CHAPTER 1 - INTRODUCTION

1.5-1

(a) $A = \pi(0.550)^2 / 4 = 0.2376 \text{ in.}^2$

$$F_u = \frac{P_u}{A} = \frac{28{,}500}{0.2376} = 120{,}000 \text{ psi} = 120 \text{ ksi}$$

$$\underline{F_u = 120 \text{ ksi}}$$

(b) $$e = \frac{2.300 - 2.030}{2.030} \times 100 = 13.3\%$$

$$\underline{e = 13.3\%}$$

(c)

$A_f = \pi(0.430)^2 / 4 = 0.1452 \text{ in.}^2$

$$\text{Change} = \frac{A_f - A_o}{A_o} \times 100 = \frac{0.1452 - 0.2376}{0.2376} \times 100 = -38.9\%$$

$$\underline{\text{Reduction} = 38.9\%}$$

1.5-2

$A = \pi(0.5)^2 / 4 = 0.1963 \text{ in.}^2$

$$f = \frac{P}{A} = \frac{13.5}{0.1963} = 68.77 \text{ ksi}$$

$$\varepsilon = \frac{\Delta L}{L} = \frac{4.66 \times 10^{-3}}{2} = 2.33 \times 10^{-3}$$

$$E = \frac{f}{\varepsilon} = \frac{68.77}{2.33 \times 10^{-3}} = 29{,}500 \text{ ksi}$$

$$\underline{E = 29{,}500 \text{ ksi}}$$

1.5-3

$A = \pi(0.510)^2 / 4 = 0.2043 \text{ in.}^2$

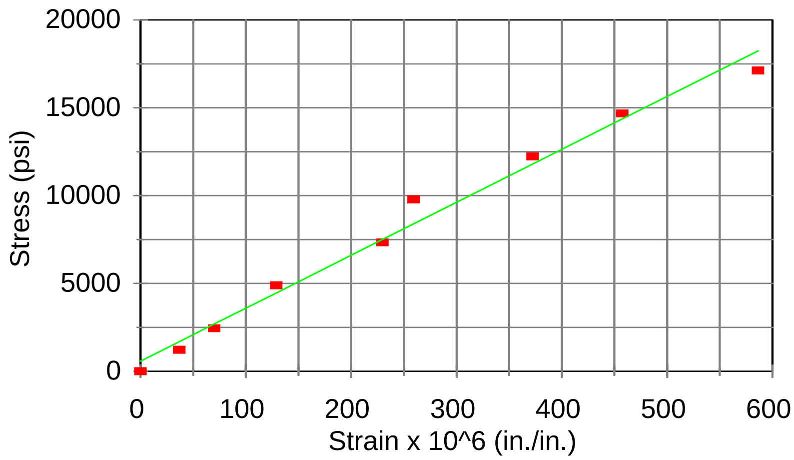
For $P = 250$ lb, $f = \dfrac{P}{A} = \dfrac{250}{0.2043} = 1224$ psi

Spreadsheet results:

(a)

Load (lb)	Stress (psi)	Strain x 10^6 (in./in.)
0	0	0
250	1224	37.1
500	2447	70.3
1000	4895	129.1
1500	7342	230.1
2000	9790	259.4
2500	12237	372.4
3000	14684	457.7
3500	17132	586.5

(b)



(c) E = slope = 30,100 ksi

1.5-4

$$A = \pi(0.5)^2 / 4 = 0.1963 \text{ in.}^2$$

$$E = \frac{f}{\varepsilon} = \frac{P/A}{\Delta L/L} = \frac{P}{\Delta L} \cdot \frac{L}{A} = 1392(4/0.1963) = 28{,}400 \text{ ksi}$$

E = 28,400 ksi

1.5-5

$$A = \pi(3/8)^2 / 4 = 0.1104 \text{ in.}^2$$

$$\text{For } P = 550 \text{ lb}, \; f = \frac{P}{A} = \frac{550}{0.1104} = 4982 \text{ psi}$$

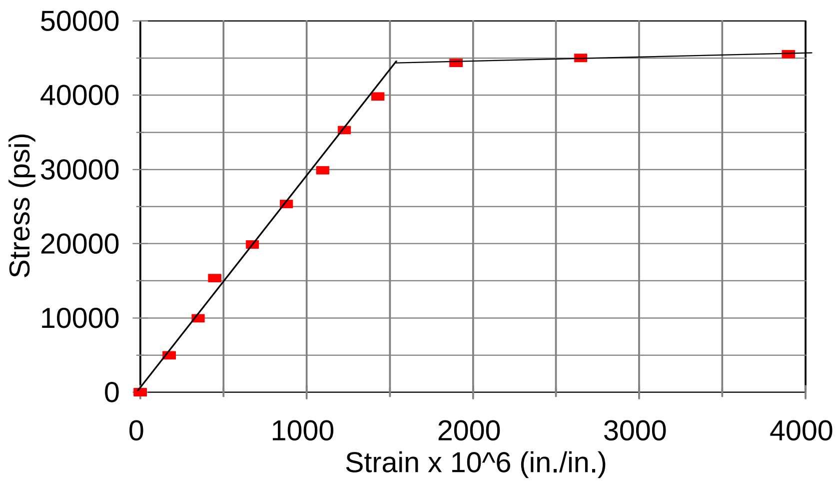
$$\varepsilon = \frac{\Delta L}{L} = \frac{350 \times 10^{-6}}{2} = 175 \times 10^{-6}$$

Spreadsheet results:

(a)

Load (lb)	Elongation x 10^6 (in.)	Stress (psi)	Strain x 10^6 (in./in.)
0	0	0	0
550	350	4982	175
1100	700	9964	350
1700	900	15399	450
2200	1350	19928	675
2800	1760	25362	880
3300	2200	29891	1100
3900	2460	35326	1230
4400	2860	39855	1430
4900	3800	44384	1900
4970	5300	45018	2650
5025	7800	45516	3900

(b)



(c) $E = \text{slope} = \dfrac{15{,}000}{500 \times 10^{-6}} = 30{,}000{,}000 \text{ psi}$

$E = 30{,}000{,}000 \text{ psi}$

(d) $F_y \approx 44{,}000 \text{ psi}$

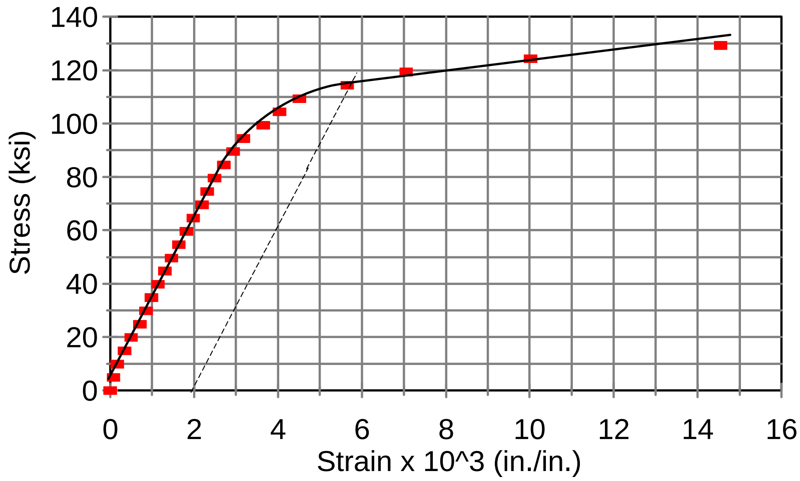
1.5-6

Spreadsheet results:

(a)

Load (kips)	Elongation x 10^3 (in.)	Stress (ksi)	Strain x 10^3 (in./in.)
0	0	0	0
1	0.16	4.973	0.080
2	0.352	9.945	0.176
3	0.706	14.92	0.353
4	1.012	19.89	0.506
5	1.434	24.86	0.717
6	1.712	29.84	0.856
7	1.986	34.81	0.993
8	2.286	39.78	1.143
9	2.612	44.75	1.306
10	2.938	49.73	1.469
11	3.274	54.70	1.637
12	3.632	59.67	1.816
13	3.976	64.64	1.988
14	4.386	69.62	2.193
15	4.64	74.59	2.320
16	4.988	79.56	2.494
17	5.432	84.54	2.716
18	5.862	89.51	2.931
19	6.362	94.48	3.181
20	7.304	99.45	3.652
21	8.072	104.4	4.036
22	9.044	109.4	4.522
23	11.31	114.4	5.655
24	14.12	119.3	7.060
25	20.044	124.3	10.02
26	29.106	129.3	14.55

(b)



(c) $E = \text{slope} = \dfrac{80-50}{0.0025-0.0015} = 30{,}000 \text{ ksi}$

$\underline{E = 30{,}000 \text{ ksi}}$

(d) $\underline{F_{p\ell} \approx 85 \text{ ksi}}$

(e) $\underline{F_y \approx 116 \text{ ksi}}$

CHAPTER 2 - CONCEPTS IN STRUCTURAL STEEL DESIGN

2-1

D = 9 kips, L_r = 5 kips, S = 6 kips, R = 7 kips, W = 8 kips

(a)

1: $1.4D = 1.4(9) = 12.6$ kips

3: $1.2D + 1.6 + 0.5W = 1.2(9) + 1.6(7) + 0.5(8) = 26$ kips

4: $1.2D + 1.0\text{W} = 1.2(9) + 1.0(8) = 18.8$ kips

$\underline{R_u = 26 \text{ kips (combination 3)}}$

(but the column must be checked for an uplift of 4.7 kips.)

(b) $\underline{\phi R_n = 26 \text{ kips}}$

(c) $R_n = \dfrac{\varphi R_n}{\varphi} = \dfrac{26}{0.90} = 28.9 \text{ kips}$ $\underline{R_n = 28.9 \text{ kips}}$

(d)

3: $D + R = 9 + 7 = 16$ kips

6. $D + 0.75(0.6W) + 0.75(R) = 9 + 0.75(0.6)(8) + 0.75(7) = 17.9$ kips

$\underline{R_a = 17.9 \text{ kips (combination 6)}}$

(but the column must be checked for an uplift of 2.6 kips)

(e) $R_n = \Omega R_a = 1.67(17.9) = 29.9 \text{ kips}$ $\underline{R_n = 29.9 \text{ kips}}$

2-2

1: $1.4D = 1.4(9) = 12.6$ kips

3: $1.2D + 1.6S + 0.5W = 1.2(9) + 1.6(6) + 0.5(8) = 24.4$ kips

4: $1.2D + 1.0W + 0.5S = 1.2(9) + 1.0(8) + 0.5(6) = 21.8$ kips

(a) $\underline{24.4 \text{ kips (combination 3)}}$

(b) $\underline{\phi R_n = 24.4 \text{ kips}}$

(c) $R_n = \dfrac{\phi R_n}{\phi} = \dfrac{24.4}{0.90} = 27.1 \text{ kips}$ $\underline{R_n = 27.1 \text{ kips}}$

(d)

3. $D + S = 9 + 6 = 15$ kips

5. $D + 0.6W = 9 + 0.6(8) = 13.8$ kips

6. $D + 0.75(0.6W) + 0.75S = 9 + 0.75(0.6)(8) + 0.75(6) = 17.1$ kips

$$\underline{17.1 \text{ kips } (\text{Combination } 6)}$$

(e) $R_n = \Omega R_a = 1.67(17.1) = 28.6$ kips $\underline{R_n = 28.6 \text{ kips}}$

2-3

(a) Combination 1: $1.4D = 1.4(45) = 63$ ft-kips

Combination 2: $1.2D + 1.6L + 0.5L_r = 1.2(45) + 1.6(63) + 0.5(0) = 154.8$ ft-kips

$$\underline{R_u = 155 \text{ ft - kips (combination 2)}}$$

(b) $R_n = \dfrac{R_u}{\phi} = \dfrac{154.8}{0.9} = 172$ ft - kips $\underline{R_n = 172 \text{ ft - kips}}$

(c) Combination 2: $D + L = 45 + 63 = 108$ ft-kips $\underline{R_a = 108 \text{ ft-kips (combination 2)}}$

(d) $R_n = \Omega R_a = 1.67(108) = 180$ ft-kip $\underline{R_n = 180 \text{ ft-kips}}$

2-4

$D = 18$ kips, $L = 2$ kips

(a)

1: $1.4D = 1.4(18) = 25.2$ kips

2: $1.2D + 1.6L = 1.2(18) + 1.6(2) = 24.8$ kips

$$\underline{R_u = 25.2 \text{ kips (combination 1)}}$$

(b)

2: $D + L = 18 + 2 = 20$ kips. $\underline{R_a = 20 \text{ kips (combination 2)}}$

2-5

$D = 21$ psf, $L_r = 12$ psf, $S = 13.5$ psf, $W = 22$ psf upward (*in this particular case, the wind load cannot be reversed, even in those cases where reversal would normally be considered.*)

Treat gravity loads as positive and wind load as negative:

(a)

1: $1.4D = 1.4(21) = 29.4$ psf

2: $1.2D + 0.5S = 1.2(21) + 0.5(13.5) = 32.0$ psf

3: $1.2D + 1.6S + 0.5W = 1.2(21) + 1.6(13.5) + 0.5(-22) =$ 35.8 psf

$1.2D + 1.6S + 0.5L = 1.2(21) + 1.6(13.5) + 0.5(0) = 46.8$ psf

$\underline{R_u = 46.8 \text{ psf (combination 3)}}$

(Combination 5, with R_u = -3.1 psf, would also need to be considered in the design of the roof in order to prevent uplift.)

(b)

3: $D + S = 21 + 13.5 = 34.5$ psf

5: $D + 0.6W = 21 + 0.6(-22) = 7.8$ psf

6: $D + 0.75(0.6W) + 0.75S = 21 + 0.75(0.6)(-22) + 0.75(13.5) = 21.2$ psf

7: $0.6D + 0.6W = 0.6(21) + (-22) = -9.4$ psf

$\underline{R_a = 34.5 \text{ psf (combination 3)}}$

(Combination 7, with R_a = -9.4 psf, would also need to be considered in the design of the roof in order to prevent uplift.)

CHAPTER 3 - TENSION MEMBERS

3.2-1

For yielding of the gross section,

$$A_g = 7(3/8) = 2.625 \text{ in.}^2, \qquad P_n = F_y A_g = 36(2.625) = 94.5 \text{ kips}$$

For rupture of the net section,

$$A_e = (3/8)\left(7 - \left(1 + \frac{3}{16}\right)\right) = 2.180 \text{ in.}^2$$

$$P_n = F_u A_e = 58(2.108) = 122.3 \text{ kips}$$

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(94.5) = 85.05 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(122.3) = 91.73 \text{ kips}$$

The design strength for LRFD is the smaller value: $\underline{\phi_t P_n = 85.1 \text{ kips}}$

b) The allowable strength based on yielding is

$$\frac{P_n}{\Omega_t} = \frac{94.5}{1.67} = 56.59 \text{ kips}$$

The allowable strength based on rupture is

$$\frac{P_n}{\Omega_t} = \frac{122.3}{2.00} = 61.15 \text{ kips}$$

The allowable service load is the smaller value: $\underline{P_n/\Omega_t = 56.6 \text{ kips}}$

Alternate solution using allowable ***stress***: For yielding,

$$F_t = 0.6F_y = 0.6(36) = 21.6 \text{ ksi}$$

and the allowable load is $F_t A_g = 21.6(2.625) = 56.7$ kips

For rupture,

$$F_t = 0.5F_u = 0.5(58) = 29.0 \text{ ksi}$$

and the allowable load is $F_t A_e = 29.0(2.180) = 63.22$ kips

The allowable service load is the smaller value = 56.7 kips

3.2-2

For yielding of the gross section,

$$A_g = 6(3/8) = 2.25 \text{ in.}^2$$

$$P_n = F_y A_g = 50(2.25) = 112.5 \text{ kips}$$

For rupture of the net section,

$$A_e = A_g = 2.25 \text{ in.}^2$$

$$P_n = F_u A_e = 65(2.25) = 146.3 \text{ kips}$$

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(112.5) = 101 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(146.3) = 110 \text{ kips}$$

The design strength for LRFD is the smaller value: $\underline{\phi_t P_n = 101 \text{ kips}}$

b) The allowable strength based on yielding is

$$\frac{P_n}{\Omega_t} = \frac{112.5}{1.67} = 67.4 \text{ kips}$$

The allowable strength based on rupture is

$$\frac{P_n}{\Omega_t} = \frac{146.3}{2.00} = 73.2 \text{ kips}$$

The allowable service load is the smaller value: $\underline{P_n/\Omega_t = 67.4 \text{ kips}}$

Alternate solution using allowable ***stress***: For yielding,

$$F_t = 0.6F_y = 0.6(50) = 30.0 \text{ ksi}$$

and the allowable load is

$$F_t A_g = 30.0(2.25) = 67.5 \text{ kips}$$

For rupture,

$$F_t = 0.5F_u = 0.5(65) = 32.5 \text{ ksi}$$

and the allowable load is

$$F_t A_e = 32.5(2.25) = 73.1 \text{ kips}$$

The allowable service load is the smaller value $= 67.5$ kips

3.2-3

For yielding of the gross section,

$$P_n = F_y A_g = 50(3.37) = 168.5 \text{ kips}$$

For rupture of the net section,

$$A_n = A_g - A_{holes} = 3.37 - 0.220\left(\frac{7}{8} + \frac{1}{8}\right) \times 2 \text{ holes} = 2.930 \text{ in.}^2$$

$$A_e = 0.85A_n = 0.85(2.930) = 2.491 \text{ in.}^2$$

$$P_n = F_e A_e = 65(2.491) = 161.9 \text{ kips}$$

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(168.5) = 152 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(161.9) = 121.4 \text{ kips}$$

The design strength is the smaller value: $\phi_t P_n = 121.4$ kips

Let $P_u = \phi_t P_n$

$$1.2D + 1.6(3D) = 121.4, \text{ Solution is: } \{D = 20.23\}$$

$$P = D + L = 20.23 + 3(20.23) = 80.9 \text{ kips}$$

$\underline{P = 80.9 \text{ kips}}$

b) The allowable strength based on yielding is

$$\frac{P_n}{\Omega_t} = \frac{168.5}{1.67} = 100.9 \text{ kips}$$

The allowable strength based on rupture is

$$\frac{P_n}{\Omega_t} = \frac{161.9}{2.00} = 80.95 \text{ kips}$$

The allowable load is the smaller value = 80.95 kips $\underline{P = 81.0 \text{ kips}}$

Alternate computation of allowable load using allowable ***stress***: For yielding,

$$F_t = 0.6F_y = 0.6(50) = 30.0 \text{ ksi}$$

and the allowable load is

$$F_t A_g = 30.0(3.37) = 101.1 \text{ kips}$$

For rupture,

$$F_t = 0.5F_u = 0.5(65) = 32.5 \text{ ksi}$$

and the allowable load is

$$F_t A_e = 32.5(2.491) = 80.96 \text{ kips}$$

3.2-4

For A242 steel and $t = ½$ in., $F_y = 50$ ksi and $F_u = 70$ ksi. For yielding of the gross section,

$$A_g = 8(1/2) = 4 \text{ in.}^2$$

$$P_n = F_y A_g = 50(4) = 200 \text{ kips}$$

For rupture of the net section,

$$A_n = A_g - A_{holes} = 4 - (1/2)\left(1 + \frac{3}{16}\right)(2) = 2.813 \text{ in.}^2$$

$$A_e = A_n = 2.813 \text{ in.}^2$$

$$P_n = F_u A_e = 70(2.813) = 196.9 \text{ kips}$$

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(200) = 180 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(196.9) = 147.7 \text{ kips}$$

The design strength for LRFD is the smaller value: $\underline{\phi_t P_n = 148 \text{ kips}}$

b) The allowable strength based on yielding is

$$\frac{P_n}{\Omega_t} = \frac{200}{1.67} = 120 \text{ kips}$$

The allowable strength based on rupture is

$$\frac{P_n}{\Omega_t} = \frac{196.9}{2.00} = 98.45 \text{ kips}$$

The allowable service load is the smaller value: $\underline{P_n/\Omega_t = 98.5 \text{ kips}}$

Alternate solution using allowable ***stress***: For yielding,

$$F_t = 0.6F_y = 0.6(50) = 30 \text{ ksi}$$

and the allowable load is

$$F_t A_g = 30(4) = 120 \text{ kips}$$

For rupture,

$$F_t = 0.5F_u = 0.5(70) = 35 \text{ ksi}$$

and the allowable load is

$$F_t A_e = 35(2.813) = 98.5 \text{ kips}$$

The allowable service load is the smaller value = 98.5 kips

3.2-5

For a thickness of $t = 3/8$ in., $F_y = 50$ ksi and $F_u = 70$ ksi. First, compute the nominal strengths. For the gross section,

$$A_g = 7.5(3/8) = 2.813 \text{ in.}^2$$

$$P_n = F_y A_g = 50(2.813) = 140.7 \text{ kips}$$

Net section:

$$A_n = 2.813 - \left(\frac{3}{8}\right)\left(1\frac{1}{8} + \frac{3}{16}\right)(2) = 1.829 \text{ in.}^2$$

$$A_e = A_n = 1.829 \text{ in.}^2$$

$$P_n = F_u A_e = 70(1.829) = 128.0 \text{ kips}$$

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(140.7) = 127 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(128.0) = 96.0 \text{ kips}$$

The design strength is the smaller value: $\phi_t P_n = 96.0$ kips

Factored load:

Combination 1: $1.4D = 1.4(25) = 35.0$ kips

Combination 2: $1.2D + 1.6L = 1.2(25) + 1.6(45) = 102$ kips

The second combination controls; $P_u = 102$ kips.

Since $P_u \ \phi >_t P_n$, (102 kips >96.0 kips), <u>The member is unsatisfactory.</u>

b) For the gross section, the allowable strength is

$$\frac{P_n}{\Omega_t} = \frac{140.7}{1.67} = 84.3 \text{ kips}$$

Alternately, the allowable stress is

$$F_t = 0.6F_y = 0.6(50) = 30 \text{ ksi}$$

and the allowable strength is $F_t A_g = 30(2.813) = 84.4$ kips

For the net section, the allowable strength is

$$\frac{P_n}{\Omega_t} = \frac{128.0}{2.00} = 64.0 \text{ kips}$$

Alternately, the allowable stress is

$F_t = 0.5F_u = 0.5(70) = 35$ ksi and the allowable strength is

$$F_t A_e = 35(1.829) = 64.02 \text{ kips}$$

The smaller value controls; the allowable strength is 64.0 kips. When the only loads are dead load and live load, ASD load combination 2 will always control:

$$P_a = D + L = 25 + 45 = 70 \text{ kips}$$

Since 70 kips > 64.0 kips, The member is unsatisfactory.

3.2-6

Compute the strength for one angle, then double it. For the gross section,

$$P_n = F_y A_g = 36(1.20) = 43.2 \text{ kips}$$

For two angles, $P_n = 2(43.2) = 86.4$ kips

Net section:

$$A_n = 1.20 - \left(\frac{1}{4}\right)\left(\frac{3}{4} + \frac{1}{8}\right) = 0.9813 \text{ in.}^2$$

$$A_e = 0.85A_n = 0.85(0.9813) = 0.8341 \text{ in.}^2$$

$$P_n = F_u A_e = 58(0.8341) = 48.38 \text{ kips}$$

For two angles, $P_n = 2(48.38) = 96.76$ kips

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(86.4) = 77.76 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(96.76) = 72.57 \text{ kips}$$

The design strength is the smaller value: $\phi_t P_n = 72.6$ kips

$$P_u = 1.2D + 1.6L = 1.2(12) + 1.6(36) = 72.0 \text{ kips} < 72.6 \text{ kips} \qquad \text{(OK)}$$

The member has enough strength.

b) For the gross section, the allowable strength is

$$\frac{P_n}{\Omega_t} = \frac{86.4}{1.67} = 51.74 \text{ kips}$$

Alternately, the allowable stress is

$$F_t = 0.6F_y = 0.6(36) = 21.6 \text{ ksi}$$

and the allowable strength is $F_tA_g = 21.6(2 \times 1.20) = 51.84$ kips

For the net section, the allowable strength is

$$\frac{P_n}{\Omega_t} = \frac{96.76}{2.00} = 48.38 \text{ kips}$$

Alternately, the allowable stress is

$$F_t = 0.5F_u = 0.5(58) = 29 \text{ ksi}$$

and the allowable strength is $F_tA_e = 29(2 \times 0.8341) = 48.38$ kips

The net section strength controls; the allowable strength is 48.4 kips. When the only loads are dead load and live load, ASD load combination 2 will always control:

$$P_a = D + L = 12 + 36 = 48 \text{ kips} < 48.4 \text{ kips} \qquad \text{(OK)}$$

The member has enough strength.

3.3-1

(a) $U = 1 - \dfrac{\bar{x}}{\ell} = 1 - \dfrac{1.47}{5} = 0.7060$

$A_e = A_gU = 5.86(0.7060) = 4.14 \text{ in.}^2$ $\qquad$ $A_e = 4.14 \text{ in.}^2$

(b) Plate with longitudinal welds only:

$$U = \frac{3\ell^2}{3\ell^2 + w^2}\left(1 - \frac{\bar{x}}{\ell}\right) = \frac{3(5)^2}{3(5)^2 + (4)^2}\left(1 - \frac{(3/8)/2}{5}\right) = 0.7933$$

$$A_e = A_gU = \left(\frac{3}{8} \times 4\right)(0.7933) = 1.19 \text{ in.}^2$$

$A_e = 1.19 \text{ in.}^2$

(c) $U = 1.0$

$A_e = A_gU = \left(\dfrac{5}{8} \times 5\right)(1.0) = 3.13 \text{ in.}^2$ $\qquad$ $A_e = 3.13 \text{ in.}^2$

(d) $U = 1.0$

$$A_g = 0.5(5.5) = 2.750 \text{ in.}^2$$

$$A_n = A_g - A_{holes} = 2.750 - \frac{1}{2}\left(\frac{3}{4} + \frac{1}{8}\right) = 2.313 \text{ in.}^2$$

$A_e = A_nU = 2.313(1.0) = 2.313 \text{ in.}^2$ $\qquad$ $A_e = 2.31 \text{ in.}^2$

(e) $U = 1.0$

$$A_g = \frac{5}{8} \times 6 = 3.750 \text{ in.}^2$$

$$A_n = A_g - A_{holes} = 3.750 - \frac{5}{8}\left(\frac{7}{8} + \frac{1}{8}\right) = 3.125 \text{ in.}^2$$

$$A_e = A_n U = 3.125(1.0) = 3.125 \text{ in.}^2 \qquad \underline{A_e = 3.13 \text{ in.}^2}$$

3.3-2

$$A_n = A_g - A_{holes} = 3.31 - \frac{7}{16}\left(\frac{7}{8} + \frac{1}{8}\right) = 2.873 \text{ in.}^2$$

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{1.15}{3} = 0.6167$$

$$A_e = A_n U = 2.873(0.6167) = 1.772 \text{ in.}^2$$

$$P_n = F_u A_e = 70(1.772) = 124 \text{ kips} \qquad \underline{P_n = 124 \text{ kips}}$$

3.3-3

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{0.775}{8} = 0.9031$$

$$A_e = A_g U = 2.49(0.9031) = 2.249 \text{ in.}^2$$

$$P_n = F_u A_e = 58(2.249) = 130.4 \text{ kips} \qquad \underline{P_n = 130 \text{ kips}}$$

3.3-4

For A588 steel, $F_y = 50$ ksi and $F_u = 70$ ksi

For yielding of the gross section,

$$P_n = F_y A_g = 50(4.79) = 239.5 \text{ kips}$$

For rupture of the net section,

$$A_n = A_g - A_{holes} = 4.79 - \frac{1}{2}\left(\frac{3}{4} + \frac{1}{8}\right) = 4.353 \text{ in.}^2$$

From AISC Table D3.1, Case 8, $U = 0.80$

$$A_e = A_n U = 4.353(0.80) = 3.482 \text{ in.}^2$$

$$P_n = F_u A_e = 70(3.482) = 243.7 \text{ kips}$$

a) The design strength based on yielding is

$$\phi_t P_n = 0.90(239.5) = 215.6 \text{ kips}$$

The design strength based on rupture is

$\phi_t P_n = 0.75(243.7) = 182.8$ kips

The design strength is the smaller value: $\phi_t P_n = 182.8$ kips

Let $P_u = \phi_t P_n$

$1.2D + 1.6(2D) = 182.8$, Solution is: 41.55

$P = D + L = 41.55 + 2(41.55) = 125$ kips $\underline{P = 125 \text{ kips}}$

b) The allowable strength based on yielding is

$$\frac{P_n}{\Omega_t} = \frac{239.5}{1.67} = 143.4 \text{ kips}$$

The allowable strength based on rupture is

$$\frac{P_n}{\Omega_t} = \frac{243.7}{2.00} = 121.9 \text{ kips}$$

The allowable load is the smaller value = 121.9 kips $\underline{P = 122 \text{ kips}}$

Alternate computation of allowable load using allowable ***stress***: For yielding,

$F_t = 0.6F_y = 0.6(50) = 30.0$ ksi

and the allowable load is

$F_t A_g = 30.0(4.79) = 143.7$ kips

For rupture,

$F_t = 0.5F_u = 0.5(70) = 35$ ksi

and the allowable load is

$F_t A_e = 35(3.482) = 121.9$ kips

3.3-5

Gross section: $P_n = F_y A_g = 36(5.86) = 211.0$ kips

Net section: $A_n = 5.86 - \left(\frac{5}{8}\right)\left(1 + \frac{3}{16}\right)(2) = 4.376 \text{ in.}^2$

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{1.03}{(3+3+3)} = 0.8856$$

$A_e = A_n U = 4.376(0.8856) = 3.875 \text{ in.}^2$

$P_n = F_u A_e = 58(3.875) = 224.8$ kips

(a) The design strength based on yielding is

$\phi_t P_n = 0.90(211.0) = 190$ kips

The design strength based on rupture is

$$\phi_t P_n = 0.75(224.8) = 168.6 \text{ kips}$$

The design strength is the smaller value: $\phi_t P_n = 169$ kips

Load combination 2 controls:

$$P_u = 1.2D + 1.6L = 1.2(50) + 1.6(100) = 220 \text{ kips}$$

Since $P_u > \phi_t P_n$, (220 kips > 169 kips), <u>The member is not adequate.</u>

(b) For the gross section, The allowable strength is $\frac{P_n}{\Omega_t} = \frac{211.0}{1.67} = 126$ kips

For the net section, the allowable strength is $\frac{P_n}{\Omega_t} = \frac{224.8}{2.00} = 112.4$ kips

The smaller value controls; the allowable strength is 112 kips.

Load combination 6 controls:

$$P_a = D + 0.75L + 0.75(0.6W) = 50 + 0.75(100) + 0.75(0.6)(45) = 145.3 \text{ kips}$$

Since 145 kips > 112 kips, <u>The member is not adequate.</u>

Alternate ASD solution using allowable stress:

$$F_t = 0.6F_y = 0.6(36) = 21.6 \text{ ksi}$$

and the allowable strength is $F_t A_g = 21.6(5.86) = 127$ kips

For the net section, $F_t = 0.5F_u = 0.5(58) = 29.0$ ksi

and the allowable strength is $F_t A_e = 29.0(3.875) = 112.4$ kips

The smaller value controls; the allowable strength is 112 kips. From load combination 6,

Since 145 kips > 112 kips, the member is not adequate.

<u>3.3-6</u>

For yielding of the gross section,

$$A_g = 5(1/4) = 1.25 \text{ in.}^2$$

$$P_n = F_y A_g = 36(1.25) = 45.0 \text{ kips}$$

For rupture of the net section, from AISC Table D3.1, case 4,

$$U = \frac{3\ell^2}{3\ell^2 + w^2}\left(1 - \frac{\bar{x}}{\ell}\right) = \frac{3(7)^2}{3(7)^2 + (5)^2}\left(1 - \frac{0.25/2}{7}\right) = 0.8394$$

$A_e = A_g U = 1.25(0.8394) = 1.049 \text{ in.}^2$

$P_n = F_u A_e = 58(1.049) = 60.84 \text{ kips}$

a) The design strength based on yielding is

$\phi_t P_n = 0.90(45.0) = 40.5 \text{ kips}$

The design strength based on rupture is

$\phi_t P_n = 0.75(60.84) = 45.63 \text{ kips}$

The design strength for LRFD is the smaller value: $\underline{\phi_t P_n = 40.5 \text{ kips}}$

b) The allowable strength based on yielding is

$$\frac{P_n}{\Omega_t} = \frac{45.0}{1.67} = 27.0 \text{ kips}$$

The allowable strength based on rupture is

$$\frac{P_n}{\Omega_t} = \frac{60.84}{2.00} = 30.42 \text{ kips}$$

The allowable service load is the smaller value: $\underline{P_n/\Omega_t = 27.0 \text{ kips}}$

3.3-7

Gross section: $P_n = F_y A_g = 50(10.3) = 515.0 \text{ kips}$

Net section: $A_n = 10.3 - 0.520\left(\frac{7}{8} + \frac{1}{8}\right)(4) = 8.220 \text{ in.}^2$

Connection is through the flanges with four bolts per line.

$$\frac{b_f}{d} = \frac{6.56}{12.5} = 0.525 < \frac{2}{3} \qquad \therefore\ U = 0.85$$

$A_e = A_n U = 8.220(0.85) = 6.987 \text{ in.}^2$

$P_n = F_u A_e = 65(6.987) = 454.2 \text{ kips}$

(a) The design strength based on yielding is

$\phi_t P_n = 0.90(515.0) = 464 \text{ kips}$

The design strength based on rupture is

$\phi_t P_n = 0.75(454.2) = 341 \text{ kips}$

The design strength is the smaller value: $\underline{\phi_t P_n = 341 \text{ kips}}$

(b) For the gross section, The allowable strength is $\dfrac{P_n}{\Omega_t} = \dfrac{515.0}{1.67} = 308 \text{ kips}$

For the net section, the allowable strength is $\frac{P_n}{\Omega_t} = \frac{454.2}{2.00} = 227$ kips

The smaller value controls; $\frac{P_n}{\Omega_t} = 227$ kips

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3.3-8

Gross section: $P_n = F_y A_g = 50(5.17) = 258.5$ kips

Net section:

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{1.30}{10} = 0.87$$

$$A_e = A_g U = 5.17(0.87) = 4.498 \text{ in.}^2$$

$$P_n = F_u A_e = 70(4.498) = 314.9 \text{ kips}$$

(a) The design strength based on yielding is

$$\phi_t P_n = 0.90(258.5) = 233 \text{ kips}$$

The design strength based on rupture is

$$\phi_t P_n = 0.75(314.9) = 236 \text{ kips}$$

The design strength is the smaller value: $\phi_t P_n = 233$ kips

Load combination 3:

$$P_u = 1.2D + 1.6S + 0.5W = 1.2(75) + 1.6(50) + 0.5(70) = 205.0 \text{ kips}$$

Load combination 4:

$$P_u = 1.2D + 1.0W + 0.5L + 0.5S = 1.2(75) + 1.0(70) + 0.5(50) = 185.0 \text{ kips}$$

Load combination 3 controls. Since $P_u < \phi_t P_n$, (205 kips < 233 kips),

The member is adequate.

(b) For the gross section, The allowable strength is $\frac{P_n}{\Omega_t} = \frac{258.5}{1.67} = 155$ kips

For the net section, the allowable strength is $\frac{P_n}{\Omega_t} = \frac{314.9}{2.00} = 157$ kips

The smaller value controls; the allowable strength is 155 kips.

Load combination 3: $P_a = D + S = 75 + 50 = 125$ kips

Load combination 6:

$$P_a = D + 0.75(0.6W) + 0.75S = 75 + 0.75(0.6)(70) + 0.75(50) = 144.0 \text{ kips}$$

Load combination 6 controls. Since 144 kips < 155 kips, The member is adequate.

3.4-1

Gross section: $A_g = 10(1/2) = 5 \text{ in.}^2$

Net section: Hole diameter $= \dfrac{7}{8} + \dfrac{1}{8} = 1$ in.

Possibilities for net area:

$$A_n = A_g - \sum t \times (d \text{ or } d') = 5 - (1/2)(1)(2) = 4.0 \text{ in.}^2$$

or $A_n = 5 - (1/2)(1) - (1/2)\left[1 - \dfrac{(2)^2}{4(3)}\right] - (1/2)\left[1 - \dfrac{(2)^2}{4(3)}\right] = 3.833 \text{ in.}^2$

or $A_n = 5 - (1/2)(1)(3) = 3.5 \text{ in.}^2$, but because of load transfer,

use $A_n = \dfrac{9}{6}(3.5) = 5.25 \text{ in.}^2$ for this possibility.

The smallest value controls. Use $A_n = 3.833 \text{ in.}^2$

$$A_e = A_n U = A_n(1.0) = 3.833 \text{ in.}^2$$

$$P_n = F_u A_e = 58(3.833) = 222 \text{ kips}$$

The nominal strength based on the net section is $\underline{P_n = 222 \text{ kips}}$

3.4-2

Compute the strength of one plate, then double it.

Gross section: $A_g = 10(1/2) = 5.0 \text{ in.}^2$

Net section: Hole diameter $= \dfrac{3}{4} + \dfrac{1}{8} = \dfrac{7}{8}$ in.

Possibilities for net area:

$$A_n = A_g - \sum t \times (d \text{ or } d') = 5 - (1/2)(7/8)(2) = 4.125 \text{ in.}^2$$

or $A_n = 5 - (1/2)(7/8) - (1/2)\left[\dfrac{7}{8} - \dfrac{(5)^2}{4(6)}\right] = 4.646 \text{ in.}^2$

Because of load transfer, use $A_n = \dfrac{10}{9}(4.646) = 5.162 \text{ in.}^2$ for this possibility.

or $A_n = 5 - (1/2)(7/8) - (1/2)\left[\dfrac{7}{8} - \dfrac{(2)^2}{4(3)}\right] - (1/2)\left[\dfrac{7}{8} - \dfrac{(2)^2}{4(3)}\right] = 4.021 \text{ in.}^2$

Because of load transfer, use $A_n = \dfrac{10}{8}(4.021) = 5.026 \text{ in.}^2$ for this possibility.

The smallest value controls. Use $A_n = 4.125 \text{ in.}^2$

$$A_e = A_n U = 4.125(1.0) = 4.125 \text{ in.}^2$$

$$P_n = F_u A_e = 58(4.125) = 239.3 \text{ kips}$$

For two plates, $P_n = 2(239.3) = 478.6$ kips

The nominal strength based on the net section is $\underline{P_n = 479 \text{ kips}}$

3.4-3

Gross section: $A_g = 8(3/8) = 3.0 \text{ in.}^2$, $P_n = F_y A_g = 36(3.0) = 108$ kips

Net section: Hole diameter $= \frac{1}{2} + \frac{1}{8} = \frac{5}{8}$ in.

$$A_n = A_g - \sum t_w \times (d \text{ or } d') = 3 - (3/8)(5/8) = 2.766 \text{ in.}^2$$

or $A_n = 3 - (3/8)(5/8) - (3/8)\left[5/8 - \frac{(3)^2}{4(2)}\right] = 2.954 \text{ in.}^2$

or $A_n = 3 - (3/8)(5/8) - (3/8)\left[5/8 - \frac{(3)^2}{4(2)}\right] \times 2 = 3.141 \text{ in.}^2$

or $A_n = [3 - (3/8)(5/8)(2)] \times \frac{6}{5} = 3.038 \text{ in.}^2$

or $A_n = \left(3 - (3/8)(5/8) - (3/8)\left[5/8 - \frac{(2.5)^2}{4(2)}\right](2)\right) \times \frac{6}{5} = 3.460 \text{ in.}^2$

Use $A_e = A_n = 2.766 \text{ in.}^2$

$$P_n = F_u A_e = 58(2.766) = 160.4 \text{ kips}$$

(a) Gross section: $\phi_t P_n = 0.90(108) = 97.2$ kips

Net section: $\phi_t P_n = 0.75(160.4) = 120$ kips $\underline{\phi_t P_n = 97.2 \text{ kips}}$

(b) Gross section: $\frac{P_n}{\Omega_t} = \frac{108}{1.67} = 64.7$ kips

Net section: $\frac{P_n}{\Omega_t} = \frac{160.4}{2.00} = 80.2$ kips $\underline{P_n/\Omega_t = 64.7 \text{ kips}}$

3.4-4

Gross section: $A_g = 5.87 \text{ in.}^2$, $P_n = F_y A_g = 50(5.87) = 293.5$ kips

Net section: Hole diameter $= 1\frac{1}{8} + \frac{3}{16} = 1.313$ in.

$$A_n = A_g - \sum t_w \times (d \text{ or } d') = 5.87 - 0.448(1.313) = 5.282 \text{ in.}^2$$

or $A_n = 5.87 - 0.448(1.313) - 0.448\left(1.313 - \frac{(1.5)^2}{4(4)}\right) = 4.757 \text{ in.}^2$

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{0.583}{6(1.5)} = 0.9352$$

$$A_e = A_n U = 4.757(0.9352) = 4.449 \text{ in.}^2$$

$$P_n = F_u A_e = 70(4.449) = 311.4 \text{ kips}$$

(a) Gross section: $\phi_t P_n = 0.90(293.5) = 264$ kips

Net section: $\phi_t P_n = 0.75(311.4) = 234$ kips (controls)

$P_u = 1.2D + 1.6L = 1.2(36) + 1.6(110) = 219 \text{ kips} < 234 \text{ kips}$ (OK)

Since $P_u < \phi_t P_n$ (219 kips < 234 kips), The member has enough strength.

(b) Gross section: $\frac{P_n}{\Omega_t} = \frac{293.5}{1.67} = 176$ kips

Net section: $\frac{P_n}{\Omega_t} = \frac{311.4}{2.00} = 156$ kips (controls)

$P_a = D + L = 36 + 110 = 146 \text{ kips} < 156 \text{ kips}$ (OK)

Since $P_a < \frac{P_n}{\Omega_t}$ (146 kips < 156 kips), The member has enough strength.

3.4-5

For A572 Grade 50 steel, $F_y = 50$ ksi and $F_u = 65$ ksi.

Compute the strength for one angle, then multiply by 2.

Gross section: $A_g = 4.00 \text{ in.}^2$, $P_n = F_y A_g = 50(4.00) = 200.0$ kips

For two angles, $P_n = 2(200.0) = 400.0$ kips

Net section: Hole diameter = $\frac{7}{8} + \frac{1}{8} = 1$ in.

$$A_n = A_g - \sum t \times (d \text{ or } d') = 4.00 - (3/8)(1) = 3.625 \text{ in.}^2$$

or $A_n = 4.00 - (3/8)(1) - (3/8)\left(1 - \frac{(3)^2}{4(1.5)}\right) = 3.813 \text{ in.}^2$

or $A_n = 4.00 - (3/8)(1) - (3/8)\left(1 - \frac{(3)^2}{4(1.5)}\right) \times 2 = 4.0 \text{ in.}^2$

or $A_n = 4.00 - (3/8)(1) \times 2 = 3.25 \text{ in.}^2$, but because of load transfer,

use $A_n = \frac{7}{6}(3.25) = 3.792 \text{ in.}^2$ for this possibility.

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{0.861}{3 + 3 + 3} = 0.9043$$

$$A_e = A_n U = 3.625(0.9043) = 3.278 \text{ in.}^2$$

$P_n = F_u A_e = 65(3.278) = 213.1 \text{ kips}$

For two angles, $P_n = 2(213.1) = 426.2 \text{ kips}$

(a) LRFD Solution

Gross section: $\phi_t P_n = 0.90(400) = 360 \text{ kips}$

Net section: $\phi_t P_n = 0.75(426.2) = 320 \text{ kips (controls)}$

$\underline{\phi_t P_n = 320 \text{ kips}}$

(b) ASD Solution

Gross section: $\dfrac{P_n}{\Omega_t} = \dfrac{400.0}{1.67} = 240 \text{ kips}$

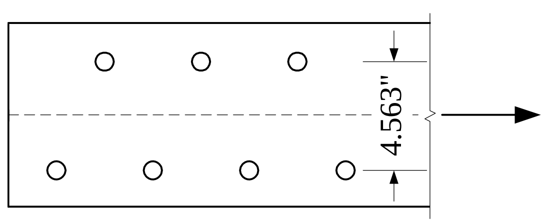
Net section: $\dfrac{P_n}{\Omega_t} = \dfrac{426.2}{2.00} = 213 \text{ kips}$

$\underline{\dfrac{P_n}{\Omega_t} = 213 \text{ kips}}$

3.4-6

Gross section: $P_n = F_y A_g = 36(3.30) = 118.8 \text{ kips}$

Net section: Use a gage distance of $2.5 + 2.5 - \dfrac{7}{16} = 4.563 \text{ in.}$



Hole diameter = $\dfrac{3}{4} + \dfrac{1}{8} = \dfrac{7}{8}$ in.

$$A_n = A_g - \sum t \times (d \text{ or } d')$$

$$= 3.30 - (7/16)(7/8) = 2.917 \text{ in.}^2$$

or $A_n = 3.30 - (7/16)(7/8) - (7/16)\left(\dfrac{7}{8} - \dfrac{(2)^2}{4(4.563)}\right) = 2.63 \text{ in.}^2$

Use $A_e = A_n = 2.63 \text{ in.}^2$, and $P_n = F_u A_e = 58(2.63) = 152.5 \text{ kips}$

(a) Gross section: $\phi_t P_n = 0.90(118.8) = 106.9 \text{ kips}$

Net section: $\phi_t P_n = 0.75(152.5) = 114.4 \text{ kips}$

Gross section controls. $\underline{\phi_t P_n = 107 \text{ kips}}$

(b) Gross section: $\dfrac{P_n}{\Omega_t} = \dfrac{118.8}{1.67} = 71.14 \text{ kips}$

Net section: $\dfrac{P_n}{\Omega_t} = \dfrac{152.5}{2.00} = 76.25 \text{ kips}$

Gross section controls. $\underline{P_n/\Omega_t = 71.1 \text{ kips}}$

3.5-1

Shear areas:

$$A_{gv} = \frac{7}{16}(4.5) = 1.969 \text{ in.}^2$$

$$A_{nv} = \frac{7}{16}[4.5 - 1.5(1.0)] = 1.313 \text{ in.}^2$$

Tension area $= A_{nt} = \dfrac{7}{16}[1.75 - 0.5(1.0)] = 0.5469 \text{ in.}^2$

For this type of connection, $U_{bs} = 1.0,$ and from AISC Equation J4-5,

$$R_n = 0.6F_uA_{nv} + U_{bs}F_uA_{nt}$$

$$= 0.6(65)(1.313) + 1.0(65)(0.5469) = 86.8 \text{ kips}$$

with an upper limit of

$$0.6F_yA_{gv} + U_{bs}F_uA_{nt} = 0.6(50)(1.969) + 1.0(65)(0.5469) = 94.6 \text{ kips}$$

$\underline{R_n = 86.8 \text{ kips}}$

3.5-2

Shear areas:

$$A_{gv} = \frac{1}{2}(2+4) \times 2 = 6 \text{ in.}^2$$

$$A_{nv} = \frac{1}{2}(2 + 4 - 1.5(1 + 3/16)) \times 2 = 4.219 \text{ in.}^2$$

Tension area $= A_{nt} = \dfrac{1}{2}(7.5 - 2 - 2 - (0.5 + 0.5)(1 + 3/16)) = 1.156 \text{ in.}^2$

For this type of connection, $U_{bs} = 1.0,$ and from AISC Equation J4-5,

$$R_n = 0.6F_uA_{nv} + U_{bs}F_uA_{nt}$$

$$= 0.6(58)(4.219) + 1.0(58)(1.156) = 214 \text{ kips}$$

with an upper limit of