1.051 Structural Engineering Design

Problem Set 5 Solutions

TENSION MEMBERS

1. Effective Net Area

Effective net area of the MC12x31 shown in Fig. 1. The holes are for 1-in bolts.

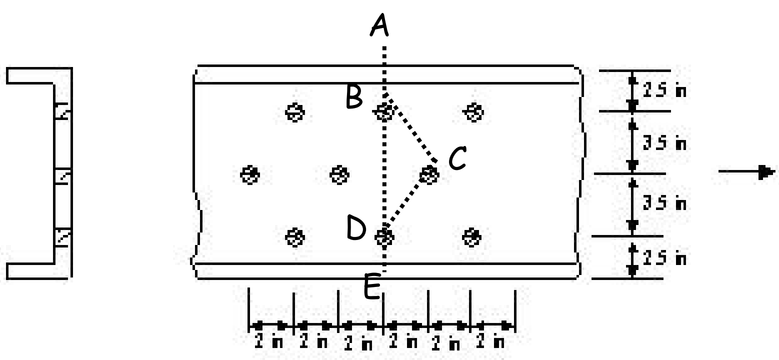

Figure 1

For MC12x31,

Area, $A = 9.12\ in^2$,

web thickness, $t_w = 0.37$ in

flange thickness, $t_f = 0.7$ in

Two possible failure paths: ABDE & ABCDE

For ABDE:

$$A_n = A_g - 2d_e t_w = 9.12 - (2)\left(1 + \frac{1}{16} + \frac{1}{16}\right)(0.37) = 8.29\ in^2$$

For ABCDE

$$A_n = A_g - 3d_e t_w + \Sigma \frac{s^2}{4g} t_w = 9.12 - (3)(1.125)(0.37) + (2)\frac{2^2}{(4)(3.5)}(0.37)$$

$$= 8.08\ in^2$$

ABDE controls

Effective area:

$A_e = UA_n$ where U=0.85 (M shape with b_f > (2/3)d)

$$A_e = 0.85(8.08) = 6.87\ in^2$$

2. Tensile and Block Shear Strength of Bolted Members

7x4x3/8 angle, three 1-in bolts, A36 steel, determine block shear strength and compare with the tensile design strength.

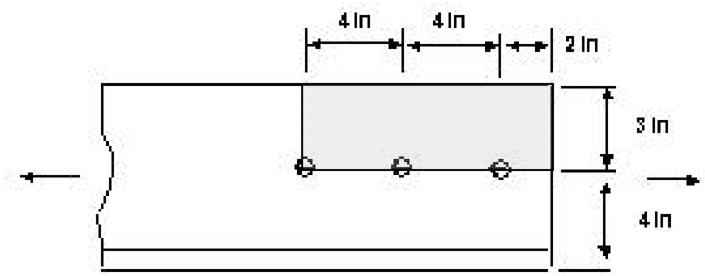

Figure 2

For 7x4x3/8 angle, $A_g = (7 + 4 - 3/8)(3/8) = 3.98 \text{ in}^2$

$$A_{gv} = (10)(\frac{3}{8}) = 3.75 \text{ in}^2$$

$$A_{gt} = (3)(\frac{3}{8}) = 1.125 \text{ in}^2$$

$$A_{nv} = 3.75 - 2.5(1.125)(\frac{3}{8}) = 2.7 \text{ in}^2$$

$$A_{nt} = 1.125 - \frac{1.125}{2}\frac{3}{8} = 0.91 \text{ in}^2$$

$F_u A_{nt} = (58)(0.91) = 52.8$ kips
$0.6 F_u A_{nv} = (0.6)(58)(2.7) = 94$ kips
$F_u A_{nt} < 0.6 F_u A_{nv}$ Use LRFD Equation J4-3b

$$\begin{aligned}\phi R_n &= \phi\left[0.6 F_u A_{nv} + F_y A_{gt}\right] \le \phi\left[F_u A_{nv} + F_u A_{nt}\right]\\ &= (0.75)\left[(0.6)(58)(2.7) + (36)(1.125)\right] \le (0.75)\left[(58)(2.7) + (58)(0.91)\right]\\ &= 100.8 \le 157.0\\ &= 100.8 \text{ kips}\end{aligned}$$

Tensile strength

Yielding of gross section

$$\phi_t P_n = \phi_t F_y A_g = (0.9)(36)(3.98) = 129 \text{ kips}$$

Fracture of the net section

$$A_n = 3.98 - (1)\left(1 + \frac{1}{16} + \frac{1}{16}\right)\left(\frac{3}{8}\right) = 3.6 \text{ in}^2$$

$U = 1 - \dfrac{\bar{x}}{L} = 1 - \dfrac{0.87}{8} = 0.89$ Note that U can be taken conservatively as 0.85 as allowed by LRFD.

$$A_e = UA_n = (0.89)(3.6) = 3.2 \text{ in}^2$$

$$\phi_t P_n = \phi_t F_u A_e = (0.75)(58)(3.2) = 139.2 \text{ kips}$$

Block shear controls failure: $\phi R_n = 100.8$ kips

3. Tensile and Block Shear Strength of Welded Members

Tensile design strength of the 6x6x1/2 angle, F_Y=50 ksi, F_u=65 ksi. Consider block shear as well as the tensile strength.

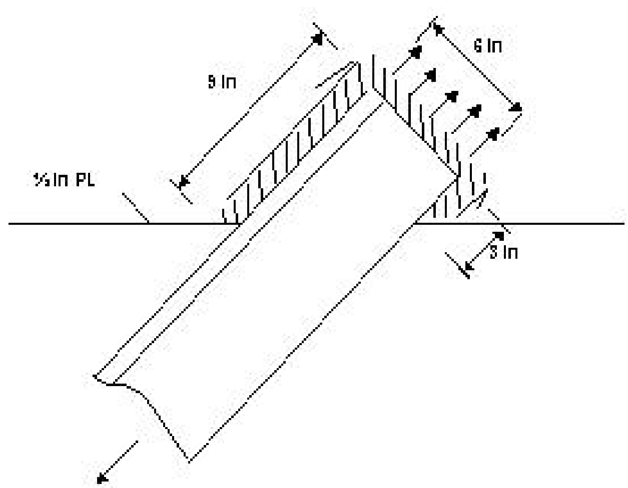

Figure 3

For the angle: $A_g = 5.75 \text{ in}^2$, $\bar{x} = 1.68$ in

Gross section yield:

$$\phi_t P_n = \phi_t F_y A_g = (0.9)(50)(5.75) = 258.8 \text{ kips}$$

Fracture of the net section:

$$A_n = A_g = 5.75 \text{ in}^2$$

Use average value of l: $l = \dfrac{3+9}{2} = 6$ in

$$w = l \Rightarrow U = 0.75$$

$$A_e = UA_n = (0.75)(5.75) = 4.3 \text{ in}^2$$

$$\phi_t P_n = \phi_t F_u A_e = (0.75)(65)(4.3) = 209.6 \text{ kips} \quad \text{(Controls)}$$

Block shear strength

$$F_u A_{nt} = (65)(5.75) = 373.8 \text{ kips}$$

$$0.6F_u A_{nv} = (0.6)(65)(9+3)(0.5) = 234 \text{ kips}$$

$$F_u A_{nt} > 0.6F_u A_{nv} \Rightarrow \text{ Use LRFD Eq. J4-3a}$$

$$\begin{aligned}\phi R_n &= \phi\left[0.6F_y A_{gv} + F_u A_{nt}\right] \le \phi\left[0.6F_u A_{nv} + F_u A_{nt}\right] \\ &= (0.75)\left[(0.6)(50)(6) + (65)(3)\right] \le (0.75)\left[(0.6)(65)(6) + (65)(3)\right] \\ &= 281.2 \le 321.8 \\ &= 281.2 \text{ kips}\end{aligned}$$

Design strength: $\phi_t P_n = 209.6$ kips