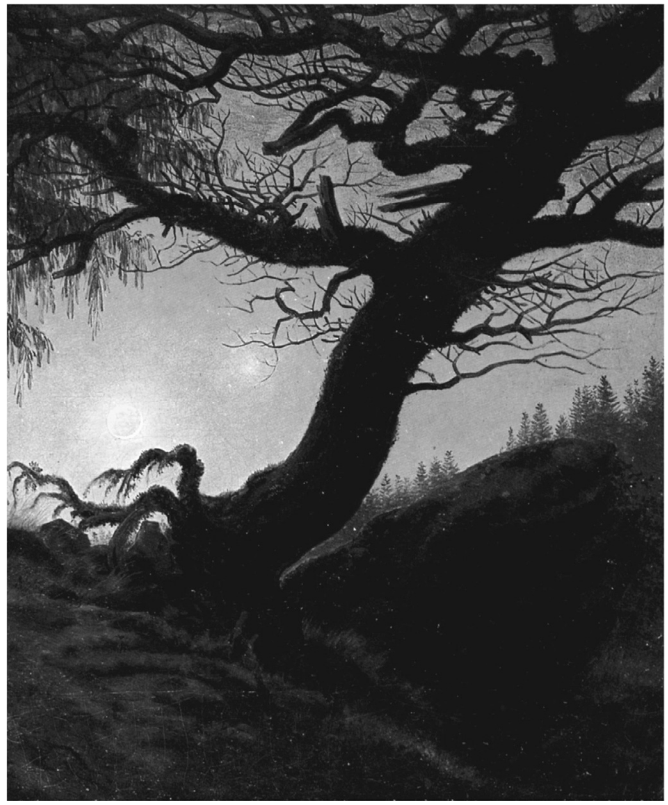
Combined Stress



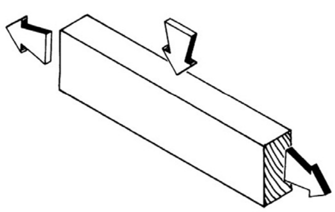
- Axial vs. Eccentric Load
- Combined Stress
- Interaction Formulas

from "Man und Frau den Mond betrachtend"
1830-35 by Caspar David Friedrich
Alte Nationalgalerie, Berlin

NDS - 3.9 Combined Bending and Axial Loading

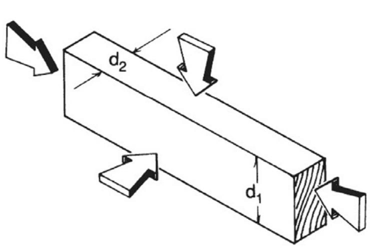
types and applications

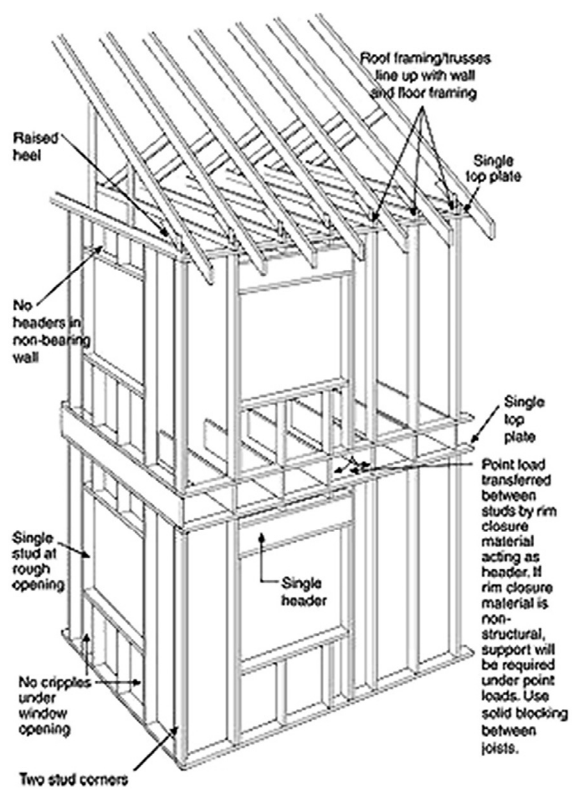
Figure 3G Combined Bending and Axial Tension



3.9.2 Bending and Axial Compression

Figure 3H Combined Bending and Axial Compression





NDS 3.9.1 Bending and Axial Tension
two conditions

3.9.1 Bending and Axial Tension

Members subjected to a combination of bending and axial tension (see Figure 3G) shall be so proportioned that:

$$\frac{f_t}{F_t'}+\frac{f_b}{F_b^*}\leq 1.0 \qquad \text{TENSION CRIT.} \qquad (3.9\text{-}1)$$

and

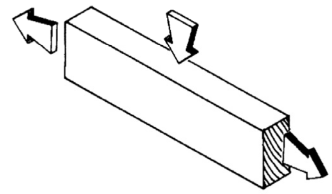
$$\frac{f_b-f_t}{F_b^{**}}\leq 1.0 \qquad \text{FLEXURE CRIT.} \qquad (3.9\text{-}2)$$

where:

F_b^* = reference bending design value multiplied by all applicable adjustment factors except C_L

F_b^{**} = reference bending design value multiplied by all applicable adjustment factors except C_V

Figure 3G Combined Bending and Axial Tension



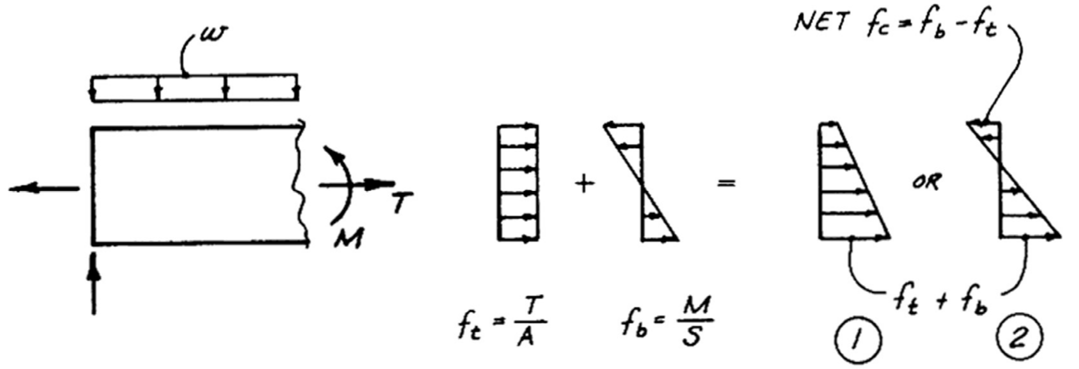
NDS 3.9.1 Bending and Axial Tension
NDS Equations

CASE 1. Tension is critical. eq. 3.9-1
* no C_L

$$\frac{f_t}{F_{t'}}+\frac{f_b}{F_b *}\leq 1.0$$

CASE 2. Flexure is critical. eq. 3.9-2
** no C_V

$$\frac{f_b-f_t}{F_b **}\leq 1.0$$

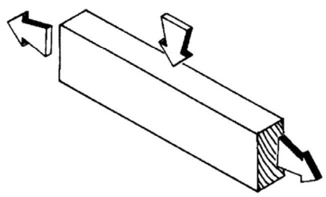


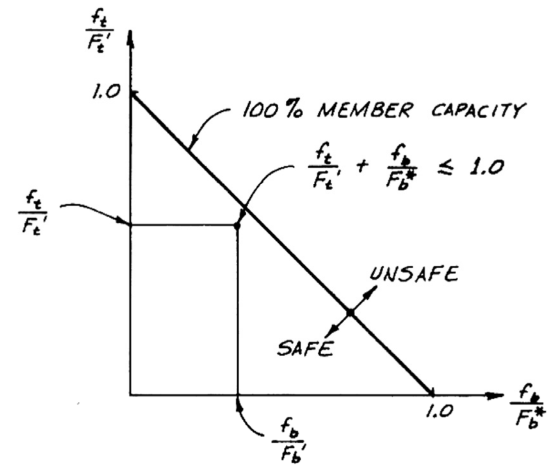
TENSION + BENDING = COMBINED STRESSES

NDS 3.9.1 Bending and Axial Tension

tension + bending

Figure 3G Combined Bending and Axial Tension





BASIC STRAIGHT LINE INTERACTION FORMULA

NDS 3.9.2 Bending and Axial Compression

two axis bending + compression

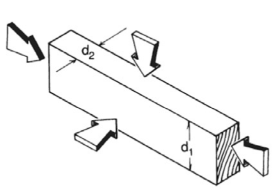
3.9.2 Bending and Axial Compression

Members subjected to a combination of bending about one or both principal axes and axial compression (see Figure 3H) shall be so proportioned that:

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-\left(f_c/F_{cE1}\right)\right]} + \frac{f_{b2}}{F_{b2}'\left[1-\left(f_c/F_{cE2}\right)-\left(f_{b1}/F_{bE}\right)^2\right]} \leq 1.0 \quad (3.9\text{-}3)$$

and **(Flatwise bending + compression)**

$$\frac{f_c}{F_{cE2}} + \left(\frac{f_{b1}}{F_{bE}}\right)^2 < 1.0 \quad (3.9\text{-}4)$$



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

$$f_b = \frac{M}{S}$$

where:

$f_c < F_{cE1} = \frac{0.822\,E_{min}'}{(\ell_{e1}/d_1)^2}$ for either uniaxial edgewise bending or biaxial bending

and

$f_c < F_{cE2} = \frac{0.822\,E_{min}'}{(\ell_{e2}/d_2)^2}$ for uniaxial flatwise bending or biaxial bending

and

$f_{b1} < F_{bE} = \frac{1.20\,E_{min}'}{(R_B)^2}$ for biaxial bending

f_{b1} = actual edgewise bending stress (bending load applied to narrow face of member) , psi

f_{b2} = actual flatwise bending stress (bending load applied to wide face of member) , psi

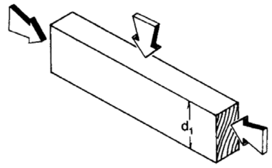
d_1 = wide face dimension (see Figure 3H), in.

d_2 = narrow face dimension (see Figure 3H), in.

NDS 3.9.2 Bending and Axial Compression

three possible combinations

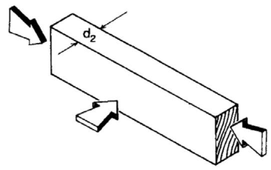
$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-\left(f_c/F_{cE1}\right)\right]} \leq 1.0$$



$$f_c < F_{cE1} = \frac{0.822\,E_{min}'}{(\ell_{e1}/d_1)^2}$$

COMP. + FLEXURE X-X

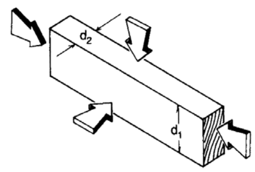
$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b2}}{F_{b2}'\left[1-\left(f_c/F_{cE2}\right)-\left(f_{b1}/F_{bE}\right)^2\right]} \leq 1.0$$



$$f_c < F_{cE2} = \frac{0.822\,E_{min}'}{(\ell_{e2}/d_2)^2}$$

COMP. + FLEXURE Y-Y

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-\left(f_c/F_{cE1}\right)\right]} + \frac{f_{b2}}{F_{b2}'\left[1-\left(f_c/F_{cE2}\right)-\left(f_{b1}/F_{bE}\right)^2\right]} \leq 1.0$$



$$f_{b1} < F_{bE} = \frac{1.20\,E_{min}'}{(R_B)^2}$$

COMP. + FLEXURE X-X + FLEXURE Y-Y

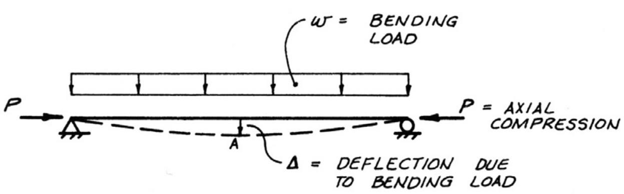
NDS 3.9.2 Bending and Axial Compression

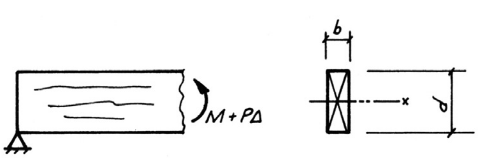
strong axis bending + compression

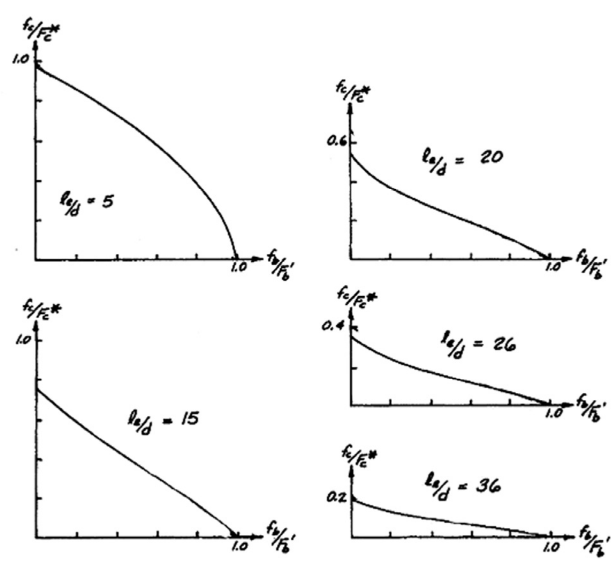
$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'}\;\frac{1}{\left[1-\left(f_c/F_{cE1}\right)\right]} \leq 1.0$$

AMPLIFICATION FACTOR

COMP. + FLEXURE X-X







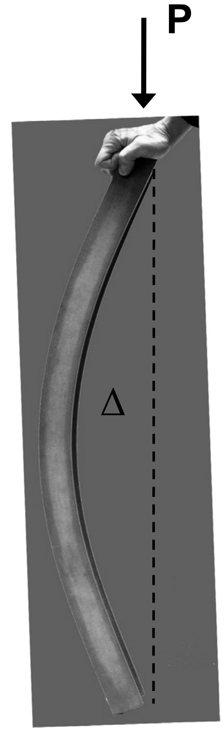
Interaction graphs for different slenderness rations - Breyer

Second Order Stress
"P Delta Effect"

With larger deflections this can become significant.

1. Eccentric load causes bending moment
2. Bending moment causes deflection, Δ
3. P x Δ causes additional moment

Accounted for by use of an amplification factor

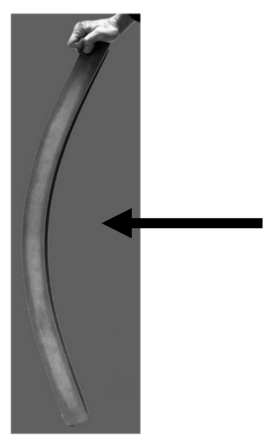


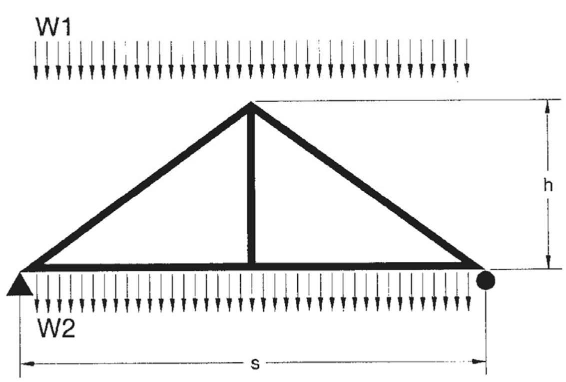
$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'}\ \underbrace{\frac{1}{\left[1-\left(f_c/F_{cE1}\right)\right]}}_{\text{AMPLIFICATION FACTOR}} \le 1.0$$

COMP. + FLEXURE X-X

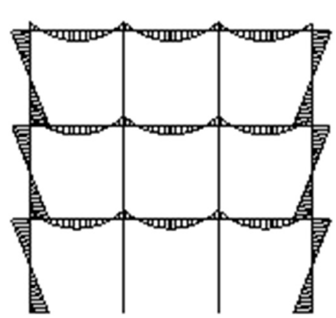
Examples
combined stress

Columns with side loading





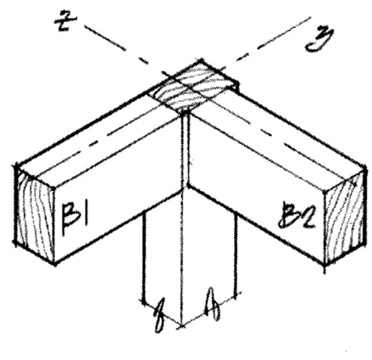
Trusses loaded on members

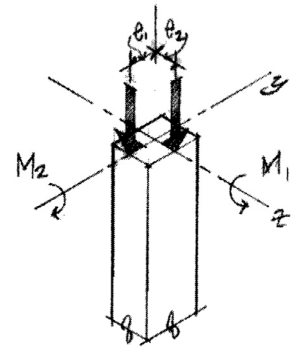


Continuous beams

Other Examples

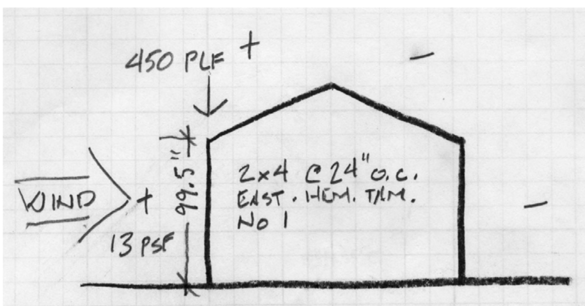
combined stress





$M_1 = P_1 \times e_1$ (ABOUT THE x-AXIS)

$M_2 = P_2 \times e_2$ (ABOUT THE y-AXIS)



Example Problem

Given: Queen Post truss

Hem-Fir No.1 & Better

F_b = 1100 psi

F_t = 725 psi

F_c = 1350 psi

E_{min} = 550000 psi

span = 30 ft. spaced 4 ft. o.c.

Projected Roof Load:

D = 14 psf S = 30 psf

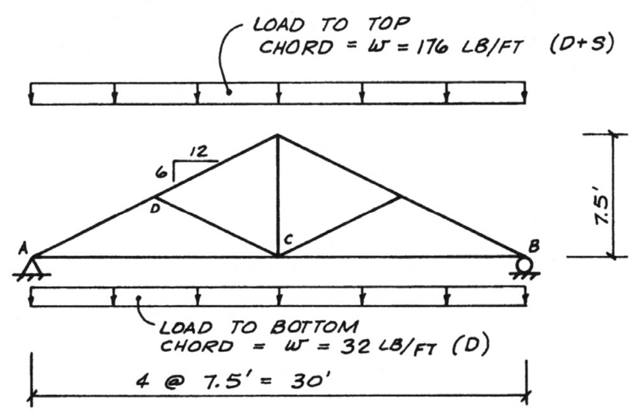
Attic + Ceiling:

D = 8 psf

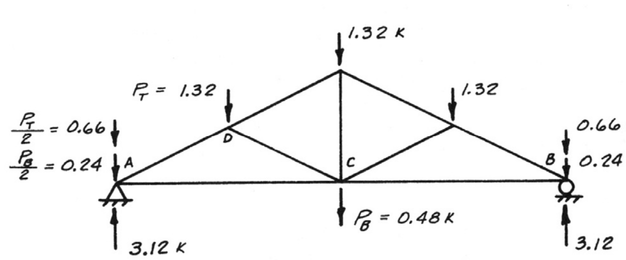
bottom chord: 2x8 (1.5” x 7.25”)

top chord: 2x10 (1.5” x 9.25”)

Find: pass/fail

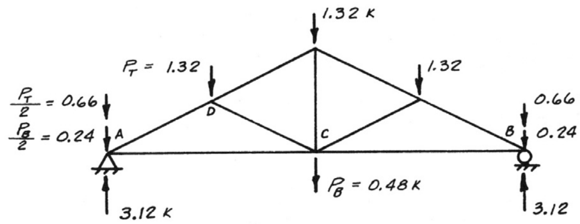


1. Determine truss joint loading

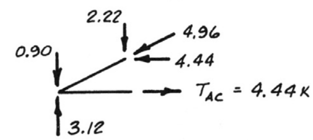


Example
truss reactions and member forces

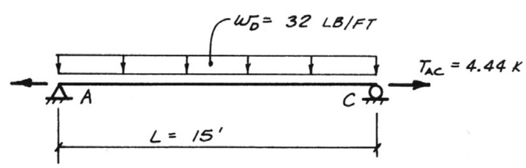
2. Determine the external **end reactions** of the whole truss. The geometry and loads are symmetric, so each reaction is ½ of the total load.



3. Use an FBD of the reaction joint to find the **chord forces**. Sum the forces horizontal and vertical to find the components.



D+S Load:
Top chord = 4.96 k compression
Bottom chord = 4.44 k tension



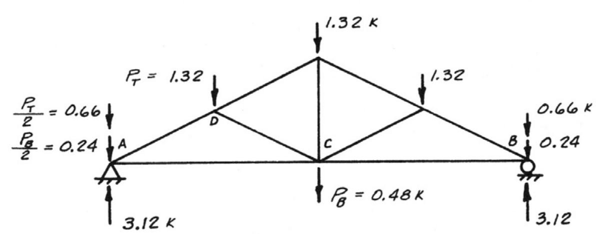
Example
bottom chord 2x8 – bending + tension

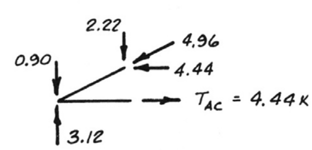
4. Determine controlling load case:

Tension Force: D+S
P_t / C_D = 4.44 lbs / 1.15 = 3.86 (controls)

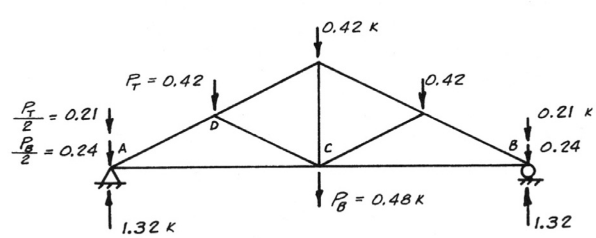
Tension Force: D
P_t / C_D = 1.74 k / 0.9 = 1.93

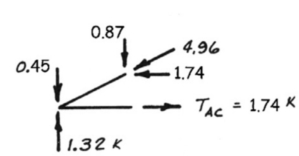
D+S





D alone

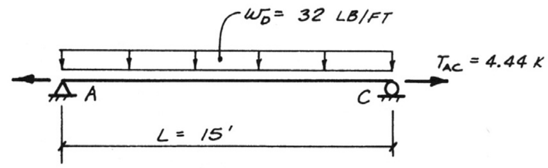




Example
bottom chord 2x8 – bending + tension

$$\frac{f_t}{F_{t'}} + \frac{f_b}{F_b*} \le 1.0 \qquad \frac{f_b - f_t}{F_b**} \le 1.0$$

D+S



5. Calculate the **actual** axial and flexural stress.

f_t = 408.3 psi

f_b = 821.9 psi

$$f_t = \frac{P}{A} = \frac{4440 \text{ lbs}}{10.875 \text{ in}^2} = 408.3 \text{ psi}$$

$$f_b = \frac{M}{S_x} = \frac{900\,(12)}{13.14} = 821.9 \text{ psi}$$

$$M = \frac{w\ell^2}{8} = \frac{32\,(15)^2}{8} = 900\ '\text{-}\#$$

$$S_x = 13.14 \text{ in}^3$$

Example
bottom chord 2x8 – bending + tension

Hem-Fir No.1 & Better
F_b = 1100 psi
F_t = 725 psi

C_L IS 1.0 BY 4.4.1
d/b = 4, ENDS ARE HELD

6. Determine **allowable** stresses using applicable factors:

Tension: D+S
$F_t' = F_t\,(C_D\,C_F)$
F_t' = 725 (1.15 1.2) = 1000 psi

F_t' = 1000 > 408.3 = f_t **ok**

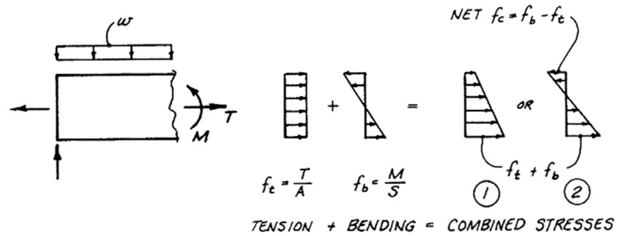
Flexure: D+S
$F_b' = F_b\,(C_D\,C_L\,C_F)$
F_b' = 1100 (1.15 1.0 1.2) = 1518 psi

F_b' = 1518 > 821.9 = f_b **ok**

Size Factors, C_F

Grades	Width (depth)	F_b Thickness (breadth) 2" & 3"	F_b Thickness (breadth) 4"	F_t	F_c
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"	$\boxed{1.2}$	1.3	$\boxed{1.2}$	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			
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

Example
bottom chord 2x8 – combined stress



3.9.1 Bending and Axial Tension

Members subjected to a combination of bending and axial tension (see Figure 3G) shall be so proportioned that:

$$\frac{f_t}{F_t'} + \frac{f_b}{F_b^*} \le 1.0 \qquad \text{TENSION CRIT.} \qquad (3.9\text{-}1)$$

and

$$\frac{f_b - f_t}{F_b^{**}} \le 1.0 \qquad \text{FLEXURE CRIT.} \qquad (3.9\text{-}2)$$

where:

F_b^* = reference bending design value multiplied by all applicable adjustment factors except C_L

F_b^{**} = reference bending design value multiplied by all applicable adjustment factors except C_V

(3.9-1)

$$\frac{408.3}{1000} + \frac{821.9}{1518}$$

$$0.4083 + 0.5414 = 0.95$$

$0.95 < 1.0$ ✓PASS

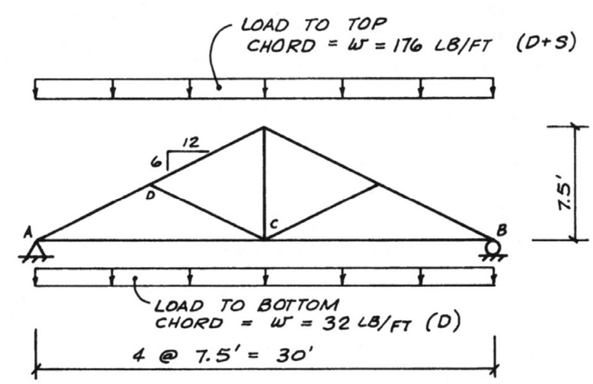
(3.9-2)

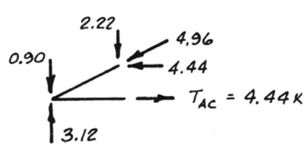
$$\frac{821.9 - 408.3}{1518} = 0.2724$$

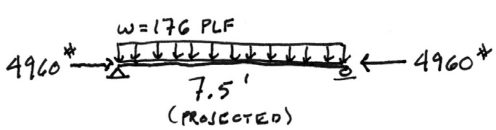
$0.27 < 1.0$ ✓PASS

Example
top chord 2x10 – bending + compression

D+S







$$M = \frac{w\ell^2}{8} = \frac{176\text{ PLF}(7.5')^2}{8} = 1237.5'\text{-}\#$$

$S_x = 21.39 \text{ in}^3$

4. Calculate the **actual** axial and flexural stress.

f_c = 357.5 psi

f_b = 694.2 psi

$$f_c = \frac{P}{A} = \frac{4960\#}{1.5 \times 9.25} = 357.5 \text{ psi}$$

$$f_b = \frac{M}{S_x} = \frac{1237.5\,(12)}{21.39} = 694.2 \text{ psi}$$

Example

top chord 2x10 – bending + compression

Hem-Fir No.1 & Better
F_b = 1100 psi
F_c = 1350 psi
E_{min} = 550000 psi

5. Determine **allowable** stresses using applicable factors:

(**compression**: D+S)
$F_c' = F_c\ (C_D\ C_F\ C_P)$
F_c' = 1350 (1.15 1.0 0.897) = 1392.7 psi > 357.5

(**flexure**: D+S)
$F_b' = F_b\ (C_D\ C_L\ C_F)$
F_b' = 1100 (1.15 1.0 1.1) = 1392 psi > 694.2

strong axis buckling

C_P

$\ell_e = 8.385'$ $d = 9.25''$

$\ell_e/d = \frac{8.385(12)}{9.25} = 10.88$

$F_{cE} = \frac{0.822\,E_{min}'}{(\ell_e/d)^2} = \frac{0.822(550000)}{10.88^2} = 3820$ psi

$F_c^* = 1350(1.15\ 1.0) = 1552.5$ psi

$F_{cE}/F_c^* = \frac{3820}{1552} = 2.46$ $c = 0.8$

$C_P = 0.897$

Size Factors, C_F

Grades	Width (depth	F_b Thickness (breadth) 2" & 3"	F_b Thickness (breadth) 4"	F_t	F_c
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"	$\boxed{1.1}$	1.2	1.1	$\boxed{1.0}$
	12"	1.0	1.1	1.0	1.0

C_L
The top chord is braced by the plywood sheathing so C_L = 1.0

Example

top chord 2x10 Eq. 3.9-3

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-(f_c/F_{cE1})\right]} \le 1.0$$

COMP. + FLEXURE X-X

$F_{CE1} = \frac{0.822(550000\text{ psi})}{(100.6''/9.25'')^2} = 3820.7$ psi

where:

$$f_c < F_{cE1} = \frac{0.822\,E_{min}'}{(\ell_{e1}/d_1)^2}$$ EULER 1 for either uniaxial edgewise bending or biaxial bending

and

$$f_c < F_{cE2} = \frac{0.822\,E_{min}'}{(\ell_{e2}/d_2)^2}$$ EULER 2 for uniaxial flatwise bending or biaxial bending

and

$$f_{b1} < F_{bE} = \frac{1.20\,E_{min}'}{(R_B)^2}$$ LTB for biaxial bending

f_{b1} = actual edgewise bending stress (bending load applied to narrow face of member)

f_{b2} = actual flatwise bending stress (bending load applied to wide face of member)

d_1 = wide face dimension (see Figure 3H)

d_2 = narrow face dimension (see Figure 3H)

COMPRESSION:

$$\left[\frac{f_c}{F_c'}\right]^2 = \left[\frac{357.5}{1392.7}\right]^2 = 0.0659$$

FLEXURE:

$$\frac{f_{b1}}{F_{b1}'} = \frac{694.2}{1392} = 0.4987$$

AMPLIFICATION FACTOR:

$$\frac{1}{1-(357.5/3820)} = \frac{1}{0.906}$$

$0.4987\,(1.103) = 0.550$

COMBINATION:

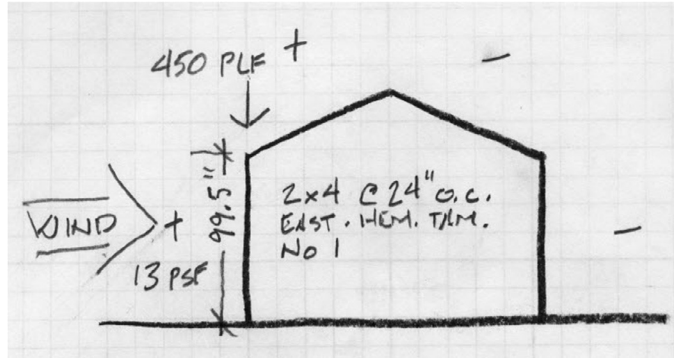
$0.0659 + 0.550 = 0.616$

$0.616 < 1.0$ ✓ PASS

Combined Stress in NDS
Stud wall example

Exterior stud wall under
bending + axial compression

1. Determine load per stud
2. Use axial load and moment to find actual stresses fc and fb
3. Determine load factors
4. Calculate factored stresses
5. Check NDS equation 3.9-3

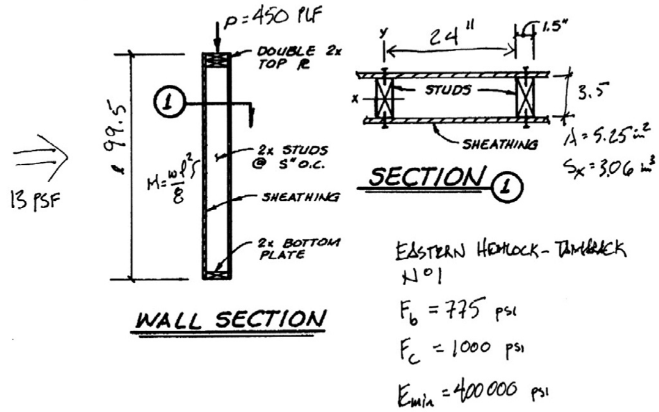


$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-\left(f_c/F_{cE1}\right)\right]} \leq 1.0 \quad (3.9\text{-}3)$$

and

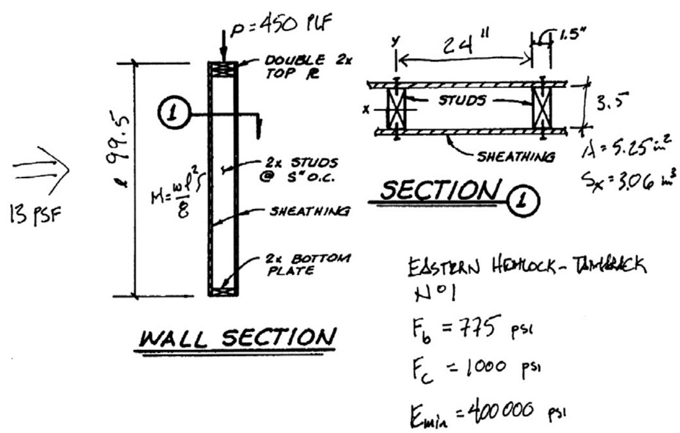
$$\frac{f_c}{F_{cE2}} + \left(\frac{f_{b1}}{F_{bE}}\right)^2 < 1.0 \quad (3.9\text{-}4)$$

flatwise bending



Combined Stress in NDS
stud wall

Exterior stud wall under
bending + axial compression



1. Determine load per stud

P = LOAD/STUD

$$P = 450 \text{ PLF } \frac{oc}{12} = 450 \frac{24}{12} = \boxed{900 \text{ LBS}}$$

$$w = 13 \text{PSF } \frac{oc}{12} = 13 \frac{24}{12} = 26 \text{ PLF/STUD}$$

2. Use axial load and moment to find actual stresses f_c and f_b

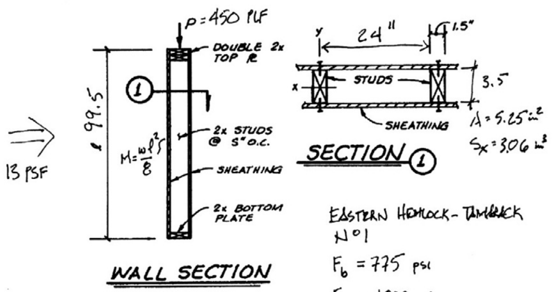
$$M_x = \frac{wl^2}{8} = \frac{26\,(99.5/12)^2}{8} = \boxed{223.4 \text{ '-\#}}$$

$$f_c = \frac{P}{A} = \frac{900}{5.25} = \boxed{171.43 \text{ PSI}}$$

$$f_b = M/S_x = \frac{223.4\,(12)}{3.06} = \boxed{875.5 \text{ PSI}}$$

Combined Stress in NDS
stud wall - bending

Exterior stud wall under
bending + axial compression



EASTERN HEMLOCK - TAMARACK
No1
$F_b = 775$ psi
$F_c = 1000$ psi
$E_{min} = 400000$ psi

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"	$\boxed{1.5}$	1.5	1.5	$\boxed{1.15}$
	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

3. Determine load factors (bending)

TABULATED STRESS:
$F_b = 775$ psi $\quad F_c = 1000$ psi $\quad E_{min} = 400\,000$ psi

FACTORS:
$C_D = \boxed{1.6}$ (WIND)
$C_F = \boxed{1.5}$ (FOR F_b) $\quad \boxed{1.15}$ (FOR F_c)
$C_L = \boxed{1.0}$ (BRACED BY SHEATHING)
$C_r = \boxed{1.15}$ ($\leq 24"$ o.c.)

Combined Stress in NDS
stud wall - bending

Exterior stud wall under
bending + axial compression

$F_b = 775$ psi

4. Calculate factored stresses

$C_D = 1.6 \qquad C_F = 1.5$
$C_M = 1.0 \qquad C_{fu} = 1.0$
$C_t = 1.0 \qquad C_i = 1.0$
$C_L = 1.0 \qquad C_r = 1.15$

Bending Stress

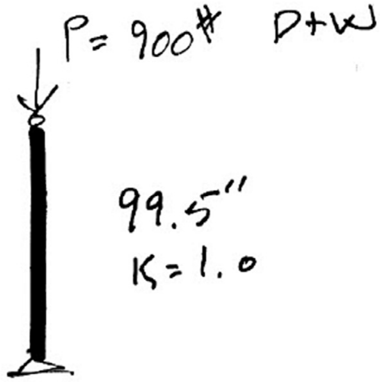
$$F'_b = 775(1.6)(1.5)(1.15) = 2139 \text{ psi}$$

Combined Stress in NDS

stud wall - compression

Exterior stud wall under
bending + axial compression

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



C_P (strong axis)

$F^* = 1000(1.6)(1.15) = 1840$

$F_{cE} = \frac{0.822(400000)}{(99.5/3.5)^2} = 406.8$

$c = 0.8$

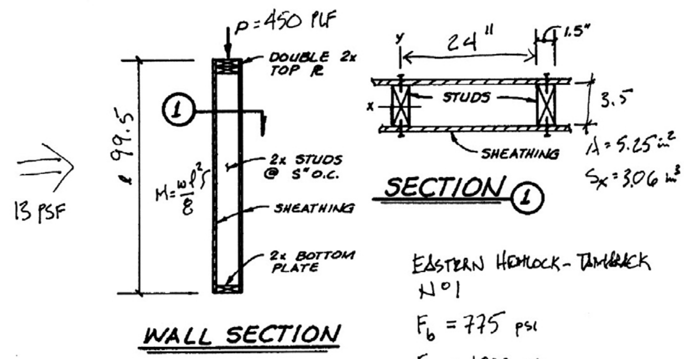
$C_p = 0.21$

3. Determine load factors
   (compression - braced in weak axis)

Combined Stress in NDS

stud wall - compression

Exterior stud wall under
bending + axial compression



EASTERN HEMLOCK-TAMARACK
No1
$F_b = 775$ psi
$F_c = 1000$ psi
$E_{min} = 400000$ psi

4. Calculate factored stresses
   $F_c' = F_c (C_D\ C_F\ C_P)$

   $C_D = 1.6$
   $C_F = 1.15$
   $C_P = 0.21$

   Compression Stress

   check fc < F'c

   (this should actually be checked for both W+D and D alone)

Actual Stress

$f_c = \frac{P}{A} = \frac{900^{\#}}{5.25} = 171.4$ psi

Factored Allowable Stress

$F_c' = 1000(1.6)(1.15)(0.21) = 386.4$ psi

Combined Stress in NDS
stud wall – combined stress

Exterior stud wall under
bending + axial compression

Combined Stress Calculation

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'}\;\frac{1}{1-\left(f_c/F_{cE1}\right)} \leq 1.0$$

$$\left[\frac{171.4}{386.4}\right]^2 + \frac{876}{2139}\;\frac{1}{1-\left(171.4/406.8\right)}$$

$$0.1967 + (0.4095)(1.728) =$$

$$0.1967 + 0.7077 = 0.9045 \leq 1.0 \checkmark \text{ok}$$

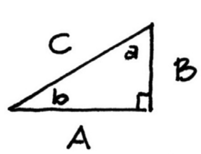
Rafters
Flexure y-y + Axial Compression

Given:
- S-P-F No.2 2x4 x 96”
- F_b = 875 psi
- F_c = 1150 psi E_{min} = 510000 psi
- P = 45 lbs.

Find: pass/fail

Find normal and axial components of the load.

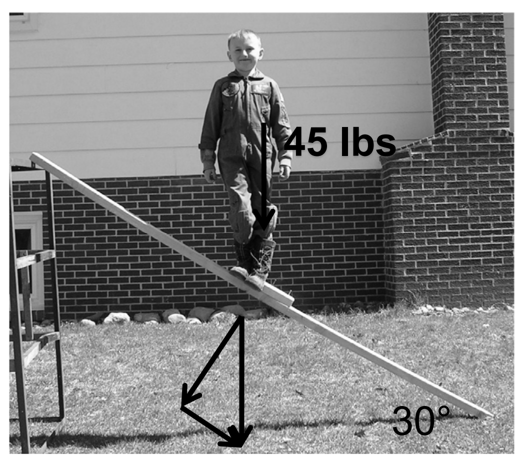
Axial = 22.5 lbs
Normal = 39 lbs



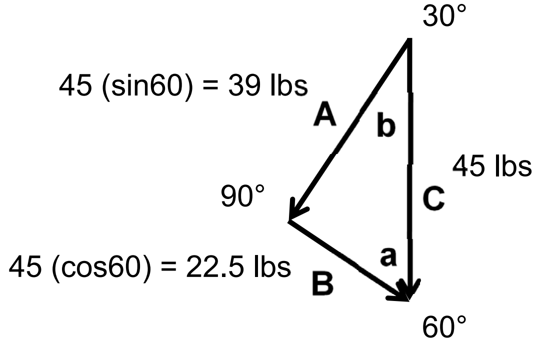
$A = C \cos b$
$A = C \sin a$
$B = C \sin b$
$B = C \cos a$
$C = \sqrt{A^2 + B^2}$

Francesco on 2x4

L_v = 48”



L_h = 83.14”



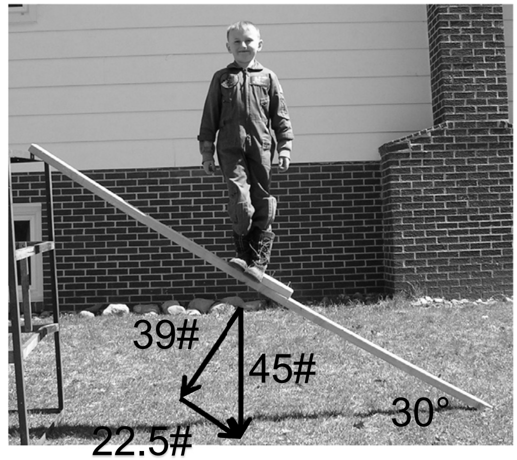
Rafters
Flexure y-y + Axial Compression

Given:
- S-P-F No.2 2x4 x 96”
- F_b = 875 psi
- F_c = 1150 psi E_{min} = 510000 psi
- P = 45 lbs. (as roof Lr)

Find: pass/fail

Axial = 22.5 lbs
Normal = 39 lbs

Francesco on 2x4



Actual stress:

COMPRESSION:

$$f_c = P/A = \frac{22.5}{5.25} = 4.285 \text{ psi}$$

$A = 5.25 \text{ in}^2$
$P = 22.5$

FLEXURE Y-Y

$$f_{b2} = \frac{M}{S_y} = \frac{936}{1.313} = 712.8 \text{ psi}$$

$$M = \frac{PL}{4} = \frac{39(96")}{4} = 936 \text{ "-\#}$$

$S_y = 1.313 \text{ in}^3$

Rafters
Flexure y-y + Axial Compression

S-P-F No.2 2x4 x 96” F_b = 875 psi
F_c = 1150 psi E_{min} = 510000 psi

Determine factored allowable stresses:

Flat Use Factor, C_{fu}

Bending design values adjusted by size factors are based on edgewise use (load applied to narrow face). When dimension lumber is used flatwise (load applied to wide face), the bending design value, F_b, shall also be permitted to be multiplied by the following flat use factors:

Flat Use Factors, C_{fu}

Width (depth)	Thickness (breadth) 2" & 3"	4"
2" & 3"	1.0	—
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.2	1.1

Compression

$F_c' = F_c(C_D C_F C_P)$
$F_c = 1150$ psi
$C_D(L_r) = 1.25$
$C_F = 1.15$

$$F_{cE} = \frac{0.822 E_{min}'}{(\ell_e/d)^2} = \frac{0.822(510000)}{(96/1.5)^2} = 102.3 \text{ psi}$$

$F_c^* = 1150(1.25\ 1.15) = 1653$ psi

$$F_{cE}/F_c^* = \frac{102.3}{1653} = 0.06191$$

$C_P = 0.0611$

$F_c' = 1150(1.25\ 1.15\ 0.0611) = 101.0$ psi

Flexure y-y

$F_{b2}' = F_b(C_D C_L C_F C_{fu})$
$F_b = 875$ psi
$C_D(L_r) = 1.25$
$C_F = 1.5$
$C_{fu} = 1.1$
$C_L = 1.0$

$F_{b2}' = 875(1.25\ 1.0\ 1.5\ 1.1) = 1804.6$ psi

Rafters
Flexure y-y + Axial Compression

Eq. 3.9-3

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b2}}{F_{b2}'\left[1-\left(f_c/F_{cE2}\right)-\left(f_{b1}/F_{bE}\right)^2\right]} \leq 1.0$$

COMP. + FLEXURE Y-Y

Check combination stresses:

- f_c = 4.258 psi
- F_c' = 101.0 psi
- f_{b2} = 712.8 psi
- F_{b2}' = 1804.6 psi
- F_{cE2} = 102.3 psi

Compression:

COMPRESSION:

$$\left(\frac{f_c}{F_c'}\right)^2 = \left(\frac{4.285}{101.0}\right)^2 = 0.00180$$

Rafters
Flexure y-y + Axial Compression

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b2}}{F_{b2}'\left[1-\left(f_c/F_{cE2}\right)-\left(f_{b1}/F_{bE}\right)^2\right]} \leq 1.0$$

COMP. + FLEXURE Y-Y

Check combination stresses:

Flexure y-y

$f_c = 4.285$ psi

$F_{cE2} = 102.3$ psi

$$\frac{f_c}{F_{cE2}} = \frac{4.285}{102.3} = 0.04188$$

$$f_{b1} = \frac{M}{S_x} = \frac{0}{3.06} = 0$$

(in this example there is no strong axis bending, so the term is zero)

FLEXURE Y-Y

$$\frac{f_{b2}}{F_{b2}'} = \frac{712.8}{1804.6} = 0.395$$

AMPLIFICATION FACTOR:

$$\frac{1}{1-(f_c/F_{cE2})-(f_{b1}/F_{bE})^2}$$

$$\frac{1}{1-\left(\frac{4.285}{1.02.3}\right)-\left(\frac{0}{F_{bE}}\right)^2} = \frac{1}{1-0.0418-0}$$

$$\frac{1}{0.9582} = 1.043$$

$$0.395(1.043) = 0.412$$

Rafters
Flexure y-y + Axial Compression

Check combination stresses:

Eq. 3.9-3

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b2}}{F_{b2}'\left[1-(f_c/F_{cE2})-(f_{b1}/F_{bE})^2\right]} \le 1.0$$

COMP. + FLEXURE Y-Y

COMPRESSION + FLEXURE Y-Y

$0.0018 + 0.412 = 0.414$

$0.414 < 1.0$ ✓OK

Rafters
Flexure y-y + Axial Compression

Check combination stresses:

Eq. 3.9-4

EQ 3.9-4 FLATWISE BENDING

$$\frac{f_c}{F_{cE2}} + \left(\frac{f_{b1}}{F_{bE}}\right)^2 < 1.0$$

$$\frac{4.285}{102.3} + \cancel{\left(\frac{0}{F_{bE}}\right)^2}$$

$0.0419 < 1.0$ PASS ✓