Summary

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

λ_c Versus $\frac{F_c}{F_y}$

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

(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

Without using Tables

(2) ASD design

Summary for Post 3a

EXAMPLE 4.2 Lc/r versus Fcr

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.

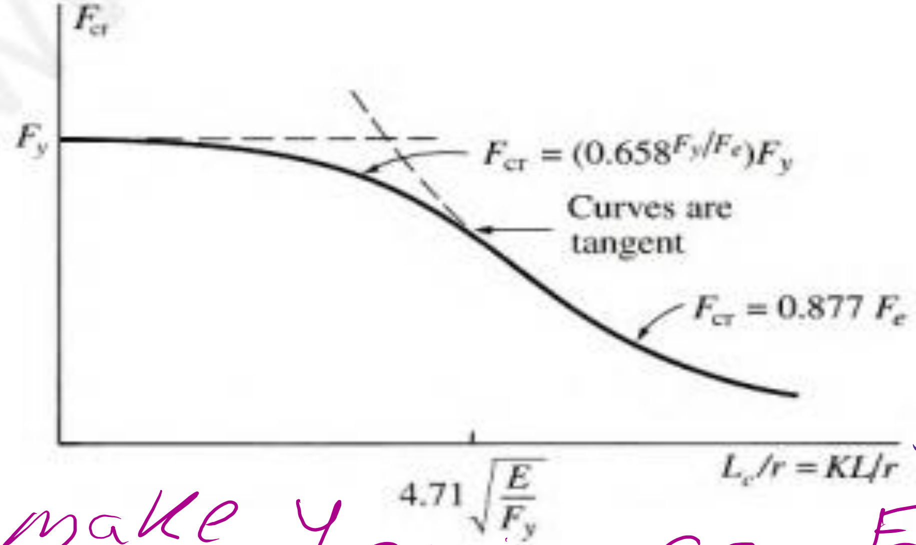
$\frac{L_c}{r}$ versus F_{cr}

Solution For CM#15 KL is replaced by L_c

x-axis $\frac{L_c}{r}$ versus F_{cr}

y axis F_{cr}

FIGURE 4.8



→ L_c/r

we Could make y axis as F_{cr}/F_y ratio CM#15

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

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

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

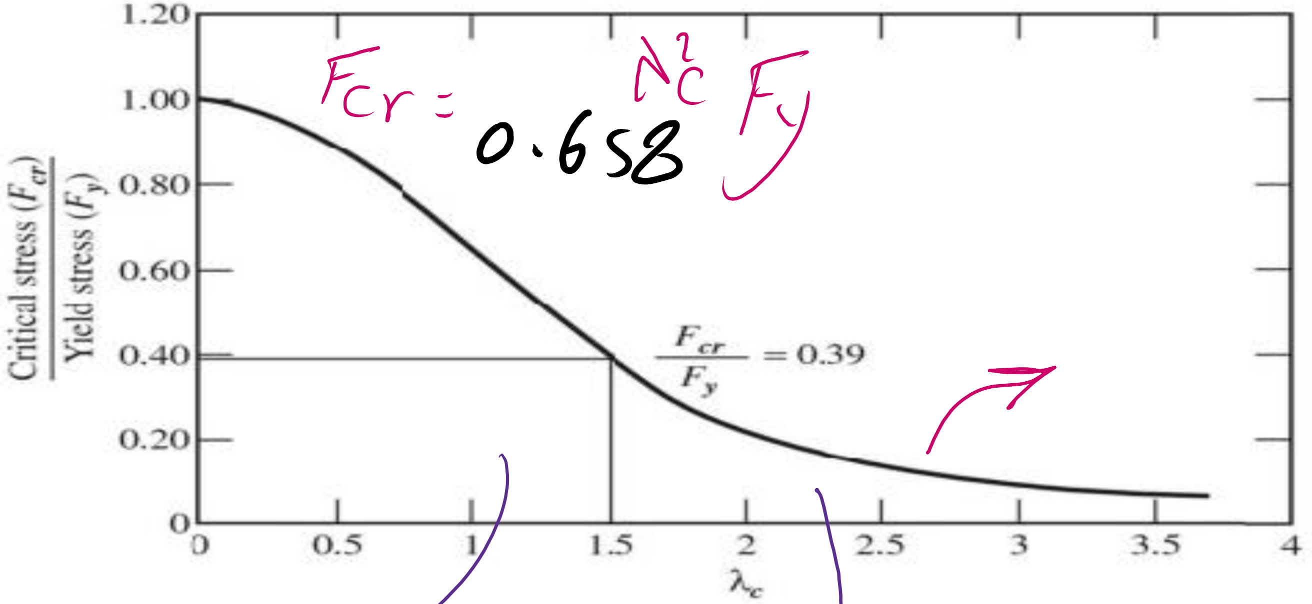


Figure 5.16 λ_c versus Critical Stress

$F_{cr} = 0.877 F_e$

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

Long columns _ Elastic

where $\lambda_c^2 \geq 2.25$

$\lambda_c \geq 1.50$

From Unified steel design

Short Column

$\lambda_c^2 \leq 2.25$

$\lambda_c \leq 1.5$

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

Introduction to λ^2

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

$E = 29000$ 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

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

Check whether column is long or short

λ_c versus F_c/F_y

Relation between λ^2 and lc/r

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

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

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

Fc/Fy at λ=1.5

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

$\lambda_c = 1.50$
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 Fcr Equation

The ratio For Short (inelastic) is

y-axis $\left\{\dfrac{F_{cr}}{F_y}\right.$ $\rightarrow$ $\dfrac{(0.658)^{\lambda_c^2} F_y}{F_y} = (0.658)^{\lambda_c^2}(1)$

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

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

Check Fcr/Fy for short column expression

From Elastic Column Fcr/Fe

Inelastic Short

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

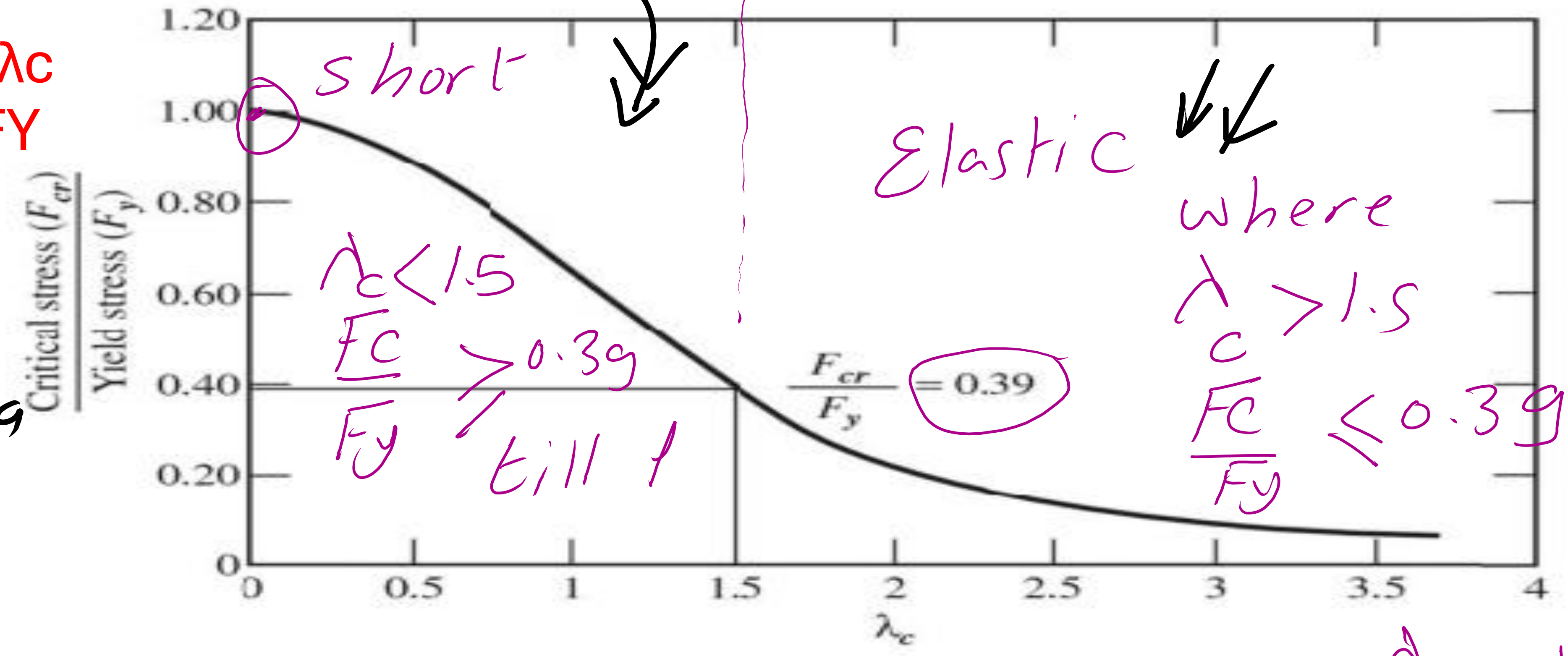
Graph

$F_{cr} = 0.877 F_e$

$\lambda_c = 1.5$

Graph between λc and Fcr/FY

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



short

$\lambda_c < 1.5$

$\frac{F_c}{F_y} > 0.39$ till 1

Elastic

where

$\lambda_c > 1.5$

$\frac{F_c}{F_y} < 0.39$

Figure 5.16 λ_c versus Critical Stress

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

For $\lambda_c^2 = 0$ ⇒ 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 $\frac{F_{cr}}{F_y}$

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

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.

Parts (a), (b)

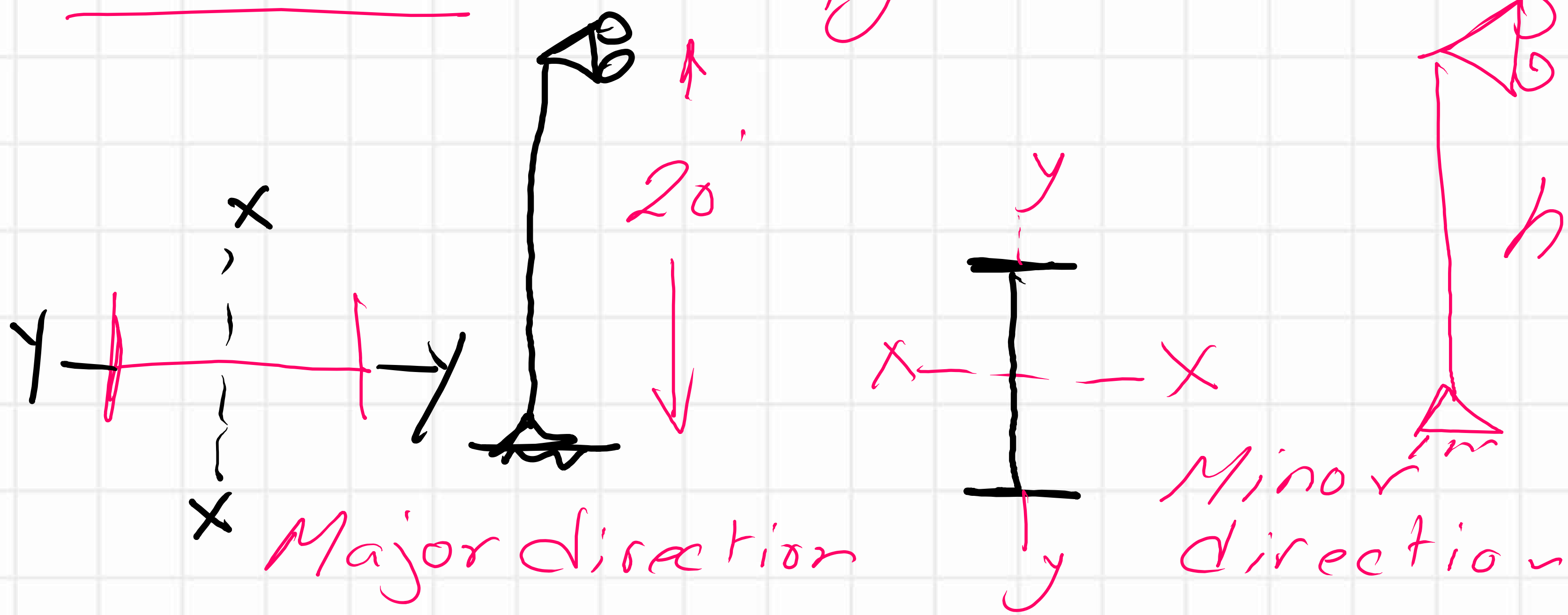
Solved problem 4.2

Solution

$F_y = 50$ ksi

W14x74

$E = 29000$ ksi



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

A_g

$K = 1$ $\quad$ $l = 20'$

$$\left(\frac{L_c}{r}\right)_x = \left(\frac{KL}{r}\right)_x \Rightarrow L_{cx} = K_x L_x = 1(20)(12) = 240''$$

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

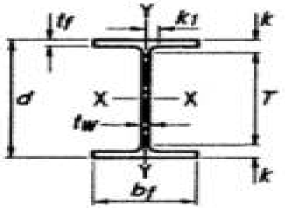


Table 1-1 (continued)
W-Shapes
Dimensions

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		

$W_{14} \times 74$

Part_1

$A_g = 21.80$ $inch^2$

Parts (a & b)

Find lc/r for both directions

Part - 2 of Table 1-1 W 14x74

$\boxed{a \& b}$

Nominal 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" $\quad I_x$: 795 inch^4

r_y : 2.48" $\quad I_y$: 134 inch^4

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

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

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

What is the Euler stress values based on directions?

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

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

Find Euler stress and lambda value

$F_y = 50$ 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 $\frac{F_{cr}}{F_y}$

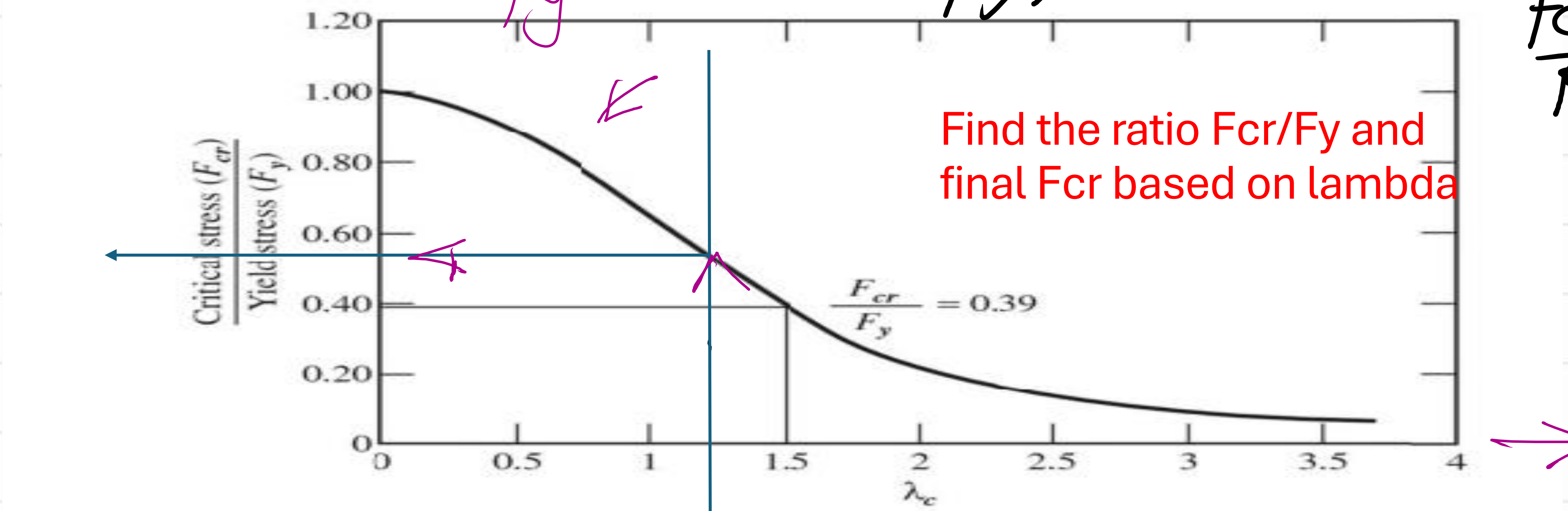


Figure 5.16 λ_c versus Critical Stress

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

λ_c 1.28

$$\frac{F_{cr}}{F_y} = 0.658^{\left(\frac{50}{30.56}\right)} = 0.5041 \begin{matrix} > 0.4 \\ < 0.6 \end{matrix} \Bigg\} \Rightarrow F_{cr} = 0.5041(50) = 25.21 \text{ ksi}$$

LRFD

inch^2 ksi

$$\phi_c A_g F_{cr} = 0.90(21.80)(25.21) = 494.62 \text{ kips}$$

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

ASD

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

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

Part (a)

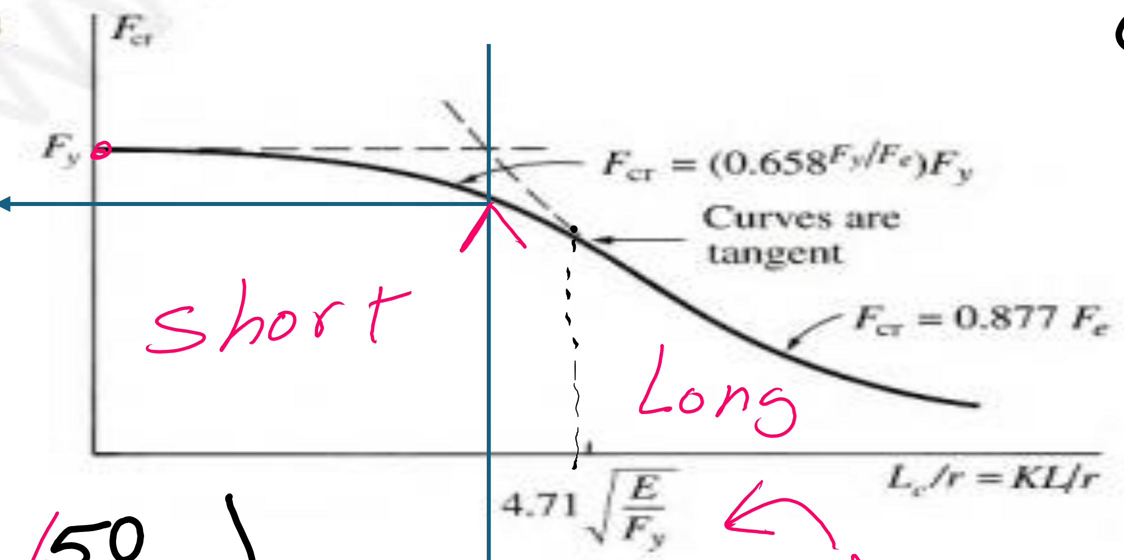
Estimate available strength LRFD and ASD iF We Use $\left(\frac{L_c}{r}\right)$ versus F_{cr} Part (b)

we have $\left(\frac{L_c}{r}\right)_y = \left(\frac{240}{2.48}\right) = 96.774 < 113.43$

as maximum

Fcr

FIGURE 4.8



113.43 λr

96.774

Column is short

$F_e = 30.56$ ksi

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

$= 25.21$ ksi

Part b-Lc/r versus Fcr

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

Design strength values based on part b.