Fifth Edition

3.4-3 An MC 9 × 23.9 is connected with ¾-inch-diameter bolts as shown in Figure P3.4-3. A572 Grade 50 steel is used.

a. Determine the design strength.

b. Determine the allowable strength.

A572 Grade 50

Solution

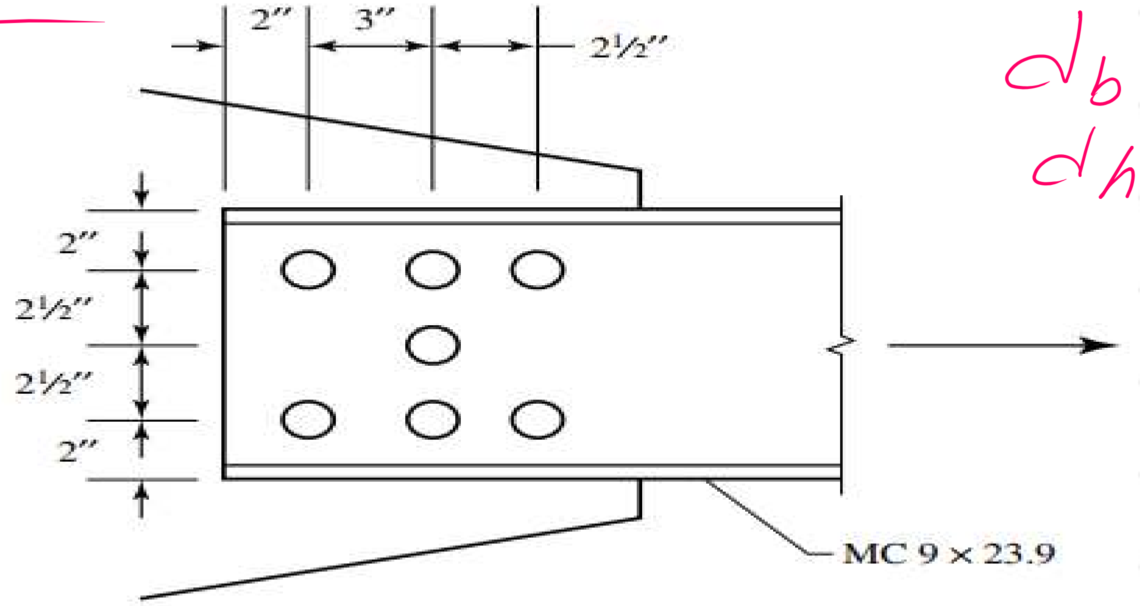

FIGURE P3.4-3

$d_b = 3/4''$

$d_h = 7/8''$

MC 9×23.9

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Table 2-4
Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation		F_y Min. Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	W	M	S	HP	C	MC	L	HSS Rect.	HSS Round	Pipe
High-Strength Low-Alloy	A572	Gr. 42	42	60										
		Gr. 50	50	65[d]										
		Gr. 55	55	70										
		Gr. 60[e]	60	75										
		Gr. 65[e]	65	80										
	A618[f]	Gr. I & II	50[g]	70[g]										
		Gr. III	50	65										
	A913	50	50[h]	60[h]										
		60	60	75										
		65	65	80										
		70	70	90										
	A992		50	65[i]										

ASTM A572 → Gr 50

MC section

$F_y = 50$ ksi

$F_u = 65$ ksi

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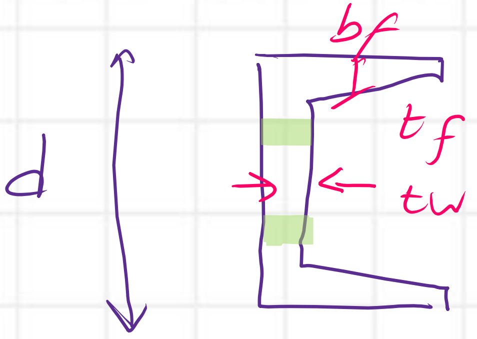
For MC 9X23.9

Refer to Table 1-6

For A_g → Part-1



b_f = 3.45"

t_f = 0.55"

d = 9.00"

t_w = 0.40"

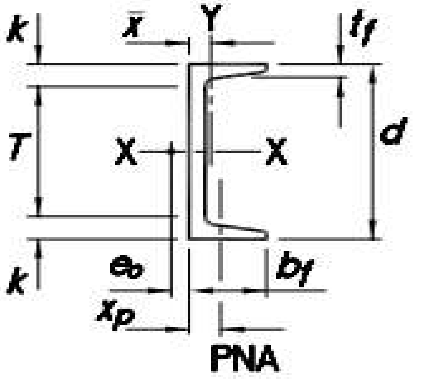


Table 1-6 (continued)
MC-Shapes
Dimensions

Shape	Area, A	Depth, d		Web: Thickness, t_w		Web: $\frac{t_w}{2}$	Flange: Width, b_f		Flange: Average Thickness, t_f		Distance: k	Distance: T	Distance: Workable Gage	r_{ts}	h_o
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
MC9×25.4	7.47	9.00	9	0.450	7/16	1/4	3.50	3 1/2	0.550	9/16	1 1/4	6 1/2	2[g]	1.20	8.45
×23.9	7.02	9.00	9	0.400	3/8	3/16	3.45	3 1/2	0.550	9/16	1 1/4	6 1/2	2[g]	1.18	8.45

A_g = 7.02 inch^2

Prepared by Eng.Maged Kamel.

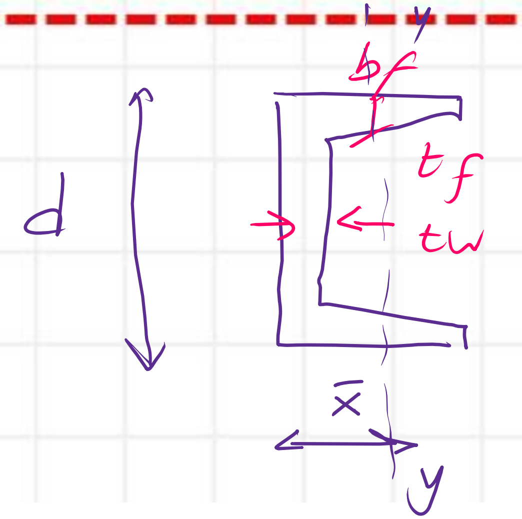
For MC 9X23.9

Refer to Table 1-6

For $\bar{x}$ bar Part-2

$A_g = 7.62$ inch^2

$\bar{x} = 0.981''$



$b_f = 3.45''$

$t_f = 0.55''$

$d = 9.00''$

Table 1-6 (continued)
MC-Shapes
Properties

MC18-MC8

Nom-inal Wt.	Shear Ctr, e_o	Axis X-X				Axis Y-Y						Torsional Properties			
		I	S	r	Z	I	S	r	$\bar{x}$	Z	x_p	J	C_w	$\bar{r}_o$	H
lb/ft	in.	in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{6}	in.	
25.4	0.986	87.9	19.5	3.43	23.5	7.57	2.99	1.01	0.970	5.70	0.415	0.691	104	4.08	0.770
23.9	1.04	84.9	18.9	3.48	22.5	7.14	2.89	1.01	0.981	5.51	0.390	0.599	98.0	4.15	0.763

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7 bolts each carries $P/7$

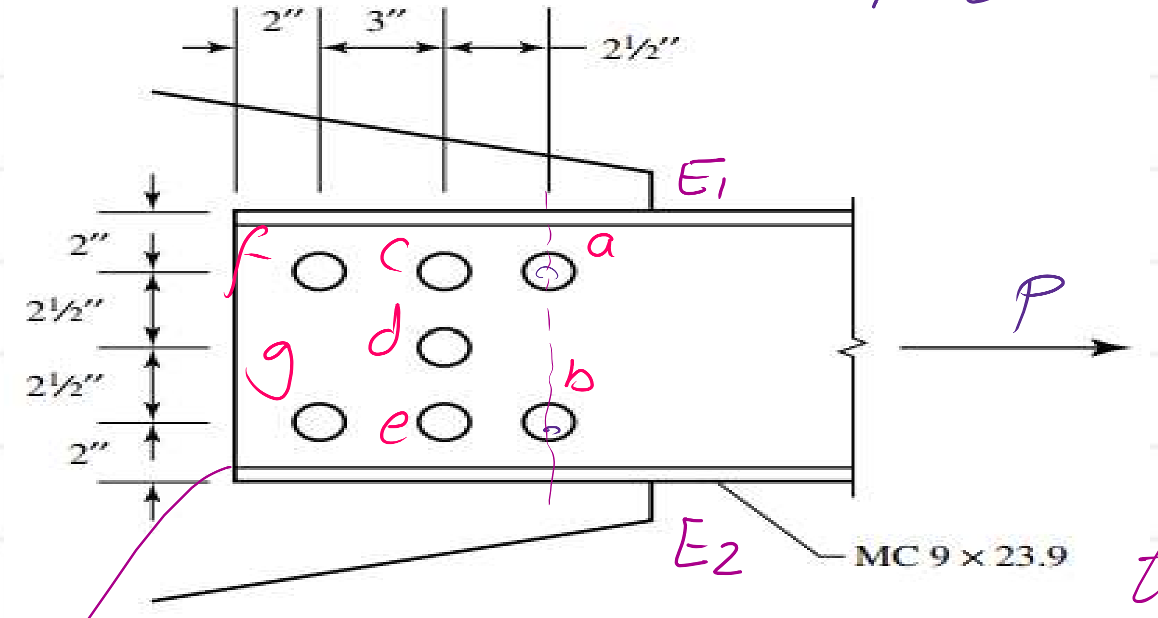
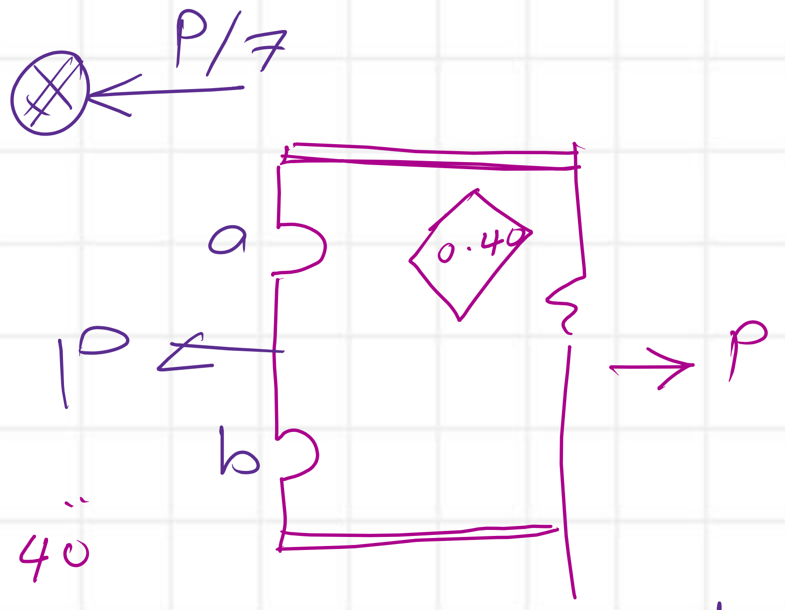


FIGURE P3.4-3



$t_w = 0.40''$

Route $E_1 a b E_2$

Deduct Two holes areas

No Tension Force at the end

$d_h = 7/8''$

$A_g = 7.02 \text{ inch}^2$

$A_n = A_g - 2 d_h \cdot t_w$

$A_n = 7.02 - 2(7/8)(0.40) = 7.02 - \frac{5.60}{8} = 6.32 \text{ inch}^2$

Transmit 100% P

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7 bolts each carries $P/7$

$\leftarrow P/7$

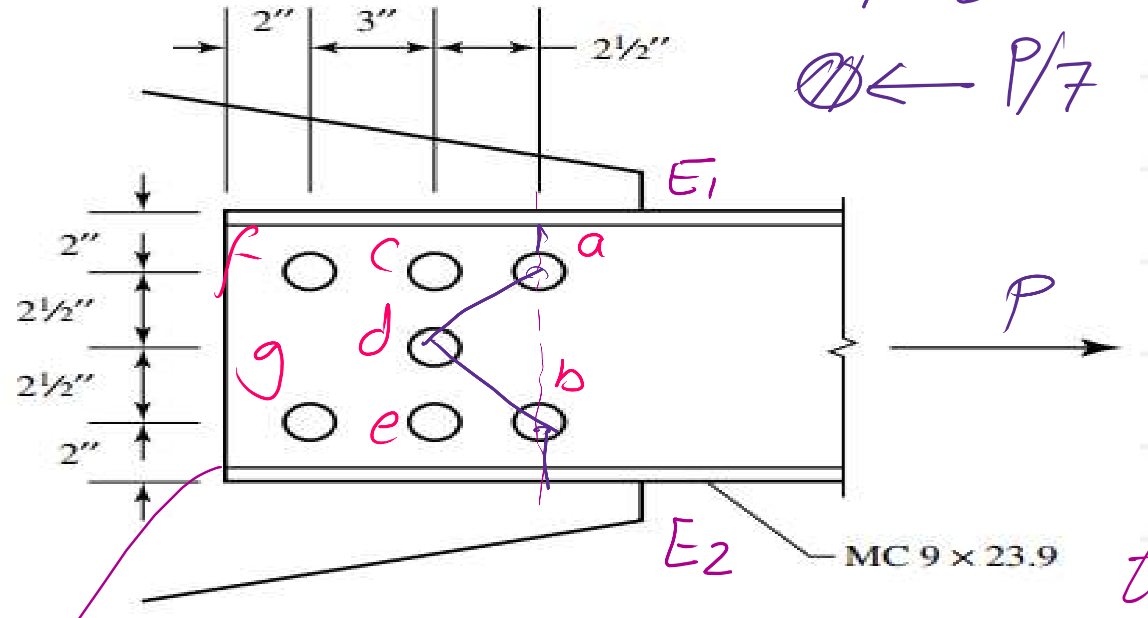
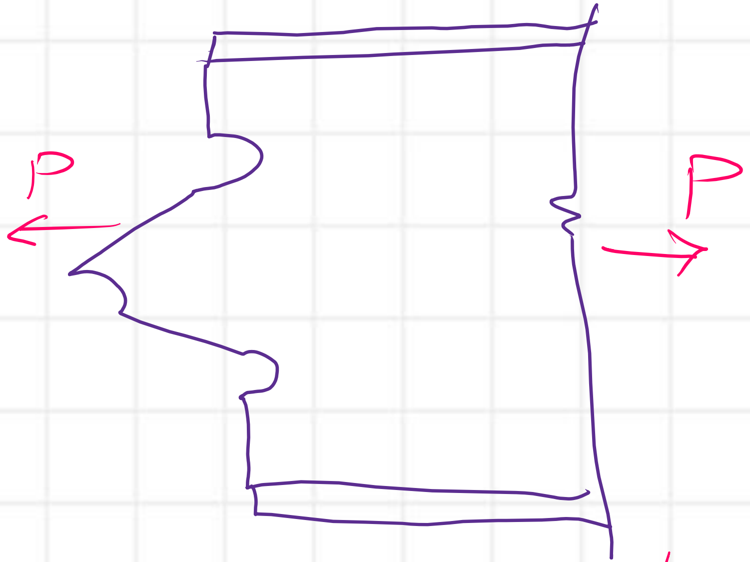


FIGURE P3.4-3



$t_w = 0.40''$

Route $E_1\,a\,d\,b$

$s_1 = s_2 = 2\frac{1}{2}''$

$g_1 = g_2 = 2\frac{1}{2}''$

No Tension Force at the end

$d_h = 7/8''$

deduct 3 holes area

$A_g = 7.02 \text{ inch}^2$

Add $\frac{s_1^2}{4g} t_w + \frac{s_2^2}{4g} t_w$

$$A_n = A_g - 3 d_h \cdot t_w + 2 \frac{s^2}{4g} t_w$$

$$A_n = 7.02 + 0.40 \left[-3\left(\frac{7}{8}\right) + \frac{2(2.5)^2}{4(2.5)} \right] = 7.02 + 0.40 \left[-\frac{21}{8} + \frac{5}{4} \right]$$

$A_n = 6.47 \text{ inch}^2 \Rightarrow 100\% \; P$

Prepared by Eng.Maged Kamel.

Route $E_1 \, Cde \, E_2$

$d_h = 7/8''$

$t_w = 0.40''$

$A_g = 7.02 \text{ inch}^2$

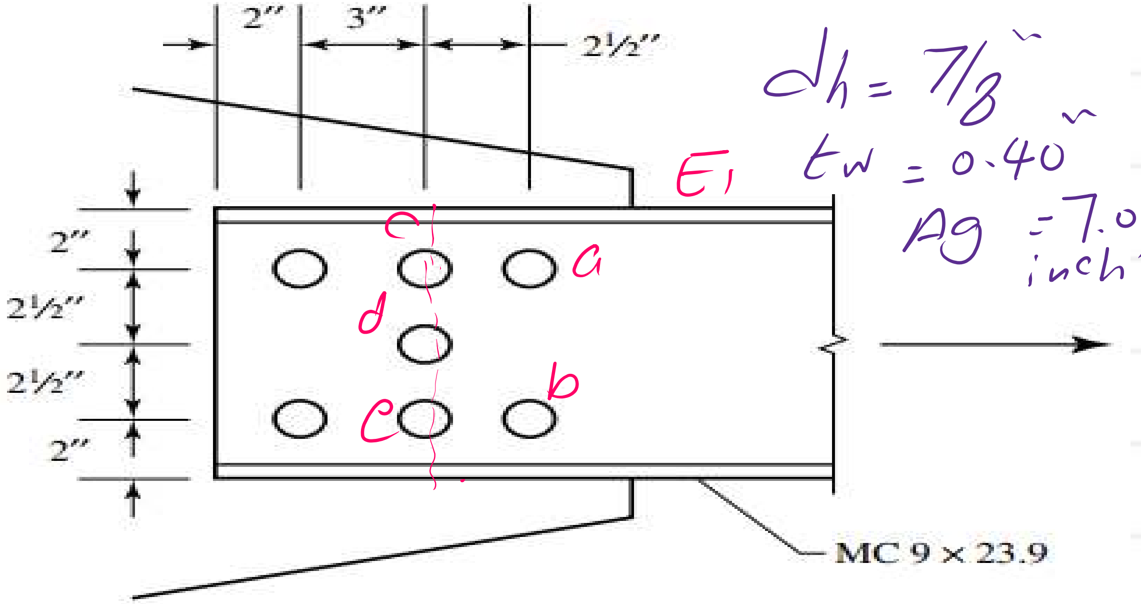
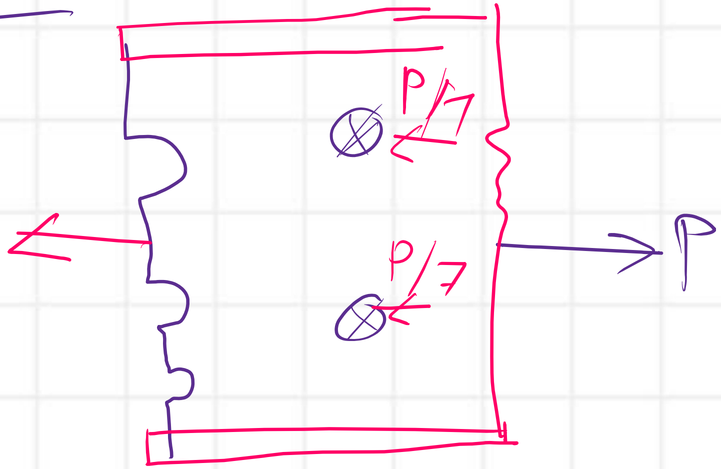


FIGURE P3.4-3



① Deduct 3 holes areas

$$A_n = A_g - 3 d_h \cdot t_w$$

$$= 7.02 - 3(7/8)(0.40)$$

$$A_n = 7.02 - \frac{21}{8}(0.40) = 5.97 \text{ inch}^2$$

$A_n \rightarrow$ Transmit $5P/7$

$$A_n \text{ For } 100\% \, P = 5.97(7/5) = 8.358 \text{ inch}^2$$

Prepared by Eng.Maged Kamel.

Route E_1 a d e E_2

$d_h = 7/8''$

$t_w = 0.40''$

$A_g = 7.02\ \text{inch}^2$

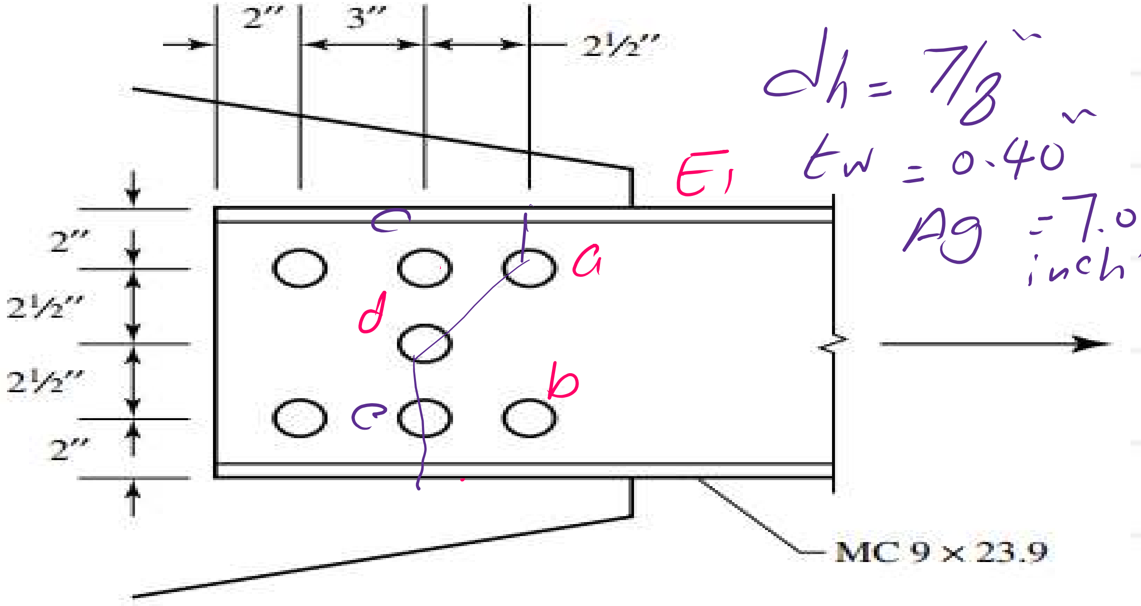
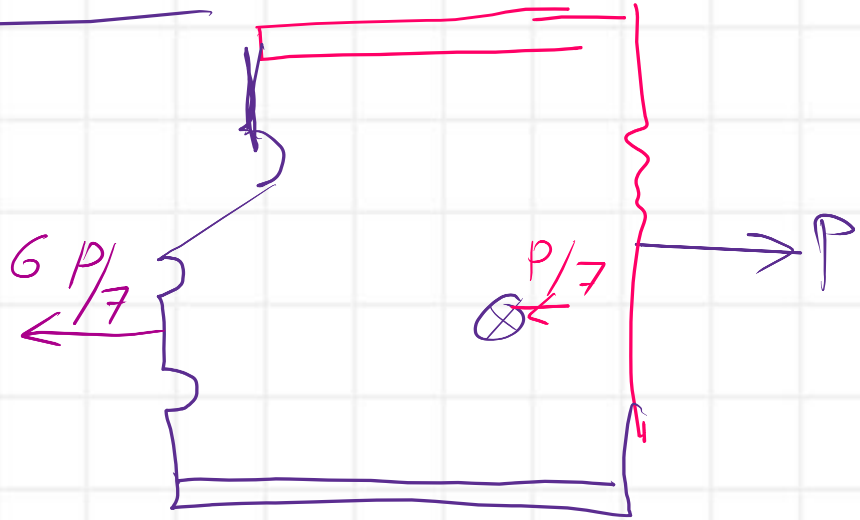


FIGURE P3.4-3



① Deduct 3holes areas

② Add $\frac{s^2}{4g} \cdot t_w$

$$A_n = A_g - 3 d_h \cdot t_w + \frac{s^2}{4g} t_w$$

$$= 7.02 - 3\left(7/8\right)(0.40) + \frac{2.5^2}{10}(0.40)$$

$$A_n = 7.02 - \frac{21}{8}(0.40) + \frac{1}{4} = 6.22\ \text{inch}^2$$

For $6P/7$

A_n For 100% P ↘ $6.22 \times \frac{7}{6} = 7.2566\ \text{inch}^2 \simeq 7.26\ \text{inch}^2$

Prepared by Eng.Maged Kamel.

$$\min A_n = \min(6.32,\ 6.47,\ 8.358,\ 7.26)$$

$$A_n = 6.32\ \text{inch}^2 \quad E_1\ adb$$

To get A_e

we need to find U value

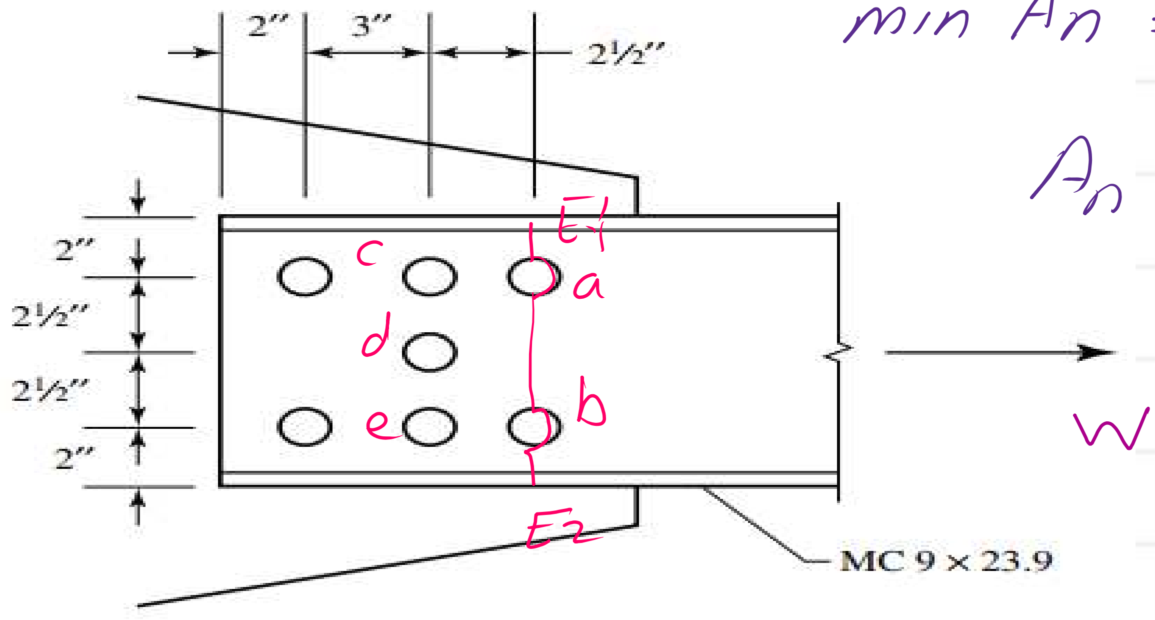


FIGURE P3.4-3

Case 2 $\quad U = 1 - \dfrac{\bar{x}}{L}$

$$l = 3 + 2\tfrac{1}{2}'' = 5\tfrac{1}{2}''$$

$$\bar{x} = 0.981''$$

$$U = 1 - \frac{0.981}{5.50} = 0.822$$

$$A_e = A_n U = 6.32(0.822) = 5.195\ \text{inch}^2$$

Prepared by Eng.Maged Kamel.

Design strength LRFD

$\phi = 0.90 \rightarrow$ yielding

$\phi = 0.75 \rightarrow$ Rupture

$A_g = 7.02$ inch^2

$A_e = 5.195$ inch^2

$F_y = 50$ ksi

$F_u = 65$ ksi

$\phi P_{ny} = 0.90(7.02)(50) = 315.90\ k$

$\phi P_{nr} = 0.75(5.195)(65) = 253.26\ k$

Failure is Controlled by rupture $\Rightarrow$ $253.26\ k \simeq 253$ kips

Prepared by Eng.Maged Kamel.

Allowable strength ASD

$\Omega = 1.67 \rightarrow$ yielding

$\Omega = 2 \rightarrow$ Rupture

$A_g = 7.02 \text{ inch}^2$

$A_e = 5.195 \text{ inch}^2$

$F_y = 50 \text{ ksi}$

$F_u = 65 \text{ ksi}$

$$\frac{1}{\Omega} P_{ny} = \frac{1}{1.67}(7.02)(50) = 210.18 \text{ k}$$

$$\frac{1}{\Omega} P_{nr} = \frac{1}{2}(5.195)(65) = 168.64 \text{ k}$$

Failure is Controlled by rupture $\Rightarrow$ 169 kips

Prepared by Eng.Maged Kamel.

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