Summary

(A) Discussion about Types of Graphs F_{cr}

λ_c versus $\frac{F_c}{F_y}$

$\left(\frac{L_c}{r}\right)$ versus $F_y \longrightarrow F_{cr}$

(B) Solved problem 4-2 From Steel Design book

Find Design Compressive strength for $W_{14} \times 74$ short Column

Based on AISC-360-16

(1) LRFD design

(2) ASD design

Without using Tables

EXAMPLE 4.2

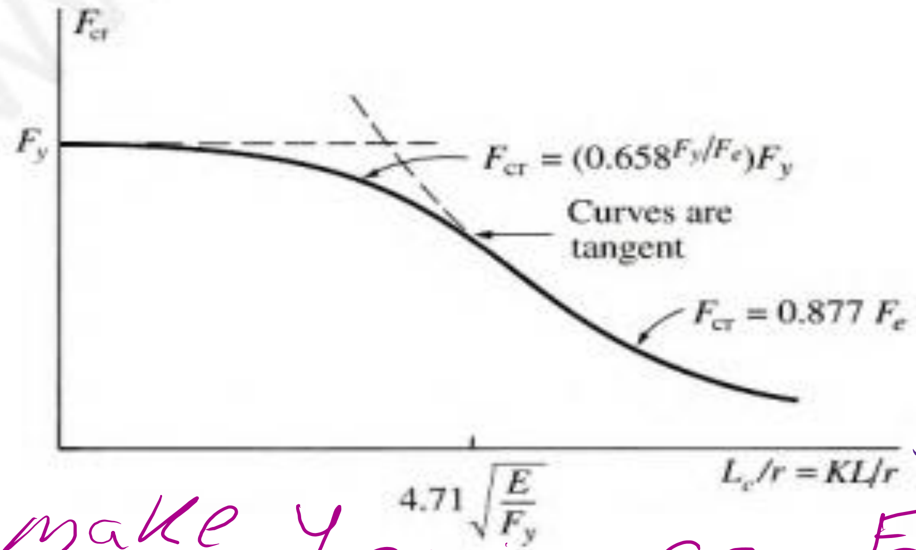
A W14 × 74 of A992 steel has a length of 20 feet and pinned ends. Compute the design compressive strength for LRFD and the allowable compressive strength for ASD.

$\frac{Lcr}{r}$ versus Fcr

Solution

For CM#15 KL is replaced by Lc

FIGURE 4.8



x-axis $\frac{Lc}{r}$ versus Fcr

y axis Fcr

Lc/r

we Could make y axis as Fcr/Fy ratio CM#15

There is another graph between λ_c versus $\frac{F_{cr}}{F_y}$

$\frac{F_{cr}}{F_y}$

$F_{cr} = 0.658^{\lambda_c^2} F_y$

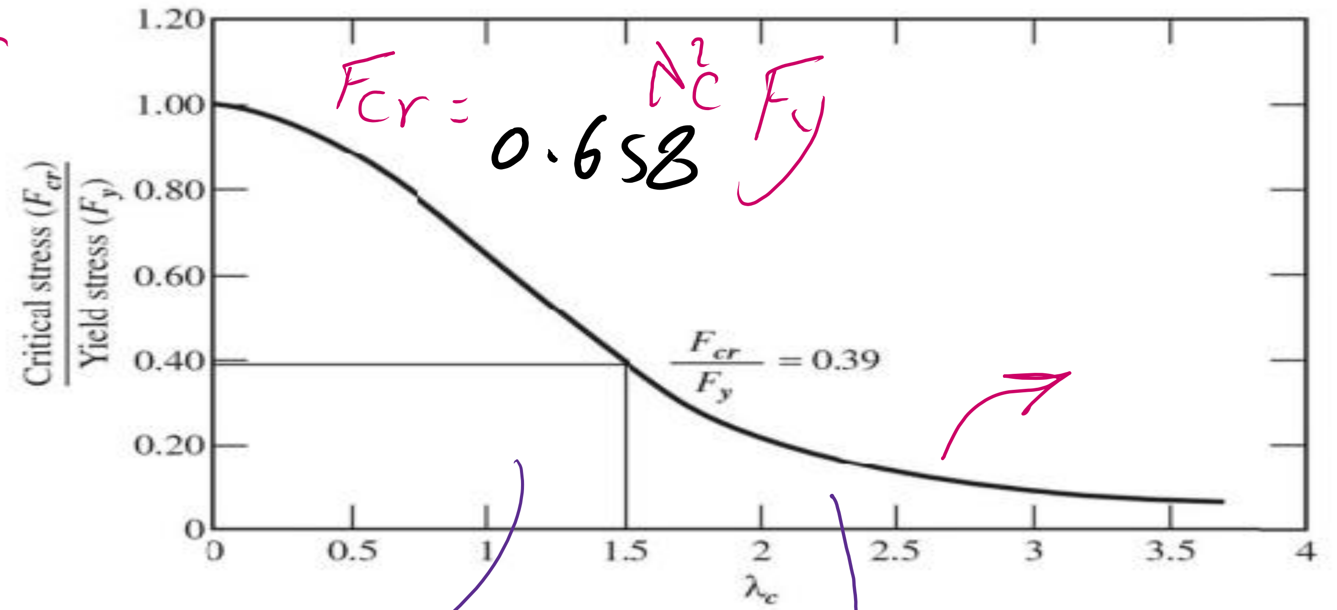


Figure 5.16 λ_c versus Critical Stress

$F_{cr} = 0.877 F_e$

$\rightarrow \lambda_c = \sqrt{F_y/F_e}$

Short Column

$\lambda_c^2 \leq 2.25$

$\lambda_c \leq 1.5$

Long columns _ Elastic

where $\lambda_c^2 \geq 2.25$

$\lambda_c \geq 1.50$

$\boxed{\lambda_c^2 = F_y/F_e}$

From Unified steel design

$$\lambda_r = 4.71\sqrt{\frac{E}{F_y}}$$

$E = 29000$ ksi

$F_y = 50$ ksi

This Equation is used to find out whether Column is Elastic (Long) or short (inelastic)

$$\lambda_r = 4.71\sqrt{\frac{29000}{50}} = 113.43 \approx \boxed{113}$$

against the Value of $\left(\frac{KL}{r}\right)_{max}$ or $\left(\frac{Lc}{r}\right)$ max Value

$\left(\frac{Lc}{r}\right) \rightarrow$ max of $\left(\frac{Lc}{r}\right)_x$ $(Lc/r)_y$

λ_c versus F_c/F_y

$$\lambda_c^2 = \frac{F_y}{F_e}$$

For Long Columns Elastic

$$F_{cr} = 0.877\,F_e$$

what is λ_c value?

$$\lambda_c^2 = \frac{F_y}{F_e} = \frac{\left(\frac{L_c}{r}\right)^2 F_y}{\pi^2 E}$$

But $F_e = \dfrac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \Rightarrow$

we have $F_y = 50$ ksi

$E = 29000$ ksi

$\pi^2 = (3.14159)^2$

$$\lambda_c^2 = \left(\frac{L_c}{r}\right)^2 \frac{50}{\pi^2(29000)} = 1.7469\,(10^{-4})\left(\frac{L_c}{r}\right)^2$$

at $\left(\frac{L_c}{r}\right) \geq 4.71\sqrt{\frac{E}{F_y}}$ For Elastic (Long) Columns

$$\left(\frac{L_c}{r}\right)^2 \geq (113.43)^2$$

For $\frac{L_c}{r} = 113.43$

Back to $\lambda_c^2 = (113.43)^2 (1.7469199(10^{-4}))$

$$\lambda_c^2 = 2.2477 \approx 2.25 = \frac{F_y}{F_e}$$

$$\lambda_c = 1.50$$

at r

The ratio y-axis Point $\frac{F_{cr}}{F_y} = \frac{0.877 F_e}{F_y} = \frac{0.877}{\lambda_r^2} = 0.3897$

$= 0.39$

At the point of intersection F_{cr} Equation

The ratio for short (inelastic) is

y-axis $\frac{F_{cr}}{F_y} \rightarrow \frac{(0.658)^{\lambda_c^2} F_y}{F_y} = (0.658)^{\lambda_c^2}(1)$

Use $\lambda_c^2 = 2.25 \leftarrow \frac{F_y}{F_e}$ For $\left(\frac{L}{r}\right) = 113.48$

$\frac{F_{cr}}{F_y} = (0.658)^{2.25} = 0.39$ Same as before

From Elastic Column F_{cr}/F_e

Inelastic Short

$F_{cr} = 0.658^{\lambda_c^2} F_y$

$\lambda_c = 1.5$

Graph

$F_{cr} = 0.877 F_e$

$\frac{F_{cr}}{F_y} > 0.39$

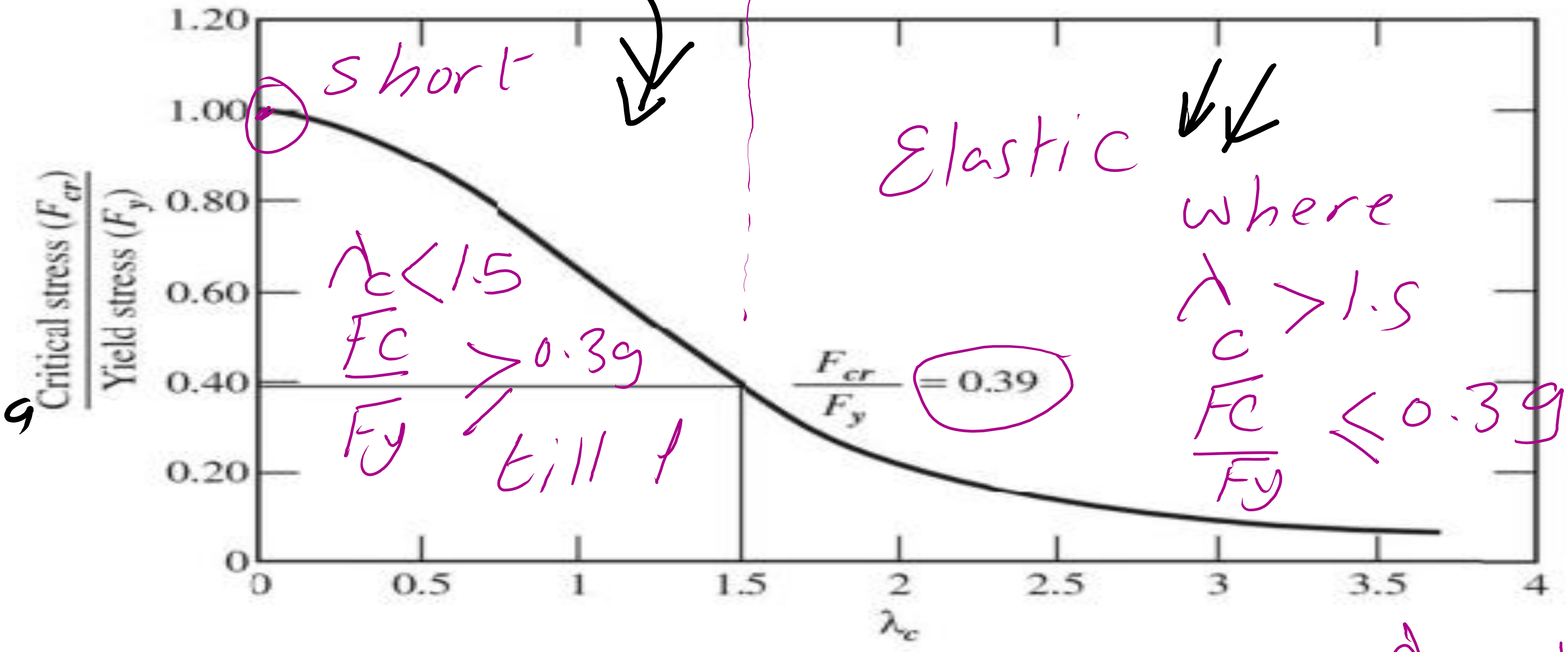


Figure 5.16 λ_c versus Critical Stress

$\lambda_c = \sqrt{\frac{F_y}{F_e}}$

For $\lambda_c^2 = 0$ $\Rightarrow$ F_e is very Large, $L/r = 0$, $F_e = \frac{\pi^2 E}{(0)^2} \approx \infty$

$F_{cr}/F_y = 0.865 = 1$

apply For (a) λ_c Versus $\frac{F_{cr}}{F_y}$

EXAMPLE 4.2

(b) $\left(\frac{L}{r}\right)$ Versus F_{cr}

A W14 × 74 of A992 steel has a length of 20 feet and pinned ends. Compute the design compressive strength for LRFD and the allowable compressive strength for ASD.

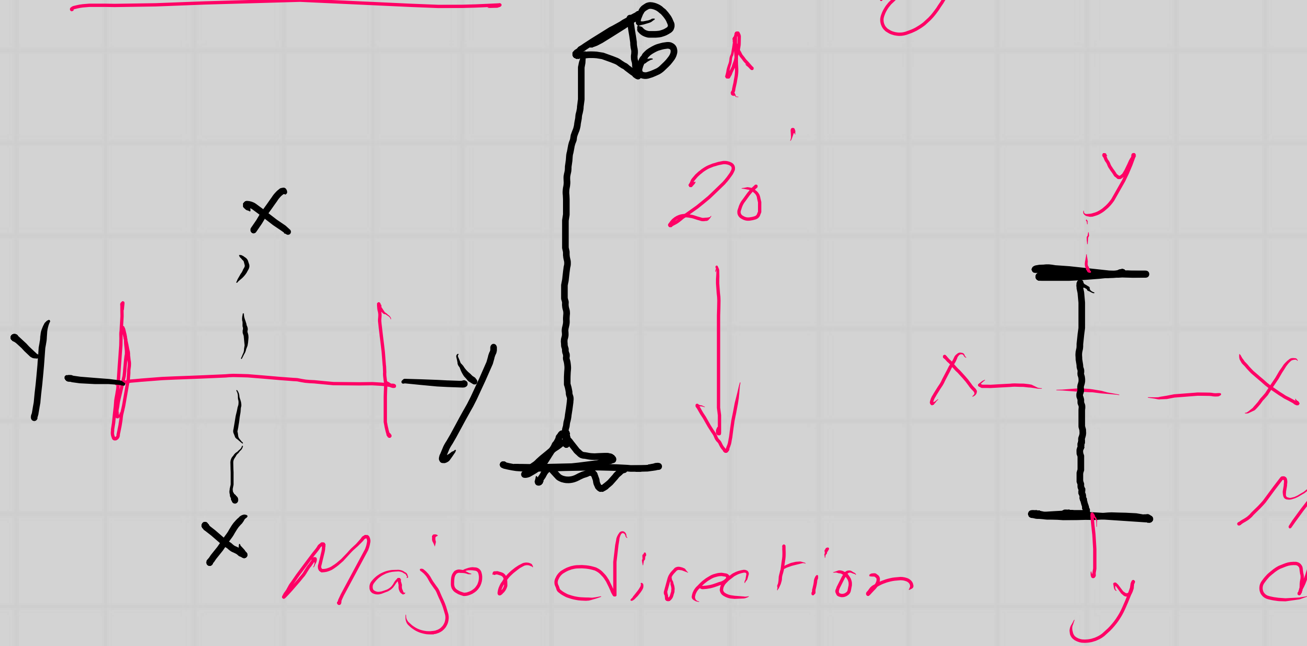
Parts (a), (b)

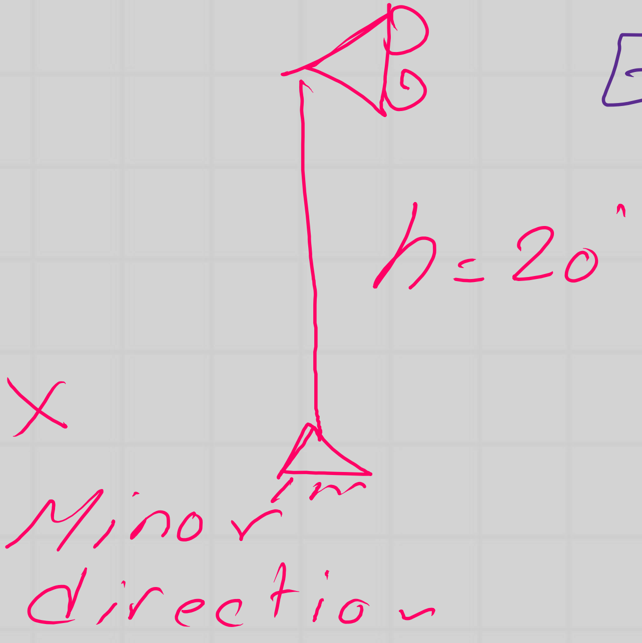
Solution

$F_y = 50$ ksi

W14 X 74

$E = 29000$ ksi





Use Table 1_1 to get r_x, r_y, I_x, I_y

$$\left(\frac{L_c}{r}\right)_x = \left(\frac{KL}{r}\right)_x \Rightarrow \quad K = 1 \quad l = 20' \quad A_g$$

$$L_{cx} = K_x L_x = 1(20)(12) = 240''$$

$$\left(\frac{L_c}{r}\right)_y = \left(\frac{KL}{r}\right)_y \quad L_{cy} = K_y L_y = 1(20)(12) = 240''$$

W14×74

Part_1

$A_g = 21.80$ inch^2

Parts (a & b)

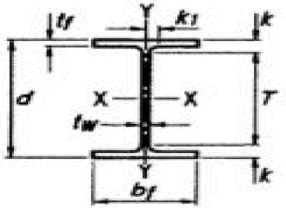


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web: Thickness, t_w		Web: $\frac{t_w}{2}$	Flange: Width, b_f		Flange: Thickness, t_f		Distance: k, k_{des}	Distance: k, k_{det}	Distance: k_1	Distance: T	Distance: Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W14×132	38.8	14.7	14 5/8	0.645	5/8	5/16	14.7	14 3/4	1.03	1	1.63	2 5/16	1 9/16	10	5 1/2
×120	35.3	14.5	14 1/2	0.590	9/16	5/16	14.7	14 5/8	0.940	15/16	1.54	2 1/4	1 1/2	↓	↓
×109	32.0	14.3	14 3/8	0.525	1/2	1/4	14.6	14 5/8	0.860	7/8	1.46	2 3/16	1 1/2	↓	↓
×99[f]	29.1	14.2	14 1/8	0.485	1/2	1/4	14.6	14 5/8	0.780	3/4	1.38	2 1/16	1 7/16	↓	↓
×90[f]	26.5	14.0	14	0.440	7/16	1/4	14.5	14 1/2	0.710	11/16	1.31	2	1 7/16	↓	↓
W14×82	24.0	14.3	14 1/4	0.510	1/2	1/4	10.1	10 1/8	0.855	7/8	1.45	1 11/16	1 1/16	10 7/8	5 1/2
×74	21.8	14.2	14 1/8	0.450	7/16	1/4	10.1	10 1/8	0.785	13/16	1.38	1 5/8	1 1/16	↓	↓
×68	20.0	14.0	14	0.415	7/16	1/4	10.0	10	0.720	3/4	1.31	1 9/16	1 1/16	↓	↓
×61	17.9	13.9	13 7/8	0.375	3/8	3/16	10.0	10	0.645	5/8	1.24	1 1/2	1	↓	↓

Part-2 of Table 1-1 W 14x74

$\boxed{a \& b}$

Nom-inal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
132	7.15	17.7	1530	209	6.28	234	548	74.5	3.76	113	4.23	13.7	12.3	25500
120	7.80	19.3	1380	190	6.24	212	495	67.5	3.74	102	4.20	13.6	9.37	22700
109	8.49	21.7	1240	173	6.22	192	447	61.2	3.73	92.7	4.17	13.4	7.12	20200
99	9.34	23.5	1110	157	6.17	173	402	55.2	3.71	83.6	4.14	13.4	5.37	18000
90	10.2	25.9	999	143	6.14	157	362	49.9	3.70	75.6	4.10	13.3	4.06	16000
82	5.92	22.4	881	123	6.05	139	148	29.3	2.48	44.8	2.85	13.4	5.07	6710
74	6.41	25.4	795	112	6.04	126	134	26.6	2.48	40.5	2.83	13.4	3.87	5990
68	6.97	27.5	722	103	6.01	115	121	24.2	2.46	36.9	2.80	13.3	3.01	5380
61	7.75	30.4	640	92.1	5.98	102	107	21.5	2.45	32.8	2.78	13.3	2.19	4710

r_x : 6.04" I_x : 795 inch^4

r_y : 2.48" I_y : 134 inch^4

$$Fe = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2_{max}}$$

$$\left(\frac{Lc_x}{r_x}\right)^2 = \left(\frac{240}{6.04}\right)^2 = 1578.878$$

$$\left(\frac{Lc_y}{r_y}\right)^2 = \left(\frac{240}{2.48}\right)^2 = 9365.244$$

$$\left(\frac{L_{c_y}}{r_y}\right)^2 > \left(\frac{L_{c_x}}{r_x}\right)^2 \Rightarrow \text{Proceed to Find } F_e$$

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r_y}\right)^2} = \frac{(3.14155)^2(29000)}{\left(\frac{240}{2.48}\right)^2} = 30.56 \text{ Ksi}$$

$F_y = 50$ Ksi as given

For Lambda C $\lambda_c = \sqrt{\frac{F_y}{F_e}}$

$$\lambda_c = \sqrt{\frac{50}{30.56}} = 1.28 < 1.5 \Rightarrow \text{Short Column}$$

1 Part (a)

$\frac{F_{cr}}{F_y} = 0.658^{\lambda_c^2}\left(\frac{F_y}{F_y}\right)$

λ_c^2 versus $\frac{F_{cr}}{F_y}$

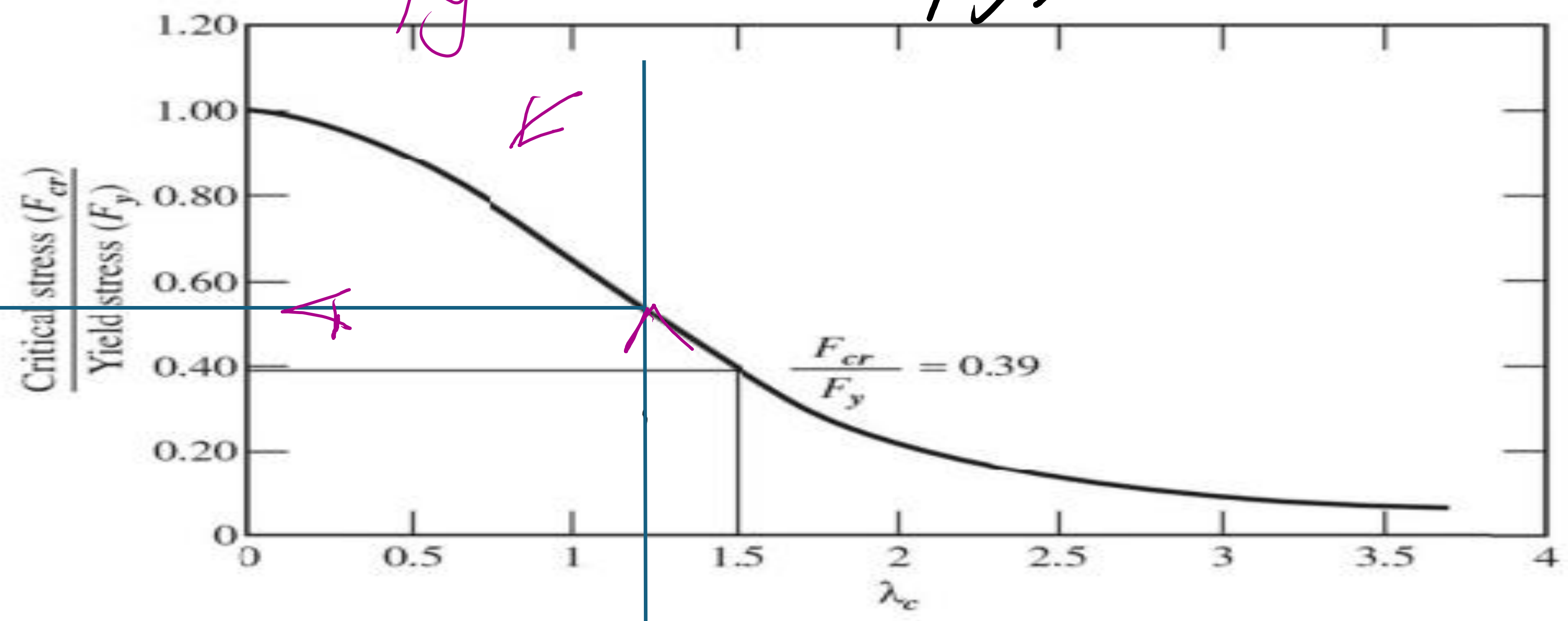


Figure 5.16 λ_c versus Critical Stress

$\rightarrow \lambda_c = \sqrt{\frac{F_y}{F_e}}$

λ_c

1.28

$\frac{F_c}{F_y} = 0.658^{\left(\frac{50}{30.56}\right)}$

$= 0.5041 \; \begin{matrix} > 0.4 \\ < 0.6 \end{matrix} \Bigg\} \Rightarrow F_{cr} = 0.5041(50)$

$= 25.21$ ksi

LRFD

$$\phi_c A_g F_{cr} = 0.90\underset{\text{inch}^2}{(21.80)}\underset{\text{ksi}}{(25.21)} = 494.62 \text{ kips}$$

$$\approx 495 \text{ kips}$$

ASD

$$\frac{1}{\Omega_c} A_g F_{cr} = \frac{1}{1.67}(21.8)(25.21) = 329.10 \text{ kips}$$

From λ_c & $\dfrac{F_{cr}}{F_y}$ relation

Part (a)

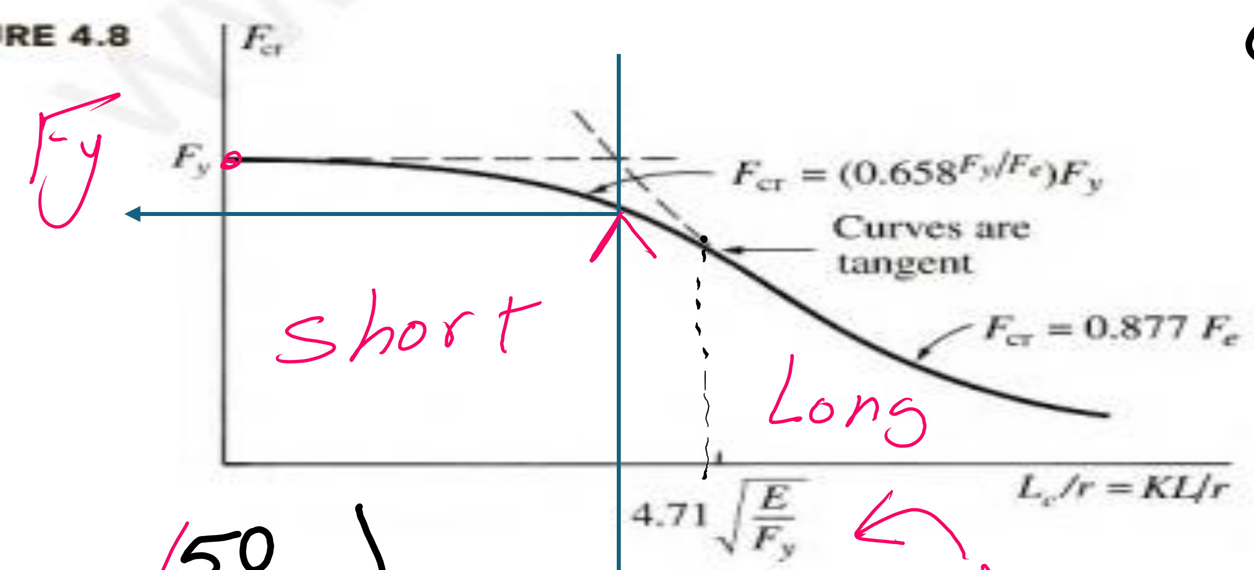
iF we Use $\left(\frac{L_c}{r}\right)$ versus F_{cr} Part (b)

we have $\left(\frac{L_c}{r}\right)_y = \left(\frac{240}{2.48}\right) = 96.774$

as maximum < 113.43

F_{cr}

FIGURE 4.8



Column is short

$F_e = 30.56$ ksi

113.43 λ_r

96.774

$F_{cr} = 0.658^{\left(\frac{50}{30.56}\right)}(50)$

$= 25.21$ ksi

LRFD

$$\phi_c A_g F_{cr} = 0.90\underset{\text{inch}^2}{(21.80)}\underset{\text{Ksi}}{(25.21)} = 494.62 \text{ Kips} \approx 495 \text{ kips}$$

ASD

$$\frac{1}{\Omega_c} A_g F_{cr} = \frac{1}{1.67}(21.8)(25.21) = 329.10 \text{ kips}$$

From $\left(\frac{L_c}{r}\right)$ & F_y relation