Design for Code Acceptance

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Design of Fire - Resistive Exposed Wood Members

Designers, regulators, and fire officials throughout the country recognize the superior fire endurance demonstrated by large wood beams and columns in actual fires. A simple, experimentally-verified, code-approved design procedure is provided in this document to quantify the fire endurance of large, exposed wood members. A comprehensive discussion of a new, mechanics-based design procedure developed by the American Wood Council can be found in a separate document entitled ***Calculating the Fire Resistance of Exposed Wood Members: Technical Report 10*** available *free*.

Simple Design Procedure

The simple design procedure permits the user to quickly calculate the endurance time of a wood member exposed to standard fire exposure conditions given the size of a wood beam or column and the percent of maximum allowable design load applied. The procedure estimates of the cross-sectional dimensions of the uncharred portion of a beam or column and the effects of elevated temperatures on the load-carrying capability of the residual section. This procedure has been incorporated in the provisions of the *International Building Code*.

Holiday Inn; Columbus, Indiana
Architects: Lennox Oldham Matthews, Inc., Indianapolis

Where specific fire resistance times are required, performance of wood members over such periods may be calculated as follows:

Beams:

(1) fire exposure on four sides

$t = 2.54\ z\ b\ [4\text{-}2(b/d)]$

(2) fire exposure on three sides

$t = 2.54\ z\ b\ [4\text{-}(b/d)]$

where:

b = breadth (width) of beam before fire exposure (in inches)

d = depth of beam before fire exposure (in inches)

z = load factor (see Figure 1)

$= 1.3$ for $r \le 0.5$

$= 0.7 + 0.3/r$ for $r > 0.5$

r = ratio of induced load to maximum allowable load

t = fire endurance (in minutes)

Columns:

(1) fire exposure on four sides

$t = 2.54\ z\ d\ [3\text{-}(d/b)]$

(2) fire exposure on three sides

$t = 2.54\ z\ d\ [3\text{-}(d/b)/2]$

where:

b = maximum dimension of column before fire exposure (in inches)

d = minimum dimension of column before fire exposure (in inches)

z = load factor (see Figure 1)

$= 1.5$ for $K_eL/d \le 11$ and $r \le 0.5$

$= 0.9 + 0.3/r$ for $K_eL/d \le 11$ and $r > 0.5$

$= 1.3$ for $K_eL/d > 11$ and $r \le 0.5$

$= 0.7 + 0.3/r$ for $K_eL/d > 11$ and $r > 0.5$

r = ratio of induced load to maximum allowable load

K_e = effective length factor (see Figure 2)

L = effective length (in inches)

t = fire endurance (in minutes)

Each of the foregoing equations relates endurance time to the percent of maximum allowable design load applied and cross section dimensions. For given member sizes, different endurance times can be achieved by varying the percent of maximum design load applied to the member. Examples of relationships between load and endurance time for wood beams exposed on three sides are shown in Figure 3.

Application

The formula for columns exposed to fire on three sides applies only when the unexposed face is the smaller column dimension. Where the column is recessed in a wall, its full dimension shall be used for the purpose of the calculations.

Allowable loads on beams and columns are determined using design procedures from the *National Design Specification® for Wood Construction (NDS®)*.

Glued laminated timber beams utilize standard laminating combinations except that a core lamination is removed, the tension zone is moved inward, and the equivalent of an extra nominal 2-inch thick outer tension lamination is added.

Where one-hour fire endurance is required, connectors and fasteners must be protected from fire exposure by 1.5 inches of wood, fire-rated gypsum board, or any coating approved for a one-hour rating. Typical details for commonly used fasteners and connectors in timber framing are shown in Figure 4 (Beam to Column Connection Not Exposed to Fire), Figure 5 (Beam to Column Connection Exposed to Fire Where Appearance is a Factor), Figure 6 (Ceiling Construction), Figure 7 (Beam to Column Connection Exposed to Fire Where Appearance is Not a Factor), Figure 8 (Column Connections - Covered), Figure 9 (Beam to Girder - Concealed Connection).

The procedure described in this brochure is intended to assist the designer of timber framed structures in achieving predictable performance within specified fire endurance requirements. Special effort has been made to assure that the information reflects the state of the art. However, the American Wood Council does not assume responsibility for particular designs or calculations prepared from this publication.

Figure 1 Determination of Load Factor, z

K_e = Buckling Length Coefficient (see Figure 2)
L = Unsupported Column Length in inches

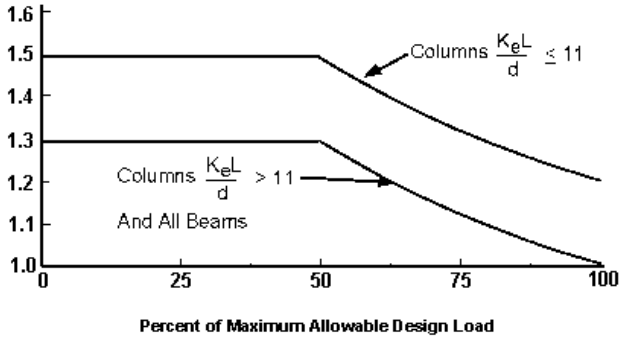


Figure 2 Buckling Length Coefficients, K_e

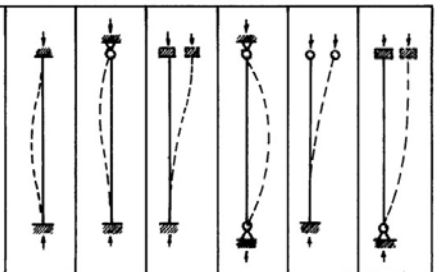
Buckling modes						
Theoretical K_e value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design K_e when ideal conditions approximated	0.65	0.80	1.2	1.0	2.10	2.4
End condition code	Rotation fixed, translation fixed Rotation free, translation fixed Rotation fixed, translation free Rotation free, translation free					

Figure 3 Fire Endurance of Wood Beams

Fire Exposure on 3 Sides

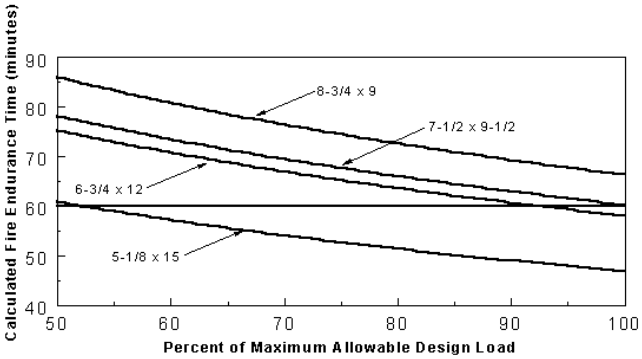


Figure 4 Beam to Column Connection

Connection Not Exposed to Fire

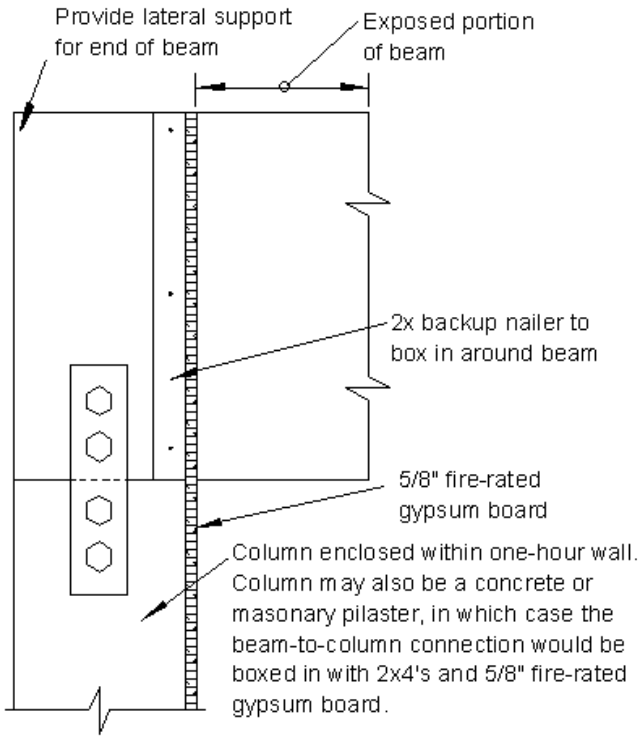


Figure 5 Beam to Column Connection

Connection Exposed to Fire Where Appearance is a Factor

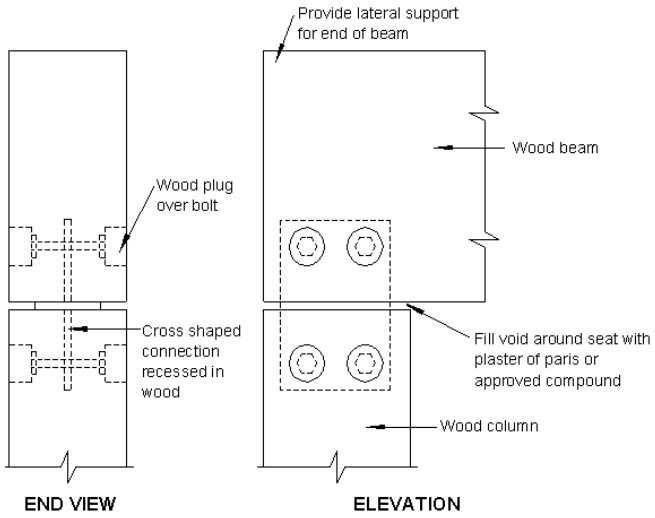


Figure 6 Ceiling Construction

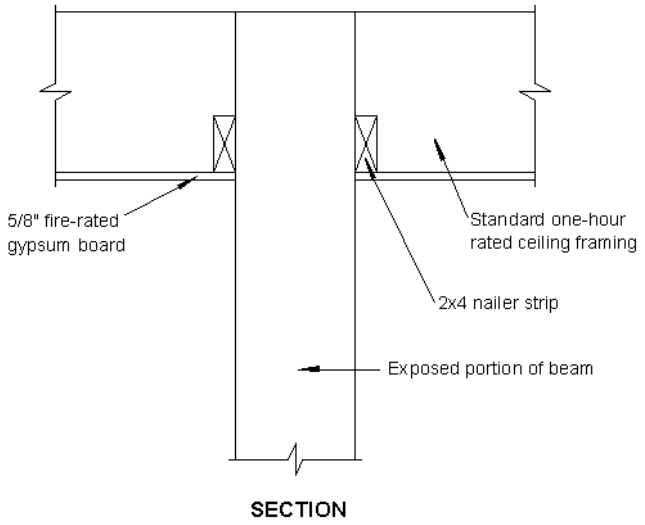


Figure 7 Beam to Column Connection

Connection Exposed to Fire Where Appearance is Not a Factor

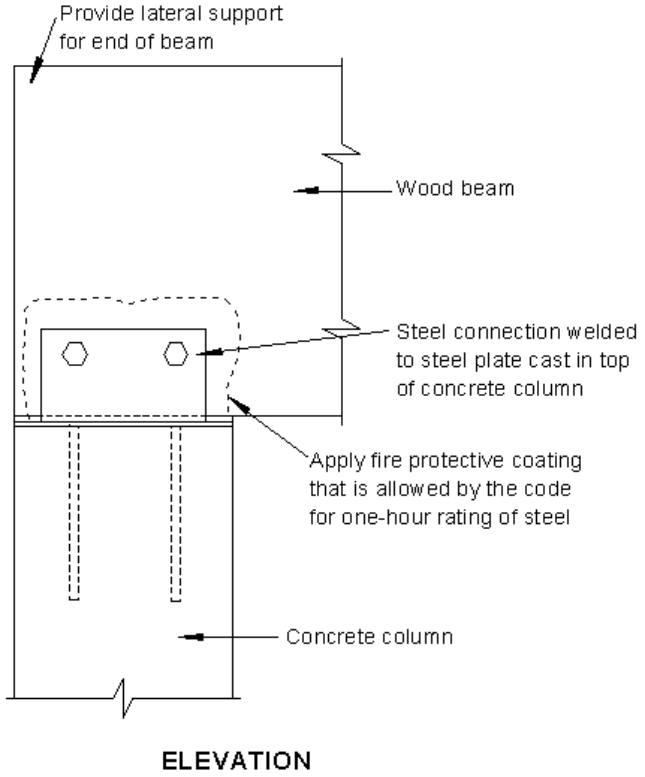


Figure 8 Column Connections - Covered

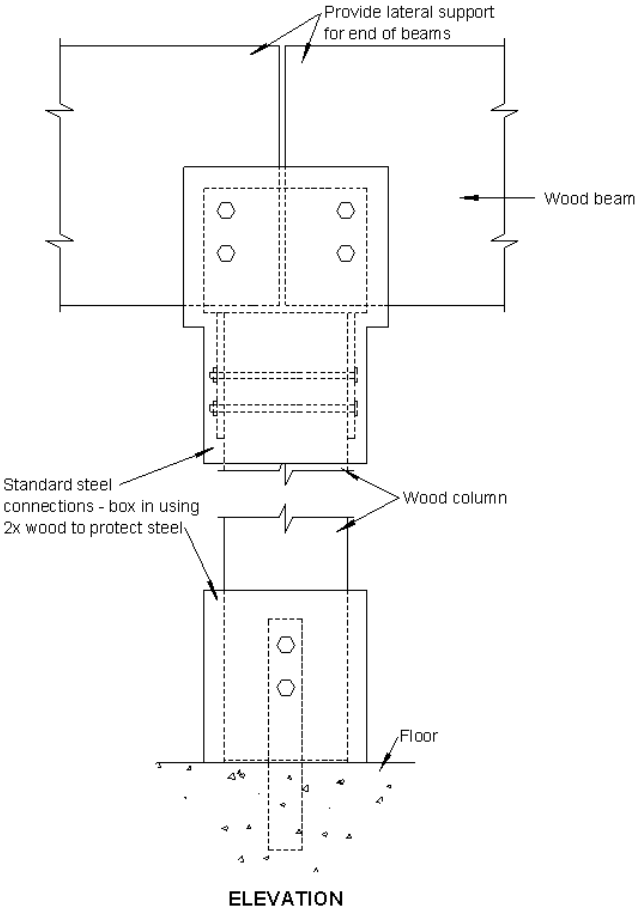
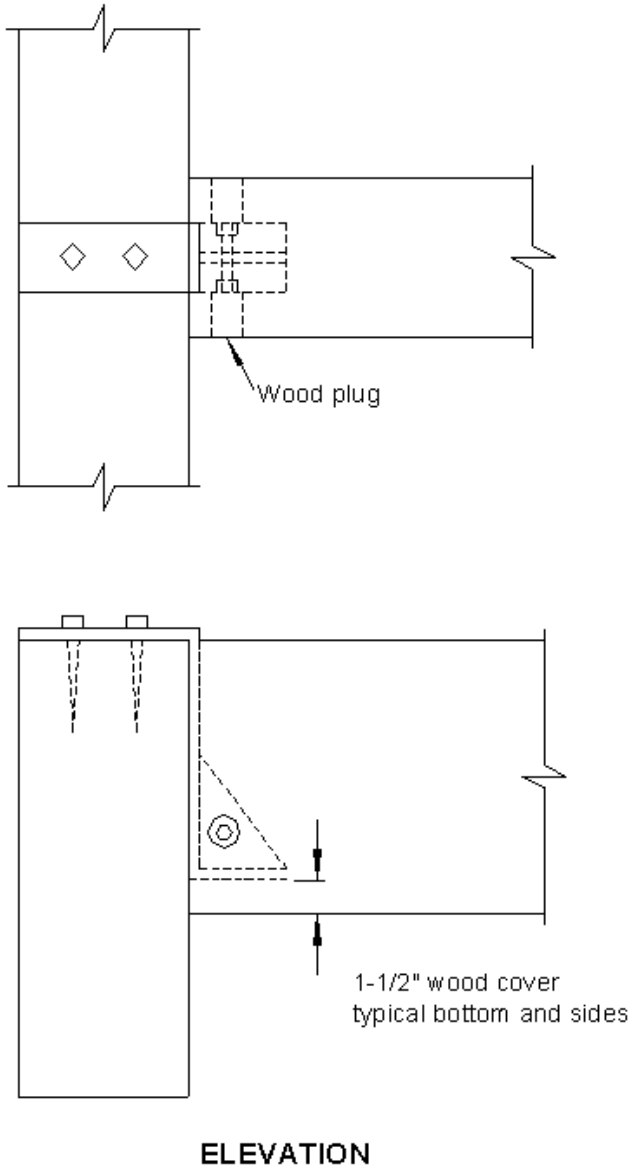


Figure 9 Beam to Girder – Concealed Connection



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