

## Wood Column Design

- Design of Wood Columns
- Stud Wall Design



## 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  $L_e/d$  SIZE  
largest ratio governs Must be  $< 50$
5. Calculate  $C_P$
6. Determine  $F'_c$  by multiplying the tabulated  $F_c$  by all the above factors
7. Revise Area:  $A = P/F'_c$
8. Revise  $C_P$
9. Repeat until  $F'_c > P/A$  ✓



# Timber Column Design

## Given:

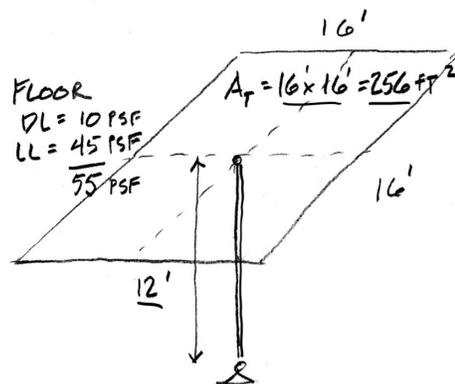
- White Oak, No.1  $F_c = 825$  psi
- dry use, normal temp., not incised
- Load:  $D+L=55$  psf

## Required:

- column size
1. Find adjustment factors (all except  $C_p$ )

$$C_D \cancel{C_M} \cancel{C_t} \cancel{C_F} \cancel{C_i}$$

2. Guess  $C_p \rightarrow$  try 0.5



**Table 4D Reference Design Values for Visually Graded Timbers (5" x 5" and larger)<sup>1,3</sup>**

(Cont.)

(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 <sup>4</sup> G	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	$E_{min}$		
<b>WHITE OAK</b>										
Select Structural No.1	Beams and Stringers	1,400	825	205	800	900	1,000,000	370,000	0.73	NELMA
No.2		1,200	575	205	800	775	1,000,000	370,000		
Select Structural No.1	Posts and Timbers	1,300	875	205	800	950	1,000,000	370,000		
No.2		1,050	700	205	800	825	1,000,000	370,000		
		600	400	205	800	400	800,000	290,000		

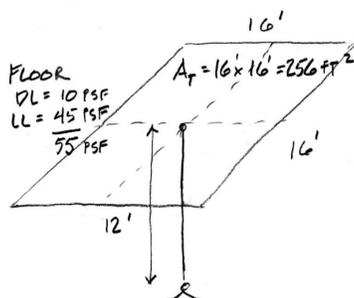
# Timber Column Design

## Given:

- White Oak, No. 1  $F_c = 825$  psi
- dry use, normal temp., not incised
- Load:  $D+L=55$  psf,  $P = 14080$  lbs

## Required:

- column size



## 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
$d \leq 12"$	1.0	1.0	1.0

## ESTIMATE SIZE:

$$\text{GUESS } C_p = 0.5$$

$$A = \frac{P}{F'_c} = \frac{14080}{825(0.5)} = 34 \text{ in}^2$$

TRY:

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

$$\text{so try } 5.5" \times 5.5"$$

TRY 6x6

$$\frac{P_e}{d} = \frac{(1)144}{5.5} \Rightarrow 26.18$$

1. Find adjustment factors (all except  $C_p$ )  
 $C_D C_M C_t C_F C_i = 1.0 \quad C_p$
2. Guess  $C_p \rightarrow$  try 0.5
3. Estimate Area and d (based on bracing)
4. Calculate slenderness ratio  $l_e/d$   
largest ratio governs. Must be  $< 50$

# Timber Column Design

## Given:

- White Oak, No.1
- $F_c = 825$  psi
- dry use, normal temp., not incised
- Load: D+L=55 psf

CHECK  $C_p$  ON GRAPH - ADJUST IF NEEDED

$$F_{cE} = \frac{0.822 (370000)}{26.18^2 \cdot \frac{1}{d}} = 443.7 \text{ psi}$$

$$F_c^* = F_c (C_D C_M C_P C_E C_t) = 825 \text{ psi}$$

## Required:

- column size

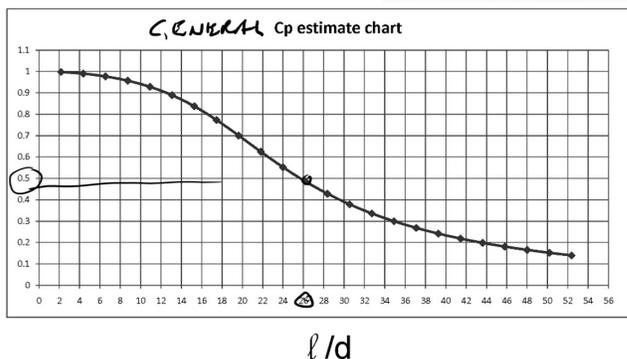
$$l_e/d = 26.18$$

- Calculate  $C_p$

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

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

$$C_p = 0.46$$



# Timber Column Design

## Given:

- White Oak, No. 1  $F_c = 825$  psi
- dry use, normal temp., not incised
- Load: D+L=55 psf

## Required:

- column size
- Determine  $F'_c$  by multiplying the tabulated  $F_c$  by all the above factors
  - Revise Area:  $A = P/F'_c$
  - Revise  $C_p$
  - Repeat until  $F'_c > P/A$

REVISED  $F'_c$

$$F'_c = F_c C_p = 825(0.46) = 379.5 \text{ psi}$$

$$A = \frac{P}{F'_c} = \frac{14080 \text{ lb}}{379.5 \text{ psi}} = 37.1 \text{ in}^2$$

6x6:  $A = 30.25 < 37.1 \therefore$  FAILS

6x8:  $A = 41.25 \text{ in}^2 > 37.1$

TRY 6x8

$$l_e/d = \frac{144}{5.5} = 26.18$$

(SAME AS 6x6)

$C_p = 0.46$  (NO CHANGE)

$$F'_c = 379.5 \text{ psi}$$

$$P/A = \frac{14080 \text{ lb}}{41.25 \text{ in}^2} = 341.3 \text{ psi}$$

6x8:  $379.5 > 341.3 \therefore$  OK

**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. <sup>2</sup>	X-X AXIS		Y-Y AXIS	
			Section Modulus $S_{xx}$ in. <sup>3</sup>	Moment of Inertia $I_{xx}$ in. <sup>4</sup>	Section Modulus $S_{yy}$ in. <sup>3</sup>	Moment of Inertia $I_{yy}$ in. <sup>4</sup>
Timbers (5" x 5" and larger) <sup>2</sup>						
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

# Timber Column Design

## Design Aids

example of a column chart

$P = 14080$  lbs

from AWC Manual for Engineered Wood Construction – 2005

**Table M4.5-2a ASD Column Capacity<sup>1,2,3,4,5</sup> (P', P<sub>x</sub>, P<sub>y</sub>), Timbers**  
6-inch nominal thickness (5.5 inch dry dressed size), C<sub>0</sub> = 1.0.

Species	Column Length (ft)	Column Capacity (lbs)									
		Select Structural			No. 1			No. 2			
		6 x 6 6" width (=5.5")	6 x 8 8" width (=7.5")		6 x 6 6" width (=5.5")	6 x 8 8" width (=7.5")		6 x 6 6" width (=5.5")	6 x 8 8" width (=7.5")		
P'	P <sub>x</sub>	P <sub>y</sub>	P'	P <sub>x</sub>	P <sub>y</sub>	P'	P <sub>x</sub>	P <sub>y</sub>			
Douglas Fir-Larch	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	
	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	
Hem-Fir	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	
	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	26,800	18,900	10,900	19,400	14,800	
Southern Pine	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	
	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	
Spruce-Pine-Fir	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	
	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	

1. P' values are based on a column continuously braced against weak axis buckling.  
 2. P<sub>x</sub> 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<sub>0</sub> = 1.0; normal temperature range, C<sub>1</sub> = 1.0; and unincised members, C<sub>2</sub> = 1.0.  
 5. Column capacities are based on concentric axial loads only and pin-pin end conditions (K<sub>x</sub> = 1.0 per NDS Appendix Table G1).

4  
M4: SAWN LUMBER

# Stud Wall Design

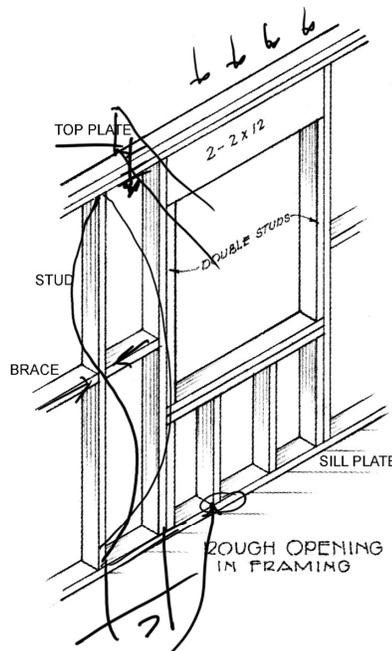
## Given:

- Lumber species, grade and size  $2 \times 4$  or  $2 \times 6$
- Conditions of use
- Load

## Required:

- Stud spacing

- Calculate slenderness ratio  $l_e/d$   
largest ratio governs. Must be  $< 50$
- Find adjustment factors (all except  $C_p$ )  
 $C_D C_M C_t C_F C_i$
- Calculate  $C_p$
- Determine  $F'_c$  by multiplying the tabulated  $F_c$  by all the above factors
- Set actual stress = allowable:  $f_c = F'_c$  MAX
- Find the capacity of one stud:  $P_{max} = F'_c A$
- Find allowable spacing ( $12"$ ,  $16"$  or  $24"$  o.c.)
- Check bearing



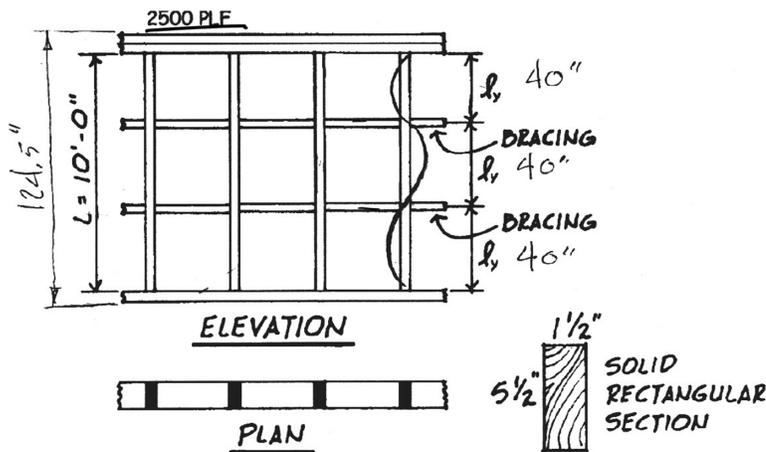
# Stud Wall Example - design

## Data:

- 2x6 *GRADE DRY*
- S-P-F, Stud M.C. = 12%
- D+L Load = 2500 PLF
- Braced as shown  $K_e = 1.0$

## Required:

- o.c. spacing ?



From NDS Supplement Table 4A

$F_c = 725 \text{ psi}$  ✓

$E_{min} = 440000 \text{ psi}$

$C_D = 1.0$  (LL) ✓

$C_{Mc} = 1.0$   $C_{ME} = 1.0$

$C_t = 1.0$

$C_F = 1.0$  (stud)

$C_P = 1.0$

$C_P = ?$

**Table 4A (Cont.) Reference Design Values for Visually Graded Dimension Lumber (2" - 4" thick)<sup>1,2,3</sup>**

(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.)

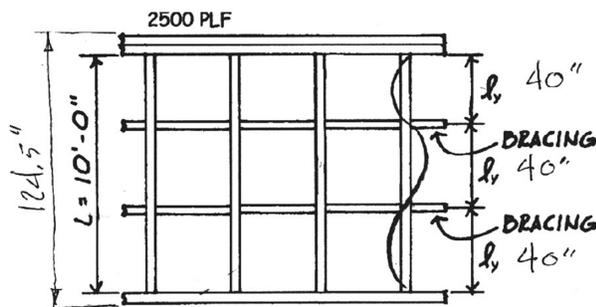
USE WITH TABLE 4A ADJUSTMENT FACTORS

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)						Modulus of Elasticity		Specific Gravity <sup>d</sup>	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 $E$	Modulus of Elasticity $E_{min}$			
									$E$		
<b>SPRUCE-PINE-FIR</b>											
Select Structural		1,250	700	135	425	1,400	1,500,000	550,000			
No. 1/ No. 2	2" & wider	875	450	135	425	1,150	1,400,000	510,000			
No. 3		500	250	135	425	650	1,200,000	440,000			
Stud	2" & wider	675	350	135	425	725	1,200,000	440,000	0.42	NLGA	
Construction Standard		1,000	500	135	425	1,400	1,300,000	470,000			
Utility	2" - 4" wide	550	275	135	425	1,150	1,200,000	440,000			
		275	125	135	425	750	1,100,000	400,000			

# Stud Wall Example

## Data:

- 2x6
- S-P-F, Stud M.C. = 12%
- D+L Load = 2500 PLF
- Braced as shown  $K_e = 1.0$
- $C_F = 1.0$  (stud) ✓



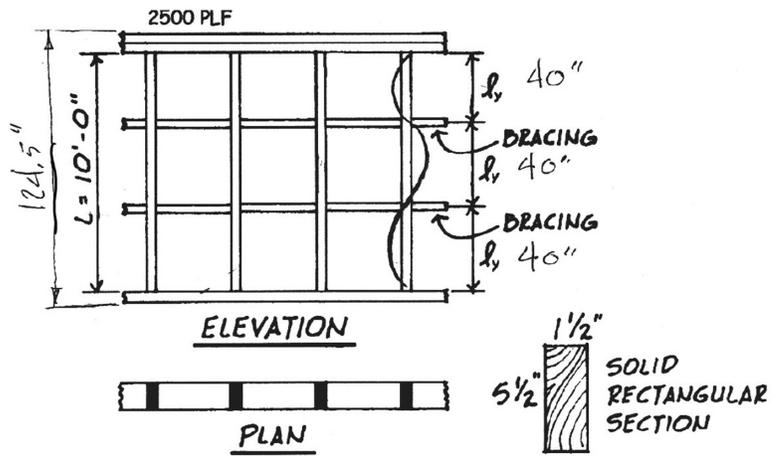
*DIM. LUM.*

Size Factors,  $C_F$

Grades	Width (depth)	$F_b$		$F_t$	$F_c$
		Thickness (breadth)			
		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
Stud	14" & wider	0.9	1.0	0.9	0.9
	2", 3", & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	1.0	1.0
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

# Stud Wall Example

From NDS Supplement Table 4A  
 $F_c = 725 \text{ psi}$   
 $E_{min} = 440000 \text{ psi}$



$$\begin{array}{l}
 \text{X-X} \\
 l_{e_x} = 124.5'' \\
 \frac{l_e}{d} = \frac{124.5''}{5.5''} = 22.6 \\
 \\
 \text{Y-Y} \\
 l_{e_y} = 40'' \\
 \frac{l_e}{d} = \frac{40''}{1.5''} = 26.7 \\
 \\
 \text{CONTROLLING } \frac{l_e}{d} = 26.7
 \end{array}$$

## Stud Wall Example - design

$C_p$

$$\begin{array}{l}
 \text{X-X} \\
 l_{e_x} = 124.5'' \\
 \frac{l_e}{d} = \frac{124.5''}{5.5''} = 22.6 \\
 \\
 \text{Y-Y} \\
 l_{e_y} = 40'' \\
 \frac{l_e}{d} = \frac{40''}{1.5''} = 26.7 \\
 \\
 \text{CONTROLLING } \frac{l_e}{d} = 26.7
 \end{array}$$

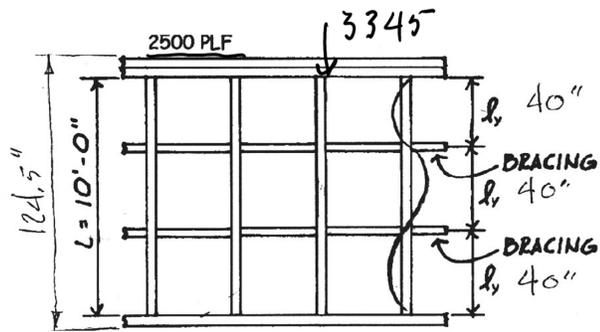
$$F_{CE} = \frac{0.822 E_{min}}{\left(\frac{l_e}{d}\right)^2} = \frac{0.822 (440000)}{26.7^2} = 508.6$$

$$\frac{F_c^*}{C} = 725 \left( \frac{1 \times 1 \times 1}{1.0} \right) = 725 \text{ psi}$$

$$\frac{F_{CE}}{F_c^*} = \frac{508.6}{725} = 0.702$$

NDS eq. 3.7-1  $\rightarrow C_p = 0.559$

# Stud Wall Example - design



Find max allowable stress,  $F'_c$

$$F'_c = \frac{F_c}{C_p} = \frac{725}{0.559} = 405.6 \text{ psi}$$

Calculate max load per stud

$$P = F'_c \cdot A = 405.6 \text{ psi} \times 8.25 \text{ in}^2 = 3345 \text{ lbs}$$

Determine max stud spacing

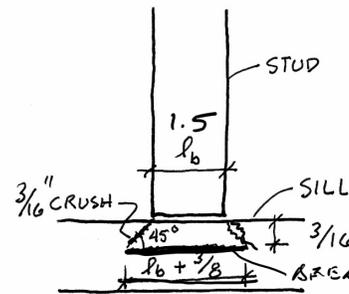
$$\frac{2500 \text{ PLF}}{3345 \text{ LBS/STUD}} \cdot \frac{12''}{16.04''} = S = 16'' \text{ O.C. (ROUND DOWN)}$$

# Stud Wall Example - design

Check bearing on sill plate

For 2x6  $\ell_b = 1.5''$

$C_b = 1.25$



### 3.10.4 Bearing Area Factor, $C_b$

Reference compression design values perpendicular to grain,  $F_{cL}$ , apply to bearings of any length at the ends of a member, and to all bearings 6" or more in length at any other location. For bearings less than 6" in length and not nearer than 3" to the end of a member, the reference compression design value perpendicular to grain,  $F_{cL}$ , shall be permitted to be multiplied by the following bearing area factor,  $C_b$ :

$$C_b = \frac{\ell_b + 0.375}{\ell_b} \quad (3.10-2)$$

where:

$\ell_b$  = bearing length measured parallel to grain, in.

Equation 3.10-2 gives the following bearing area factors,  $C_b$ , for the indicated bearing length on such small areas as plates and washers:

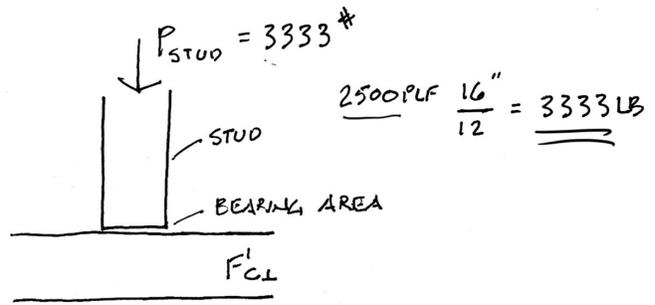
$\ell_b$	0.5"	1"	1.5"	2"	3"	4"	6" or more
$C_b$	1.75	1.38	1.25	1.19	1.13	1.10	1.00

For round bearing areas such as washers, the bearing length,  $\ell_b$ , shall be equal to the diameter.

# Stud Wall Example - design

Check bearing on sill plate

- determine  $C_b$
- calculate  $F'_{c\perp}$
- calculate  $f_{c\perp}$
- check stress



$b = 1.5''$   
 $C_b = 1.25 \checkmark$

$F_{c\perp} = 425 \text{ psi}$      $F'_{c\perp} = 425(1.25) = 531 \text{ psi}$

$f_{c\perp} = \frac{P}{A} = \frac{3333\#}{8.25 \text{ in}^2} = 404 \text{ psi}$

$f_{c\perp} = 404 < 531 = F'_{c\perp} \checkmark \text{OK}$

**Table 4A Reference Design Values for Visually Graded Dim (2" - 4" thick)<sup>1,2,3</sup>**

(All species except Southern Pine—see Table 4B) (Tat duration and dry service conditions. See NDS 4.3 for a comp adjustment factors.)

USE WITH TABLE 4A ADJUSTMENT FAC

Species and commercial grade	Size classification	Design values in pounds per sq ft				Corr p t t	1,200,000	440,000	0.42	NLGA
		Bending $F_b$	Tension parallel to grain $F_t$	Shear parallel to grain $F_v$	Compression perpendicular to grain $F_{c\perp}$					
<b>SPRUCE-PINE-FIR</b>										
Select Structural		1,250	700	135	425					
No. 1/ No. 2	2" & wider	875	450	135	425					
No. 3		500	250	135	425					
Stud	2" & wider	675	350	135	425	725	1,200,000	440,000	0.42	NLGA
Construction		1,000	500	135	425	1,400	1,300,000	470,000		
Standard	2" - 4" wide	550	275	135	425	1,150	1,200,000	440,000		
Utility		275	125	135	425	750	1,100,000	400,000		