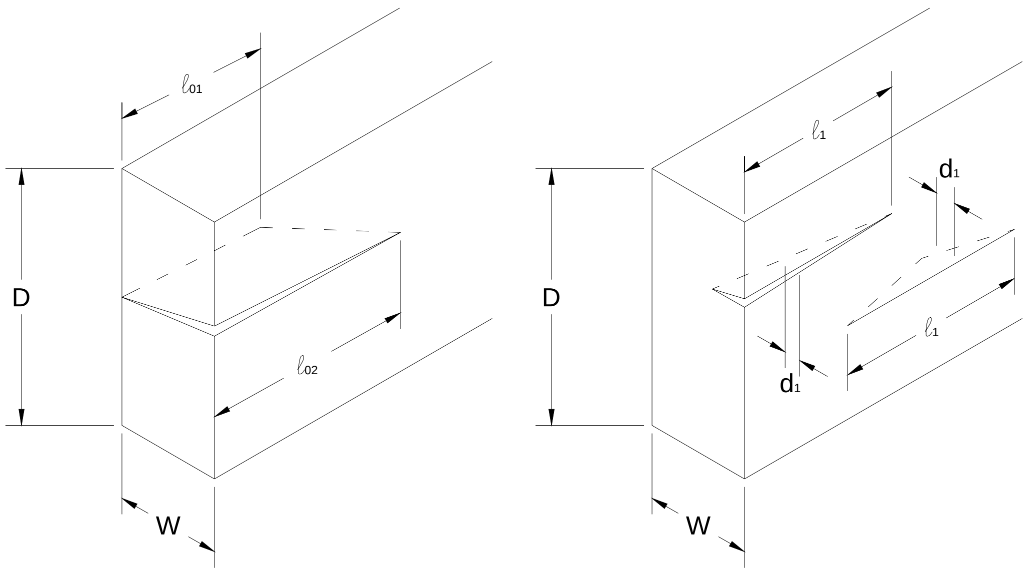

Figure 2. *Determination of effective check size.*

Allowable Check Size

Side checks and end checks are illustrated in **Figure 2.** Allowable check sizes in the shear critical zone are determined with the following equations. The length (ℓ_1) of side checks is not restricted.

$$d_{allowable} = 0.15W \qquad \text{(Side Checks)}$$
$$\ell_{allowable} = 0.15W \qquad \text{(End Checks)}$$

where: W = beam width
$d_{allowable}$ = allowed effective side check size without reduction in shear capacity
$\ell_{allowable}$ = allowed effective end check size without reduction in shear capacity

The shear critical zone is defined as the middle one half of the depth of the beam centered on the neutral axis at any section stressed to 50% or more of the maximum shear produced by the loading configuration. For a simply supported, uniformly loaded beam the shear critical zone is within a distance of ¼ of the span from the support (**Figure 3**). **Table 2** shows the maximum check sizes allowed in the shear critical zone with no reduction in shear capacity for selected beam widths.

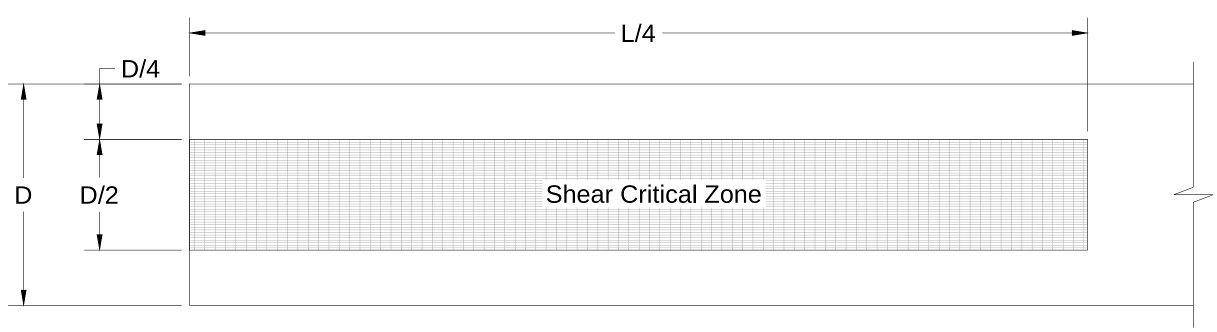

Figure 3. Shear critical zone for a simply supported, uniformly loaded beam.

When the effective check size does not exceed the values in **Table 2**, the full allowable horizontal shear value may be used in design. For check sizes exceeding these values, a reduction in the allowable horizontal shear stress is required based on a ratio of the depth of check to width of member, considering the vertical location of the check in the member.

Table 2. *Allowed check sizes in shear critical zone with no shear capacity reduction.*

Beam Width (W) (in.)	Allowable Check Size (in.)
2 ½	3/8
3, 3 $^{1}/_{8}$, 3 ½	1/2
5, 5 $^{1}/_{8}$, 5 ½	3/4
6 ¾	1
8 ½ , 8 ¾	1-1/4
10 ½ , 10 ¾	1-1/2

Allowable Check Size Outside of Middle Half of Beam Depth

The effective check size (d_1 or ℓ_0), is limited to 0.15W for the center half height of a bending member within a distance L/4 from a support. Check size is allowed to increase to a maximum size of 0.8W at the top and bottom of the member as shown in **Figure 4**. Within the limits described above, no reduction in allowable shear stress is required.

Example (1) Determine Allowable Size of Side Check

Given: 5-1/8 in. x 24 in. beam.
Side check with average depth (d_1) = 2in.
Side check located 3" up from bottom face of beam (9 in. below neutral axis).
No other section reducing characteristics at check location.

Determine: Is the check within the allowed size without reduction of capacity?

Solution:

- Determine the location of the check as a fraction of depth from neutral axis.

$$\frac{y}{D} = \frac{-9\text{ in.}}{24\text{ in.}} = -0.375$$

- Locate this value on the vertical axis of **Figure 4**.

- Follow across horizontally to the diagonal line, then down to the "fraction of beam width" value - this gives a value of 0.56.

- Calculate the allowable depth of the side check at this location.

$$d_{allowable} = 0.56W = 0.56(5.125\text{ in.}) = 2.87\text{ in.}$$
$$d_{allowable} = 2.87\text{ in.}$$

- Compare the effective check size (d_1) to allowable check size ($d_{allowable}$).

$$d_1 = 2\text{ in.} < d_{allowable} = 2.87\text{ in.} \quad \therefore \text{O.K.}$$

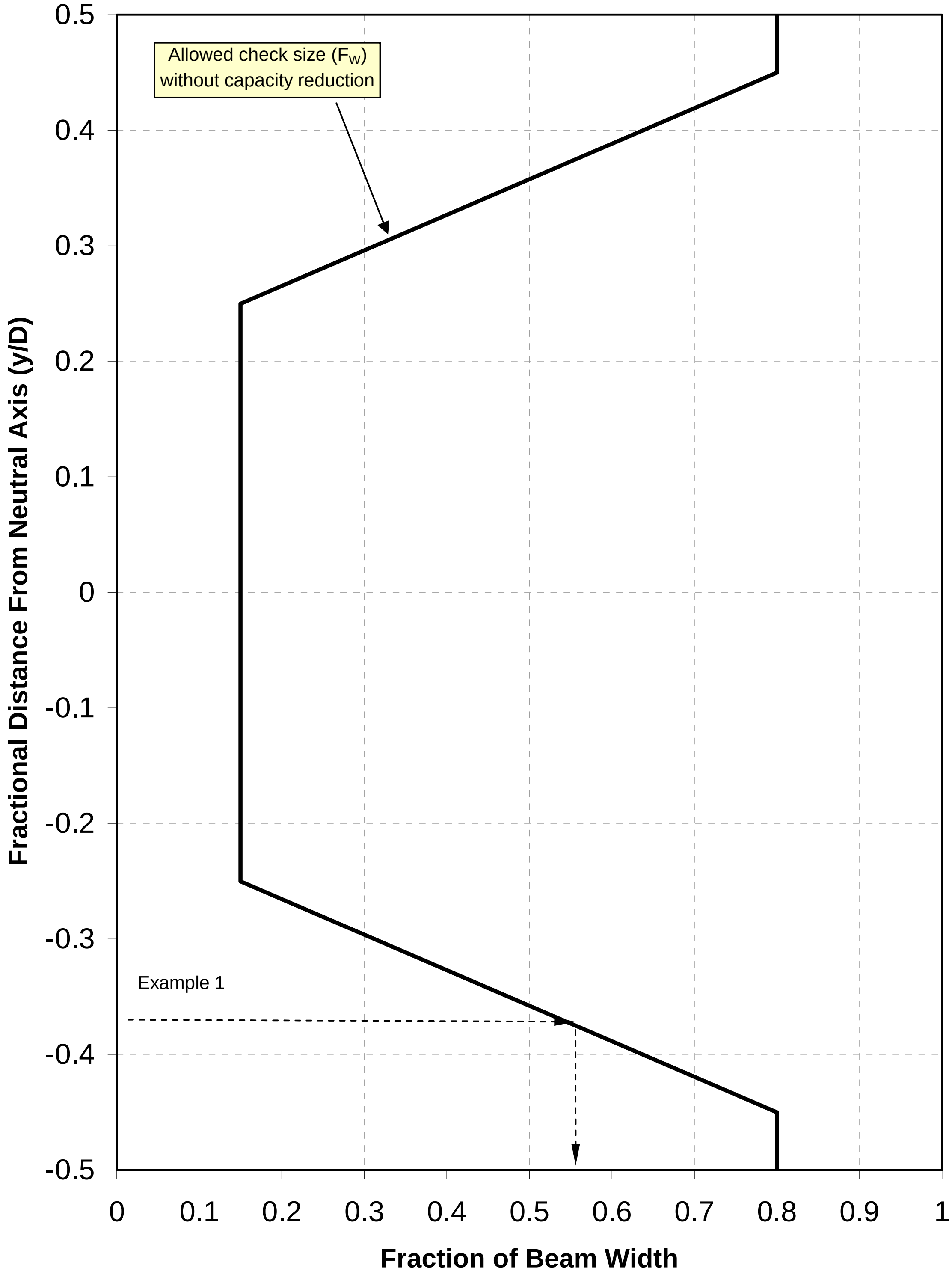

Figure 4. *Allowable check sizes (relative to width) in a glulam cross section without capacity reduction.*

Shear Reduction Factor (C_{VC})

If the size of the observed check exceeds the allowable check size as calculated above, the allowable shear stress in the member must be reduced. The shear reduction factor for checking (C_{VC}) is calculated as follows.

$$C_{VC} = \frac{\left(1 - \frac{s}{W}\right)}{(1 - F_W)} \leq 1.0$$

where: C_{VC} = shear reduction factor for checking
s = effective check size = d_1 or ℓ_0
W = beam width
F_W = allowed check size without capacity reduction

$$F_W = 0.15 \quad \text{for} \quad 0 \leq \left|\frac{y}{D}\right| \leq 0.25$$

$$F_W = 3.25\left(\left|\frac{y}{D}\right|\right) - 0.66 \quad \text{for} \quad 0.25 < \left|\frac{y}{D}\right| \leq 0.45$$

$$F_W = 0.8 \quad \text{for} \quad 0.45 < \left|\frac{y}{D}\right| \leq 0.50$$

Example (2): Calculate Shear Reduction Factor

Given:
- Beam dimensions:
  W = 5 $^1/_8$ in.
  D = 24 in.
  L = 28 ft
- Side check as shown in Figure 5.
  Maximum depth = 3 in.
  Minimum depth = 0 in.
  Length = 16 in.
- Distance from bottom of beam to check = 10 ½ in.

Wanted:
- Determine effective check size.
- Determine allowable check size without capacity reduction.
- Calculate shear reduction factor.

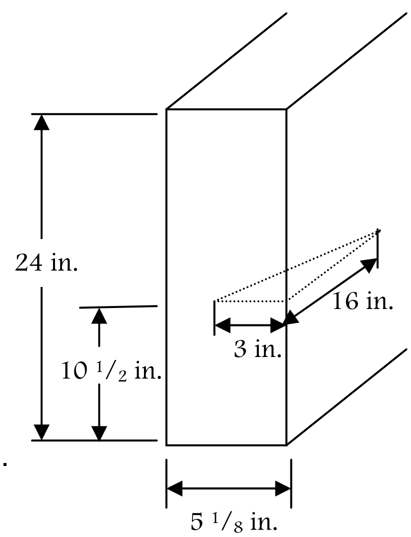

Figure 5. Illustration for Example 2

Solution:

Determine check size

$$d_1 = \frac{3\,\text{in.} + 0\,\text{in.}}{2}$$

$$d_1 = 1.5\,\text{in.}$$

Determine location of check in terms of fraction of depth from neutral axis

$$\frac{y}{D} = \frac{1.5}{24} = 0.0625$$

Because y/D < 0.25, the check is in the shear critical zone, therefore…

$$d_{allowable} = 0.15W$$
$$d_{allowable} = 0.15(5.125\text{ in.})$$
$$d_{allowable} = 0.77\text{ in.}$$

Compare check size to allowable check size

$$d_1 = 1.5\text{ in.} \geq d_{allowable} = 0.77\text{ in.} \qquad \therefore \text{Shear capacity must be reduced.}$$

Calculate shear reduction factor

$$F_W = 0.15$$

$$C_{VC} = \frac{\left(1 - \frac{s}{W}\right)}{\left(1 - F_W\right)} = \frac{\left(1 - \frac{1.5\text{ in.}}{5.125\text{ in.}}\right)}{\left(1 - 0.15\right)}$$
$$C_{VC} = 0.83$$

Determine Adequacy of Beam

For a given loading, the maximum shear stress at any cross section along the length of a beam can be determined using principles of mechanics of materials. The maximum shear stress in the cross section at the location of deep checks should be compared to the reduced allowable shear stress, with the following design requirement:

$$F_V^* C_{VC} \geq f_V$$

where: F_V* = Tabulated design value for shear multiplied by all applicable adjustment factors except C_{VC}.
C_{VC} = Shear reduction factor for checks.
f_V = Shear stress at neutral axis in cross section at check location.

REFERENCES

1. AITC. 1987. *Checking in Glued Laminated Timber, Technical Note No. 11.* American Institute of Timber Construction. Englewood, Colorado.

2. AITC. 1979. *Recommended Practice for Protection of Structural Glued Laminated Timber During Transit, Storage and Erection*, *AITC 111-79.* American Institute of Timber Construction. Englewood, Colorado.

3. USDA. 1999. *Wood Handbook: Wood as an Engineering Material*. FPL-GTR-113. U.S. Department of Agriculture. Forest Products Laboratory. Madison, Wisconsin.

4. Peterson, J. N. 1995. *Shear Strength of Checked and Split Southern Pine Lumber*. Master's Thesis. Washington State University. Pullman, Washington.

5. Murphy, J. F. 1980. Strength of Wood Beams with Side Cracks. Prepared for International Union of Forestry Research Organizations Timber Engineering Group s5.02. Oxford, England. Available from USDA Forest Products Laboratory, Madison, Wisconsin.