Local Buckling For Builtup Section

Step by Step Guide to determine

Q_a, Q_s, F_{cr} → f value A_{gross}

Thru Solved Problem 6-19-4

Prof. Salmon's book

Prepared by Eng.Maged Kamel.

CHAPTER E

DESIGN OF MEMBERS FOR COMPRESSION

CM # 14 AISC-360-10

This chapter addresses members subject to axial compression through the centroidal axis.

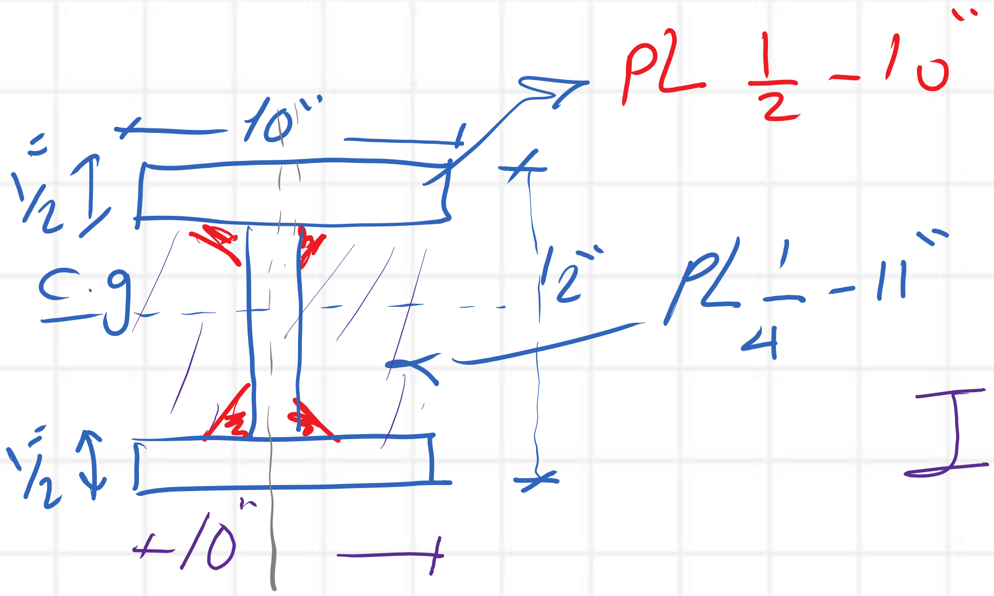
The chapter is organized as follows:

- E1. General Provisions
- E2. Effective Length
- E3. Flexural Buckling of Members without Slender Elements
- E4. Torsional and Flexural-Torsional Buckling of Members without Slender Elements
- E5. Single Angle Compression Members
- E6. Built-Up Members → Section E6 For Built up member
- E7. Members with Slender Elements → Slender

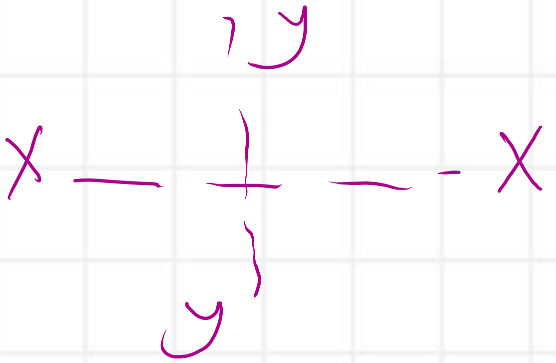
User Note: For cases not included in this chapter the following sections apply:

• H1 – H2	Members subject to combined axial compression and flexure
• H3	Members subject to axial compression and torsion
• I2	Composite axially loaded members
• J4.4	Compressive strength of connecting elements

Example 6-19-4 Determine the nominal axial compressive strength Pn for the non-standard shape of Fig. 6.19.4 for an effective length KL equal to 8 ft. Use Fy = 100 ksi and the AISC LRFD Method.



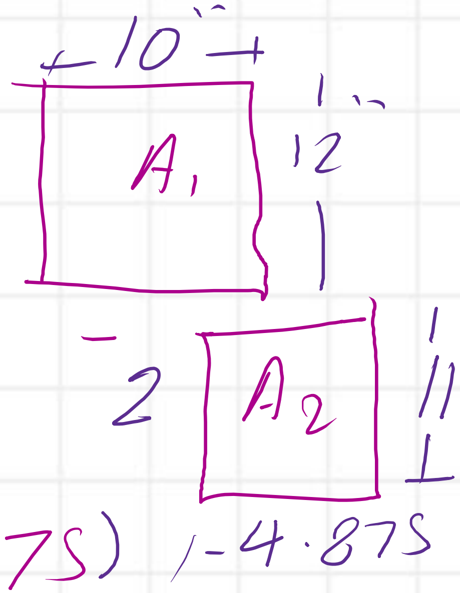
6.19.4



Solution

$KL = 8'$

$F_y = 100$ ksi



$I_x = I_{x1} - I_{x2}$

$= \left(\frac{10(12)^3}{12} - 2\left(4.875\frac{(11)^3}{12}\right)\right)$

$I_x = 10(12)^2 - 1081.44$

$= 358.56$ inch^4

Example 6-19-4 Determine the nominal axial compressive strength Pn for the non-standard shape of Fig. 6.19.4 for an effective length KL equal to 8 ft. Use Fy = 100 ksi and the AISC LRFD Method.

Solution

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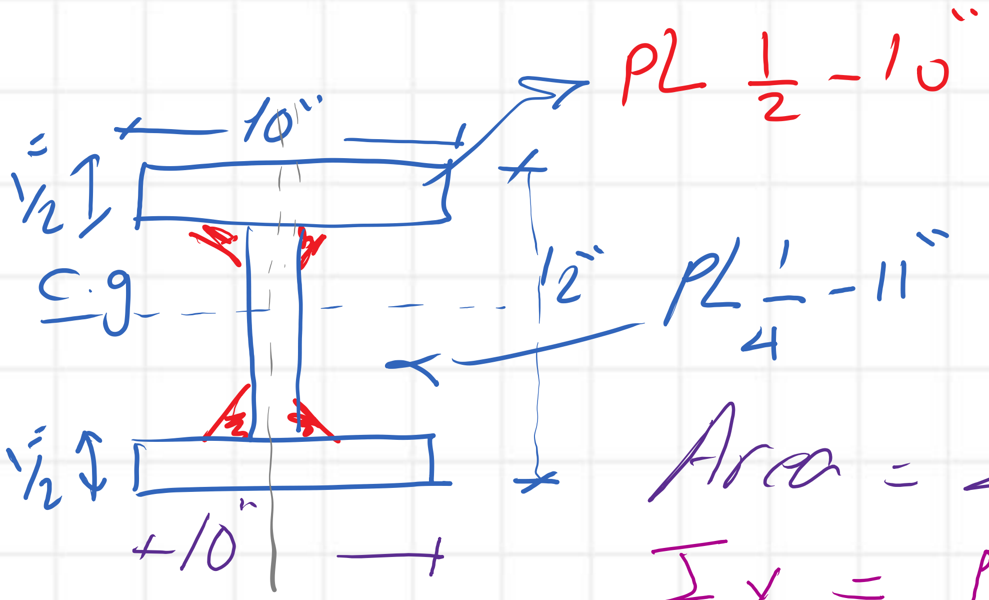
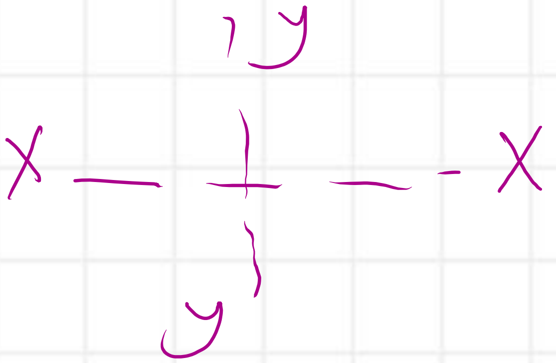
Built-up section



6.19.4



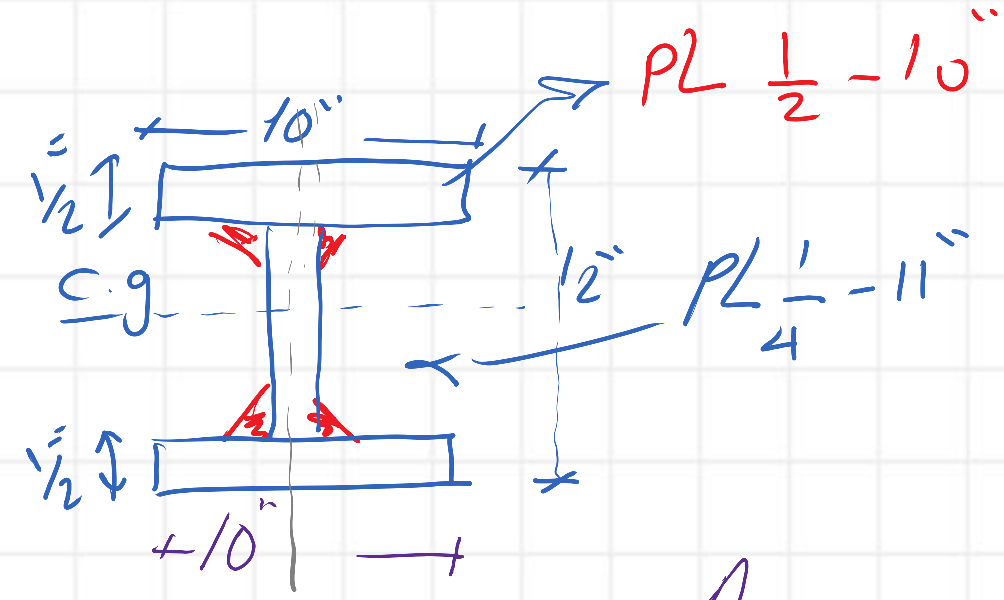
$$Area = 2(10'')\left(\frac{1}{2}\right) + 11\left(\frac{1}{4}\right) = 12.75 \text{ inch}^2$$

$$I_y = \frac{1}{2}\frac{(5)^3}{3}(4) + \frac{11}{12}\left(\frac{1}{4}\right)^3 =$$

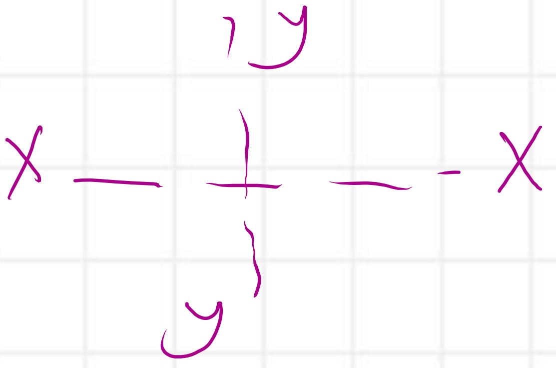
$$= \frac{1000}{12} + \frac{11}{64}\left(\frac{1}{12}\right) = 83.35 \text{ inch}^4$$

$$r_y = \sqrt{83.35 / 12.75} = 2.56 \text{ inches}$$

Example 6-19-4 Determine the nominal axial compressive strength Pn for the non-standard shape of Fig. 6.19.4 for an effective length KL equal to 8 ft. Use Fy = 100 ksi and the AISC LRFD Method.



(6.19.4)



Solution

$I_x = 358.56 \text{ inch}^4$

$KL = 8'$

$F_y = 100$ ksi

$\text{Area} = 2(10")(\tfrac{1}{2}) + 11(\tfrac{1}{4}) = 12.75 \text{ inch}^2$

$r_x = \sqrt{\dfrac{I_x}{A}} = \sqrt{\dfrac{358.56}{12.75}} = 5.30$ inches

$\left(\dfrac{KL}{r_x}\right) = 8(12)/5.30 = 11.62$

$\left(\dfrac{KL}{r_y}\right) = 8(12)/2.56 = 37.5$ → bigger

Unstiffened

16-1-41

(b) For flanges, angles and plates projecting from built-up I-shaped columns or other compression members:

Q_s

(i) When $\frac{b}{t} \le 0.64\sqrt{\frac{Ek_c}{F_y}}$

$$Q_s = 1.0 \quad \text{(E7-7)}$$

(ii) When $0.64\sqrt{\frac{Ek_c}{F_y}} < \frac{b}{t} \le 1.17\sqrt{\frac{Ek_c}{F_y}}$

$$Q_s = 1.415 - 0.65\left(\frac{b}{t}\right)\sqrt{\frac{F_y}{Ek_c}} \quad \text{(E7-8)}$$

(iii) When $\frac{b}{t} > 1.17\sqrt{\frac{Ek_c}{F_y}}$

$$Q_s = \frac{0.90Ek_c}{F_y\left(\frac{b}{t}\right)^2} \quad \text{(E7-9)}$$

(a) Determine k_c

where

b = width of unstiffened compression element, as defined in Section B4.1, in. (mm)

$k_c = \frac{4}{\sqrt{h/t_w}}$, and shall not be taken less than 0.35 nor greater than 0.76 for calculation purposes

t = thickness of element, in. (mm)

$$K_c = \frac{4}{\sqrt{h/t_w}} = \frac{4}{\sqrt{\frac{11}{1/4}}} = 0.603$$

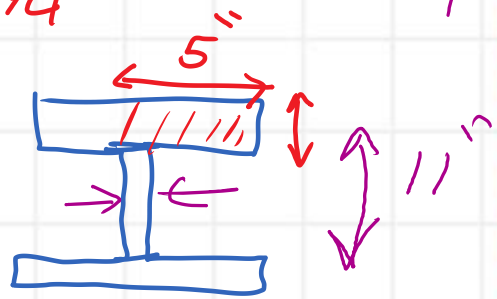
$t_w = 1/4''$

(b) $\frac{b}{t} \le 0.64\sqrt{\frac{29000(0.603)}{100}}$ (k_c)

→ 8.46

$\frac{b}{t} = \frac{5}{1/2} = 10$

$b/t > 8.46$



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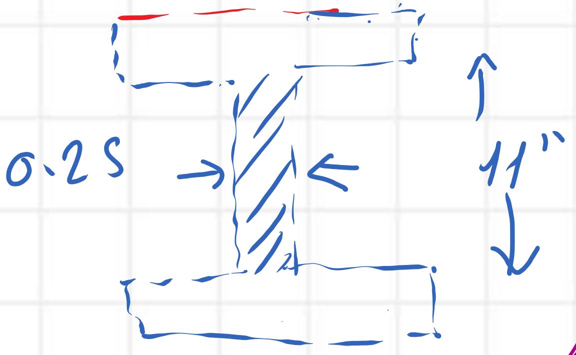
Check Local buckling

Stiffned →

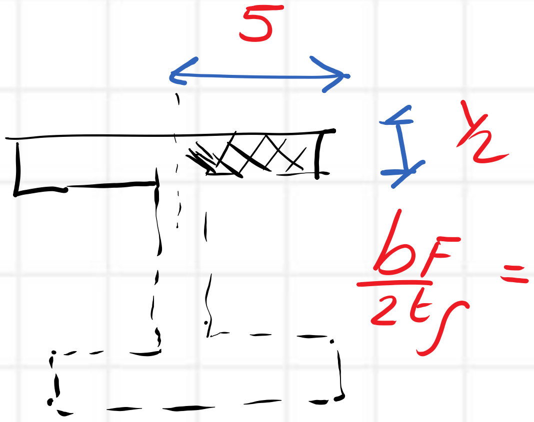


h/t_w

$$\frac{11}{0.25} = 44$$

Unstiffned

$k_c = 0.603$



$$\frac{b_f}{2t_f} = \frac{5}{1/2} = 10$$

check $\frac{b}{t} > 0.64\sqrt{\frac{E k_c}{f_y}}$

$$1.17\sqrt{\frac{E k_c}{f_y}} = 1.17\sqrt{\frac{29000(0.603)}{100}}$$

$$= 15.47$$

$$\frac{b}{t} > 0.64\sqrt{\frac{E k_c}{f_y}}, \quad < 1.17\sqrt{\frac{E k_c}{f_y}} \Rightarrow E7\text{-}8$$

$$Q_s = 1.415 - 0.65\left(\frac{b}{t}\right)\left(\sqrt{\frac{F_y}{E_y k_c}}\right)$$

$$= 1.415 - 0.65(10)\left(\sqrt{\frac{100}{29000(0.603)}}\right)$$

$$Q_s = 0.923$$

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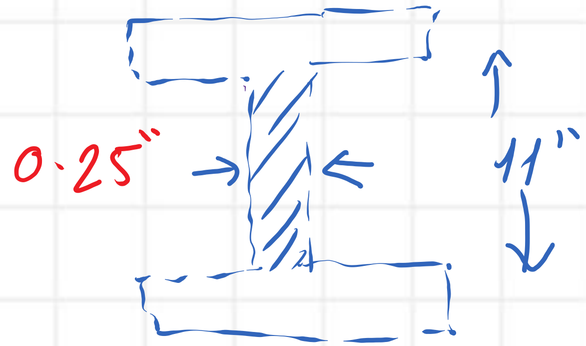
$$\frac{h}{t_w} = 44$$



$$1.49\sqrt{\frac{29000}{100}} = 25.4$$

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{(b/t)}\sqrt{\frac{E}{f}}\right] \leq b$$

2. Slender Stiffened Elements, Q_a

Q_a

The reduction factor, Q_a , for slender *stiffened elements* is defined as follows:

$$Q_a = \frac{A_e}{A_g} \quad \text{(E7-16)}$$

where

A_g = gross cross-sectional area of member, in.^{2} (mm^2)

A_e = summation of the effective areas of the cross section based on the reduced *effective width*, b_e, in.^{2} (mm^2)

The reduced effective width, b_e, is determined as follows:

(a) For uniformly compressed slender elements, with $\frac{b}{t} \geq 1.49\sqrt{\frac{E}{f}}$, except flanges of square and rectangular sections of uniform thickness:

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{(b/t)}\sqrt{\frac{E}{f}}\right] \leq b \quad \text{(E7-17)}$$

where

f is taken as F_{cr} with F_{cr} calculated based on $Q = 1.0$

as F_{cr} $Q = 1$

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Limiting factor $= 4.71\sqrt{\frac{E}{\varphi F_y}}$

$E = 29000$ ksi

$F_y = 100$ ksi

Consider $\varphi_a = 1$, $\varphi_s = 0.923$

Consider $\varphi = 1$

$= 4.71\sqrt{\frac{29000}{1(100)}} = 80.208$

$\left(\frac{KL}{r}\right)_y = 37.5$

$\left(\frac{KL}{r}\right)_y < 80.208$

inelastic Column

$F_{cr} = 0.658^{\varphi \frac{F_y}{F_E}} (F_y \varphi)$

$F_E = \pi^2 E / \left(\frac{KL}{r}\right)_y^2 = \overline{3.14159}^2 \frac{(29000)}{(37.5)^2} \simeq 204$ ksi

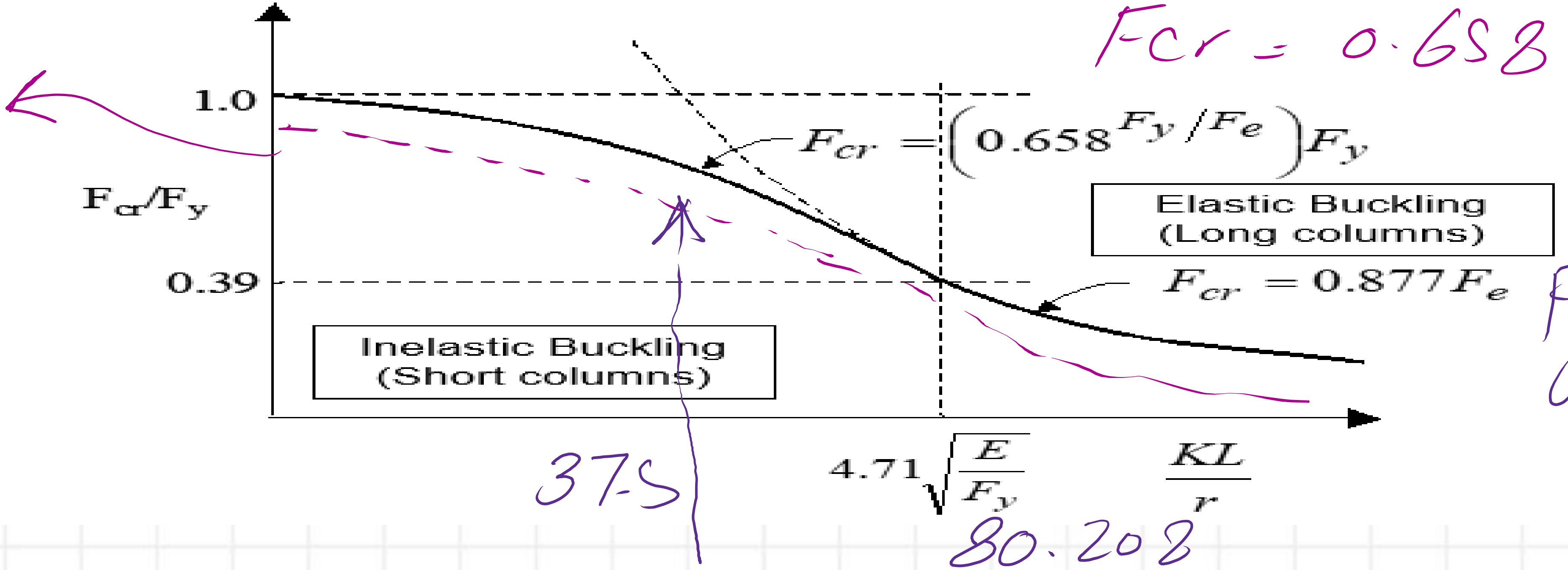
$$F_{cr} = 0.658^{\frac{QF_y}{F_E}}(QF_y) \rightarrow Q = Q_s \cdot Q_a = 0.923(1) = 0.923$$

$$= 0.658^{\frac{0.923(100)}{204}} \; 0.923(100) =$$

$$= 76.38 \text{ ksi}$$

$$F_{cr} = 0.658^{QF_y/F_E}(QF_y)$$

$$F_y = 100 \text{ ksi}$$



Find be

$$f = 0.923(76.38) = 70.50 \text{ ksi}$$

The reduced effective width, b_e, is determined as follows:

(a) For uniformly compressed slender elements, with $\frac{b}{t} \geq 1.49\sqrt{\frac{E}{f}}$, except flanges of square and rectangular sections of uniform thickness:

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{(b/t)}\sqrt{\frac{E}{f}}\right] \leq b \quad \text{(E7-17)}$$

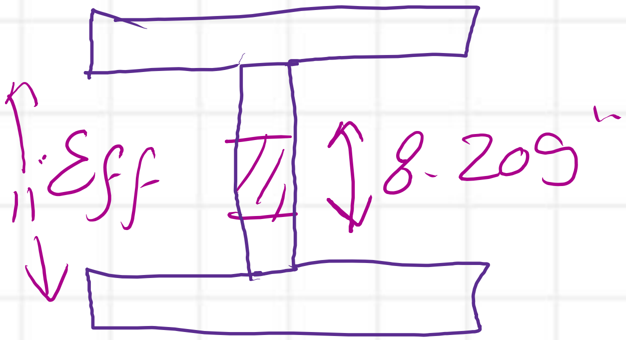
where

f is taken as F_{cr} with F_{cr} calculated based on $Q = 1.0$

$$b_e = 1.92(0.25)\sqrt{\frac{29000}{(70.50)}}\left[1 - \frac{0.34}{\left(\frac{11}{0.25}\right)}\sqrt{\frac{29000}{70.5}}\right]$$

$$A_{e_w} = b_e \cdot t_w$$

$$b_e = 0.48(20.2817)(1 - 0.15672) = 8.209'' < 11''$$



Effective Ae For Section

$$A_e = A_g - b_w h_w + b_e t_w$$

$$= 12.75 - (11)\left(\tfrac{1}{4}\right) + 8.205\left(\tfrac{1}{4}\right)$$

$$= 12.05 \text{ inch}^2$$

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Back to $Q_a = \frac{A_{eff}}{A_g} = \frac{12.05}{12.75} = 0.945$

$Q_s = 0.923$
$Q_a = 0.945$ } $\Rightarrow Q = 0.8722$

$Q_a(Q_s)$ → 0.8722

Get new value for f_{cr}

$F_{cr} = 0.685^{\frac{(0.8722)(100)}{204}}(0.8722)(100)$

$= 72.94$ Ksi

Get new value For $f = QF_{cr} = 0.8722(72.94)$

$= 63.60$ Ksi

Stiffened - web

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{(b/t)}\sqrt{\frac{E}{f}}\right] \le b \qquad \text{(E7-17)}$$

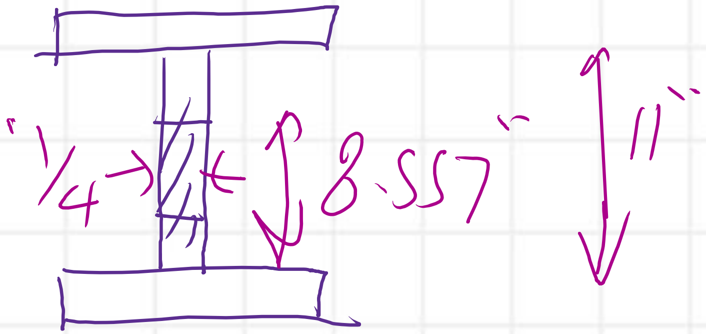
where $f = 63.6$ ksi

$$\left(\frac{b}{t}\right)_w = \frac{11}{1/4}$$

$$b_e = 1.92(0.25)\sqrt{\frac{29000}{63.6}}\left[1 - \frac{0.34}{44}\sqrt{\frac{29000}{63.60}}\right]$$

$= 8.557" < 11"$ h_w

Re estimate Ae For section



$$A_e = 12.75 - 11\left(\frac{1}{4}\right) - \left(8.557\left(\frac{1}{4}\right)\right)$$

$= 12.14 \text{ inch}^2$

Get New Value For $Q_a = \frac{A_{eff}}{A_g} = \frac{12.14}{12.75} = 0.945$

$Q_s = 0.923$
$Q_a = 0.945$
$\} \; Q = 0.872$

$[0.872]\left[\frac{100}{204}\right]$

$[100][0.872]$

$\downarrow F_{cr} = 0.675$
$= 72.94$ ksi

$f \rightarrow Q F_{cr} = 0.872(72.94) = 63.6$ ksi

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{(b/t)}\sqrt{\frac{E}{f}}\right] \le b \qquad \text{(E7-17)}$$

where

$$b_e = 1.92\left(\frac{1}{4}\right)\sqrt{\frac{29000}{63.6}}\left[1 - \frac{0.34}{44}\sqrt{\frac{29000}{63.60}}\right] = 8.557''$$

$$A_e = 12.75 - \left(\overset{h_w t_w}{11\left(\tfrac{1}{4}\right)}\right) + \left(\overset{b_e t_w}{8.557}\right)\left(\tfrac{1}{4}\right) = 12.14 \text{ inch}^2$$

Estimate $Q_a = \dfrac{A_{eff}}{A_g} = \dfrac{12.14}{12.75} = 0.952$

$$Q = Q_s \cdot Q_a$$

$$= 0.923\,(0.952) = 0.879$$

$$F_{cr} = 0.658^{\left[0.879\left(\frac{100}{204}\right)\right]}\,[879] = 73.40 \text{ ksi} \simeq 73 \text{ ksi}$$

$$P_n = F_{cr} A_g = 73\,(12.75) = 931 \text{ kips}$$

$$\phi_c P_n = 0.9\,(931) = 838 \text{ kips}$$

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