Summary of the content of post 5

Solved problem 4-9 CM #14

Find available strength for W12 X58 → different Bracing Conditions in x, y direction

William T. SEGUI

x-direction → Controls Design

1. Use Calculations
2. Use Table 4-1) $\phi_c P_n$, $\frac{P_n}{\Omega_c}$
3. Use Table 4-22 → $\phi_c F_{cr}$, $\frac{F_{cr}}{\Omega_c}$

Prepared by Eng.Maged Kamel.

Example 4-9 CM # 14 Page 110

A W12 × 58, 24 feet long, is pinned at both ends and braced in the weak direction at the third points, as shown in Figure 4.11. A992 steel is used. Determine the available compressive strength.

Solved problem 4.9

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Table 1-1
$f_y = 50$ ksi

Solution

W12 X 58

$A_g = 17$ inch^2

$I_x = 475$ inch^4

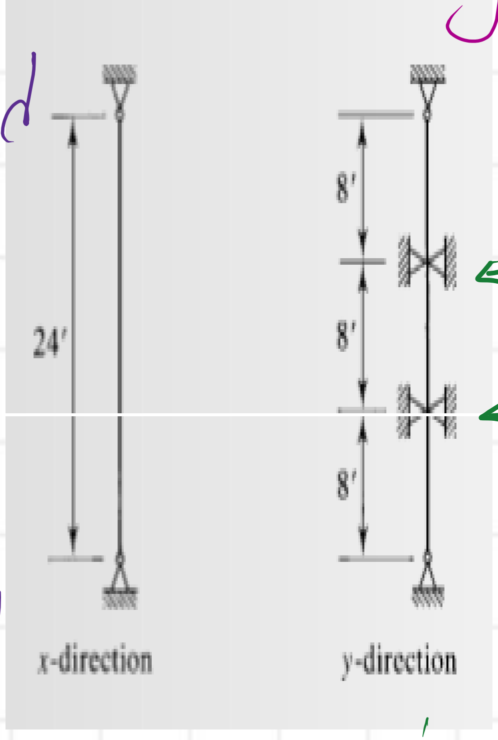
$I_y = 107$ inch^4

$r_y = 2.51''$

$r_x = 5.28''$

$\ell_x = 24'$

Pinned



Pinned

X –

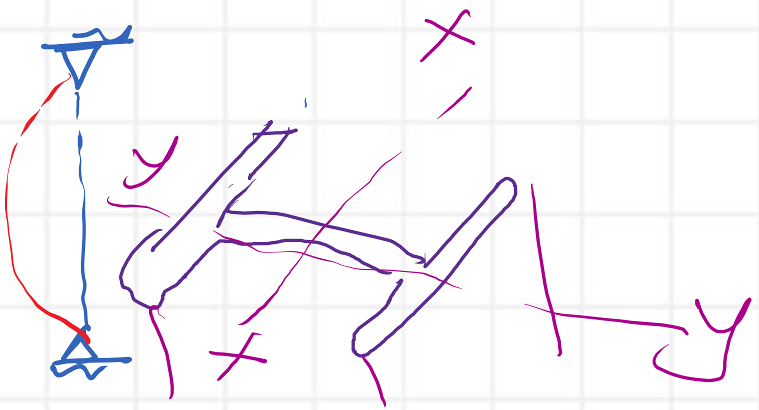
Y

← weak y

← weak y

$F_e = \frac{P_{cr}}{A} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$

K = 1



$\left(\frac{KL}{r}\right)_x = \frac{1(24)(12)}{5.28}$

$\left(\frac{KL}{r}\right)_x = 54.55$

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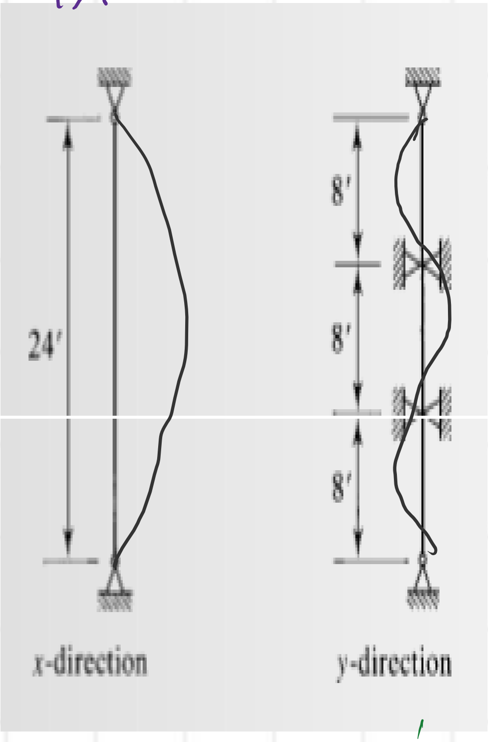
4-9 CM #14

A W12 × 58, 24 feet long, is pinned at both ends and braced in the weak direction at the third points, as shown in Figure 4.11. A992 steel is used. Determine the available compressive strength.



→ Buckling in x-direction

Minor and major buckling lengths

Strong axis buckling

$(KL)_x = 24'$ → $r_x = 5.28''$

Minor axis buckling

$(KL)_y = 8'$; $r_y = 2.51''$

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Available Comprensive strength Can be evaluated from the following three options:

Steps to solve the problem and options

1- General Equation after checking the value of $\left(\frac{KL}{r}\right)$ whether bigger than definite value of

$$4.71\sqrt{\frac{E}{f_y}}$$

→ $0.877 f_e (A)$ → $< 4.71\sqrt{\frac{E}{F_y}}$

→ $0.658^{\frac{F_e}{F_y}} (F_y) A$ → if $> 4.71\sqrt{\frac{E}{F_y}}$

2- Use table 4-1, with the $(KL)_y$ required

check $(KL)_x$ → $(KL)_r = \frac{(KL)_x}{\frac{r_x}{r_y}}$ or $(KL)_y$ } select the bigger value

2 → 4-1a → Manual-15 $F_y = 50$ ksi

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The third option is from table 4-22 → Construction manual-14

Use Available Critical Stress for Compression Members 4-322

$\left(\frac{KL}{r}\right)$ → choose the bigger value of

$\frac{\left(\frac{KL}{r}\right)_x}{\frac{r_x}{r_y}}$ or $\left(\frac{KL}{r}\right)_y$ ⇒ get ϕF_c → multiply by Area

$\frac{F_c}{\Omega}$ → multiply by area

The table becomes Table 4-14 → Construction manual -15

The third option-Table 4-14/4-22

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Which direction control deflection:

AISC Tables are based on $(KL)_y$ → Table 4-1 or Table 4-22 → $(\frac{KL}{r})_y$, assuming that deflection always in the Y-direction.

but if $(KL)_x > (KL)_y$ → to use table 4-1

Convert $(KL)_x$ → Fake value $\left(\frac{KL}{\frac{r_x}{r_y}}\right)$ and Compare with existing $(KL)_y$ → select the bigger value

Which direction controls?

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For a Column under Load P → $F_e = P/A$ ⟹ To Convert From x ↓ y

$$F_e = \frac{\pi^2 E I}{(KL/r)_x^2} = \frac{\pi^2 E I}{\left(\frac{KL}{r}\right)_y^2} \Rightarrow \left(\frac{KL}{r}\right)_x^2 = \left(\frac{KL}{r}\right)_y^2$$

Take square root of both and Equate

$$KL/r_x = KL/r_y$$

Derive Expresion

So Equivalent $(KL)_y$ For $(KL)_x$ Can be written as

$$(KL)_{y\,Fake} = \frac{(KL)_x}{\left(\frac{r_x}{r_y}\right)}$$

For general Expresion and Table 4-1

What is(Kl)y eq?

$$\left(\frac{KL}{r_y}\right)_{Fake} = \left(\frac{KL}{r_x}\right)$$

For table 4-22 → manual-14

4-21a manual-15

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Available strengths in axial compression are given for W-shapes with $F_y = 50$ ksi (ASTM A992). The tabulated values are given for the effective length with respect to the y-axis $(KL)_y$. However, the effective length with respect to the x-axis $(KL)_x$ must also be investigated. To determine the available strength in axial compression, the table should be entered at the larger of $(KL)_y$ and $(KL)_{y\,eq}$, where

(Kl)y eq equation

$$(KL)_{y\,eq} = \frac{(KL)_x}{\frac{r_x}{r_y}} \tag{4-1}$$

Values of the ratio r_x/r_y and other properties useful in the design of W-shape compression members are listed at the bottom of Table 4-1.

We have $(KL)_x = 24'$ → $(KL)_y = \frac{24}{\frac{5.28}{2.51}} = 11.409'$

$(KL)_y = 8'$

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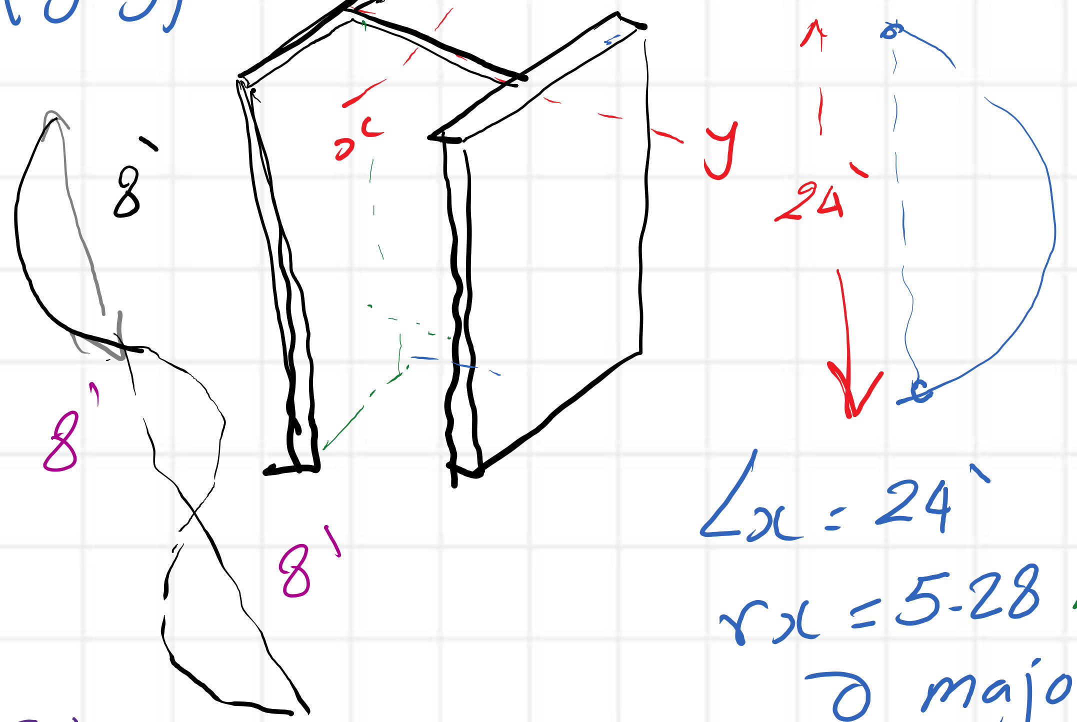
Sketch for buckling about y direction

$(K_y L_y)$



$L_x = 24'$

$r_x = 5.28$ inch²

→ major axis

② Compare with y

① get the Fake Length

→ minor axis

to be compared to $(K_y L_y)$

Fake Length

$\left(\frac{K_x L_x}{\frac{r_x}{r_y}}\right)$

given y-direction

$L_{ey} = 8'$

$r_y = 2.51$

mini map

Converted to ⇒ $\frac{24}{\left(\frac{5.28}{2.51}\right)} = 11.41'$

reduced

Example 4-9 CM # 14 Page 110

Estimate Kl/r for x and y directions

A W12 × 58, 24 feet long, is pinned at both ends and braced in the weak direc-
... Determine
the available compressive strength.

Table 1-1 $f_y = 50$ ksi

Pg 1-26, 27

Solution

W12 X 58

$A_g = 17$ inch^2

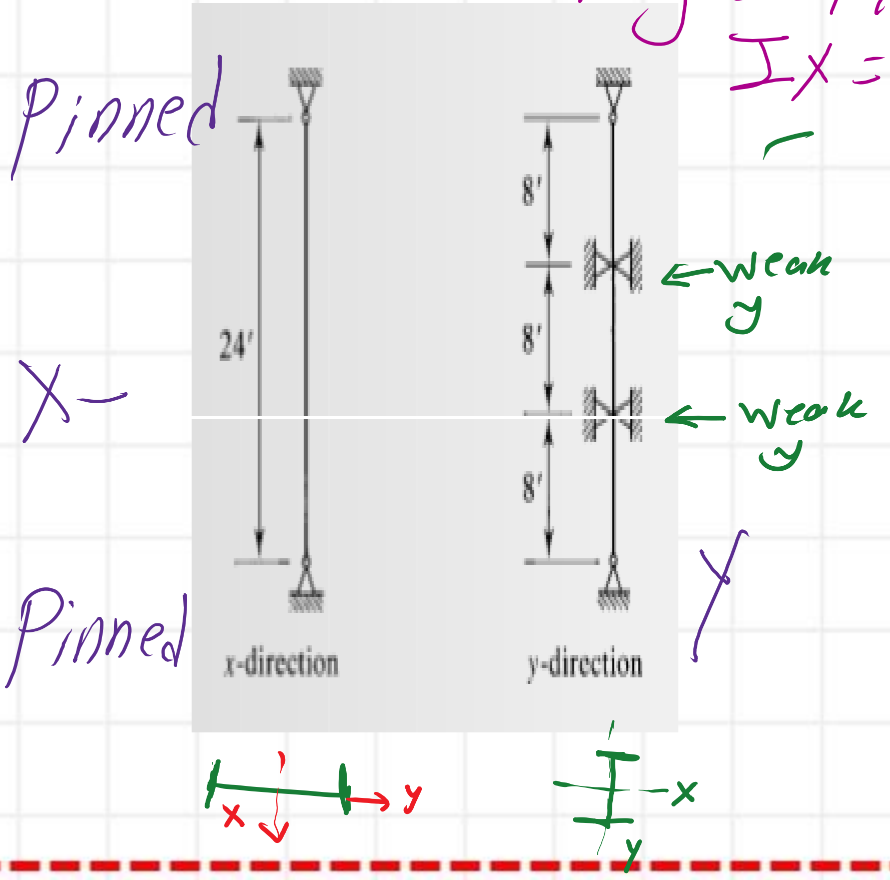
$I_x = 475$ inch^4

$I_y = 107$ inch^4

$r_y = 2.51''$

$r_x = 5.28''$

$l_x = 24'$



$\left(\frac{KL}{r}\right)_x = \frac{1(24)(12)}{(5.28)} = 54.55$

$\left(\frac{KL}{r}\right)_y = \frac{(8)(12)}{2.51} = 38.25$

Select bigger value $= 54.55$

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Limiting ratio

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

$F_y = 50\text{ksi}$

$E = 29000\text{ ksi}$

$$= 4.71\sqrt{\frac{29000}{50}} = 113.43$$

$$\left(\frac{KL}{r}\right)_x = 54.55 \Rightarrow < \lambda \swarrow$$

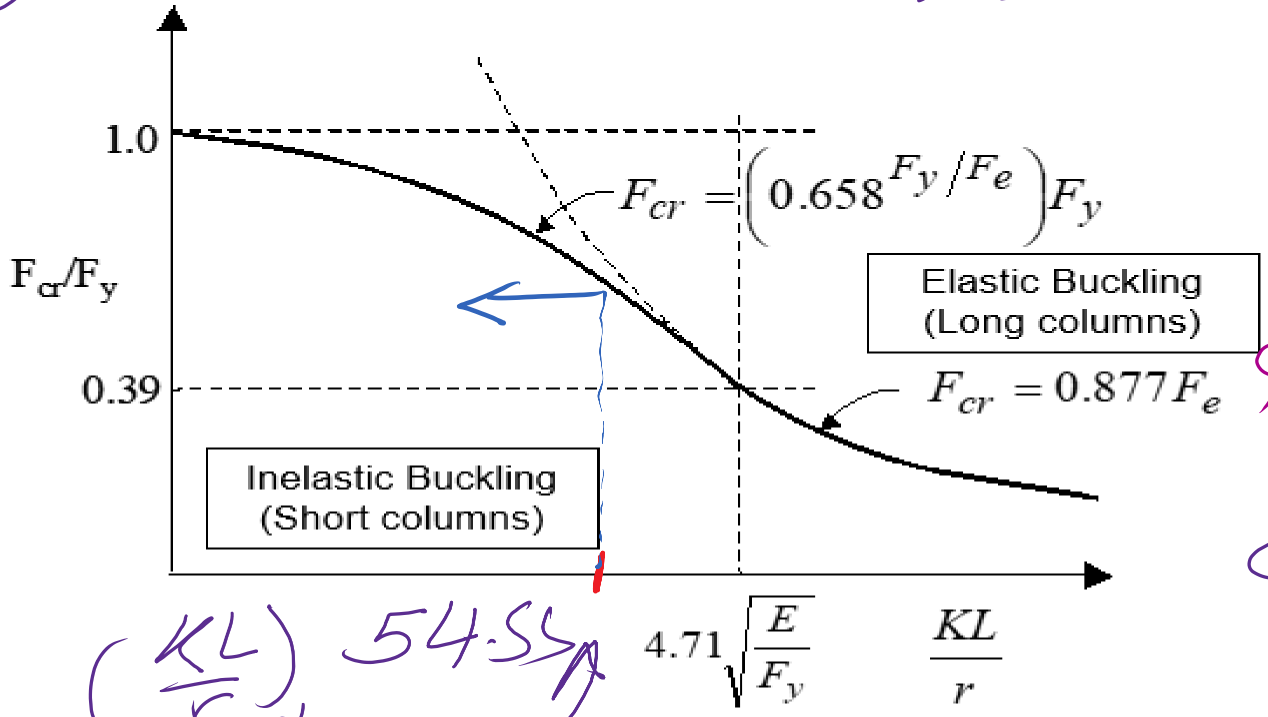
Column is in Elastic

get $F_E = \dfrac{\pi^2 E}{\left(\frac{KL}{r}\right)_x^2} = \dfrac{3.14159^2(29000)}{(54.55)^2} = 96.19$ ksi

Get final Fe

$A_g = 17\ \text{inch}^2$, $F_e = 96.19\ \text{ksi} \Rightarrow F_{cr,in} = 0.658^{(50/96.15)}(50)$

$= 40.22\ \text{ksi}$



LRFD $\phi_c F_{cr}$

$\phi_c = 0.90$ $= 36.201\ \text{ksi}$

$\phi_c P_n = 36.201(17)$

$= 615.40\ \text{kips}$

ASD $\dfrac{P_n}{\Omega_c} = \dfrac{40.22(17)}{1.67} = 409.43\ \text{kips}$

Use appropriate Fcr equation and find available strength

2nd option.

$\phi_c P_n$ from table 4-1- Construction manual 14

$(KL)_r = 11.409'$

Table 4-1 (continued)
Available Strength in Axial Compression, kips

$F_y = 50$ ksi

W12×58

W-Shapes

W12

Use second option-Table 4-1-Find LRFD value

Shape		W12×									
lb/ft		58		53		50		45		40	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length, KL (ft), with respect to least radius of gyration, r_y	0	509	765	467	702	437	657	392	589	350	526
	6	479	720	439	660	396	595	355	534	317	476
	7	469	705	429	646	382	574	342	515	305	459
	8	457	687	419	629	367	551	329	494	293	440
	9	445	668	407	611	350	526	313	471	279	420
	10	431	647	394	592	332	500	297	447	265	398
	11	416	625	380	571	314	472	281	422	250	375
	12	400	601	365	549	295	443	263	396	234	352
	13	384	577	350	526	275	413	246	369	218	328
	14	367	551	334	502	255	384	228	343	202	304
	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

effective Length

(KL)

$\phi_c P_n = 625$ kips

for $(KL)_r = 11$

For $(KL)_r = 12$

$\phi_c P_n = 601$ kips

By interpolation

$$\phi_c P_n = 625 - \left(\frac{625-601}{1}\right) 0.409$$

$$= 615.18$$

$$\phi_c P_n \simeq 616 \text{ kips}$$

2nd option P_n/Ω_c → from table 4-1

Table 4-1 (continued)
Available Strength in Axial Compression, kips

W12 W12x58

W-Shapes

F_y = 50 ksi

Shape		W12×									
lb/ft		58		53		50		45		40	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
[L]east radius of gyration, r_y	0	509	765	467	702	437	657	392	589	350	526
	6	479	720	439	660	396	595	355	534	317	476
	7	469	705	429	646	382	574	342	515	305	459
	8	457	687	419	629	367	551	329	494	293	440
	9	445	668	407	611	350	526	313	471	279	420
	10	431	647	394	592	332	500	297	447	265	398
	→ 11	416	625	380	571	314	472	281	422	250	375
	12	400	601	365	549	295	443	263	396	234	352
	13	384	577	350	526	275	413	246	369	218	328
	14	367	551	334	502	255	384	228	343	202	304
	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

$(KL)_r = 11.409'$

$\frac{P_n}{\Omega_c} = 416$ kips for $(KL)_r = 11$

For $(KL)_r = 12$

$\frac{P_n}{\Omega_c} = 400$ kips

By interpolation

$$\frac{P_n}{\Omega_c} = [416 - (16)(0.409)] = 409.45 \cong 410 \text{ kips}$$

Use second option-Table 4-1-Find ASD value

Third option

Use Table 4-22

$\frac{KL}{r} = 54.55$

$A_g = 17 \text{ inch}^2$

Table 4-22 (continued)
Available Critical Stress for Compression Members

@ LRFD

Use table 4-22-LRFD value

$F_y = 50$ ksi

$F_y = 35$ ksi			$F_y = 36$ ksi			$F_y = 42$ ksi			$F_y = 46$ ksi			$F_y = 50$ ksi		
$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD
54	18.1	27.1	54	18.5	27.8	54	21.0	31.6	54	22.6	34.0	54	24.2	36.4
55	18.0	27.0	55	18.4	27.6	55	20.9	31.4	55	22.5	33.8	55	24.0	36.1
56	17.9	26.8	56	18.3	27.5	56	20.7	31.2	56	22.3	33.5	56	23.8	35.8
57	17.7	26.7	57	18.2	27.3	57	20.6	31.0	57	22.1	33.3	57	23.6	35.5
58	17.6	26.5	58	18.1	27.1	58	20.5	30.7	58	22.0	33.0	58	23.4	35.2
59	17.5	26.4	59	17.9	27.0	59	20.3	30.5	59	21.8	32.8	59	23.2	34.9
60	17.4	26.2	60	17.8	26.8	60	20.2	30.3	60	21.6	32.5	60	23.0	34.6

by table $\frac{KL}{r}$

$\frac{KL}{r} = 54 \rightarrow \phi_c F_{cr} = 36.4$

$55 \rightarrow \phi_c F_{cr} = 36.10$ ksi

$\Rightarrow 36.4 - \frac{0.30}{1}(0.55) = 36.24$ ksi

$\phi_c F_{cr} A_g = 36.24(17) = 616.08$ kips

Prepared by Eng.Maged Kamel.

Third option Use Table 4-22 $\frac{KL}{r} = 54.55$

$A_g = 17.0\ inch^2$

Table 4-22 (continued)
Available Critical Stress for Compression Members

(b) ASD

Use table 4-22-ASD value

$F_y = 50$ ksi

KL/r	F_y = 35 ksi F_{cr}/Ω_c ksi ASD	F_y = 35 ksi $\phi_c F_{cr}$ ksi LRFD	KL/r	F_y = 36 ksi F_{cr}/Ω_c ksi ASD	F_y = 36 ksi $\phi_c F_{cr}$ ksi LRFD	KL/r	F_y = 42 ksi F_{cr}/Ω_c ksi ASD	F_y = 42 ksi $\phi_c F_{cr}$ ksi LRFD	KL/r	F_y = 46 ksi F_{cr}/Ω_c ksi ASD	F_y = 46 ksi $\phi_c F_{cr}$ ksi LRFD	KL/r	F_y = 50 ksi F_{cr}/Ω_c ksi ASD	F_y = 50 ksi $\phi_c F_{cr}$ ksi LRFD
54	18.1	27.1	54	18.5	27.8	54	21.0	31.6	54	22.6	34.0	54	24.2	36.4
55	18.0	27.0	55	18.4	27.6	55	20.9	31.4	55	22.5	33.8	55	24.0	36.1
56	17.9	26.8	56	18.3	27.5	56	20.7	31.2	56	22.3	33.5	56	23.8	35.8
57	17.7	26.7	57	18.2	27.3	57	20.6	31.0	57	22.1	33.3	57	23.6	35.5
58	17.6	26.5	58	18.1	27.1	58	20.5	30.7	58	22.0	33.0	58	23.4	35.2
59	17.5	26.4	59	17.9	27.0	59	20.3	30.5	59	21.8	32.8	59	23.2	34.9
60	17.4	26.2	60	17.8	26.8	60	20.2	30.3	60	21.6	32.5	60	23.0	34.6

by table $\frac{KL}{r}$

$\frac{KL}{r} = 54 \rightarrow \frac{1}{\Omega} F_{cr} = 24.2$

$55 \rightarrow \frac{1}{\Omega} F_{cr} = 24.0$ ksi

$\Rightarrow 24.2 - (0.2)\,0.55 = 24.09$ ksi

$\frac{1}{\Omega_c} F_{cr} A_g = 24.05(17) = 409.53$ kips

Prepared by Eng.Maged Kamel.