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Summary

① Discussion about Types of Graphs F_{cr}

λ_c Versus $\frac{F_c}{F_y}$

$(\frac{L_c}{r})$ Versus $\frac{F_c}{F_y} \rightarrow F_{cr}$

② 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



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.

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

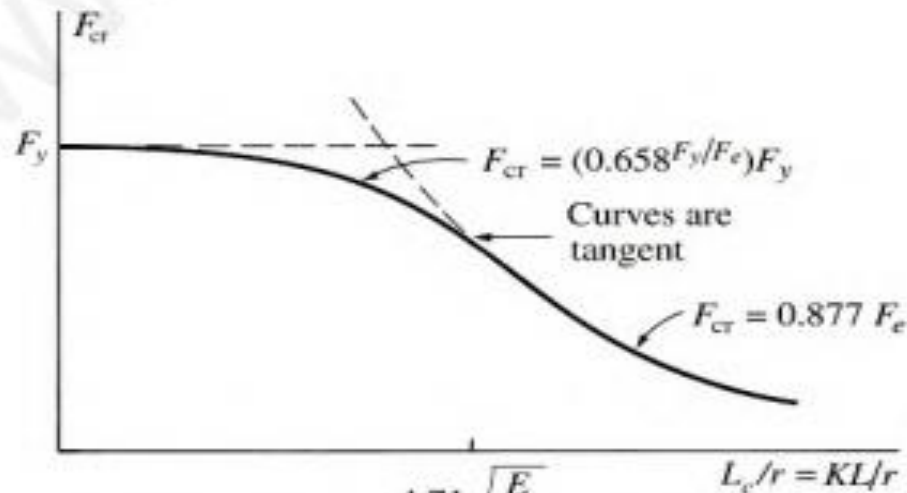
Solution

For $CM \neq 1.5$

KL is replaced by L_c

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

FIGURE 4.8



y axis F_{cr}

we could make y axis as F_{cr}/F_y ratio $CM \neq 1.5$

$\rightarrow L_c/r$

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

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

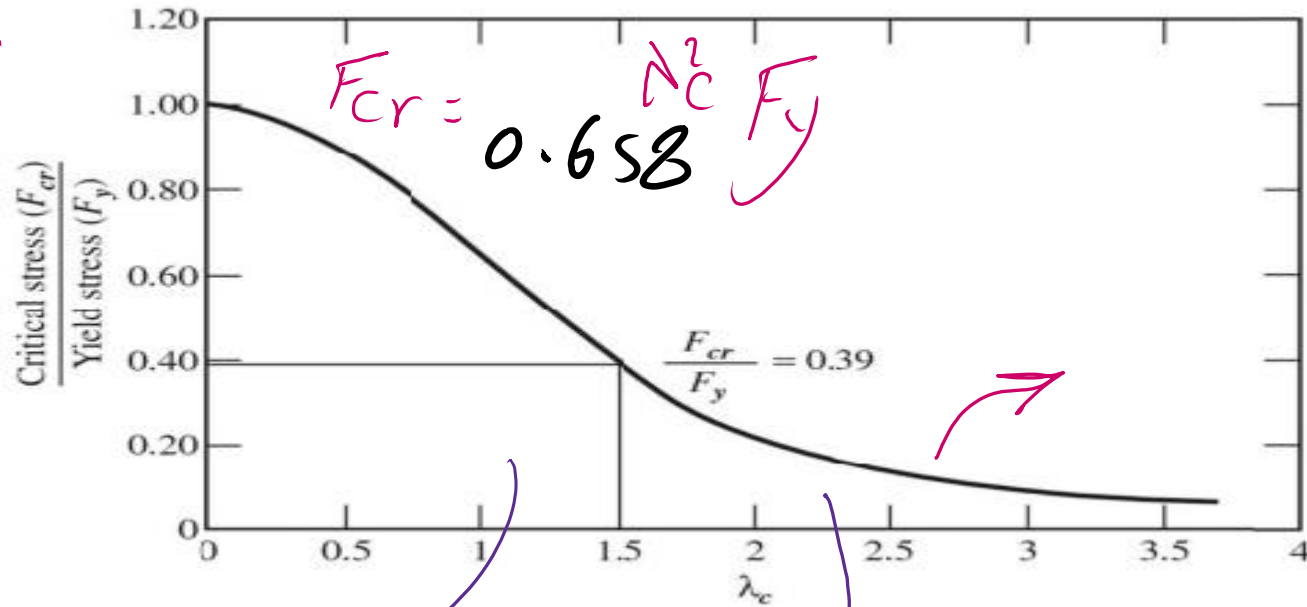


Figure 5.16 λ_c versus Critical Stress

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

$$F_{cr} = 0.877 F_e$$

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

Long columns - Elastic

where $\lambda_c^2 \geq 2.25$

$$\lambda_c \geq 1.50$$

Short Column

$$\lambda_c^2 < 2.25$$

$$\lambda_c \leq 1.5$$

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

From Unified steel design

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

$$E = 29000 \text{ Ks.}$$

$$F_y = 50 \text{ Ks.}$$

This Equation is used to Find out whether

Column is Elastic (Long) or Short (inelastic)

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

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

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

λ_c versus F_c/F_y

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

For Long Columns Elastic

$$F_{cr} = 0.877 F_e \quad \text{what is } \lambda_c \text{ value?}$$

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

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

We have $F_y = 50 \text{ ksi}$

$$E = 29000 \text{ ksi}$$

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

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

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

$$\left(\frac{L_c}{r}\right)^2 \geq (113.43)^2 \quad \text{For } \frac{L_c}{r} = 113.43$$

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

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

$$\lambda_c = 1.50$$

at r

The ratio $\frac{F_{cr}}{F_y} = \frac{0.877 F_e}{F_y} = \frac{0.877}{\lambda_c^2} = 0.3897$
y-axis Point $= 0.39$

At the point of intersection F_{cr} Equation

The ratio F_{cr} short (inelastic) is

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

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

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

From Elastic Columns
 F_{cr}/F_e

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

Graph

$F_{cr} = 0.877 F_e$

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

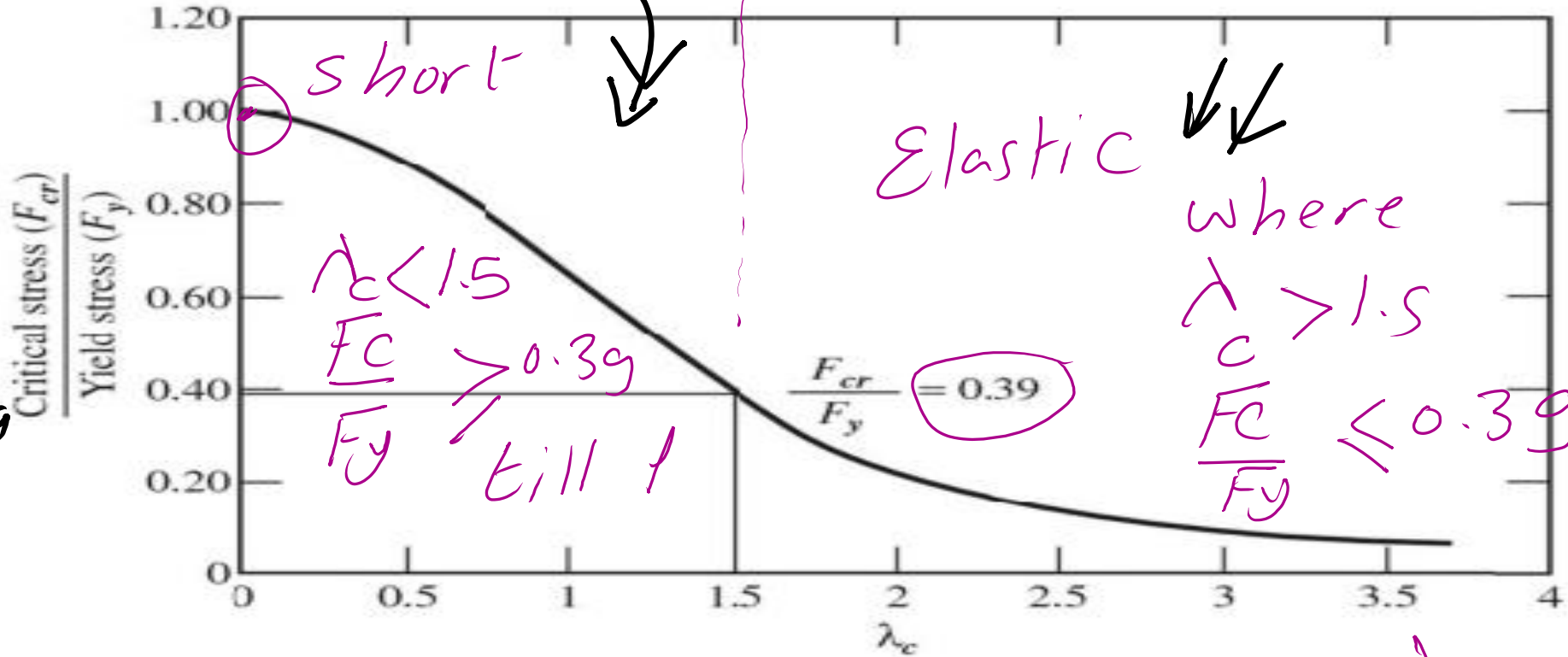


Figure 5.16 λ_c versus Critical Stress

For $\lambda_c = 0 \Rightarrow F_e$ is very large
 $F_{cr}/F_y = 0.865 = 1$

$F_e = \frac{\pi^2 E I}{(L/r)^2} \approx \infty$

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

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

EXAMPLE 4.2

(b) $(\frac{L}{r})$ Versus F_c

A W14 x 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.

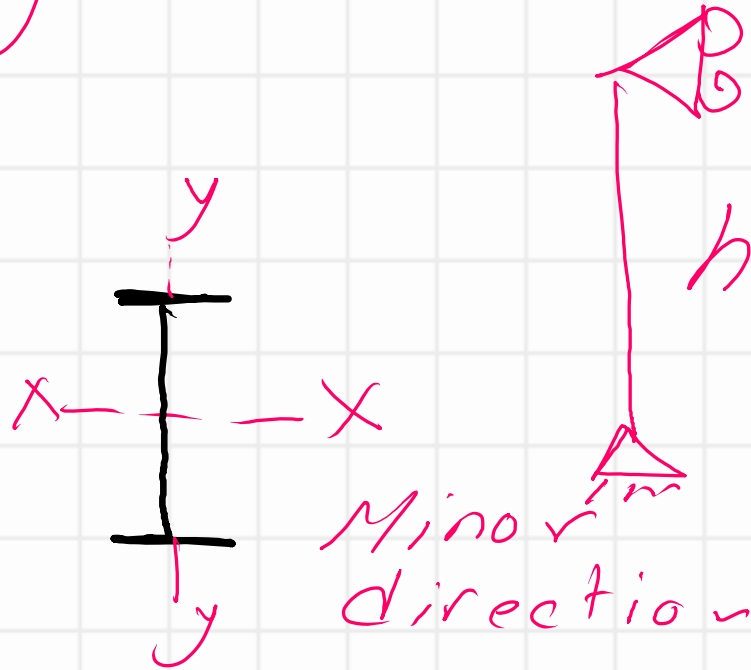
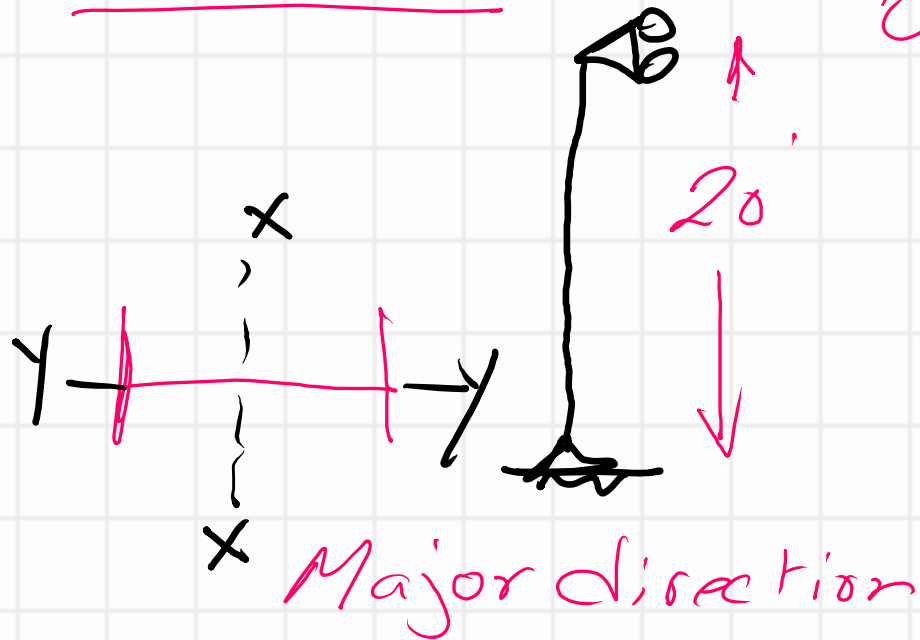
Parts (a), (b)

Solution

$F_y = 50 \text{ ksi}$

W14 x 74

$E = 29000 \text{ ksi}$



$h = 20'$

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

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

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

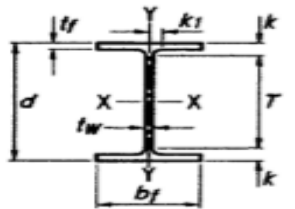
W14x74

Part - 1

$$Ag = 21.80 \text{ inch}^2$$

Parts (a & b)

Table 1-1 (continued)
W-Shapes
Dimensions



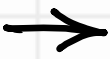
Shape	Area, A in. ²	Depth, d in.		Web		Flange			Distance				Workable Gage in.		
				Thickness, tw in.	tw/2 in.	Width, bf in.	Thickness, tr in.	k		k1 in.	T in.				
								kdes in.	kdet in.						
W14x132	38.8	14.7	14 ⁵ / ₈	0.645	5/8	5/16	14.7	14 ³ / ₄	1.03	1	1.63	2 ⁵ / ₁₆	19/16	10	5 ¹ / ₂
x120	35.3	14.5	14 ¹ / ₂	0.590	9/16	5/16	14.7	14 ⁵ / ₈	0.940	1 ⁵ / ₁₆	1.54	2 ¹ / ₄	1 ¹ / ₂		
x109	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		
x99 ^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		
x90 ^f	26.5	14.0	14	0.440	7/16	1/4	14.5	14 ¹ / ₂	0.710	1 ¹ / ₁₆	1.31	2	1 ⁷ / ₁₆		
W14x82	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 ¹ / ₁₆	1 ¹ / ₁₆	10 ⁷ / ₈	5 ¹ / ₂
x74	21.8	14.2	14 ¹ / ₈	0.450	7/16	1/4	10.1	10 ¹ / ₈	0.785	1 ³ / ₁₆	1.38	1 ⁵ / ₈	1 ¹ / ₁₆		
x68	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		
x61	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 14 x 74

a & b

Nominal Wt. lb/ft	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts} in.	h_o in.	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I in. ⁴	S in. ³	r in.	Z in. ³	I in. ⁴	S in. ³	r in.	Z in. ³			J in. ⁴	C_w 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



$r_x : 6.04''$ $I_x : 795 \text{ inch}^4$
 $r_y : 2.48''$ $I_y : 134 \text{ inch}^4$

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

$\rightarrow \left(\frac{L_{c_x}}{r_x}\right)^2 = \left(\frac{240}{6.04}\right)^2 = 1578.878$
 $\left(\frac{L_{c_y}}{r_y}\right)^2 = \left(\frac{240}{2.48}\right)^2 = 9365.244$

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

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

$$F_y = 50 \text{ ksi as given} = 30.56 \text{ ksi}$$

$$\text{For Lambda C } \lambda_c = \sqrt{\frac{F_y}{F_e}}$$
$$\lambda_c = \sqrt{\frac{50}{30.56}} = 1.28 < 1.5 \Rightarrow$$

Short Column

1 Part (a)

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

λ_c^2 versus $\frac{F_{cr}}{F_y}$

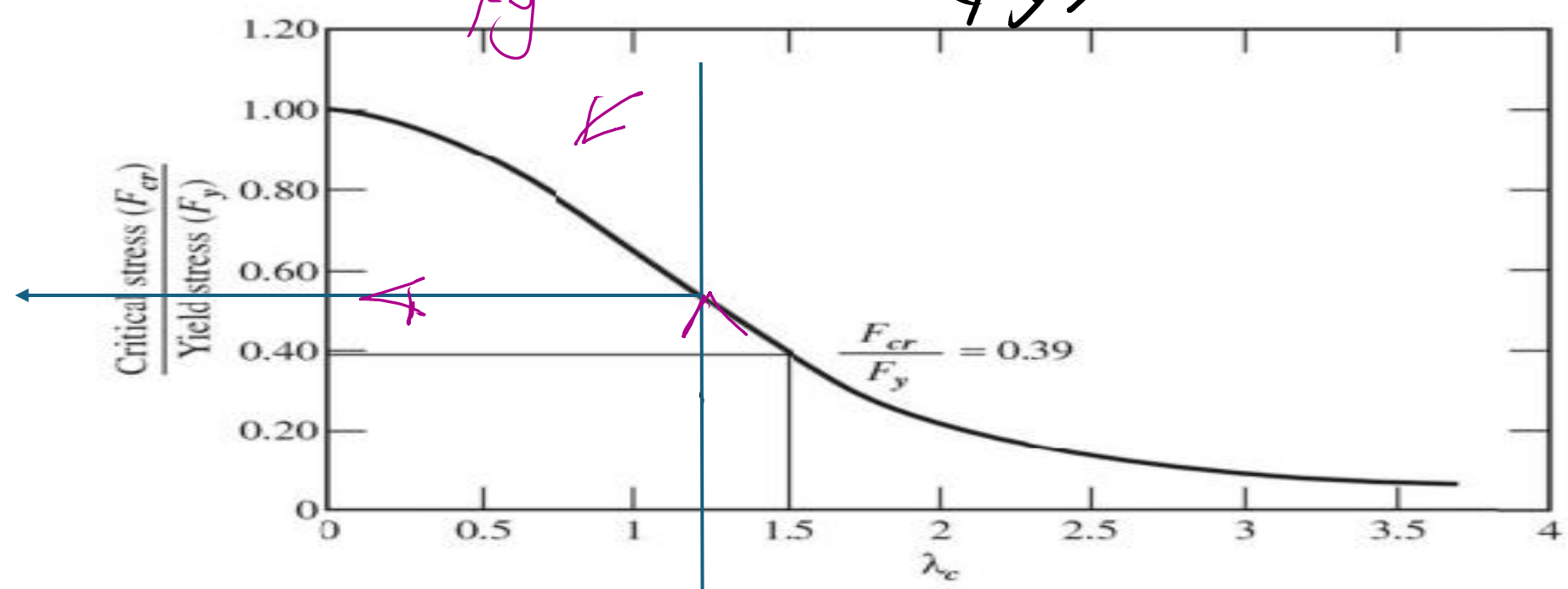


Figure 5.16 λ_c versus Critical Stress

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

$$\frac{F_{cr}}{F_y} = 0.658 \left(\frac{50}{30.56} \right)^2 = 0.5041$$

$\left. \begin{array}{l} > 0.4 \\ < 0.6 \end{array} \right\} \Rightarrow F_{cr} = 0.5041 (50) = 25.21 \text{ kN}$

LRFD inch² Ks.

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

$\approx 495 \text{ Kips}$

ASD

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

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

Part (a)

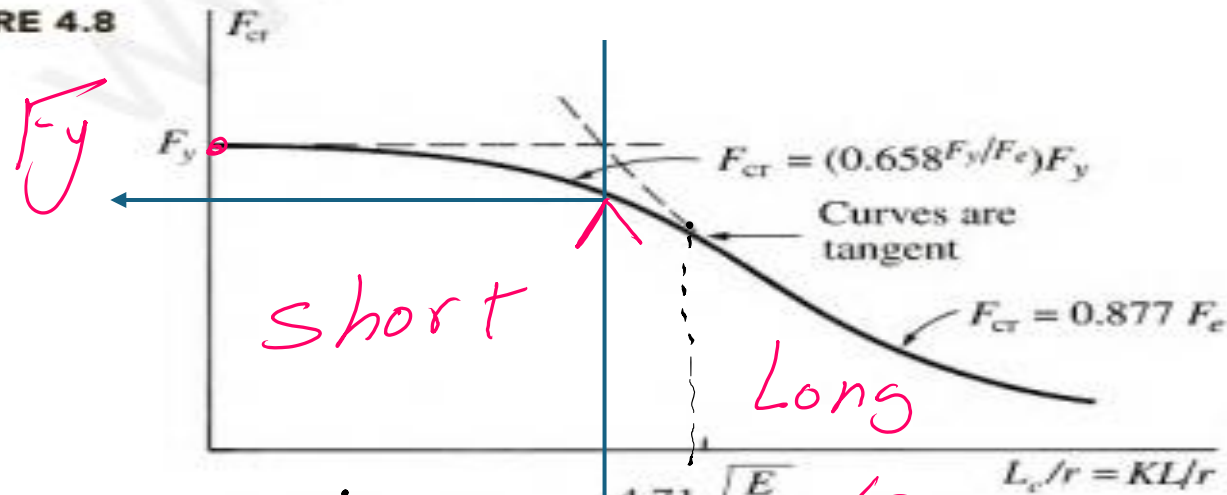
if we use $\left(\frac{L_c}{r}\right)$ versus F_{cr} Part (b)

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

F_{cr}

Column is short

FIGURE 4.8



$F_c = 30.56$
ksi

$F_{cr} = 0.658 \left(\frac{50}{30.56}\right) (50)$
 $= 25.21$ ksi

$4.71 \sqrt{\frac{E}{F_y}}$
 113.43
 96.774

LRFD inch² Ks.

$$\phi_c A_g F_{cr} = 0.90 (21.80) (25.21) = 494.62 \text{ Kips}$$
$$\approx 495 \text{ Kips}$$

ASD

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

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