PDHonline Course S169 (3 PDH)

Design of Wood Beam-Columns with Spreadsheet

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Course Content

INTRODUCTION

A beam carries a load that is transverse to its axis. The load causes shear and bending stresses. A column carries a load that aligns with its axis. The load causes axial stress. A beam-column carries a load or loads that cause both bending and axial stress. This occurs, for example, when an axial load is not centered on a column or when the wind blows on a stud wall that is holding up a roof. Formulas based on fundamental theory and extensive experimentation have been developed for wood beam-columns. The formulas are quite involved and lend themselves well to the use of a spreadsheet. This course provides information about solid rectangular shaped wood beam-column design and illustrates the use of an Excel© 2003 spreadsheet, BEAMCOL©, with six examples. <u>The student must have a licensed copy of Excel to use this spreadsheet.</u> Traditional (English) units and the allowable stress design (ASD) approach are used.

RELEVANT WOOD PROPERTIES

The design of wood structural elements is complicated, in part, because of the variability of wood. Dozens of wood species are used in structures and the relevant properties vary between and within species. Information on engineering properties of wood are available from sources such as the American Forest & Paper Association or from manufacturers of “engineered” wood products such as laminated veneer lumber. The references listed at the end of this discussion provided useful technical information.

The natural growth of wood consists primarily of small tubular cells that are aligned with the length of the tree. The cells grow at different seasonal rates, and in exogenous wood, create annular rings of different density and color (annual rings). Since lumber is sawn with the length of the tree, these cells also align generally with the length of a piece of lumber. The cell walls create the “grain” of the wood. In a typical piece of lumber, the end cut is perpendicular to the cells. Loads applied to the end of the lumber directed along its length, as a typical column load is applied, is parallel to grain load. A load applied at 90º to the side or face of the piece of lumber is perpendicular to grain load. These are illustrated in Figure 1.

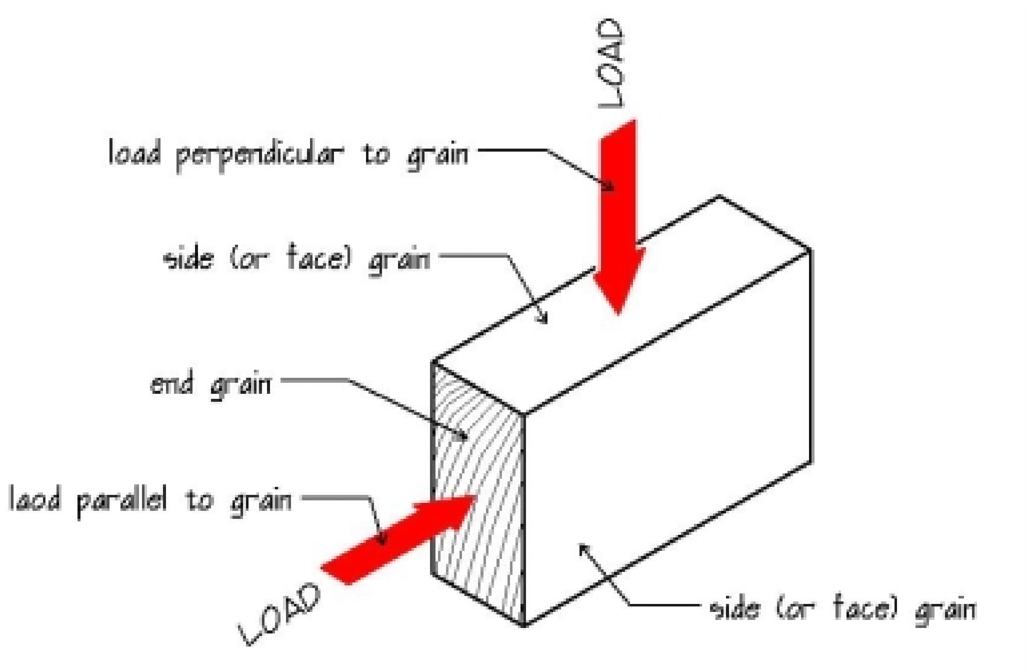

Figure 1. Wood Load and Grain Orientation

Wood may contain varying amounts of water. It may be in "cells" (open pores) that would otherwise contain air or it may be in the cell walls. Moisture content (M.C.) is expressed as a percentage and is calculated by dividing the weight of water present in a specimen by the weight of the dry specimen. It could vary from above 100% to 0%. A sample that weighs 80 grams and is completely dried to 65 grams had a moisture content of:

(80 grams-65 grams) /65 grams = 23% moisture content.

Lumber is typically dried in air or by kiln from the "green" condition when it is harvested to a "dry" condition for use. A typical range of moisture content for "dry" structural lumber as used is about 6% to 19% with 19% M.C. serving as the break point between dry and wet lumber. (Ref. 2, p. 186). The moisture content of wood changes in response to its environment. This is associated with volume changes that differ in different directions within the wood. Adjustments to design values for damp conditions of use are discussed later.

ALLOWABLE STRESSES FOR WOOD

Grading agencies publish basic allowable stresses and other relevant engineering properties for structural wood. For beam-columns the properties of interest are:

F_b = basic allowable bending stress
F_c = basic allowable compression stress parallel to grain (for crushing)
E = basic modulus of elasticity parallel to grain

The basic allowable stresses are subject to modification for several situations as indicated in Table 1. A brief description of each relevant factor follows.

Table 1. Stress Adjustment Factors for Sawn Lumber (Ref. 1, p. 27)

$F_b' = F_b$ x	C_D	C_F	C_M	C_t	C_i	C_{fu}	C_r	C_f	C_L	-	-
$F_c' = F_c$ x	C_D	C_F	C_M	C_t	C_i	-	-	-	-	C_P	-
$E' = E$ x	-	-	C_M	C_t	C_i	-	-	-	-	-	C_T

C_D, Duration of Load Factor. The capacity of wood to support a given load depends on how long the load will be in place. The basic allowable stresses are modified or "adjusted" by multiplying by the appropriate factor. Consideration must be given to all load combinations to determine the controlling situation. The addition of a load of short duration may not control the design since the allowable stresses can be increased. This is illustrated below. The equation for calculating duration factor (after Ref. 2, p.8) is:

$$C_D = (1.7512)(T^{-.04635}) + .29575 \quad \text{where T is time in seconds.}$$

The factors given in Table 2 are for commonly encountered situations.

Table 2. Load Duration Factors, C_D (Ref. 3, p.8)

Maximum Load Duration	C_D	Typical Design Load
Permanent	.9	Dead Load
10 years	1.0	Occupancy Live Load
2 months	1.15	Snow Load (when appropriate)
7 days	1.25	Construction Load
10 minutes	1.6	Wind/Earthquake/Impact

Using the information from Table 2 and a wood of F_b = 600 psi with wind load controlling:

$$F_b' = 1.6\,(600) = 960 \text{ psi}$$

Suppose, however, the following loads:

Dead Load = 2400 pound and
Occupancy Live Load = 3600 pounds and
Wind Load = 2000 pounds

The dead load, which might be alone, has an allowable stress of (.9)(600) = 540 psi. The dead load plus the occupancy live load has an allowable stress of (1)(600) = 600 psi. The total load has an allowable stress of (1.6)(600) = 960 psi since the total load is of short duration because of the wind. The controlling load can be found by taking the largest of the following ratios: 2400/.9 = 2670, (2400 + 3600)/1.0 = 6000, (2400 + 3600 + 2000)/1.6 = 5000. Dead load plus occupancy live load control. Wind load may be neglected in this instance and C_D = 1.0.

C_F, Size Factor. Tabulated allowable stresses for most lumber species are for fairly large sizes of lumber. Allowable stresses are modified for different widths of 2" to 4" thick lumber as shown in Table 3. This factor is built into allowable stresses published for southern pine species.

Table 3. Size Factors for Bending and Compression (Ref. 4, p.30)

Grades	**Select Struct., No.1, No.2, No.3**							**Stud**	**Stud**
Nom.Width	2,3	4	5	6	8	10	12	2,3,4	5,6
Factors for F_b	1.5	1.5	1.4	1.3	1.2	1.1	1.0	1.1	1.0
Factors for F_c	1.15	1.15	1.1	1.1	1.05	1.0	1.0	1.05	1.0

If the bending member is over 4" wide and 12" deep (d) the formula below applies:

$$C_F = (12/d)^{.1111}$$

C_M, Wet Service Factor. If the moisture content of dimension lumber in use is greater than 19%, $C_M = .85$ for bending stress (F_b) and $C_M = .8$ for compression stress (F_c) for the higher allowable stress grades and species. If $C_F F_b \leq 1150$ psi, $C_M = 1.0$ for bending stress and if $C_F F_c \leq 750$ psi, $C_M = 1.0$ for compression stress. If the moisture content of dimension lumber in use is greater than 19% the C_M for modulus of elasticity is .9. For dry (M.C. ≤ 19%) conditions of use $C_M = 1.0$ (Ref. 4, p. 30). For timber sizes (greater than 5"x5") for bending stress and modulus of elasticity $C_M = 1.0$; for compression stress $C_M = 1.0$.

Pressure treatments with preservatives or fire retardant chemicals may require allowable stress adjustments. That information should be obtained from the treatment company.

C_t, Temperature Factor. If temperatures exceed 100F the factors shown in Table 4 apply.

Table 4. Temperature Factors (Ref. 1, p. 9)

	M.C. in Use	**100<T≤125**	**125<T≤150**
F_b , F_c	≤19%	.8	.7
E	any	.9	.9

C_i, Incised Factor. Lumber may be incised (cut) to aid in pressure treatment. Incising may be parallel to grain up to .4" deep and 3/8" long with a density of 1100 incisions per square foot (Ref. 1, p.27). If so, the factor for F_b and F_c is .8 and the factor for E is .95.

C_{fu}, Flat Use Factor. Tabulated stresses for bending is for bending about the major axis as is typical for joists, rafters and beams. For bending about the minor axis as is the case for planks, for example, for lumber 2" to 4" thick a factor is applied to adjust the allowable stress. The factors are given in Table 5.

Table 5. Flat Use Factors for Bending (Ref. 4, p.30)

Nom. Width	2,3	4	5	6	8	10 and wider
2” and 3” thick	1.0	1.1	1.1	1.15	1.15	1.2
4” thick	-	1.0	1.05	1.05	1.05	1.1

C_r, Repetitive Member Factor. When is possible for bending members to work together through lamination or by being tied together by a load distributing device, the allowable bending stress can be increased by a factor of 1.15. This is limited to 2” and 4” thick lumber that is spaced not more than 24” on center (Ref. 1, p.27). This factor is appropriate to use, for example, for rafters if there is solid decking connecting them.

C_f, Form Factor. Tabulated stresses are for rectangular shapes. For round shapes, $C_f = 1.18$. For diamond shapes, $C_f = 1.414$ (Ref. 1, p.15). The spreadsheet demonstrated in this discussion is limited to rectangular shapes.

C_L, Beam Stability Factor. The most complex factor applied to bending stress adjusts for the tendency for sideways buckling of bending members. This is particularly pronounced for members that are deep and narrow. Sideways buckling is prevented by lateral support which can be provided by bridging or solid blocking or by continuous support of the compression edge. The latter can be provided by properly attached sheathing or decking. Two different approaches are used to account for beam lateral stability. One approach is to provide adequate lateral support to make $C_L = 1.0$. This is done by following the guidelines given in Table 6. In this table “d” is the nominal depth of the bending member and “b” is the nominal width. For example, the actual size of a 2x8 is 1 ½ ”x7 ¼ ” and the nominal size is 2 by 8.

Table 6. Minimum Lateral Support Spacing for $C_L = 1$ (Ref. 1, p.28)

depth/width ratio	lateral support needed at
$d/b < 2$	none required
$2<d/b<4$	ends (points of bearing)
$4<d/b<5$	ends and continuous support at compression edge
$5<d/b<6$	ends and continuous support at compression edge and bridge or block at 8’ maximum on center
$6<d/b<7$	ends and continuous support at compression edge and at tension edge

The alternate method is used to calculate a C_L based on the actual lateral support situation (after Ref. 1, pp. 13-15). If the depth of the beam exceeds its width, at the least, lateral support is required at the support points. The following nomenclature is used:

b = actual width of member (inches) d = actual depth of member (inches)
L_u = distance between lateral supports including at points of bearing (inches)
Le = effective length for bending as defined in Table 7.

Table 7. Effective Length for Bending Members (Ref. 1, p.14)

beam type	**load type/location**	**when $L_u/d < 7$**	**when $L_u/d \geq 7$**
cantilever	uniformly distributed	Le = 1.33Lu	Le = .90Lu + 3d
cantilever	concentrated at unsupported end	Le = 1.87 Lu	Le = 1.44Lu + 3d
cantilever	other	Le = 2.06 Lu	see note below*
single span	uniformly distributed	Le = 2.06 Lu	Le = 1.63Lu + 3d
single span	conc. load & no lateral support at cntr	Le = 1.80 Lu	Le = 1.37Lu + 3d
single span	conc. load & lateral support at center	Le = 1.11 Lu	Le = 1.11 Lu
single span	conc. load & lateral support at 1/3 pts	Le = 1.68 Lu	Le = 1.68 Lu
single span	conc. load & lateral support at 1/4 pts	Le = 1.54 Lu	Le = 1.54 Lu
single span	conc. load & lateral support at 1/5 pts	Le = 1.68 Lu	Le = 1.68 Lu
single span	conc. load & lateral support at 1/6 pts	Le = 1.73 Lu	Le = 1.73 Lu
single span	conc. load & lateral support at 1/7 pts	Le = 1.78 Lu	Le = 1.78 Lu
single span	≥ 7 conc. loads & lateral supports	Le = 1.84 Lu	Le = 1.84 Lu
single span	equal end moments	Le = 1.84 Lu	Le = 1.84 Lu
single span	other	Le = 2.06 Lu	see note below*
multiple span	as single span or engineering analysis		

*when $7 \leq Lu/d \leq 14.3$ Le = 1.63Lu + 3d when $Lu/d > 14.3$ Le = 1.84 Lu

$R_B = (L_e d/b^2)^{.5}$ not to exceed 50

K_{bE} = .439 for visually graded lumber

= .561 for machine evaluated lumber

(see Ref. 1, p. 154 for other cases)

$F_{bE} = K_{bE}E'/ R_B^2$

F_b*= F_b times applicable adjustment factors (not C_{fu} or C_L)

$H = (1+ F_{bE} / F_b*)/1.9$

$C_L = H – (H^2 - 1.052F_{bE} / F_b*)^{.5}$

If the compression edge of the beam is continuously supported or if the width of the beam equals or exceeds its depth $C_L = 1.0$.

This discussion uses the “other” condition shown in Table 7 for calculating the effective bending length for eccentric axial loading when unaccompanied by side loading.

<u>C_P, Column Stability Factor.</u> The tendency of a column to buckle is accounted for in the column stability factor. The effective length, L_e, of a column is the product of the actual unbraced column length, L_u, and the degree of restraint, K_e, at the column ends. Table 8 gives K_e values for several cases. The K_e may differ for the major and minor axes. In the spreadsheet, these are represented by $K_{e1}$and K_{e2} respectively. The effective length for column action is <u>not the same</u> as the effective length for beam action.

Table 8. Column Effective Buckling Length Coefficients (Ref. 1, p. 156).

rotation	translation	theoretical K_e	recommended K_e
both ends fixed	both ends fixed	.5	.65
one end fixed, one end hinged	both ends fixed	.7	.80
both ends fixed	one end free	1.0	1.2
both ends hinged	both ends fixed	1.0	1.0
one end fixed, one end free*	non-fixed end free	2.0	2.1
one end fixed, one end hinged	non-hinged end free	2.0	2.4

*"flagpole"

The following variables are used to calculate C_P for solid columns (after Ref. 1, p. 19):

c = .8 for sawn lumber
(see Ref. 1, p. 19 for other cases)
K_{cE} =.3 for visually graded lumber
= .384 for machine evaluated lumber
(see Ref. 1, p. 19 for other cases)
Q = larger of L_{e1}/d and L_{e2}/b where L_{e1} is the "d" dimension effective unbraced length and L_{e2} is the "b" dimension effective unbraced length (see Figure 2). Neither L_{e1}/d or L_{e2}/b is allowed to exceed 50 for permanent construction.
$F_{cE} = K_{cE} E'/(Q)^2$
$F_c^* = F_c$ times applicable factors except C_P
$J = (1+ F_{cE} /F_c^*)/2c$
$C_P = J - (J^2 - F_{cE} /cF_c^*)^{.5} \leq 1.0$

For combined bending and compression, to be discussed following, the following variables are defined:

$F_{cE1} = K_{cE} E'/(L_{e1}/d)^2$
$F_{cE2} = K_{cE} E'/(L_{e2}/b)^2$

C_T, Buckling Stiffness Factor (Ref. 1, pp. 28, 29). This factor applies to the modulus of elasticity, E, of 2x4 or smaller truss members in combined axial and bending loading in dry conditions of use with properly attached plywood sheathing of at least 3/8" thickness attached to the narrow edge of the member. The following variables are used to calculate C_T.

L_e = effective column length of column compression member $\leq$ 96"
K_M = 2300 if moisture content of member is $\leq$ 19% when sheathing applied
= 1200 if moisture content of member is > 19% when sheathing applied
K_T = .59 for visual graded lumber
= .75 for machine evaluated lumber
(see Ref. 1, p. 29 for other cases)
$C_T = 1+ K_M L_e/(K_T E)$

COMBINING FACTORS

All factors relevant to a design situation are used. Thus, several factors may be multiplied for a given condition. Assume, for example, that 2x8 rafters at 16" on center with ½" decking with snow load controlling have a basic allowable bending stress of 1200 psi. Assume that other conditions are "normal" (factors are 1.0).

$$F_b' = (1200 \text{ psi})(1.15)(1.2)(1.15) = 1380 \text{ psi}$$

The first 1.15 is C_D from Table 2, the 1.2 is C_F from Table 3, and the 1.15 is C_r for a repetitive member. Care must be exercised in selecting the correct C_D as was discussed earlier.

MEMBERS WITH BENDING OR COMPRESSION ONLY

The formula for allowable moment, M, for bending only is:

$$M \text{ (foot pounds)} = F_b'S/12$$

F_b' is the allowable bending stress in psi as adjusted and S is the appropriate section modulus in inches^3. The formula for section modulus, S, for rectangular shapes is $S = bd^2/6$ where d is the dimension of the beam in the direction of the load. The section modulus of a 2x8 used as a joist (i.e., the deep way) is:

$$S = (1.5)(7.25)^2/6 = 13.1 \text{ in}^3$$

The same 2x8 used as a plank (i.e., flatways) has a section modulus of:

$$S = (7.25)(1.5)^2/6 = 2.72 \text{ in}^3$$

The formula for allowable axial load, P, for axial load only is:

$$P = F_c'bd$$

F_c' is the allowable compression stress in psi as adjusted and b and d are the dimensions of the column cross section.

Members with bending or compression only can be thought of as special cases of combined bending and compression. Thus, the more complex formulas to be described following and the spreadsheet apply to the simple cases of bending only and compression only.

COMBINED BENDING AND COMPRESSION

Combined bending and compression is present when a side load is imposed on a column or when a column axial load is eccentric (i.e., does not center on the column). Depending on the location of the side load or eccentric load, bending may be present about either the major or minor axis or about both axes of the column. Figure 2 illustrates the most general combined bending and compression loading situation and gives nomenclature. In Figure 2, "b" buckling refers to buckling about the minor (weaker) axis and "d" buckling refers to buckling about the major (stronger) axis and

$$L_{e1} = K_{e1}L_{u1} \text{ and } L_{e2} = K_{e2}L_{u2} .$$

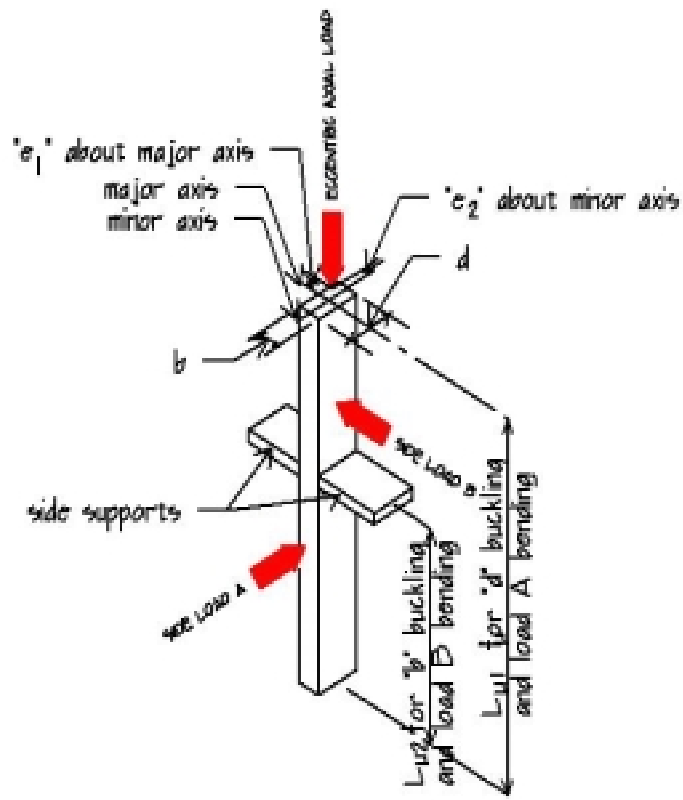

Figure 2. Beam Column Nomenclature

The formula used for combined bending and compression loads (beam-columns) is an interaction equation. It is essentially a trial and error approach in which bending and compression stresses are calculated and used in the equation. The formula and additional nomenclature for calculating allowable loads follows (see previous discussion for other nomenclature) (after Ref. 1, p. 137).

e_1 = major axis eccentricity
e_2 = minor axis eccentricity

F_{b1} '= allowable edgewise (major axis) bending stress if only it existed
F_{b2}'= allowable flat ways (minor axis) bending stress if only it existed
f_{b1}= computed bending stress about major axis
f_{b2}= computed bending stress about minor axis
F_c' = allowable compression stress if only it existed
f_c = computed axial stress
$F_{bE} = K_{bE}E'/R_b^2$
$A = 6e_1/d$
$B = 6e_2/b$

$$I = (f_c/F_c')^2 + [f_{b1}+f_cA(1+.234f_c/F_{cE1})]/[F_{b1}'(1-f_c/F_{cE1})] + \{f_{b2} + f_cB[1+.234f_c/F_{cE2} + .234((f_{b1} + f_cA)/F_{bE})^2]\}/\{F_{b2}'[1-f_c/F_{cE2} - ((f_{b1} + f_cA)/F_{bE})^2]\} \leq 1.0$$

USING THE SPREADSHEET

The Excel© 2003 spreadsheet, BEAMCOL©, has the appropriate formulas embedded and provides some useful technical data. These are in protected cells so that they will not be inadvertently changed. Data for other species and grades can be obtained from references 3 and 4 or similar sources. Information provided by the user is entered into yellow colored unprotected cells. An unprotected light yellow "Job Notes" pad is also provided. Results of the calculations are provided in red colored cells. Insofar as possible, the nomenclature used in the foregoing explanation is used in the spreadsheet. Many of the cells have explanatory notes attached. The student must have a licensed copy of Excel to use this spreadsheet.

Example problems follow with explanations. Example Problem 1 is entered into the spreadsheet.

Example Problem 1: Check the adequacy of a 96" long #2 Douglas Fir-Larch 3"x 6" beam-column loaded as follows: axial load is 1000 pounds with major axis eccentricity of 1.0" and minor axis eccentricity of .5". There is a major axis bending moment of 800 lb-ft caused by a uniform load and a minor axis bending moment of 200 lb-ft. The minor axis is braced at 1/3 points. The load is ordinary live load and other conditions are normal.

The values entered into the various spreadsheet cells are shown in Table 9.

Table 9. Spreadsheet Entries for Example Problem 1.

Cell	E15	E16	E17	E18	E19	E21	E22	E23	E24	E25	E26
entry	800	200	1000	1.00	0.50	1.0	1.30	1.10	1.0	1.0	1.0
Cell	E27	E28	E29	E30	E31	E32	E33	D35	D36	D37	D40
entry	1.0	1.0	1.0	1.0	1.15	1.0	1.0	3.0	6.0	32	65.9
Cell	D41	D42	D45	D49	D50	D51	D52	D53	D54	D57	
entry	.439	1600000	900	1.00	.80	.80	.30	96	32	1350	

The .80 value in cell D50 is a judgment call about the nature of restrain at the "ends" of continuous 32" long columns. The spreadsheet returns an answer of .767 which means that the design is adequate.

Example Problem 2: Same as problem 1 except determine the maximum axial load that can be applied.

The values entered into the various spreadsheet cells are shown in Table 10.

Table 10. Spreadsheet Entries for Example Problem 2.

Cell	E15	E16	E17	E18	E19	E21	E22	E23	E24	E25	E26
entry	800	200	2848	1.00	0.50	1.0	1.30	1.10	1.0	1.0	1.0
Cell	E27	E28	E29	E30	E31	E32	E33	D35	D36	D37	D40
entry	1.0	1.0	1.0	1.0	1.15	1.0	1.0	3.0	6.0	32	65.9
Cell	D41	D42	D45	D49	D50	D51	D52	D53	D54	D57	
entry	.439	1600000	900	1.00	.80	.80	.30	96	32	1350	

The 2848 pound value (rounded off) in cell E17 can be entered by trial and error until the interaction equation gives an answer of 1.00 or Excel© 2003 provides a search method called "goal seek" that can be used to provide the same result more efficiently.

Example Problem 3: Check the adequacy of a 12' long #1 Redwood SAS 6x8 column loaded as follows: axial load is 10000 pounds with major axis eccentricity of 1.5". The load is snow load and the column is outdoors.

The values entered into the various spreadsheet cells are shown in Table 11.

Table 11. Spreadsheet Entries for Example Problem 3.

Cell	E15	E16	E17	E18	E19	E21	E22	E23	E24	E25	E26
entry	0	0	10000	1.50	0.0	1.15	1.00	1.00	1.00	.91	1.00
Cell	E27	E28	E29	E30	E31	E32	E33	D35	D36	D37	D40
entry	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.5	7.5	144	265
Cell	D41	D42	D45	D49	D50	D51	D52	D53	D54	D57	
entry	.439	1300000	1200	1.00	1.00	.80	.30	144	144	1050	

The entries in cell E25 is because of assumed moist conditions. The spreadsheet returns an answer of .536 which means that the design is adequate. The "goal seek" function shows that the load could go as high as 14397 pounds (rounded off).

Example Problem 4: Check the adequacy of 93" long stud grade pine 2x4 studs @ 16" o.c. with the following conditions: weak way lateral support provided by nailed plywood sheathing, wind side uniform load moment of 240 lb-ft, axial roof live load of 530 pounds with assumed major and minor axes eccentricities of 0". Other conditions are normal.

The values entered into the various spreadsheet cells are shown in Table 12.

Table 12. Spreadsheet Entries for Example Problem 4.

Cell	E15	E16	E17	E18	E19	E29	E22	E23	E24	E25	E26
entry	240	0	530	0.0	0.0	1.60	1.50	1.15	1.00	1.00	1.00
Cell	E27	E28	E29	E30	E31	E32	E33	D35	D36	D37	D40
entry	1.0	1.0	1.0	1.0	1.1	1.15	1.0	1.5	3.5	6	12.36
Cell	D41	D42	D45	D49	D50	D51	D52	D53	D54	D57	
entry	.439	1200000	675	1.00	1.00	.80	.30	93	6	725	

The entry in cell E32 is based on the assumption that the studs qualify as repetitive members. The entries in cells D37 and D54 are based on the assumption that the sheathing nails spaced at 6" o.c. provide lateral support. The spreadsheet returns an answer of .680 which means that the design is adequate.

Example Problem 5: What is the maximum major axis eccentricity for a 10' long S4S 6x6 #2 Red Oak column with the following load conditions?
Axial load = 8000 pounds. All conditions are normal. Assume column end conditions are equivalent to hinged and 0.0" minor axis eccentricity.

The values entered into the various spreadsheet cells are shown in Table 13.

Table 13. Spreadsheet Entries for Example Problem 5.

Cell	E15	E16	E17	E18	E19	E21	E22	E23	E24	E25	E26
entry	0	0	8000	.21	0.0	1.00	1.00	1.00	1.00	1.00	1.00
Cell	E27	E28	E29	E30	E31	E32	E33	D35	D36	D37	D40
entry	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.5	5.5	120	120
Cell	D41	D42	D45	D49	D50	D51	D52	D53	D54	D57	
entry	.439	1000000	575	1.00	1.00	.80	.30	120	120	350	

The entry in cell E18 is found by trial and error or by the "goal seek" command consistent with the interaction value in cell C63 being equal to or slightly less than 1.00.

Example Problem 6: What is the allowable major axis bending stress and maximum major axis moment for a No. 1 Eastern Hemlock S4S 4x12 beam used as described following? Span = 16', one concentrated load and lateral support at the center and ends. All conditions are normal.

The values entered into the various spreadsheet cells are shown in Table 14.

Table 14. Spreadsheet Entries for Example Problem 6.

Cell	E15	E16	E17	E18	E19	E21	E22	E23	E24	E25	E26
entry	4707	0	0	*	*	1.00	1.00	*	1.00	*	1.00
Cell	E27	E28	E29	E30	E31	E32	E33	D35	D36	D37	D40
entry	1.0	1.0	1.0	1.0	1.1	1.0	1.0	3.5	11.25	48	53.3
Cell	D41	D42	D45	D49	D50	D51	D52	D53	D54	D57	
entry	.439	1100000	775	*	*	*	*	*	*	*	

* no value or any value. Not relevant to answer.

The allowable major axis bending stress is 770 psi as given in cell E47. The allowable moment is 4737 lb-ft, the entry in cell E15, as found by trial and error or by the "goal seek" command consistent with the interaction value in cell C64 being equal to or slightly less than 1.00.

REFERENCES

1. American Forest and Paper Association (AF&PA), American Wood Council, 2001, *National Design Specification ANSI/AF&PA NDS-2001*, Washington D.C.
2. American Forest and Paper Association (AF&PA), American Wood Council, 1997, *Commentary on National Design Specification*, Washington, D.C.
3. American Forest and Paper Association (AF&PA), American Wood Council, 1999, *Allowable Stress Design Supplement Structural Connections*, Washington, D.C.
4. American Forest and Paper Association (AF&PA), American Wood Council, 2001, *National Design Specification Supplement*, Washington, D.C.