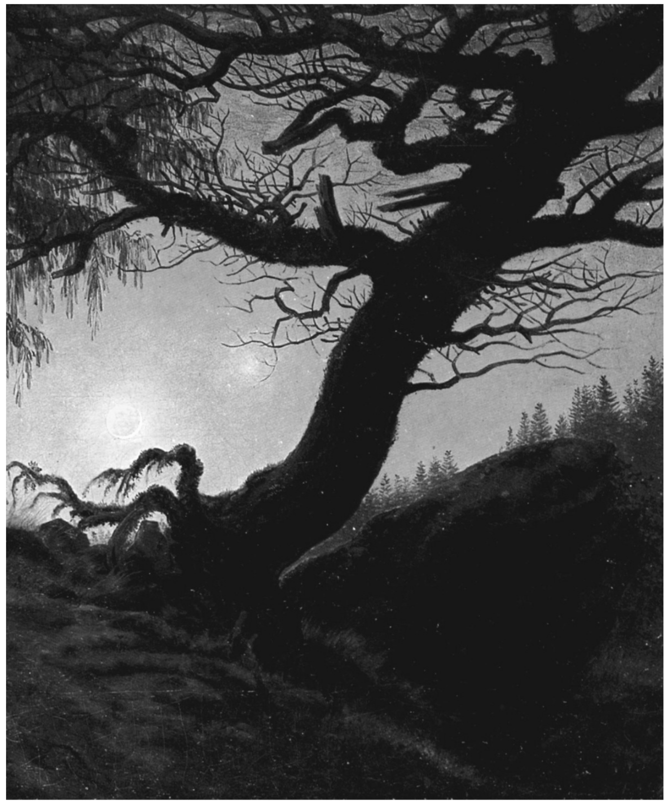
Combined Stress

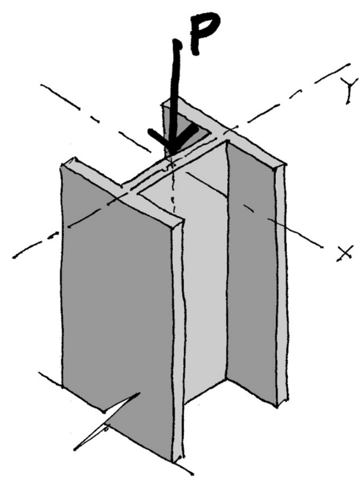


- Axial vs. Eccentric Load
- Combined Stress
- Interaction Formulas

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

Axial Stress

- Loads pass through the centroid of the section , i.e. axially loaded
- Member is straight
- Load less than buckling load

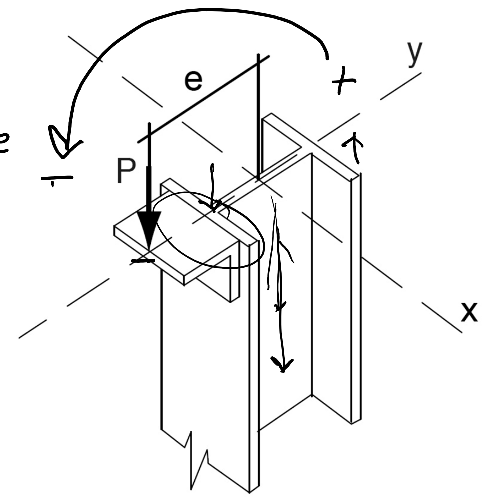


Then:

$$\boxed{f_a = \frac{P}{A}}$$

Eccentric Loads

M = Pe



- Load is offset from centroid
- Bending Moment = P e
- Total load = P + M

Interaction formula

$$\boxed{f = \frac{P}{A} \pm \frac{Mc}{I}}$$

AXIAL CAPACITY

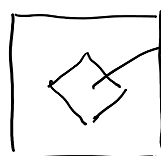
ACTUAL FLEXURE CAPACITY

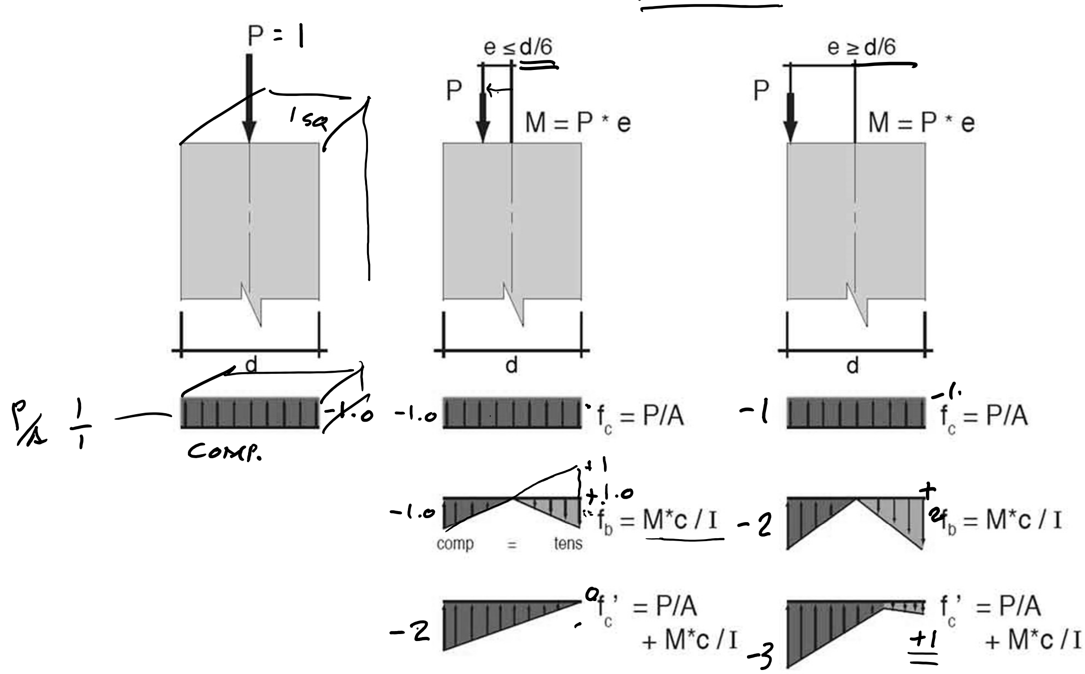
$$\boxed{\frac{f_a}{F_a} \pm \frac{f_b}{F_b} \leq 1.0} \quad 100\,\%$$

ALLOW.

Combined Stress

- Stresses combine by superposition
- Values add or subtract by sign





axial loaded - uniform compressive stress.

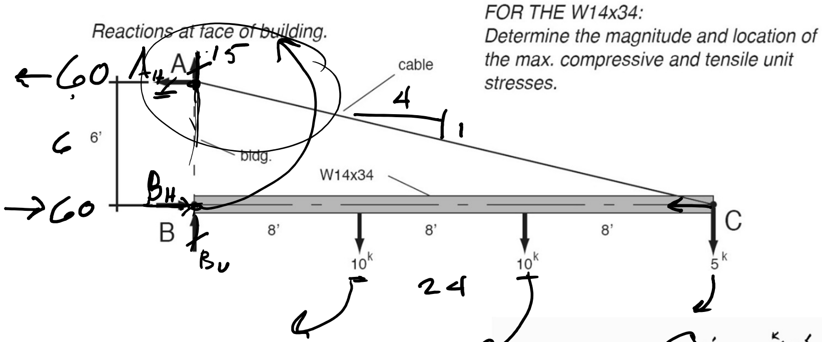
small eccentricity - linearly varying stress.

large eccentricity - tensile stress on part of cross section.

Example

CANOPY CONSTRUCTION PROJECTING FROM FACE OF BUILDING.
The supporting cable is pin-connected on the centroidal axis of the steel beam.

FOR THE W14x34:
Determine the magnitude and location of the max. compressive and tensile unit stresses.



1. Determine external reactions

$\Sigma M_A = 0 = -B_H 6' + 10^k(8') + 10^k(16') + 5^k(24')$

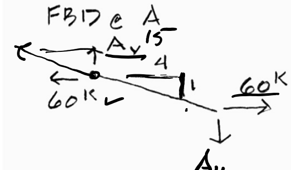
$B_H = 60^k$

$\Sigma M_B = 0 = -A_H(6') + 10^k(8') + 10^k(16') + 5^k(24')$

$A_H = 60^k$

CHECK $\Sigma F_H = 0 = 60^k - 60^k$ ✓

FBD @ A



$\frac{60}{4} : \frac{A_V}{1}$

$A_V = 15^k$

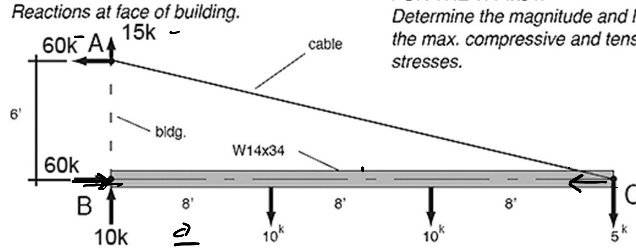
$\Sigma F_V = 0 = 15^k - 10^k - 10^k - 5^k + B_V$

$B_V = 10^k$

Example

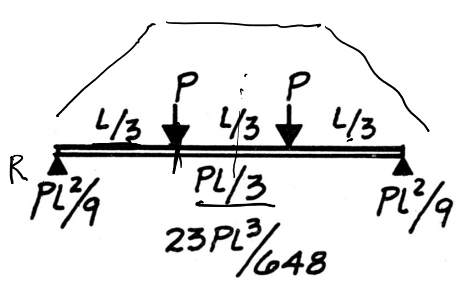
CANOPY CONSTRUCTION PROJECTING FROM FACE OF BUILDING.
The supporting cable is pin-connected on the centroidal axis of the steel beam.

FOR THE W14x34:
Determine the magnitude and location of the max. compressive and tensile unit stresses.



2. Determine internal member **forces**: Axial and Flexural

3. Determine axial and flexural **stresses**



W14x34 $A = 10.0 \text{ in}^2$

$S_x = 48.6 \text{ in}^3$

FORCE:

AXIAL $= 60^K$

FLEXURAL $= M = PL/3 = 10^K(8') = 80^{'-K}$

STRESS:

AXIAL $= f_a = \frac{P}{A} = 60^K / 10 \text{ in}^2 = 6.0 \text{ KSI}$

FLEXURAL $: f_b = M/S_x = 80^{'-K}(12)/48.6 \text{ in}^3 = 19.75 \text{ KSI}$

Example

2. Use interaction formula to determine combined stresses at key locations (e.g. extreme fibers)

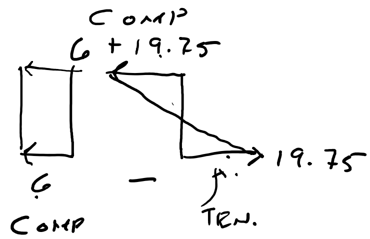
COMBINED STRESS

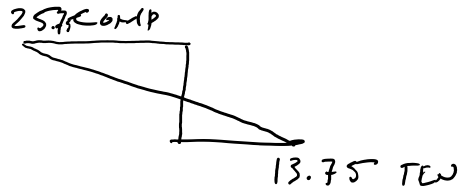
TOP SIDE:

$$f_a + f_b = 6.0 + 19.75 = \underline{25.75 \text{ KSI}} \text{ (COMP)}$$

BOTTOM SIDE:

$$f_a - f_b = 6.0 - 19.75 = \underline{-13.75 \text{ KSI}} \text{ (TENS)}$$

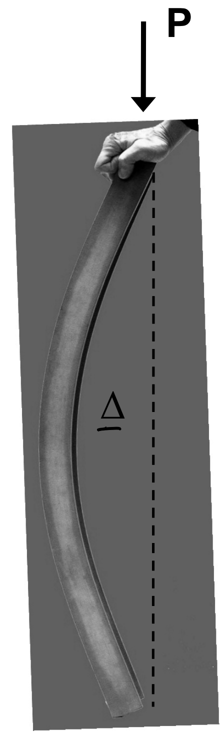




Second Order Stress
"P Delta Effect"

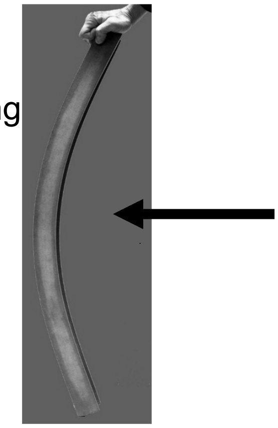
With larger deflections this can become significant.

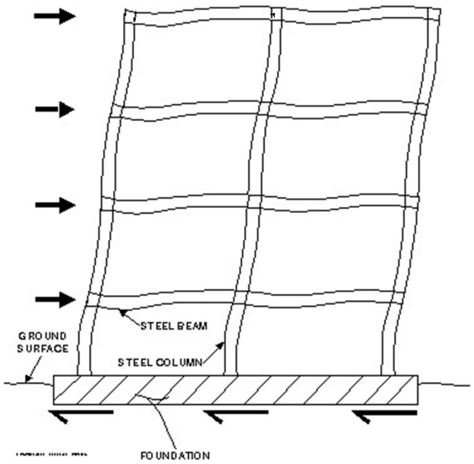
1. Eccentric load causes bending moment
2. Bending moment causes deflection, Δ
3. P x Δ causes additional moment



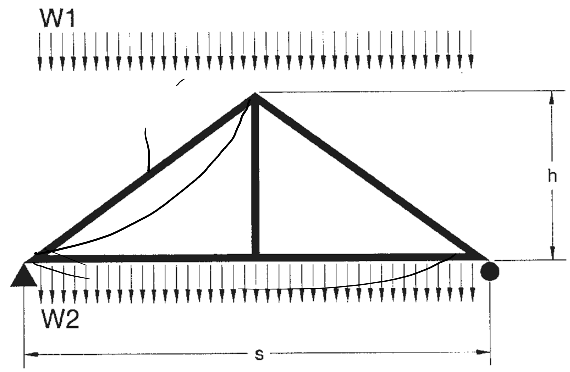
Other Examples of Combined Stress

Columns with side loading



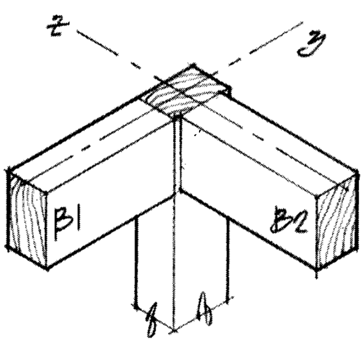


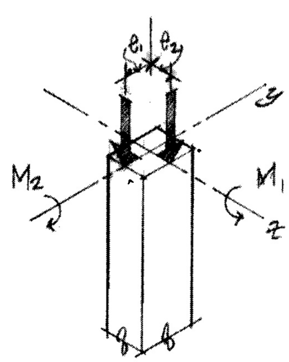
Moment frames



Trusses loaded on members

Other Examples of Combined Stress

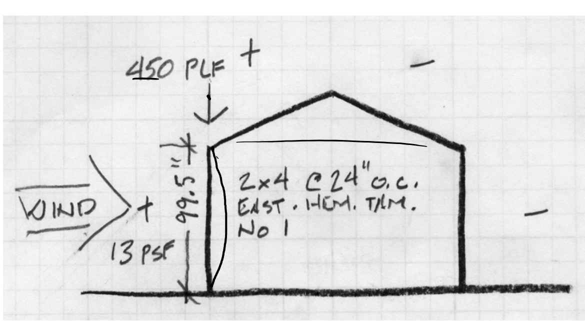




$M_1 = P_1 \times e_1$ (ABOUT THE x-AXIS)

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

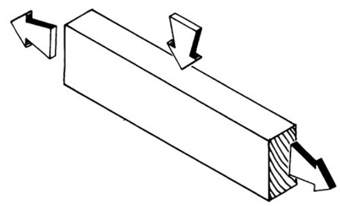
Eccentrically loaded columns



Wind load on walls

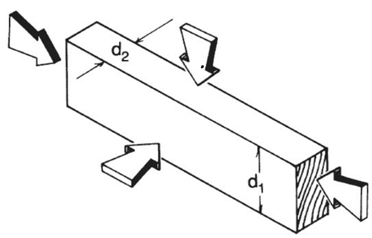
Combined Stress in NDS

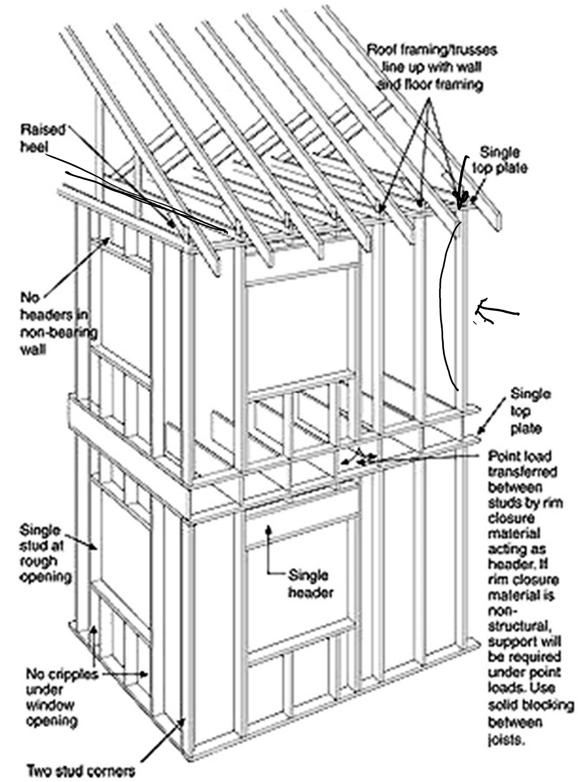
Figure 3G   Combined Bending and Axial Tension



3.9.2 Bending and Axial Compression

Figure 3H   Combined Bending and Axial Compression





Tension + Flexure

NDS Equations

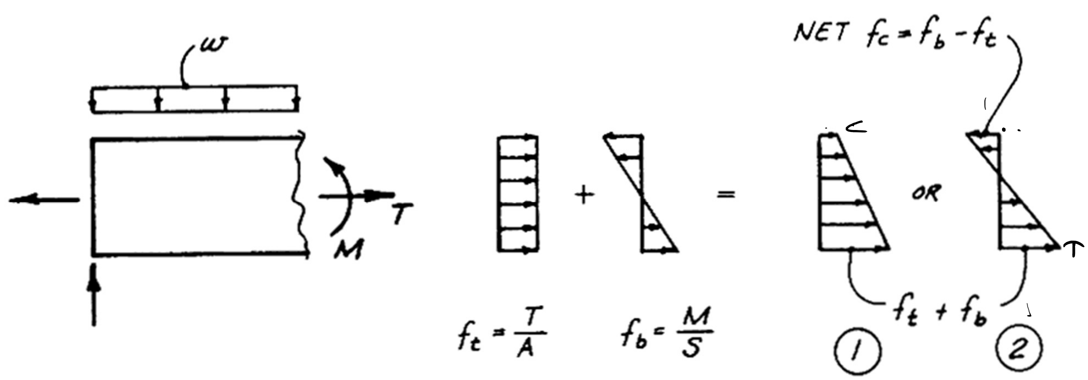
%t + %c

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

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

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

$$\boxed{\frac{f_b - f_t}{F_b{**}} \le 1.0}$$



TENSION + BENDING = COMBINED STRESSES

Tension + Flexure

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:

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

and

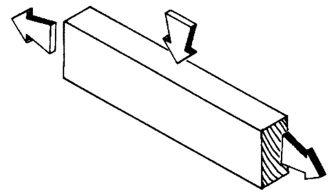
$$\frac{f_b - f_t}{F_b^{**}} \leq 1.0 \quad \text{FLEXURE CRIT.} \quad (3.9\text{-}2)$$

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

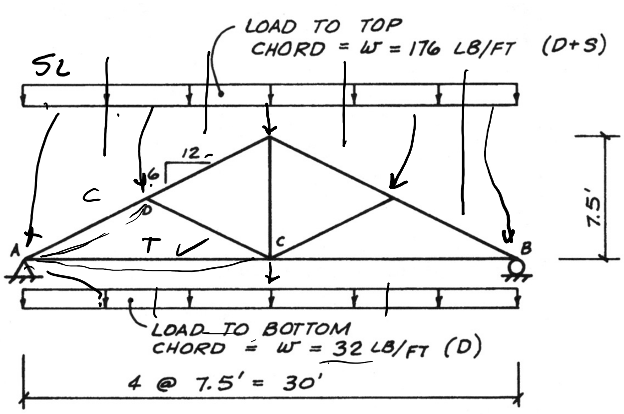


Example Problem

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 48” o.c.
- D + S Load = 44 psf (projected)
- D (attic + ceiling) = 8 psf

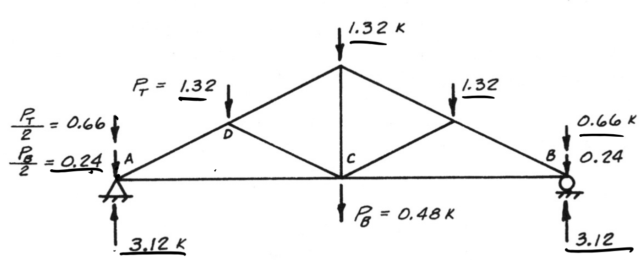
- bottom chord: 2x8
- top chord: 2x10



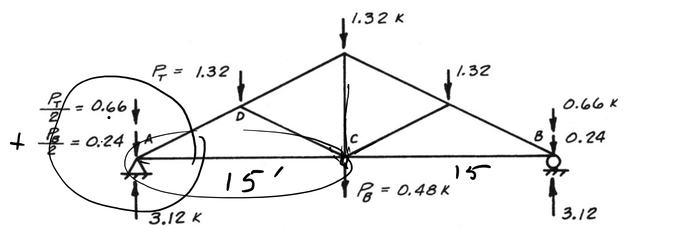
Find: pass/fail

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

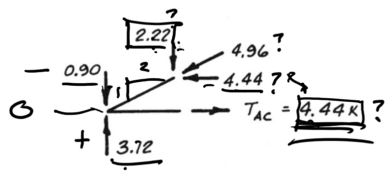
1. Determine truss joint loading



Example (cont.)



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.

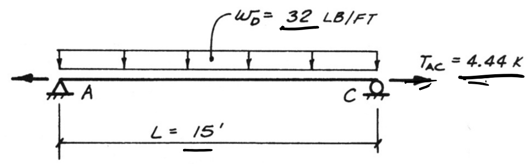


$\Sigma F_V = -.9 + 3.12 - V = 0$

$\Sigma F_H = -4.44 + T_{AC} = 0$

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

   Top chord = 4.96 k compression
   Bottom chord = 4.44 k tension



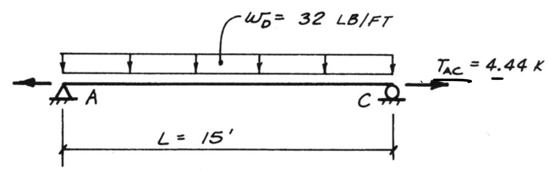
Example

bottom chord 2x8
A = 10.875 in.
S_x = 13.13 in^3

$$\frac{f_t}{F_t'} + \frac{f_b}{F_b^*} \le 1.0$$

and

$$\frac{f_b - f_t}{F_b^{**}} \le 1.0$$



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

   f_t = 408.3 psi
   f_b = 821.9 psi

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

$f_b = \frac{M}{S_x} = \frac{900(12)}{13 \text{ in}^3} = 821.9$ psi

$M = \frac{w l^2}{8} = \frac{32(15)^2}{8} = 900$ '#

$S_x = 13.14$ in^3

5. 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 > 408.3
   SL

   (flexure: D+S)
   $F_b' = F_b\,(C_D\,C_L\,C_F)$
   $F_b' = 1100\,(1.15\ 1.0\ 1.2) = 1518$ psi > 821.9 psi

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

Example
bottom chord 2x8

$\frac{d}{b}$ $\frac{8}{4}$ = 2

$$\frac{f_t}{F_t'} + \frac{f_b}{F_b^*} \le 1.0$$

and

$$\frac{f_b - f_t}{F_b^{**}} \le 1.0$$

5. 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 > 408.3
SL

(flexure: D+S)
$F_b' = F_b\ (C_D\ C_L\ C_F)$
$F_b' = 1100\ (1.15\ 1.0\ 1.2) = 1518$ psi > 821.9 psi
SL CL

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

4.4.1 Stability of Bending Members

4.4.1.1 Sawn lumber bending members shall be designed in accordance with the lateral stability calculations in 3.3.3 or shall meet the lateral support requirements in 4.4.1.2 and 4.4.1.3.

4.4.1.2 As an alternative to 4.4.1.1, rectangular sawn lumber beams, rafters, joists, or other bending members, shall be designed in accordance with the following provisions to provide restraint against rotation or lateral displacement. If the depth to breadth, d/b, based on nominal dimensions is:

(a) d/b ≤ 2; no lateral support shall be required.

(b) 2 < d/b ≤ 4; the ends shall be held in position, as by full depth solid blocking, bridging, hangers, nailing, or bolting to other framing members, or other acceptable means.

CL=1

Example
bottom chord 2x8

$f_b = 821.9$ psi $f_t = 408.3$ psi
$F'_b = 1518$ psi $F'_t = 1000$ psi

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 95%

0.95 < 1.0 ✓PASS

(3.9-2)

$$\frac{\overset{f_b}{821.9} - \overset{f_t}{408.3}}{1518} = 0.2724$$

0.27 < 1.0 ✓PASS

Bending + Axial 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:

EDGEWISE ✓

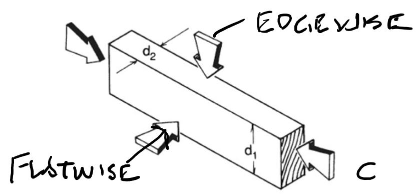
$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-(f_c/F_{cE1})\right]} + \frac{f_{b2}}{F_{b2}'\left[1-(f_c/F_{cE2})-(f_{b1}/F_{bE})^2\right]} \le 1.0 \quad (3.9\text{-}3)$$

AMPLIFICATION FACTOR > 1.0

FLATWISE

and

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



where:

BUCKLING

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

and

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

and

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

Example

top chord 2x10

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

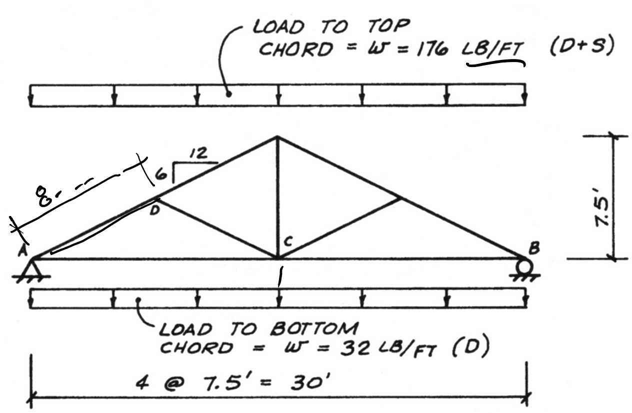
2x10:

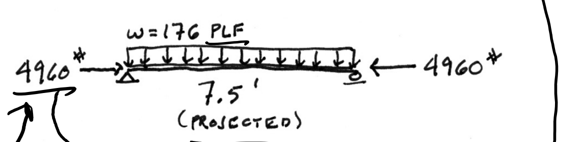
$A = 9.25\ in^2$ $f_c = 357.5$ psi

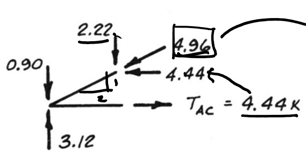
$Sx = 21.39\ in^3$ $f_{b1} = 694.2$ psi

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

EULER







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

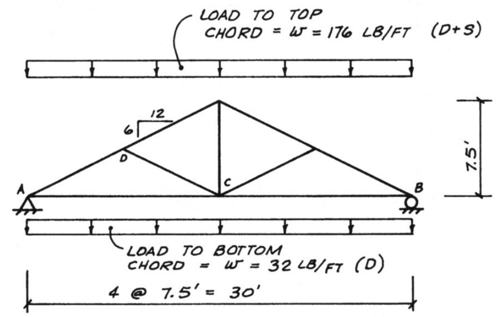
$f_b = \dfrac{M}{S_x} = \dfrac{1237.5\ (12)}{21.39\ in^3} = 694.2$ psi

$M = \dfrac{w\ell^2}{8} = \dfrac{176\ PLF\,(7.5')^2}{8} = 1237.5$ 1-#

$S_x = 21.39\ in^3$

Example
top chord 2x10

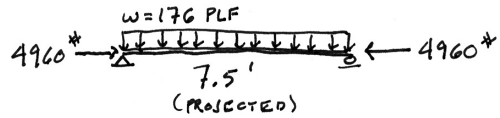
$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-\left(f_c/F_{cE1}\right)\right]}$$



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

   (compression: D+S)
   $F_c' = F_c\,(C_D\ C_F\ C_P)$
   $F_c' = \underbrace{1350}_{NDS}\ (\underbrace{1.15}_{SL}\ \ 1.0\ \ 0.897\ ) = 1392.6$ psi > 357.5

   (flexure: D+S)
   $F_b' = F_b\,(C_D\ C_L\ C_F)$
   $F_b' = \underbrace{1100}_{NDS}\ (1.15\ \ 1.0\ \ 1.1) = 1391.5$ psi > 694.2



Cp

$l_e = 8.385'\quad d = 9.25''$

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

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

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

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

$C_p = \boxed{0.897}$

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

Example
top chord 2x10

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

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			
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

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

   (compression: D+S)
   $F_c' = F_c\,(C_D\ C_F\ C_P)$
   $F_c' = 1350\ (\underbrace{1.15}_{SL}\ \ \underbrace{1.0}_{}\ \ \underbrace{0.897}_{C_P}\ ) = \underbrace{1392.6\text{ psi}}_{} > \underbrace{357.5}_{f_c}$

   (flexure: D+S)
   $F_b' = F_b\,(C_D\ C_L\ C_F)$
   $F_b' = 1100\ (\underbrace{1.15}_{SL}\ \ \underbrace{1.0}_{C_L}\ \ 1.1) = 1391.5$ psi > $\underbrace{694.2}_{f_b}$

3.3.3 Beam Stability Factor, C_L

3.3.3.3 When the compression edge of a bending member is supported throughout its length to prevent lateral displacement, and the ends at points of bearing have lateral support to prevent rotation, $C_L = 1.0$.

Example

top chord 2x10

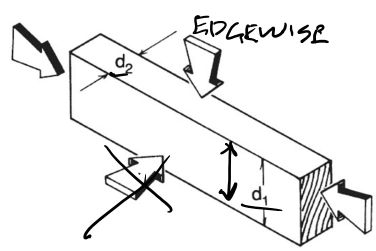
Eq. 3.9-3

.0659

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

COMP. + FLEXURE X-X + ~~FLEX Y-Y~~

Figure 3H Combined Bending and Axial Compression



where:

EULER 1

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

and

~~EULER 2~~

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

and

~~LTB~~

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

$$\text{ACT/ALL}\quad \left[\frac{f_c}{F_c'}\right]^2 = \left[\frac{357.5}{1392.6}\right]^2 = 0.0659 < 1.0$$

Eq. 3.9-3

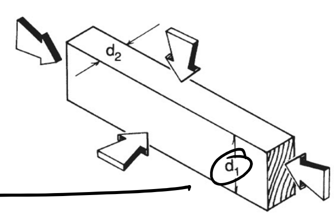
Example

top chord 2x10

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

COMP. + FLEXURE X-X

Figure 3H Combined Bending and Axial Compression



EULER 1

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

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

d_1 = wide face dimension (see Figure 3H)

d_2 = narrow face dimension (see Figure 3H)

ACTUAL

$f_c = \dfrac{P}{A} = \dfrac{4960^*}{1.5 \times 9.25} = 357.5 \text{ psi}$

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

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

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

$f_c = 357.5 \text{ psi}$

$E_{min} = 550\,000 \text{ psi}$ NDS

$\ell_{e1} = 8.385'$ ACTUAL

$d_1 = 9.25''$

$\ell_{e1}/d_1 = \dfrac{8.385(12)}{9.25''} = 10.88$

$F_{CE1} = \dfrac{0.822\,(550000)}{10.88^2}$ E

$= 3820 \text{ psi}$

FLEXURE:

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

AMPLIFICATION FACTOR:

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

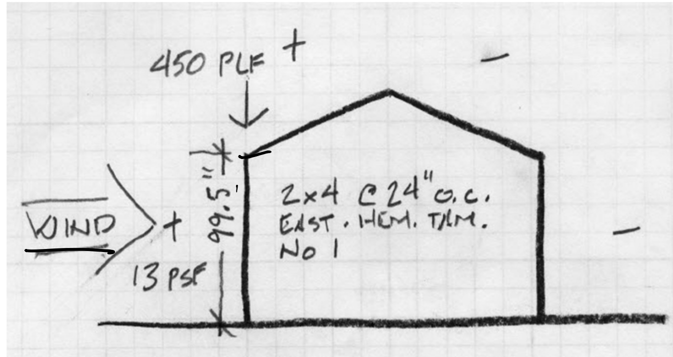
$0.4987\,(1.103) = 0.550$

COMBINATION:

$0.0659 + 0.550 = 0.616$

$0.616 < 1.0$ ✓ PASS ✓

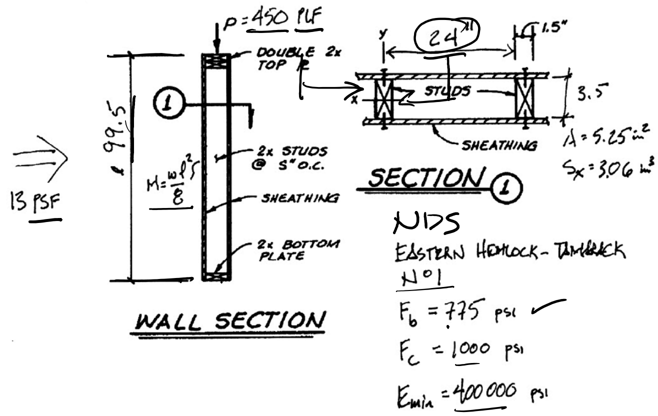
Combined Stress in NDS
procedure



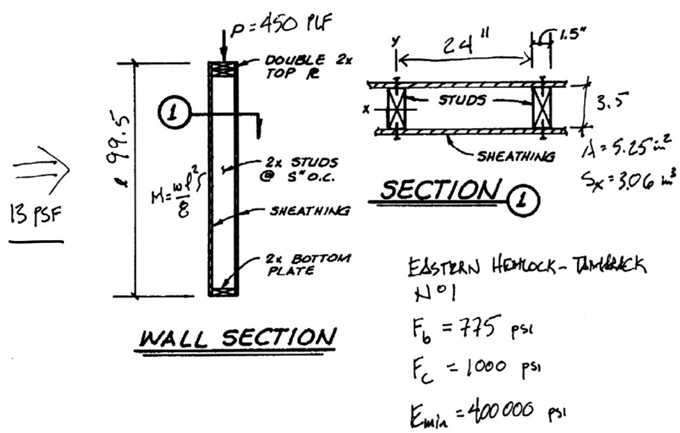
Exterior stud wall under
bending + axial compression

1. Determine load per stud
2. Use axial load and moment to find actual stresses f_c and f_b
3. Determine load factors
4. Calculate factored stresses
5. Check NDS equations

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



Combined Stress in NDS
example



Exterior stud wall under
bending + axial compression

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

1. Determine load per stud

P = LOAD/STUD

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

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

2. Use axial load and moment to find actual stresses fc and fb

$M_x = \frac{w l^2}{8} = \frac{26 \,(99.5/12)^2}{8} = \boxed{223.4 \text{ 1-\#}}$

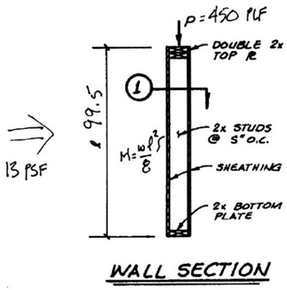
$f_c = \frac{P}{A} = \frac{900}{5.25} = \boxed{171.43 \text{ PSI}}$

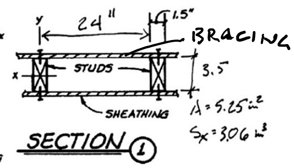
2x4 → 5.25

$f_b = M/S_x = \frac{223.4\,(12)}{3.06 \text{ in}^3} = \boxed{875.5 \text{ psi}}$

Combined Stress in NDS
example

Exterior stud wall under
bending + axial compression





EASTERN HEMLOCK - TAMARACK
N° 1
F_b = 775 psi
F_c = 1000 psi
E_{min} = 400000 psi

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"	$\boxed{1.5}$	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
	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

F_b = 775 psi F_c = 1000 psi E_{min} = 400 000 psi

F_b FACTORS :

$C_D = \boxed{1.6}$ (WIND)
$C_F = \boxed{1.5}$ (FOR F_b) $\boxed{1.15}$ (FOR F_c)
$C_L = \boxed{1.0}$ (BRACED BY SHEATHING)
$C_r = \boxed{1.15}$ (≤ 24" OC) ✓

3. Determine load factors (bending)

Combined Stress in NDS
example

Exterior stud wall under
bending + axial compression

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

F_b = 775 psi

C_D = 1.6
C_M = 1.0
C_t = 1.0
C_L = 1.0
NONE

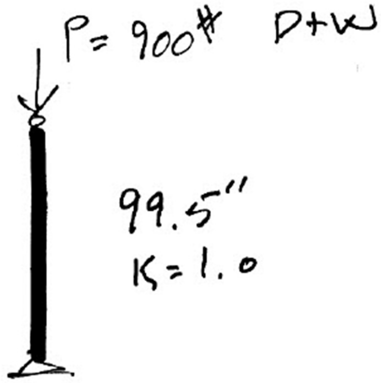
C_F = 1.5
C_{fu} = 1.0 ✗
C_i = 1.0 ✗
C_r = 1.15

F_b' = 775 (1.6)(1.5)(1.15)
= 2139 psi

4. Calculate factored stresses
(bending stress)

Combined Stress in NDS
example

Exterior stud wall under bending + axial compression



3. Determine load factors (compression)

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

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

c = 0.8 for sawn lumber

C_p

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

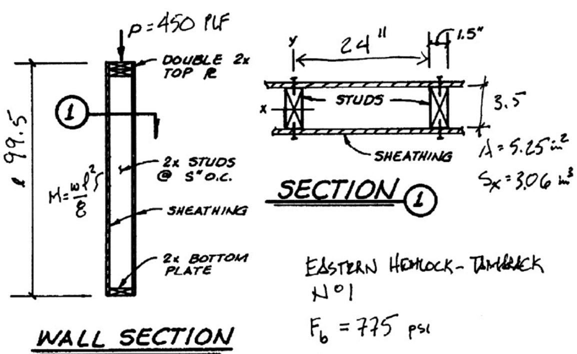
$$F_{cE} = \frac{0.822(400000)}{(99.5/3.5)^2} = 406.8$$

$c = 0.8$

$C_p = \boxed{0.21}$

Combined Stress in NDS
example

Exterior stud wall under bending + axial compression



EASTERN HEMLOCK-TAMARACK
No1

$F_b = 775$ psi

$F_c = 1000$ psi

$E_{min} = 400000$ psi

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

4. Calculate stresses (compression stress)

Actual Stress

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

COMP
Factored Allowable Stress

$$F_c' = \underbrace{1000}_{F_c}\underbrace{(1.6)}_{C_D}\overset{\text{WIND}}{}\overset{C_{FV}}{(1.15)}\underbrace{(0.21)}_{C_P} = 386.4\ psi$$

Combined Stress in NDS
example

Exterior stud wall under
bending + axial compression

5. Combined Stress Calculation
   (eq. 3.9-3)

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

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

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

COMP. + FLEXURE X-X

ACTUAL

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

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

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

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

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

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