Calculating Fire Resistance of Glulam Beams and Columns

Number EWS Y245B
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INTRODUCTION

Glulam beams and columns provide architectural warmth and beauty along with structural strength and natural fire resistance. In the presence of fire, the outer portion of a glulam member becomes charred. This layer of charred wood then functions as an insulator, helping to protect the undamaged interior of the member from the heat. The rate of advancement of this insulating char layer into the remaining, undamaged portion of the member has been well documented (approximately 0.025 inches [0.6 mm] per minute) and forms the theoretical basis of the equations used to predict fire endurance.[1] Full-scale fire tests on loaded beams and columns[2] have confirmed the validity of the equations in predicting their load-carrying capability under fire conditions and the method is recognized by the International Building Code (IBC).

DESIGN METHODOLOGY

Calculation of the ability of a glulam beam or column to resist fire for up to one hour is described in the 2009 International Building Code (IBC), Section 721.6. The equations apply to members with fire on three or four sides.

Beams:

Fire on 3 sides $\quad t = 2.54ZB\left[4 - \dfrac{B}{D}\right]$ ....(1)

Fire on 4 sides $\quad t = 2.54ZB\left[4 - \dfrac{2B}{D}\right]$ ....(2)

Columns:

Fire on 3 sides $\quad t = 2.54ZB\left[3 - \dfrac{B}{2D}\right]$ ....(3)

Fire on 4 sides $\quad t = 2.54ZB\left[3 - \dfrac{B}{D}\right]$ ....(4)

Where:

t = fire resistance in minutes

Z = partial load compensation factor (see Figure 3) which is a function of applied load to design capacity

B = the breadth or width of a beam or the smaller dimension of a column (in.) (see Figure 1)

D = the depth of a beam or the larger dimension of a column (in.) (see Figure 1)

(1) Lie, T. T., 1977. A method for assessing the fire resistance of laminated timber beams and columns. Fire Research Section, Division of Building Research, National Research Council of Canada, Ottawa, Ont., Canada.

(2) Fackler, J. P., 1961. Essais de résistance au feu. Centre Scientifique et Technique du Bâtiment, Cahier 415, et al.

APA

These equations apply to glulams with a minimum nominal size of six inches by six inches before exposure to fire. Equation 3 is accurate only when the smallest dimension (B) is the side not exposed to the fire. When a beam or column is partially recessed into a wall, floor or ceiling, the full dimension of the member, including the portion of the column recessed into the wall, floor or ceiling may be used in the calculations to obtain the maximum calculated fire resistance.

Equations 3 and 4 are slightly altered from the way they appear in the IBC. In the column equations, the dimensions B and D are reversed to maintain consistency and clarity of notation on glulam beams and columns (see Figure 1). B is assumed to be the narrowest dimension of the column (weak axis buckling).

Tables 1a, 1b and 1c show the minimum dimensions of a glulam member that will provide 100 percent design capacity and one-hour fire protection. These tables have been generated using Equations 1–4.

Beams and columns with dimensions less than those shown in Tables 1a, 1b and 1c, but at least 6 inches by 6 inches nominal size, may meet the requirements for one-hour fire resistance when the member is over-designed for the applied load. This principle is demonstrated in the design examples that follow.

SPECIFYING A ONE-HOUR FIRE-RATED GLULAM

Tension laminations of glulam beams are always positioned as the outermost laminations of the beam subjected to maximum tension stresses, and in a fire, the outermost fibers in a wood member are the first to be damaged. For this reason, when a one-hour rating is required for a glulam beam, the designer should specify one additional tension lamination in place of a core lamination (see Figure 2) and the glulam should be marked "Fire-rated one-hour" by the manufacturer. For a balanced beam layup, an additional tension lamination should be added to both outer zones. An additional tension lamination is not required for columns and arches.
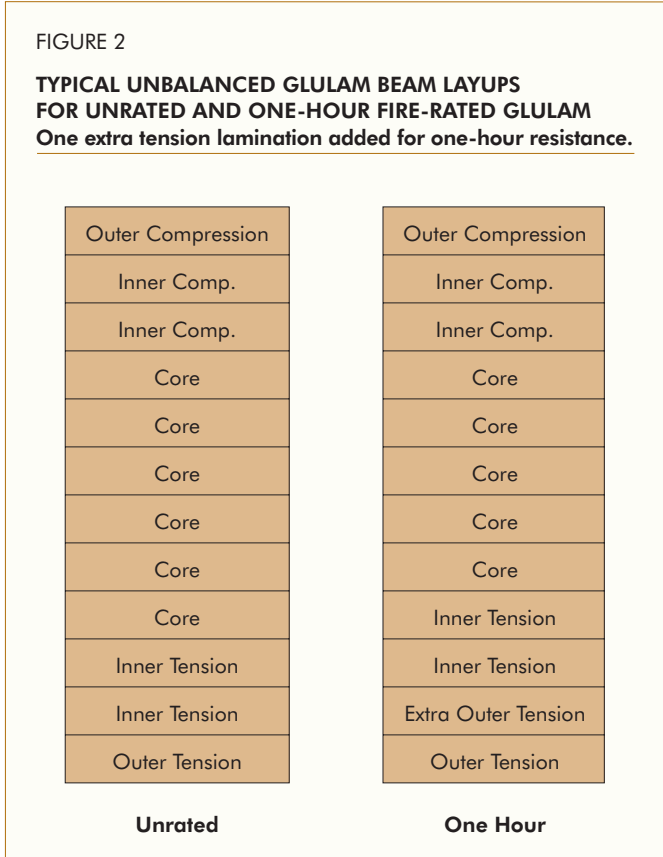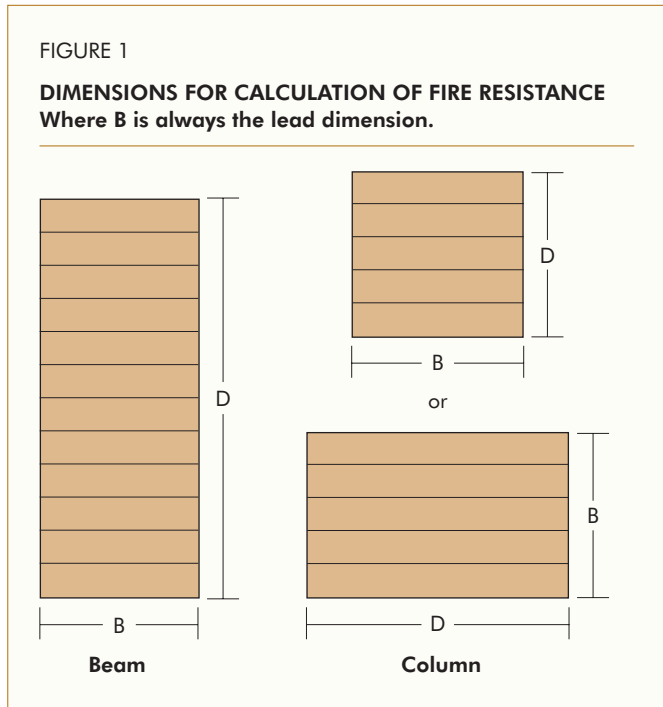

FIGURE 1

DIMENSIONS FOR CALCULATION OF FIRE RESISTANCE
Where B is always the lead dimension.

Beam

Column

FIGURE 2

TYPICAL UNBALANCED GLULAM BEAM LAYUPS
FOR UNRATED AND ONE-HOUR FIRE-RATED GLULAM
One extra tension lamination added for one-hour resistance.

Unrated	One Hour
Outer Compression	Outer Compression
Inner Comp.	Inner Comp.
Inner Comp.	Inner Comp.
Core	Core
Core	Core
Core	Core
Core	Core
Core	Core
Core	Inner Tension
Inner Tension	Inner Tension
Inner Tension	Extra Outer Tension
Outer Tension	Outer Tension

TABLE 1a

Member Type	Beam									
Fire Exposure	Fire Three Sides					Fire Four Sides				
Beam Width (in.)	6-3/4	8-1/2	8-3/4	10-1/2	10-3/4	6-3/4	8-1/2	8-3/4	10-1/2	10-3/4
Minimum Depth (in.): 1-1/2" thick Laminations	13-1/2	–	7-1/2	–	6	27	–	13-1/2	–	12
Minimum Depth (in.): 1-3/8" thick Laminations	13-3/8	6-7/8	–	6-7/8	–	27-1/2	13/3-4	–	12-3/8	–

TABLE 1b

Member Type	Column							
Fire Exposure	Fire Three Sides*							
$K_e l/d$ Condition[a]	≤ 11				> 11			
Column Width (in.)	8-1/2	8-3/4	10-1/2	10-3/4	8-1/2	8-3/4	10-1/2	10-3/4
Minimum Depth (in.): 1-1/2" thick Laminations	–	9	–	7-1/2	–	15	–	10-1/2
Minimum Depth (in.): 1-3/8" thick Laminations	8-1/4	–	8-1/4	–	19-1/4	–	9-5/8	–

*Minimum dimensions are only valid when the unexposed side of the column is the smaller side.
(a) See Figure 8.

TABLE 1c

Member Type	Column							
Fire Exposure	Fire Four Sides							
$K_e l/d$ Condition[a]	≤ 11				> 11			
Column Width (in.)	8-1/2	8-3/4	10-1/2	10-3/4	8-1/2	8-3/4	10-1/2	10-3/4
Minimum Depth (in.): 1-1/2" thick Laminations	–	12	–	10-1/2	–	30	–	13-1/2
Minimum Depth (in.): 1-3/8" thick Laminations	12-3/8	–	9-5/8	–	38-1/2	–	13-3/4	–

(a) See Figure 8.

General Note for Tables 1a, 1b and 1c:
Glulam members having a net width of 8-1/2" or 10-1/2" are typically manufactured using 1-3/8" thick laminations. Glulam members having a net width of 8-3/4" or 10-3/4" are typically manufactured using 1-1/2" thick laminations.

FASTENERS

Because metal fasteners conduct heat directly into the member, exposed fasteners must be given rated protection from fire that is equivalent to that expected of the member. For a one-hour rating, sufficient wood, gypsum wallboard or other material must be applied to protect the exposed portions of the fasteners for one hour. This may be 1-1/2 inches (38 mm) of wood, 5/8 inch (16 mm) Type X gypsum board or other approved material. Example details can be found in Figures 9–14.

DESIGN EXAMPLE 1: GLULAM BEAM FOR ONE-HOUR FIRE RATING IN ACCORDANCE WITH THE 2009 INTERNATIONAL BUILDING CODE

Assume a simply supported roof beam is to span 30 feet, carry 240 lb/ft of total load (dead load plus snow load) and be used in a dry service condition. It is continuously supported along its compression side and will have three sides exposed to fire. A one-hour rating is required. The beam used will be a 24F-V4/DF (Douglas-fir) with the following allowable design stresses:

F_b = 2400 psi

E = 1.8 x 10^6 psi

F_v = 265 psi

What size glulam beam should be used?

From Table 3 of EWS Data File *Glued Laminated Beam Design Tables,* Form EWS S475, select a 5-1/8 x 15 beam with total capacity of 266 plf, which is greater than 240 plf. (Note that the tabulated capacity in EWS S475 has considered the dead weight of the beam.)

Determining the actual beam depth that will continue to carry the design load for one hour is aided by the use of Figure 4, *Beams – Fire 3 Sides.* From this graph, the range of depths that might be practical to use can be anywhere from approximately 12 to 30 inches. Obviously, this beam must be deeper than 15 inches as the beam in this example is stressed to approximately 90 percent of design capacity.

All of the 5-1/8-inch-wide beams in the depth range of 12 to 30 inches will retain 50–60 percent of design capacity after one hour. An initial estimate of a percentage that corresponds with this range of beam depths is 55 percent, which corresponds to a beam depth of 18 inches.

Section modulus, $S = \dfrac{5.125(18)^2}{6} = 276.75$ in.^{3}

Determine if this beam will have sufficient strength left after one hour of fire exposure to continue to carry the design load by determining the ratio of applied moment to design flexural capacity. Beam size will also have to be checked for shear and deflection.

Determine $F_b{'}$

Volume factor $= C_v = \left(\dfrac{12}{D}\right)^{\frac{1}{10}} \left(\dfrac{5.125}{B}\right)^{\frac{1}{10}} \left(\dfrac{21}{L}\right)^{\frac{1}{10}}$

$\qquad\qquad C_v = \left(\dfrac{12}{18}\right)^{\frac{1}{10}} \left(\dfrac{5.125}{5.125}\right)^{\frac{1}{10}} \left(\dfrac{21}{30}\right)^{\frac{1}{10}} = 0.9266$

$F_b{'} = F_b C_D C_v = (2,400)(1.15)(0.9266) = 2,557$ lb/in.^{2}

Determine f_b

Calculate beam weight using 35 lb/ft^3

Beam weight $= \dfrac{(5.125)(18)(12)}{12^3}(35) = 22.4$ lb/ft

$M_{Applied} = w\dfrac{L^2}{8} = (240 + 22.4)\dfrac{30^2}{8} = 29,520$ ft-lb $= 354,240$ in.-lb

$f_b = \dfrac{M}{S} = \dfrac{354,240}{276.75} = 1,280$ lb/in.^{2}

Check the ratio of applied moment to flexural capacity

$$\frac{f_b}{F_b'} = \frac{1,280}{2,557} = 0.50 < 55\% \Rightarrow \textbf{OK}$$

Check fire endurance:

From Figure 3, for a beam loaded to 50% of capacity, Z is approximately 1.3.

Using Equation 1:

$$t = 2.54(1.3)(5.125)\left[4 - \frac{5.125}{18}\right] = 62.9 \text{ minutes} > 60 \Rightarrow \textbf{OK}; \underline{\text{use 5-1/8-inch x 18-inch 24F-V4 Douglas-fir glulam beam.}}$$

This beam has a moment capacity that is significantly greater than is needed if the one-hour fire resistance is not a requirement. In some cases, a wider beam may be required to satisfy a beam depth limitation while still meeting the one-hour fire resistance requirement. For instance, a 6-3/4-inch-wide beam that is 13-1/2-inch deep, and has the extra tension lamination, will carry 100 percent of its design load after one hour of fire exposure on three sides. See Table 1a and Figure 4.

The designer will also need to confirm that the design shear and deflection values for the trial beam size are less than 50 percent of these capacities.

When specifying the beam, advise the manufacturer to eliminate one core lamination and substitute one additional tension lamination (Figure 2) and mark the beam "Fire-rated one-hour."

ALTERNATIVE SOLUTION IN ACCORDANCE WITH THE 2005 NATIONAL DESIGN SPECIFICATION, CHAPTER 16

Step 1: From Table 3 of Data File, *Glued Laminated Beam Design Tables,* Form EWS S475, select a 5-1/8-inch by 15-inch beam with total capacity of 266 plf which is greater than 240 plf (note that the tabulated capacity in EWS S475 has considered the dead weight of the beam).

Step 2: Determine the actual beam depth that will continue to carry the design load when exposed to a one-hour fire as follows:

Step 2a: From Chapter 16 of NDS,

$$\beta_{eff} = \frac{1.2\beta_n}{t^{0.187}}$$

Where:

β_n = nominal char rate of 1.5 in./hr
β_{eff} = effective char rate (in./hr)
t = exposure time (hrs)

Therefore, when t = 1 hr, β_{eff} = 1.8 in./hr

Step 2b: The residual cross section after a one-hour fire exposure on three sides (top of the beam is protected from fire damage) can be calculated as:

$b_{residual} = 5.125 - (1.8 \times 2) = 1.525$ in.
$h_{residual} = 15 - 1.8 = 13.2$ in.
$S_{residual} = 1.525 \times 13.2^2/6 = 44.3$ in.^{3}

Step 2c: The residual moment capacity after a one-hour fire exposure on three sides can be calculated based on Table 16.2.2 of the 2005 NDS.

$M_{residual} = 2.85\ F_b' \times S_{residual} = 2.85 \times 2,400 \times 0.9437 \times 44.3/12 = 23,821$ ft-lb.

Where:

F_b' = adjusted allowable bending stress, including beam volume effect factor, but not the load duration factor.

0.9437 = glulam beam volume effect factor (see Appendix A of EWS S475)

Step 2d: The applied moment due to the 240 lb/ft of total load and the beam weight of 18.7 lb/ft can be calculated as:

$$M_{applied} = \frac{\omega \ell^2}{8} = \frac{(240 + 18.7) \times 30^2}{8} = 29,102 \text{ ft-lb} > 23,821 \text{ ft-lb} \Rightarrow \mathbf{NG}$$

Step 2e: Therefore, the beam size should be increased to accommodate the one-hour fire exposure. Select a 5-1/8-inch by 18-inch beam. From Table 3 of EWS S475, the load carrying capacity of this beam is 470 plf which is greater than 240 plf.

Step 2f: Repeat Steps 2b and 2c for one-hour fire exposure,

$b_{residual} = 5.125 - (1.8 \times 2) = 1.525$ in.
$h_{residual} = 18 - 1.8 = 16.2$ in.
$S_{residual} = 1.525 \times 16.2^2/6 = 66.7$ in.^{3}
$M_{residual} = 2.85\ F_b' \times S_{residual} = 2.85 \times 2,400 \times 0.9266 \times 66.7/12 = 35,213$ ft-lb.
$M_{applied} = \frac{\omega \ell^2}{8} = \frac{(240 + 22.4) \times 30^2}{8} = 29,522 \text{ ft-lb} < 35,213 \text{ ft-lb} \Rightarrow \mathbf{OK}$

Therefore, use a 5-1/8-inch by 18-inch 24F-V4 Douglas-fir glulam beam.

DESIGN EXAMPLE 2: GLULAM COLUMN FOR ONE-HOUR FIRE RATING IN ACCORDANCE WITH THE 2009 INTERNATIONAL BUILDING CODE

An existing building is to be remodeled with a change of occupancy requiring that the glulam columns meet a one-hour fire-resistance requirement. The existing glulam column is 20-foot high, measures B = 8-3/4-inches wide by D = 10-1/2-inches deep and will remain dry in service. It supports a concentrated total floor load (DL + LL) of 50,000 lb. (C_D = 1.0) applied concentrically to the top of the column. The column is not subjected to any lateral loads. From the original specifications, the glulam is a Douglas-fir Combination 2 (see Table 3, Form EWS Y240). Determine if the column is adequate to carry the imposed axial load for one hour with fire on four sides and how long it can be expected to carry the applied load. If it is not adequate, determine what size column is required.

To address these issues, the total load capacity of the column must be determined along with the percentage of the total load capacity used by the applied load and the partial-load compensation factor, Z.

Determine Load Capacity

B = 8.75 in.

D = 10.5 in.

A = B x D = 8.75(10.5) = 91.875 in.^{2}

C_D = 1.0 for DL plus floor LL

E = 1,600,000 lb/in.^{2}

F_c = 1,950 lb/in.^{2}

ℓ = 20(12) = 240 in.

K_e = 1.0 (see Figure 8) Column is assumed to be pinned at both ends.

$\ell_e = \ell\, K_e$ = 240(1.0) = 240 in.

$\dfrac{\ell_e}{B} = \dfrac{240}{8.75} = 27.43$

c = 0.9

Where:

E = tabulated modulus of elasticity (lb/in.^{2})

E′ = adjusted modulus of elasticity (lb/in.^{2})

F_c = tabulated compression design value parallel to grain (lb/in.^{2})

A = area of cross section (in.^{2})

B = least dimension being evaluated for potential buckling (in.)

ℓ = length of column (in.)

$\ell_e = \ell\, K_e$ = effective length of column (in.)

K_e = buckling length coefficient for compression members

c = coefficient that depends on member type (0.9 for glulam)

$$E'_{min.} = \frac{(E'[1 - 1.645\ COV_E]\ 1.05)}{1.66} = \frac{(1,600,000[1 - (1.645)(0.10)]\ 1.05)}{1.66} = 845,566\ \text{lb/in.}^2$$

Where:

COV_E = coefficient of variation in modulus of elasticity = 0.10 for glulam

1.05 = conversion factor to obtain true E (1.05 for glulam)

1.66 = factor of safety

F_c^* = tabulated compression design value multiplied by all applicable adjustment factors except C_p (lb/in.^{2})

$$F_{cE} = \frac{0.822\ E'_{min.}}{\left(\dfrac{l_e}{B}\right)^2} = \frac{0.822(845,566)}{27.43^2} = 924\ \text{lb/in.}^2$$

$$\frac{F_{cE}}{F_c^*} = \frac{924}{1,950} = 0.474$$

$$C_p = \frac{1 + \dfrac{F_{cE}}{F_c^*}}{2c} - \sqrt{\left[\dfrac{1 + \dfrac{F_{cE}}{F_c^*}}{2c}\right]^2 - \dfrac{\left(\dfrac{F_{cE}}{F_c^*}\right)}{c}} = \frac{1 + 0.474}{2(0.9)} - \sqrt{\left[\dfrac{1 + 0.474}{2(0.9)}\right]^2 - \dfrac{0.474}{0.9}} = 0.440$$

$F_c' = F_c^* C_p$ = allowable compressive stress (lb/in.^{2})

$F_c' = 1,950(0.440) = 857\ \text{psi}$

Axial load capacity = AF_c' = 91.875(857) = 78,737 lb > 50,000 $\Rightarrow$ **OK** for concentric axial load without fire endurance consideration

Check fire endurance based on ratio of applied load to design capacity

$$\frac{\text{Applied Load}}{\text{Design Capacity}} = \frac{50,000}{78,737} = 0.635 = 63.5\%$$

From Figure 7, for a column 8-3/4-inches wide and $l_e/B > 11$, 63.5% corresponds to about a 13-1/2-inch depth which is greater than the existing column's depth of 10-1/2 inches. The existing column will therefore **not** carry the applied load for the full duration of the prescribed one-hour fire.

To check this conclusion, calculate the fire endurance

From Figure 3, for a column with $l_e/B > 11$ and the load at 63.5% of capacity, Z is approximately 1.16.

Using Equation 4:

B = 8.75 in.

D = 10.5 in.

$$t = 2.54ZB\left[3 - \frac{B}{D}\right] = 2.54(1.16)(8.75)\left[3 - \frac{8.75}{10.5}\right] = 56\ \text{minutes} < 60 \Rightarrow \textbf{NG}$$

The existing column is inadequate to meet the one-hour fire-resistance requirement even though it is adequate to carry the applied load in occupancies not requiring a one-hour fire rating.

Determine column size necessary to carry the design load and meet the one-hour requirement

Using Figure 7 as a guide, try a 10-3/4-inch x 10-1/2-inch glulam, Douglas-fir Combination 2, assuming a depth of 10-1/2 inches is a design requirement.

$A = 10.75(10.5) = 112.875$ in.^{2}

Slenderness ratio $= l_e/B = 240/10.5 = 22.86$

$$F_{cE} = \frac{0.822\,E'_{min}}{\left(\dfrac{l_e}{B}\right)^2} = \frac{0.822(845,566)}{22.86^2} = 1,330 \text{ lb/in.}^2$$

$F_c^* = 1,950$ lb/in.^{2}

$$\frac{F_{cE}}{F_c^*} = \frac{1,330}{1,950} = 0.682$$

$$C_p = \frac{1 + \dfrac{F_{cE}}{F_c^*}}{2c} - \sqrt{\left[\frac{1 + \dfrac{F_{cE}}{F_c^*}}{2c}\right]^2 - \frac{\left(\dfrac{F_{cE}}{F_c^*}\right)}{c}} = \frac{1 + 0.682}{2(0.9)} - \sqrt{\left[\frac{1 + 0.682}{2(0.9)}\right]^2 - \frac{0.682}{0.9}} = 0.595$$

$F_c' = 1,950(0.595) = 1,160$ lb/in.^{2}

Axial load capacity $= AF_c' = 112.875(1,160) = 130,939$ lb $> 50,000$ lbs. $\Rightarrow$ **OK**

Check the fire endurance

$$\frac{\text{Applied Load}}{\text{Maximum Capacity}} = \frac{50,000}{130,939} = 0.382 = 38.2\%$$

Z, from Figure 3, is 1.3.

Using Equation 4:

B = 10.5 in.

D = 10.75 in.

$$t = 2.54ZB\left[3 - \frac{B}{D}\right] = 2.54(1.30)(10.5)\left[3 - \frac{10.5}{10.75}\right] = 70 \text{ minutes} > 60 \Rightarrow \textbf{OK};$$

use 10-3/4-inch x 10-1/2-inch Combination 2 Douglas-fir glulam column.

ALTERNATIVE SOLUTION IN ACCORDANCE WITH THE 2005 NATIONAL DESIGN SPECIFICATION, CHAPTER 16

Step 1: The 8-3/4-inch by 10-1/2-inch glulam column capacity can be calculated based on Section 3.7.1 of the 2005 NDS as 78,713 lb $> 50,000$ lb $\Rightarrow$ **OK**

Step 2: Determine the actual column size that will continue to carry the design load when exposed to a one-hour fire as follows:

Step 2a: From Chapter 16 of NDS,

$$\beta_{eff} = \frac{1.2\beta_n}{t^{0.187}}$$

Where:

β_n = nominal char rate of 1.5 in./hr

β_{eff} = effective char rate (in./hr)

t = exposure time (hrs)

Therefore, when t = 1 hr, β_{eff} = 1.8 in./hr

Step 2b: The residual cross section after a one-hour fire exposure on four sides can be calculated as:

$b_{residual}$ = 8.75 – (1.8 x 2) = 5.15 in.
$h_{residual}$ = 10.5 – (1.8 x 2) = 6.90 in.
$A_{residual}$ = 5.15 x 6.90 = 35.54 in.^{2}

Step 2c: The residual axial capacity after a one-hour fire exposure on four sides can be calculated based on Table 16.2.2 of the 2005 NDS.

F_c' = 2.58 x F_c x C_p = 2.58 x 1,950 x 0.1273 = 640.4 psi
$P_{residual}$ = F_c' x $A_{residual}$ = 640.4 x 35.54 = 22,755 lb < 50,000 lb $\Rightarrow$ **NG**

Where:

C_p = column stability factor, which can be calculated based on Section 3.7.1 of the 2005 NDS with the exception that the column buckling strength F_{cE} is determined using equation given in Table 16.2.2 of the 2005 NDS

Step 2d: Therefore, the column size would need to be increased to accommodate the one-hour fire exposure. Select 10-3/4 inches by 10-1/2 inches. The column capacity can be calculated based on Section 3.7.1 of the 2005 NDS as 130,939 lb > 50,000 lb $\Rightarrow$ **OK**

Step 2e: Repeat Steps 2b and 2c for one-hour fire exposure,

$b_{residual}$ = 10.75 – (1.8 x 2) = 7.15 in.
$h_{residual}$ = 10.5 – (1.8 x 2) = 6.90 in.
$A_{residual}$ = 7.15 x 6.90 = 49.34 in.^{2}
F_c' = 2.58 x F_c x C_p = 2.58 x 1,950 x 0.2253 = 1,133.3 psi
$P_{residual}$ = F_c' x $A_{residual}$ = 1,133.3 x 49.34 = 55,911 lb > 50,000 lb $\Rightarrow$ **OK**

Therefore a <u>10-3/4-inch by 10-1/2-inch Combination 2 Douglas-fir glulam column</u> is required to meet the one-hour fire rating.

Summary

As shown by the preceding examples, glued laminated timber members can be designed to provide a one-hour fire rating when required. Based on the 2009 IBC, Tables 1a, 1b and 1c provide basic minimum dimensions for one-hour fire-rated glulam beams and columns when the applied load represents 100 percent of the member design capacity. Figures 4, 5, 6 and 7 provide estimated sizes of beams and columns that will satisfy a requirement for a one-hour fire rating when the member is loaded to less than 100 percent of capacity. Alternatively, the design methodology provided in Chapter 16 of the 2005 NDS can be used to design one-hour fire-rated glulam beams and columns.

For additional information related to the design of glulams, contact APA Product Support Help Desk, 7011 South 19th St., Tacoma, Washington 98466-5333, Phone (253) 620-7400.

FIGURE 3
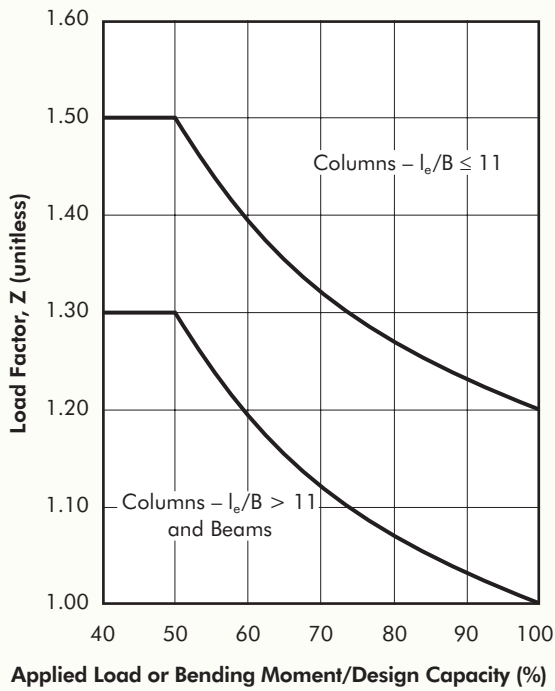
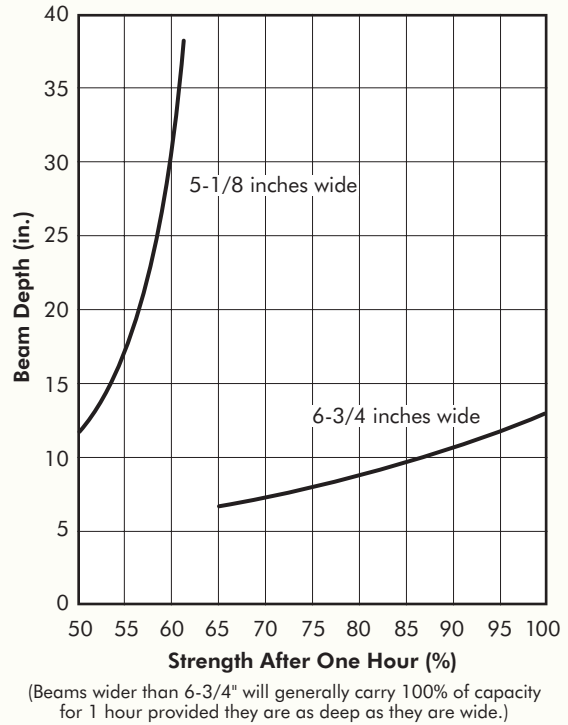**FACTOR Z AS A PERCENTAGE OF DESIGN CAPACITY**

Columns – $l_e/B \leq 11$

Columns – $l_e/B > 11$ and Beams

Load Factor, Z (unitless)

Applied Load or Bending Moment/Design Capacity (%)

FIGURE 4

BEAMS – FIRE 3 SIDES

5-1/8 inches wide

6-3/4 inches wide

Beam Depth (in.)

Strength After One Hour (%)

(Beams wider than 6-3/4" will generally carry 100% of capacity for 1 hour provided they are as deep as they are wide.)

FIGURE 5

BEAMS – FIRE 4 SIDES

6-3/4 inches wide

8-3/4 inches wide

10-3/4 inches wide

Beam Depth (in.)

Strength After One Hour (%)
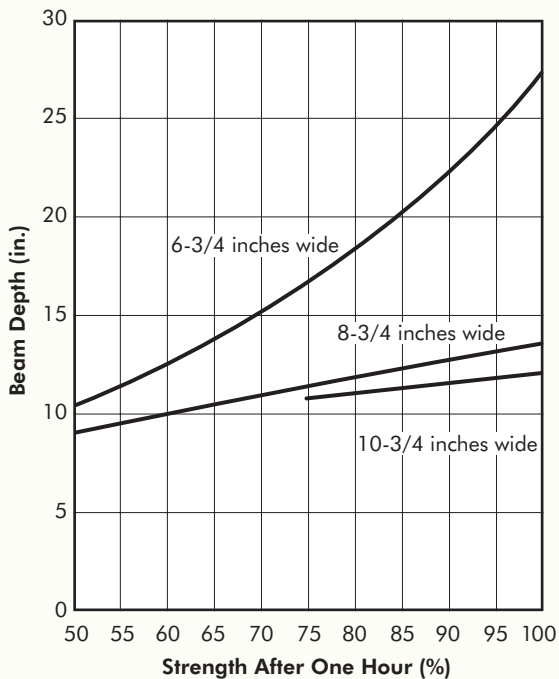
FIGURE 6

COLUMNS – FIRE 3 SIDES

6-3/4 inches wide – $l_e/B > 11$

6-3/4 inches wide – $l_e/B \leq 11$

8-3/4 inches wide – $l_e/B > 11$

Column Depth (in.)

Strength After One Hour (%)
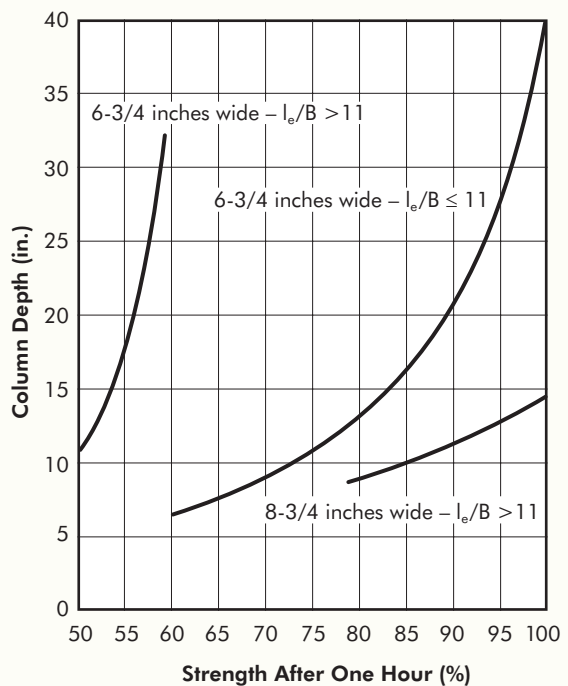
FIGURE 7

COLUMNS – FIRE 4 SIDES
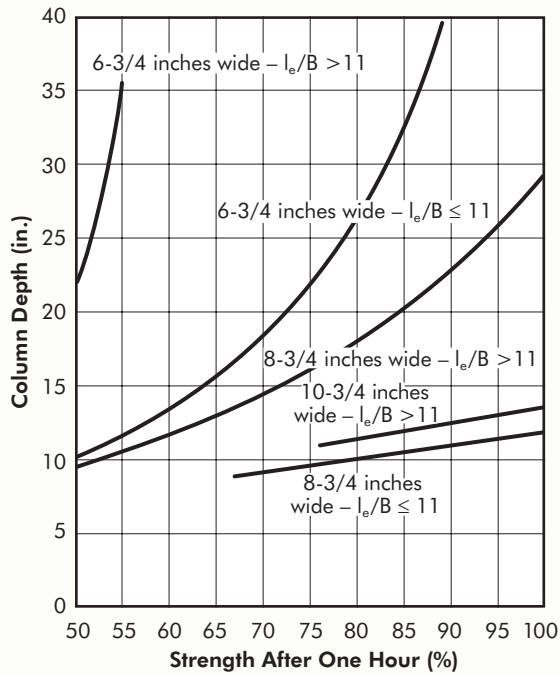
FIGURE 8

APPENDIX G, 2005 NDS – EFFECTIVE COLUMN LENGTH
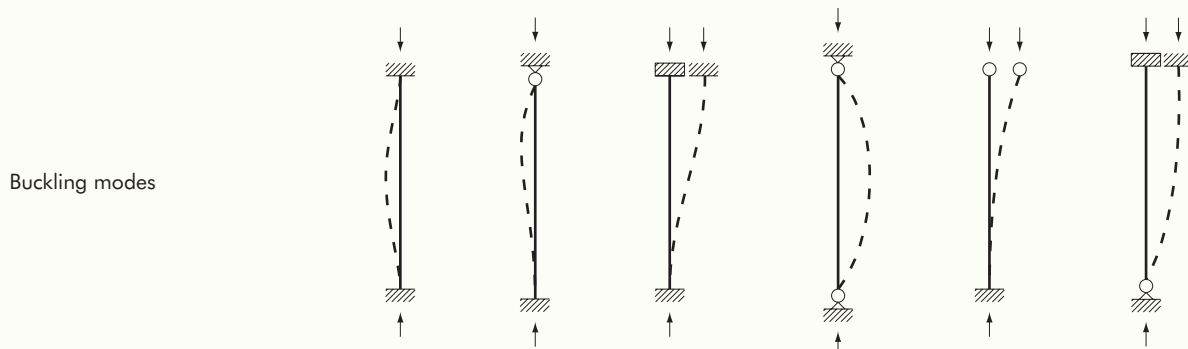
Buckling modes						
Theoretical K_e value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design K_e when ideal conditions approximated	0.65	0.8	1.2	1.0	2.1	2.4

End condition code

Rotation fixed, translation fixed

Rotation free, translation fixed

Rotation fixed, translation free

Rotation free, translation free

FIGURE 9

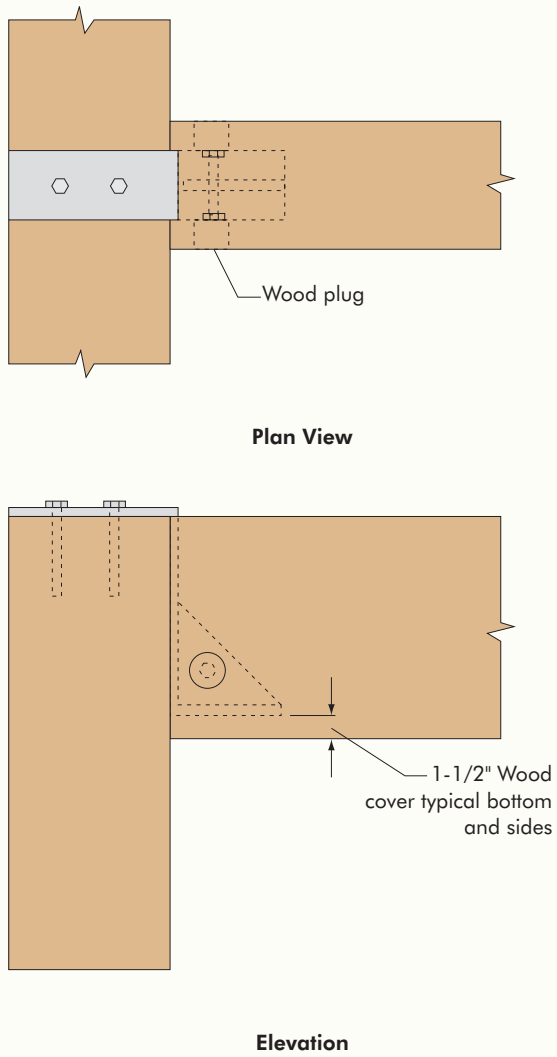**BEAM TO GIRDER – CONCEALED CONNECTION**

Wood plug

Plan View

1-1/2" Wood cover typical bottom and sides

Elevation

FIGURE 10

COLUMN CONNECTIONS – COVERED

Provide lateral support for end of beams

Wood beam

Standard steel connections – box in using 2x wood to protect steel

Wood column

Floor

Elevation
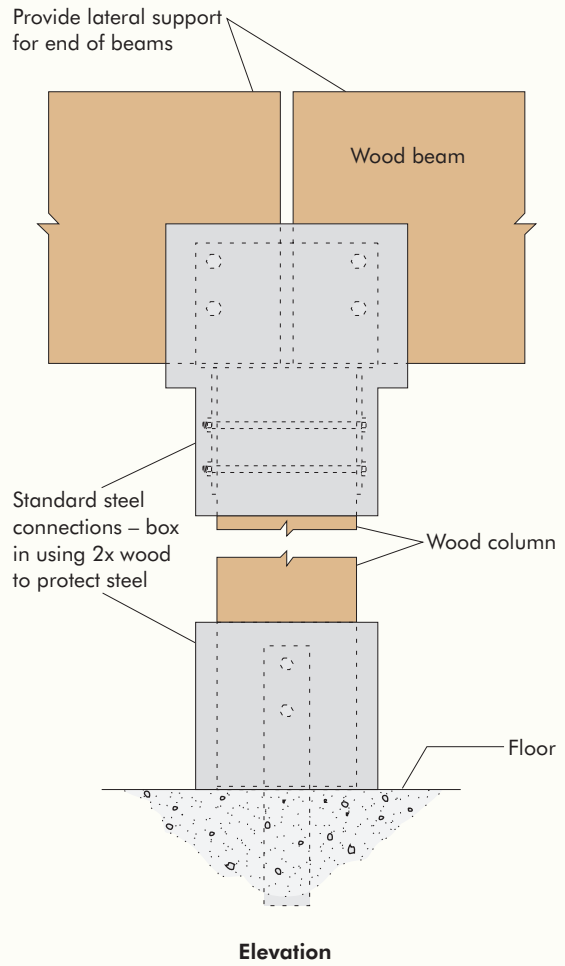
FIGURE 11

BEAM-TO-COLUMN CONNECTION
Connection not exposed to fire

Provide lateral support for end of beam

Exposed portion of beam

2x backup nailer to box in around beam

5/8" Fire-rated gypsum board

Column enclosed within one-hour wall. Column may also be a concrete or masonry pilaster, in which case the beam-to-column connection would be boxed in with 2x4s and 5/8" fire-rated gypsum board.

Elevation
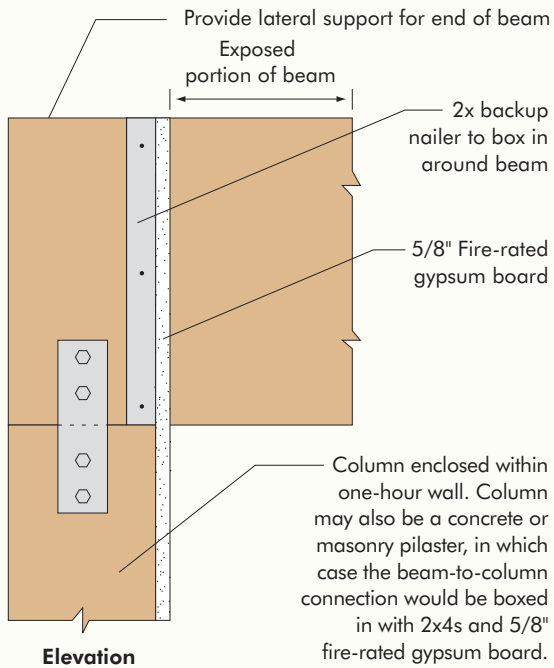
FIGURE 12

BEAM-TO-COLUMN CONNECTION
Connection exposed to fire where appearance is a factor

Provide lateral support for end of beam

Wood beam

Wood plug over bolt

Cross-shaped connection recessed in wood

Fill void around seat with plaster of Paris or approved compound

Wood column

End View   **Elevation**
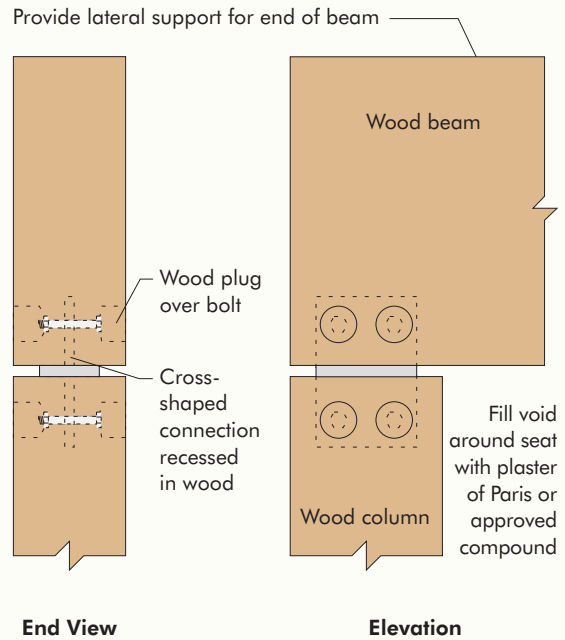
FIGURE 13

BEAM-TO-COLUMN CONNECTION
Connection exposed to fire where
appearance is not a factor

Provide lateral support for end of beam

Steel connection welded to steel plate cast in top of concrete column

Apply fire protective coating that is allowed by the code for one-hour rating of steel

Concrete column

Elevation

FIGURE 14

CEILING CONSTRUCTION

Standard one-hour rated ceiling framing
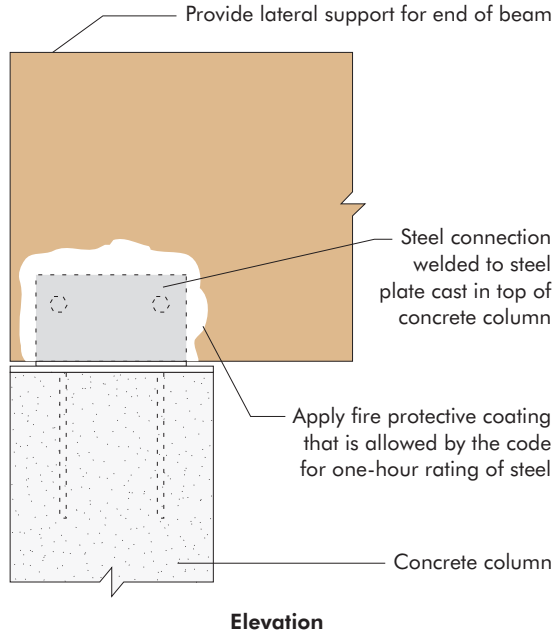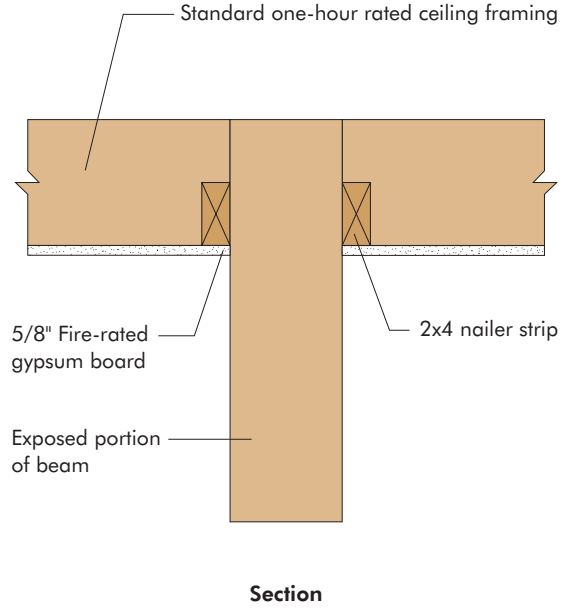
5/8" Fire-rated gypsum board

2x4 nailer strip

Exposed portion of beam

Section

Calculating Fire Resistance of Glulam Beams and Columns

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