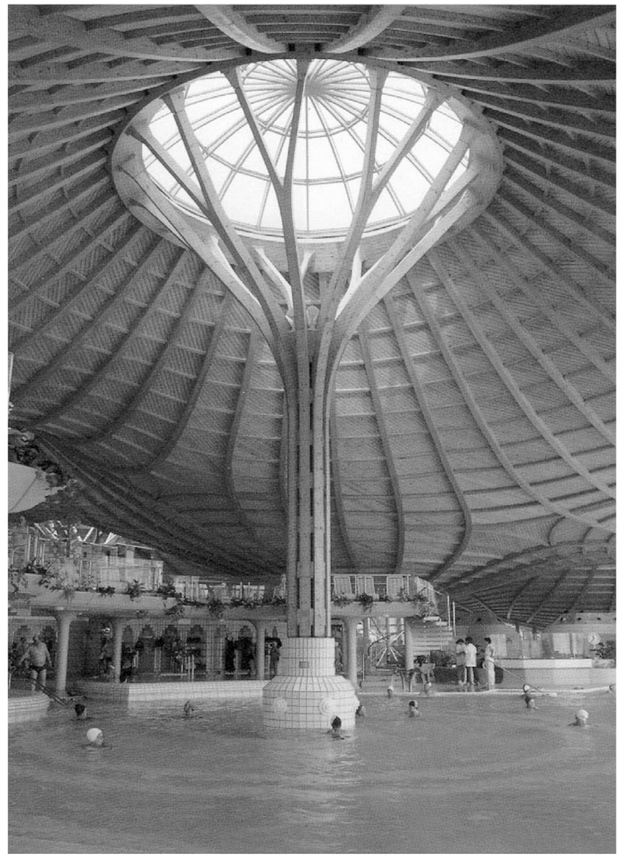
Architecture 544

Wood Columns

- Failure Modes
- Euler Equation
- End Conditions and Lateral Bracing
- Analysis of Wood Columns
- Design of Wood Columns



Solemar, Bad Dürrheim
Klaus Linkwitz, 1987

Failure Modes

FLEXURE **AXIAL**

Strength

$$f_b = \frac{Mc}{I} \qquad f_v = \frac{VQ}{Ib}$$

$$f_c = \frac{P}{A}$$

Stability

$$C_L = \frac{1+\left(F_{bE}/F_b^*\right)}{1.9} - \sqrt{\left[\frac{1+\left(F_{bE}/F_b^*\right)}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}}$$

$$C_P = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+\left(F_{cE}/F_c^*\right)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}}$$

Serviceability

Deflection **Bearing (crushing limit)**

Leonhard Euler (1707 – 1783)

Euler Buckling (elastic buckling)

$$P_{cr} = \frac{\pi^2 AE}{\left(\frac{KL}{r}\right)^2} = \frac{\pi^2 IE}{(KL)^2}$$

$$r = \sqrt{\frac{I}{A}}$$

$$I = Ar^2$$

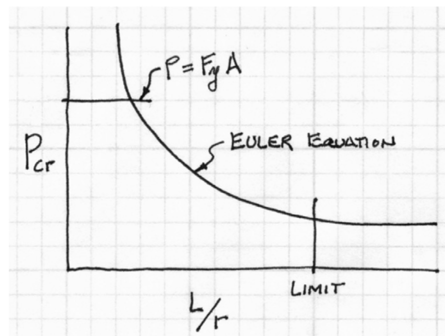
portrait by Emanuel Handmann,1753

- A = Cross sectional area (in^2)
- E = Modulus of elasticity of the material (lb/in^2)
- K = Stiffness (curvature mode) factor
- L = Column length between pinned ends (in.)
- le = K L
- r = radius of gyration (in.)

$$f_{cr} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

$$F_{cE} = \frac{0.822\ \mathrm{E'}_{\min}}{\left(\frac{le}{d}\right)^2}$$

$$r = d/\sqrt{12}$$



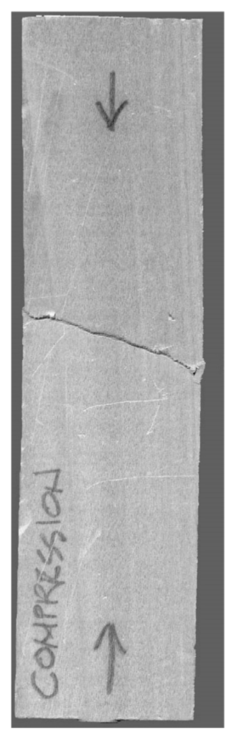
Failure Mode - Strength

Short Columns – fail by crushing

$$f_c = \frac{P}{A} \leq F_c$$

$$A = \frac{P}{F_c}$$

- f_c = Actual compressive stress
- A = Cross-sectional area of column (in^2)
- P = Load on the column
- F_c = Allowable compressive stress per codes



Failure Modes – Stability

Long Columns – fail by buckling

Traditional Euler

$$f_{cr} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

- E = Modulus of elasticity of the column material (psi)
- K = Stiffness (curvature mode) factor
- L = Column length between ends (inches)
- r = radius of gyration = $\sqrt{I/A}$ (inches)

$r = d/\sqrt{12}$

NDS Equation

$$F_{cE} = \frac{0.822E'_{min}}{\left(\frac{l_e}{d}\right)^2}$$

- E'min = reduced E modulus (psi)
- ℓe = Ke ℓ (inches)
- d (inches)
- 0.822 = $\pi^2/12$

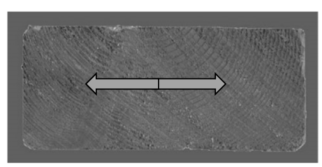
Slenderness Ratio ℓ_e/d

Slenderness Ratios:

The larger ratio will govern.
Try to balance for efficiency.

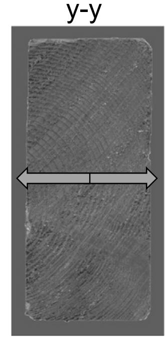
Slenderness Limited to < 50

x-x



d = 3.5

y-y



b = 1.5

ratios for an 8 ft long 2x4:

X- X

$K_e = 1.0$

$\ell_e = 1.0(96)$

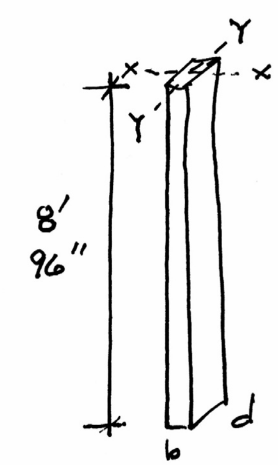
$\frac{\ell_e}{d} = \frac{96}{3.5} = 27.4$

Y- Y

$K_e = 1.0$

$\ell_e = 1.0(96)$

$\frac{\ell_e}{b} = \frac{96}{1.5} = 64$



End Support Conditions

NDS 3.7.1.2

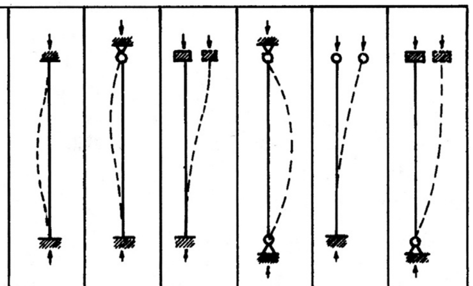
K_e is a constant based on the end conditions

ℓ is the actual length

ℓ_e is the effective length (curved part)

$\ell_e = K_e \ell$

Table G1 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					

use these →

Allowable Flexure Stress F_c'

F_c from tables determined by species and grade

$F_c' = F_c$ (adjustment factors)

Actual Flexure Stress f_b

$f_c = P/A$

$$F_c' \geq f_c$$

Table 4A (Cont.) Base Design Values for Visually Graded Dimension Lumber (2"-4" thick)[1,2]

(All species except Southern Pine — see Table 4B) (Tabulated design values are for normal load duration and dry service conditions. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4A ADJUSTMENT FACTORS

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)						Grading Rules Agency
		Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity E	
EASTERN HEMLOCK-BALSAM FIR								
Select Structural	2" & wider	1250	575	140	335	1200	1,200,000	NELMA NSLB
No.1		775	350	140	335	1000	1,100,000	
No.2		575	275	140	335	825	1,100,000	
No.3		350	150	140	335	475	900,000	
Stud	2" & wider	450	200	140	335	525	900,000	
Construction	2"-4" wide	675	300	140	335	1050	1,000,000	
Standard		375	175	140	335	850	900,000	
Utility		175	75	140	335	550	800,000	

Adjustment Factors

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD											LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

Allowable Flexure Stress F_c'

F_c from tables determined by species and grade

$F_c' = F_c\,(C_D\, C_M\, C_t\, C_F\, C_i\, C_P)$

Adjustment factors for compression:

- C_D Load Duration Factor
- C_t Temperature Factor

Table 2.3.2 Frequently Used Load Duration Factors, C_D[1]

Load Duration	C_D	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact[2]	2.0	Impact Load

(1) Actual stress due to (DL) ≤ (0.9) (Design value)
(2) Actual stress due to (DL+LL) ≤ (1.0) (Design value)
(3) Actual stress due to (DL+WL) ≤ (1.6) (Design value)
(4) Actual stress due to (DL+LL+SL) ≤ (1.15) (Design value)
(5) Actual stress due to (DL+LL+WL) ≤ (1.6) (Design value)
(6) Actual stress due to (DL+SL+WL) ≤ (1.6) (Design value)
(7) Actual stress due to (DL+LL+SL+WL) ≤ (1.6) (Design value)

Table 2.3.3 Temperature Factor, C_t

Reference Design Values	In-Service Moisture Conditions[1]	C_t		
		T≤100°F	100°F<T≤125°F	125°F<T≤150°F
F_t, E, E_{min}	Wet or Dry	1.0	0.9	0.9
F_b, F_v, F_c, and $F_{c\perp}$	Dry	1.0	0.8	0.7
	Wet	1.0	0.7	0.5

1. Wet and dry service conditions for sawn lumber, structural glued laminated timber, prefabricated wood I-joists, structural composite lumber, wood structural panels and cross-laminated timber are specified in 4.1.4, 5.1.4, 7.1.4, 8.1.4, 9.3.3, and 10.1.5 respectively.

Allowable Flexure Stress F_c'
(For Dimensioned Lumber)

F_c from tables determined by species and grade

$F_c' = F_c\ (C_D\ C_M\ C_t\ C_F\ C_i\ C_P\ )$

Adjustment factors for compression:

- C_M Moisture Factor
- C_F Size Factor

Wet Service Factor, C_M

When dimension lumber is used where moisture content will exceed 19% for an extended time period, design values shall be multiplied by the appropriate wet service factors from the following table:

Wet Service Factors, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
0.85*	1.0	0.97	0.67	0.8**	0.9

* when $(F_b)(C_F) \le 1{,}150$ psi, $C_M = 1.0$

** when $(F_c)(C_F) \le 750$ psi, $C_M = 1.0$

Size Factors, C_F

		F_b		F_t	F_c
		Thickness (breadth)			
Grades	Width (depth)	2" & 3"	4"		
Select Structural, No.1 & Btr, No.1, No.2, No.3	2", 3", & 4"	1.5	1.5	1.5	1.15
	5"	1.4	1.4	1.4	1.1
	6"	1.3	1.3	1.3	1.1
	8"	1.2	1.3	1.2	1.05
	10"	1.1	1.2	1.1	1.0
	12"	1.0	1.1	1.0	1.0
	14" & wider	0.9	1.0	0.9	0.9
Stud	2", 3", & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	1.0	1.0
	8" & wider	Use No.3 Grade tabulated design values and size factors			
Construction, Standard	2", 3", & 4"	1.0	1.0	1.0	1.0
Utility	4"	1.0	1.0	1.0	1.0
	2" & 3"	0.4	—	0.4	0.6

Allowable Flexure Stress F_c'
(For Timbers)

F_c from tables determined by species and grade

$F_c' = F_c\ (C_D\ C_M\ C_t\ C_F\ C_i\ C_P\ )$

Adjustment factors for compression:

- C_M Moisture Factor
- C_F Size Factor

Size Factor, C_F

When visually graded timbers are subjected to loads applied to the narrow face, tabulated design values shall be multiplied by the following size factors:

Size Factors, C_F

Depth	F_b	F_t	F_c
d > 12"	$(12/d)^{1/9}$	1.0	1.0
d ≤ 12"	1.0	1.0	1.0

Wet Service Factor, C_M

When timbers are used where moisture content will exceed 19% for an extended time period, design values shall be multiplied by the appropriate wet service factors from the following table (for Southern Pine and Mixed Southern Pine, use tabulated design values without further adjustment):

Wet Service Factors, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
1.00	1.00	1.00	0.67	0.91	1.00

Allowable Flexure Stress F_c'

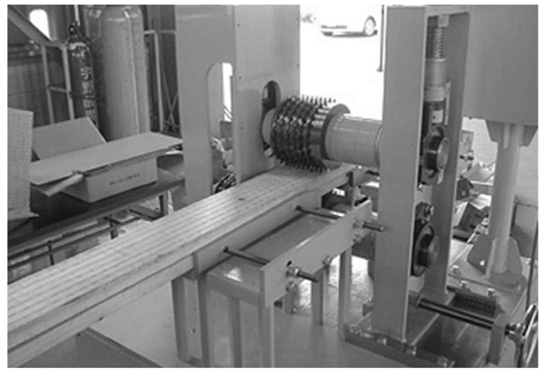
F_c from tables determined by species and grade

$F_c' = F_c\,(C_D\ C_M\ C_t\ C_F\ C_i\ C_P)$

Adjustment factors for compression :
C_i Incising Factor

Table 4.3.8 Incising Factors, C_i

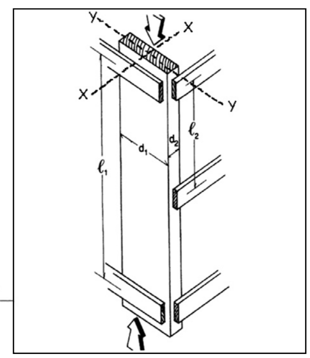
Design Value	C_i
E, E_{min}	0.95
F_b, F_t, F_c, F_v	0.80
$F_{c\perp}$	1.00



Allowable Flexure Stress F_c'

F_c from tables determined by species and grade

$F_c' = F_c\,(C_D\ C_M\ C_t\ C_F\ C_i\ C_P)$



3.7 Solid Columns

3.7.1 Column Stability Factor, C_P

3.7.1.1 When a compression member is supported throughout its length to prevent lateral displacement in all directions, $C_P = 1.0$.

3.7.1.2 The effective column length, ℓ_e, for a solid column shall be determined in accordance with principles of engineering mechanics. One method for determining effective column length, when end-fixity conditions are known, is to multiply actual column length by the appropriate effective length factor specified in Appendix G, $\ell_e = (K_e)(\ell)$.

3.7.1.3 For solid columns with rectangular cross section, the slenderness ratio, ℓ_e/d, shall be taken as the larger of the ratios ℓ_{e1}/d_1 or ℓ_{e2}/d_2 (see Figure 3F) where each ratio has been adjusted by the appropriate buckling length coefficient, K_e, from Appendix G.

3.7.1.4 The slenderness ratio for solid columns, ℓ_e/d, shall not exceed 50 except that during construction ℓ_e/d shall not exceed 75.

3.7.1.5 The column stability factor shall be calculated as follows:

$$C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_P (see 2.3), psi

$$F_{cE} = \frac{0.822\ E_{min}'}{(\ell_e/d)^2}$$

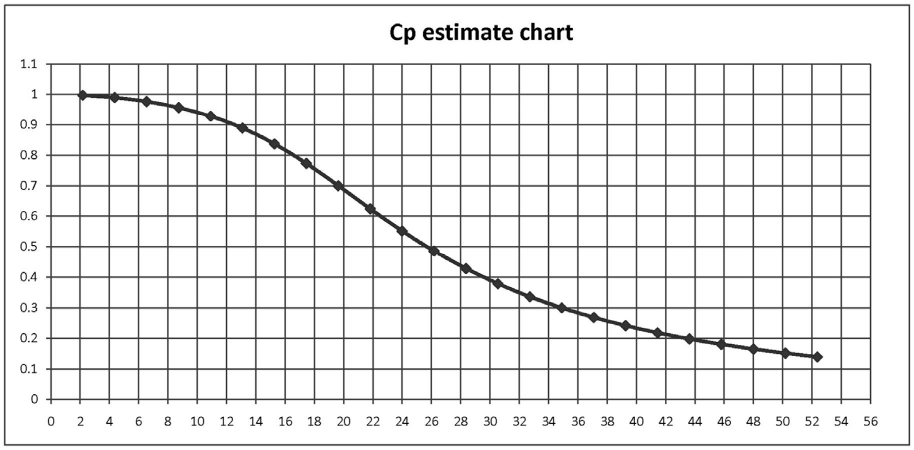
c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

C_P estimation

C_P



ℓ/d

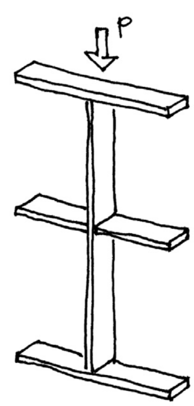
Analysis of Wood Columns

Data:

- Column – size, length
- Support conditions
- Material properties – F_c , E
- Load

Required:

- Pass/Fail or margin of safety

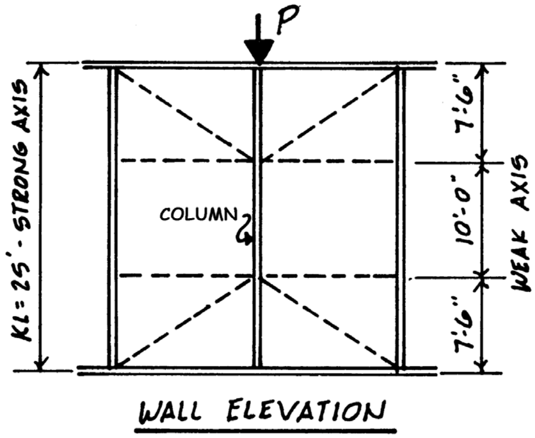


1. Calculate slenderness ratio ℓ_e/d
   largest ratio governs. Must be < 50
2. Find adjustment factors (all except C_P)
   C_D C_M C_t C_F C_i
3. Calculate C_P
4. Determine F'c by multiplying the tabulated Fc by all the above factors
5. Calculate the actual stress: fc = P/A
6. Compare Allowable and Actual stress.
   F'c > fc passes

Analysis Example:

Data: section 4x8 (nominal)
Douglas Fir-Larch No1
M.C. 15%
P = 7000 LBS (Snow Load)

Find: Pass/Fail



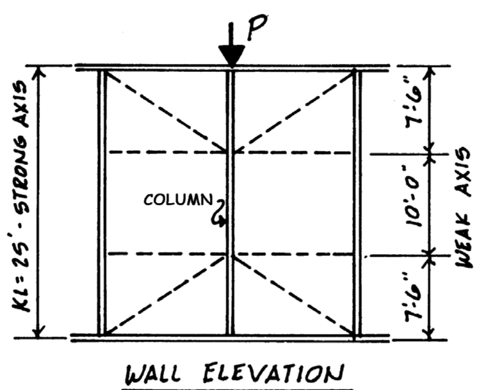
From NDS Supplement Table 4A
Fc = 1500 psi
Emin = 620000 psi

C_D = 1.15 (snow)
C_M = 1.0
C_t = 1.0
C_F = 1.05 (4x8)
C_i = 1.0
C_P = ?

Size Factors, C_F

Grades	Width (depth)	F_c
Select Structural, No.1 & Btr, No.1, No.2, No.3	2", 3", & 4"	1.15
	5"	1.1
	6"	1.1
	8"	1.05
	10"	1.0
	12"	1.0
	14" & wider	0.9
Stud	2", 3", & 4"	1.05
	5" & 6"	1.0
	8" & wider	
Construction, Standard	2", 3", & 4"	1.0
Utility	4"	1.0
	2" & 3"	0.6

Analysis Example:



Calculate C_P

$$C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_p (see 2.3), psi

$$F_{cE} = \frac{0.822\, E_{min}'}{(\ell_e/d)^2}$$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

X-X

$\ell_{ex} = 25' = 300''$

$\ell_{ex}/d_1 = \frac{300''}{7.25''} = 41.4$

Y-Y

$\ell_{ey} = 10' = 120''$

$\ell_{ey}/d_2 = \frac{120''}{3.5''} = 34.3$

$\ell_e/d = 41.4 < 50$ ✓

Analysis Example:

Calculate C_P

$$C_p = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_p (see 2.3), psi

$F_{cE} = \frac{0.822\ E_{min}'}{(\ell_e/d)^2}$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

$$F_{cE} = \frac{0.822\ E'_{min}}{(\ell_e/d)^2} = \frac{0.822(620000)}{(41.4)^2} = 297.6 \text{ psi}$$

$$F_c^* = 1500(1.15\ \ 1.05) = 1811.25 \text{ psi}$$

$$F_{cE}/F_c^* = \frac{297.6}{1811.25} = 0.164$$

$$c = 0.8$$

Analysis Example:

Calculate C_P

$$C_p = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_p (see 2.3), psi

$F_{cE} = \frac{0.822\ E_{min}'}{(\ell_e/d)^2}$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

$$C_p = \frac{1+0.164}{2(0.8)} - \sqrt{\left[\frac{1+0.164}{2(0.8)}\right]^2 - \frac{0.164}{.8}}$$

$$C_p = 0.1584$$

$$F'_c = 1500(1.15\ \ 1.05\ \ 0.1584) = 286.9 \text{ psi}$$

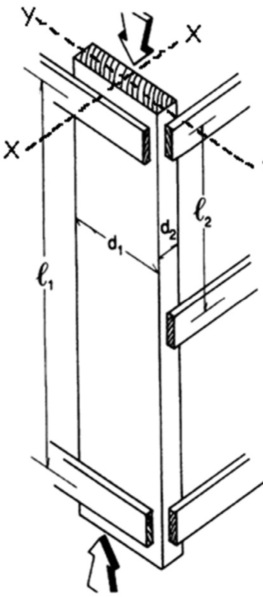
$$f_c = \frac{P}{A} = \frac{7000^{\#}}{25.38 \text{ in}^2} = 275.8 \text{ psi}$$

Compare Allowable and Actual stress

F'c > fc passes

$F'_c > f_c$ ✓ OK

Capacity Analysis of Columns



Data:

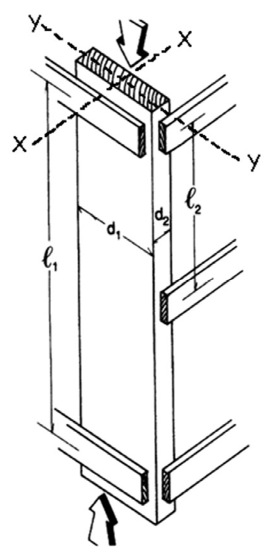
- Column – <u>size</u>, length
- Support conditions
- Material properties – F_c , E

Required:

- Maximum Load, Pmax

1. Calculate slenderness ratio ℓ_e/d
   largest ratio governs. Must be < 50
2. Find adjustment factors (all except C_P)
   C_D C_M C_t C_F C_i
3. Calculate C_P
4. Determine F'c by multiplying the tabulated Fc by all the above factors
5. Set actual stress = allowable, fc = F'c
6. Find the maximum allowable load
   Pmax = F'c A

Capacity Example



Data:

- 4x10
- Hem – Fir, No 2 M.C. = 20%
- Wind Load
- L_1 = 8' L_2 = 4' K_e=1.0

Required:

- Maximum Load, Pmax

From NDS Supplement Table 4A

Fc = 1300 psi
Emin = 470000 psi

C_D = 1.6
C_{Mc} = 0.8 C_{ME} = 0.9
C_t = 1.0
C_F = 1.0
C_i = 1.0
C_P = ?

x - x

$\ell_{ex} = 8' = 96''$

$\frac{\ell_{ex}}{d_1} = \frac{96}{9.25} = 10.4$

y - y

$\ell_{ey} = 4' = 48''$

$\frac{\ell_{ey}}{d_2} = \frac{48}{3.5} = 13.7$

$\ell_e/d = 13.7 < 50$ ✓

Allowable Flexure Stress F_c'

4 x 10 M.C 20% Fc = 1300psi

F_c from tables determined by species and grade

$F_c' = F_c (C_D C_M C_t C_F C_i C_P)$

Adjustment factors for compression:

C_M Moisture Factor

C_F Size Factor

Wet Service Factor, C_M

When dimension lumber is used where moisture content will exceed 19% for an extended time period, design values shall be multiplied by the appropriate wet service factors from the following table:

Wet Service Factors, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
0.85*	1.0	0.97	0.67	0.8**	0.9

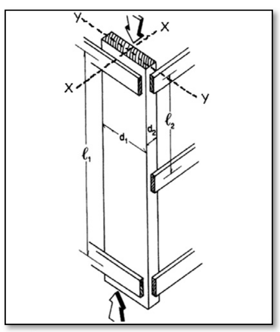
* when $(F_b)(C_F) \le 1{,}150$ psi, $C_M = 1.0$

** when $(F_c)(C_F) \le 750$ psi, $C_M = 1.0$

Size Factors, C_F

		F_b		F_t	F_c
		Thickness (breadth)			
Grades	Width (depth)	2" & 3"	4"		
Select Structural, No.1 & Btr, No.1, No.2, No.3	2", 3", & 4"	1.5	1.5	1.5	1.15
	5"	1.4	1.4	1.4	1.1
	6"	1.3	1.3	1.3	1.1
	8"	1.2	1.3	1.2	1.05
	10"	1.1	1.2	1.1	1.0
	12"	1.0	1.1	1.0	1.0
	14" & wider	0.9	1.0	0.9	0.9
Stud	2", 3", & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	1.0	1.0
	8" & wider	Use No.3 Grade tabulated design values and size factors			
Construction, Standard	2", 3", & 4"	1.0	1.0	1.0	1.0
Utility	4"	1.0	1.0	1.0	1.0
	2" & 3"	0.4	—	0.4	0.6

Capacity Example



Find C_P

$$C_p = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_P (see 2.3), psi

$$F_{cE} = \frac{0.822\ E_{min}'}{(\ell_e/d)^2}$$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

$$F_{cE} = \frac{0.822\ E'_{min}}{(\ell_e/d)^2}$$

$$= \frac{0.822(470000\ (0.9))}{13.7^2}$$

$$= 1848.7\ psi$$

$$F_c^* = 1300(1.6\ \ 0.8)$$

$$= 1664.\ psi$$

$$F_{cE}/F_c^* = \frac{1848.7}{1664.} = 1.111$$

$$C_p = 0.7261$$

Find the maximum load, Pmax

$$F_c' = 1300(1.6\ \ 0.8\ \ 0.7261)$$

$$= 1208\ psi$$

$$P_{max} = F_c'\ A = 1208(32.38) = 39115\ \#$$

Timber Column Design

Given:

- Lumber species, grade
- Conditions of use
- Load

Required:

- column size

1. Find adjustment factors (all except C_P)

   C_D C_M C_t C_F C_i
2. Guess C_P
3. Estimate Area and d (based on bracing)
4. Calculate slenderness ratio l_e/d

   largest ratio governs. Must be < 50
5. Calculate C_P
6. Determine F'c by multiplying the tabulated Fc by all the above factors
7. Revise Area: A = P/F'c
8. Revise C_P

Timber Column Design

Given:

- White Oak, No.1
- dry use, normal temp., not incised
- Load: D+L=55 psf

Required:

- column size

1. Find adjustment factors (all except C_P)

   C_D C_M C_t C_F C_i
2. Guess C_P → try 0.5

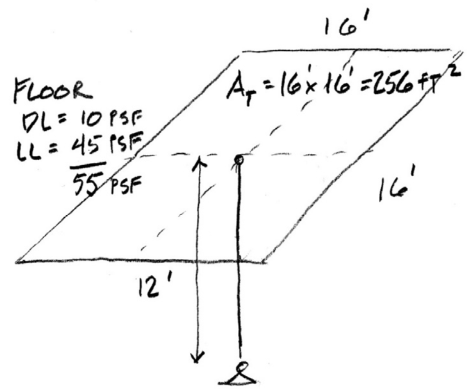


Table 4D (Cont.) **Reference Design Values for Visually Graded Timbers (5" x 5" and larger)[1,3]**

(Tabulated design values are for normal load duration and dry service conditions, unless specified otherwise. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4D ADJUSTMENT FACTORS

Species and commercial Grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
WHITE OAK										
Select Structural	Beams and Stringers	1,400	825	205	800	900	1,000,000	370,000	0.73	NELMA
No.1	Beams and Stringers	1,200	575	205	800	775	1,000,000	370,000	0.73	NELMA
No.2	Beams and Stringers	750	375	205	800	475	800,000	290,000	0.73	NELMA
Select Structural	Posts and Timbers	1,300	875	205	800	950	1,000,000	370,000	0.73	NELMA
No.1	Posts and Timbers	1,050	700	205	800	825	1,000,000	370,000	0.73	NELMA
No.2	Posts and Timbers	600	400	205	800	400	800,000	290,000	0.73	NELMA

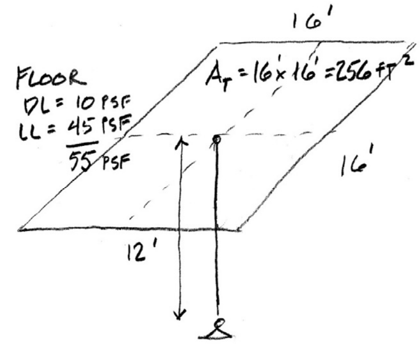
Timber Column Design

Given:

- White Oak, No.1
- dry use, normal temp., not incised
- Load: D+L=55 psf

Required:

- column size



1. Find adjustment factors (all except C_P)

   C_D C_M C_t C_F C_i

2. Guess C_P → try 0.5
3. Estimate Area and d (based on bracing)
4. Calculate slenderness ratio l_e/d

   largest ratio governs. Must be < 50

ESTIMATE SIZE:

GUESS $C_P = 0.5$

$$A = \frac{P}{F_c'} = \frac{14080\#}{825(.5)} = 34 \text{ in}^2$$

TRY:

$\sqrt{A} = d$ $\quad \sqrt{34} = 5.8$

SAY 5.5" x 5.5"

Timber Column Design

Given:

- White Oak, No.1
- dry use, normal temp., not incised
- Load: D+L=55 psf

Required:

- column size

5. Calculate C_P

TRY 6x6

$$\frac{l_e}{d} = \frac{(1)144''}{5.5} = 26.18$$

CHECK C_P ON GRAPH – ADJUST IF NEEDED

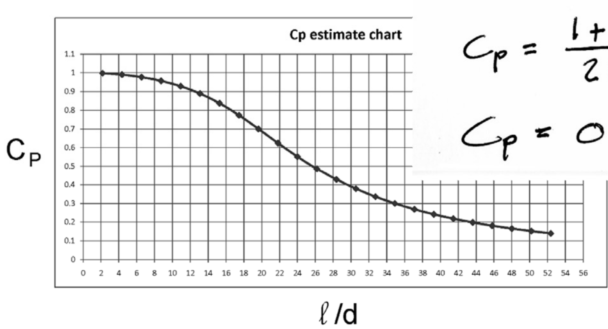
$$F_{cE} = \frac{0.822\,(370\,000)}{26.18^2} = 443.7 \text{ psi}$$

$$F_c^* = F_c\,(C_D C_M C_F C_t C_i) = 825 \text{ psi}$$

$$F_{cE}/F_c^* = \frac{443.7}{825} = 0.5378$$

$$C_P = \frac{1+0.5378}{2(0.8)} - \sqrt{\left[\frac{1+0.5378}{2(0.8)}\right]^2 - \frac{0.5378}{0.8}}$$

$C_P = 0.46$



Timber Column Design

Given:

- White Oak, No.1
- dry use, normal temp., not incised
- Load: D+L=55 psf

Required:

- column size

6. Determine F'c by multiplying the tabulated Fc by all the above factors
7. Revise Area: A = P/F'c
8. Revise C_P

Table 1B Section Properties of Standard Dressed

Nominal Size b x d	Standard Dressed Size (S4S) b x d in. x in.	Area of Section A in.[2]	X-X AXIS Section Modulus S_{xx} in.[3]	X-X AXIS Moment of Inertia I_{xx} in.[4]	Y-Y AXIS Section Modulus S_{yy} in.[3]	Y-Y AXIS Moment of Inertia I_{yy} in.[4]
Timbers (5" x 5" and larger)[2]						
Post and Timber (see NDS 4.1.3.4 and NDS 4.1.5.3)						
5 x 5	4-1/2 x 4-1/2	20.25	15.19	34.17	15.19	34.17
6 x 6	5-1/2 x 5-1/2	30.25	27.73	76.26	27.73	76.26
6 x 8	5-1/2 x 7-1/2	41.25	51.56	193.4	37.81	104.0
8 x 8	7-1/2 x 7-1/2	56.25	70.31	263.7	70.31	263.7
8 x 10	7-1/2 x 9-1/2	71.25	112.8	535.9	89.06	334.0

REVISED F'_c

$F'_c = 825(0.46) = 379.5$

$A = \frac{P}{F'_c} = \frac{14080^{\#}}{379.5^{\#}/_{in^2}} = 37.1\ in^2$

$6 \times 6: A = 30.25 < 37.1 \therefore$ FAILS

$6 \times 8 = 41.25\ in^2 > 37.1$

TRY 6×8

$\ell e/d = \frac{144''}{5.5''} = 26.18$

(SAME AS 6×6)

$C_p = 0.46$ (NO CHANGE)

$\therefore 6 \times 8$ PASSES

Timber Column Design

Design Aids

example of a column chart

from AWC Manual for Engineered Wood Construction – 2005

Table M4.5-2a ASD Column Capacity[1,2,3,4,5] (P', P'x, P'y), Timbers
6-inch nominal thickness (5.5 inch dry dressed size), $C_D = 1.0$.

Species	Column Length (ft)	Select Structural 6 x 6 6" width (=5.5") P'	Select Structural 6 x 8 8" width (=7.5") P'x	Select Structural 6 x 8 8" width (=7.5") P'y	No. 1 6 x 6 6" width (=5.5") P'	No. 1 6 x 8 8" width (=7.5") P'x	No. 1 6 x 8 8" width (=7.5") P'y	No. 2 6 x 6 6" width (=5.5") P'	No. 2 6 x 8 8" width (=7.5") P'x	No. 2 6 x 8 8" width (=7.5") P'y
	2	34,500	47,200	47,000	30,000	41,100	40,900	21,000	28,800	28,700
	4	33,400	46,400	45,500	29,200	40,500	39,800	20,500	28,400	28,000
	6	31,100	45,000	42,500	27,600	39,500	37,600	19,600	27,800	26,700
Douglas Fir-Larch	8	27,300	42,700	37,300	24,800	37,800	33,800	18,000	26,800	24,500
	10	22,300	39,200	30,400	20,900	35,300	28,500	15,700	25,400	21,400
	12	17,500	34,600	23,900	16,800	31,800	22,900	13,000	23,400	17,700
	14	13,700	29,500	18,700	13,300	27,800	18,200	10,500	20,900	14,300
	16	10,900	24,700	14,800	10,700	23,700	14,600	8,500	18,200	11,500
	2	29,200	40,000	39,800	25,500	34,900	34,800	17,300	23,600	23,600
	4	28,200	39,300	38,500	24,800	34,400	33,800	16,900	23,400	23,000
	6	26,200	38,100	35,800	23,300	33,500	31,800	16,100	22,900	22,000
	8	22,800	36,000	31,100	20,800	31,900	28,400	14,900	22,100	20,300
Hem-Fir	10	18,400	32,900	25,100	17,400	29,700	23,700	13,100	21,000	17,800
	12	14,300	28,800	19,600	13,800	26,600	18,900	10,900	19,400	14,800
	14	11,200	24,300	15,200	10,900	23,000	14,900	8,800	17,400	12,000
	16	8,800	20,200	12,000	8,700	19,500	11,900	7,200	15,200	9,800
	2	28,500	39,000	38,900	24,800	33,900	33,800	15,800	21,600	21,500
	4	27,700	38,500	37,800	24,200	33,500	33,000	15,500	21,400	21,100
	6	26,200	37,500	35,700	23,100	32,800	31,500	15,000	21,000	20,400
	8	23,500	35,900	32,100	21,200	31,600	28,900	14,100	20,500	19,200
Southern Pine	10	19,900	33,500	27,100	18,400	29,900	25,100	12,700	19,700	17,400
	12	16,000	30,200	21,800	15,200	27,500	20,700	11,000	18,500	15,000
	14	12,700	26,400	17,300	12,300	24,500	16,700	9,200	17,100	12,500
	16	10,100	22,400	13,800	9,900	21,300	13,500	7,600	15,300	10,300
	2	24,000	32,900	32,700	21,000	28,800	28,700	15,000	20,600	20,500
	4	23,400	32,400	31,900	20,500	28,400	28,000	14,700	20,300	20,100
	6	22,100	31,600	30,100	19,600	27,800	26,700	14,100	19,900	19,300
	8	19,900	30,300	27,100	18,000	26,800	24,500	13,100	19,300	17,900
Spruce-Pine-Fir	10	16,800	28,300	23,000	15,700	25,400	21,400	11,600	18,400	15,800
	12	13,600	25,600	18,500	13,000	23,400	17,700	9,800	17,100	13,400
	14	10,800	22,400	14,700	10,500	20,900	14,300	8,000	15,500	11,000
	16	8,600	19,100	11,800	8,500	18,200	11,500	6,500	13,700	8,900

1. P'_x values are based on a column continuously braced against weak axis buckling.
2. P'_y values are based on a column continuously braced against strong axis buckling.
3. To obtain LRFD capacity, see *NDS* Appendix N.
4. Tabulated values apply to members in a dry service condition, $C_M = 1.0$; normal temperature range, $C_t = 1.0$; and unincised members, $C_i = 1.0$.
5. Column capacities are based on concentric axial loads only and pin-pin end conditions ($K_e = 1.0$ per *NDS* Appendix Table G1).

4

M4: SAWN LUMBER