

Solved problem 4-9 CM #14

Find available strength
For W12 x 58 → different
Bracing conditions in

William-T.

SEGUI

} direction

x-direction

→ Controls Design

① Use calculations

② Use Table 4-1) $\phi_c P_n, \frac{P_n}{A_c}$

③ Use Table 4-22 → $\phi_c F_{cr}, \frac{F_{cr}}{A_c}$

Example 4-9 CM # 14

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A W12 x 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.

Pg 1-26
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Table 4-1
 $f_y = 50 \text{ ksi}$

Solution

W12 X 58
 $A_g = 17 \text{ inch}^2$

$I_y = 107 \text{ inch}^4$

$r_y = 2.51 \text{ in}$
 $r_x = 5.28 \text{ in}$

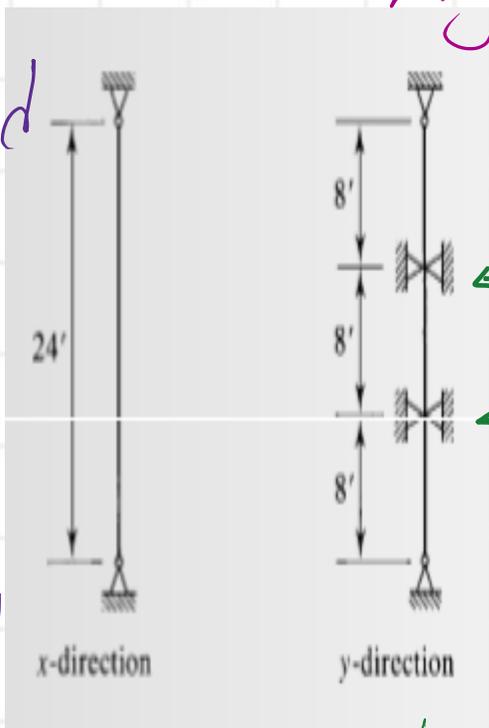
$L_x = 24'$

Pinned



X-

Pinned



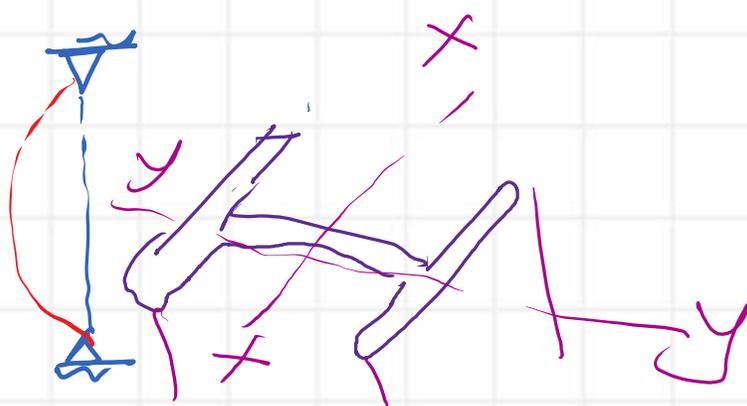
$$F_e = \frac{P_{cr}}{A} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

← weak
y

← weak
y

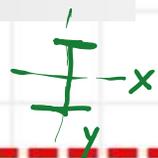
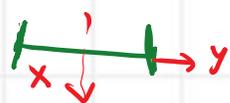
$K=1$

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



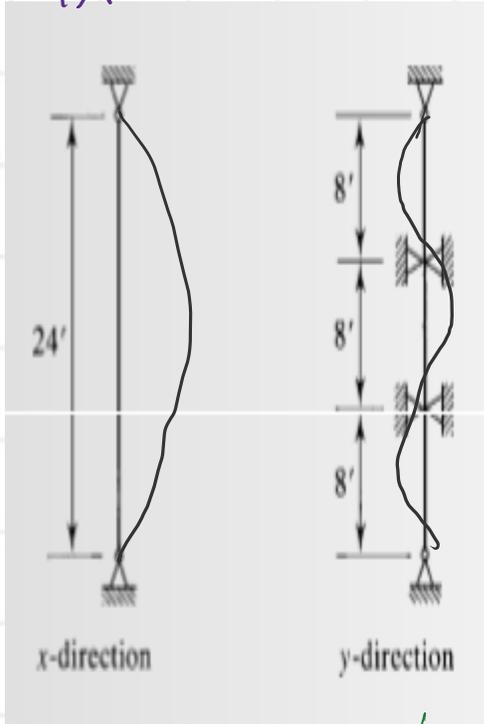
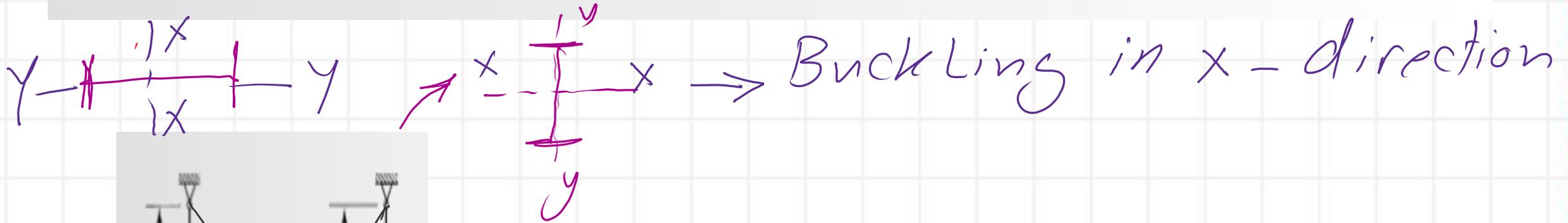
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$$\left(\frac{KL}{r}\right)_y = 54.55$$

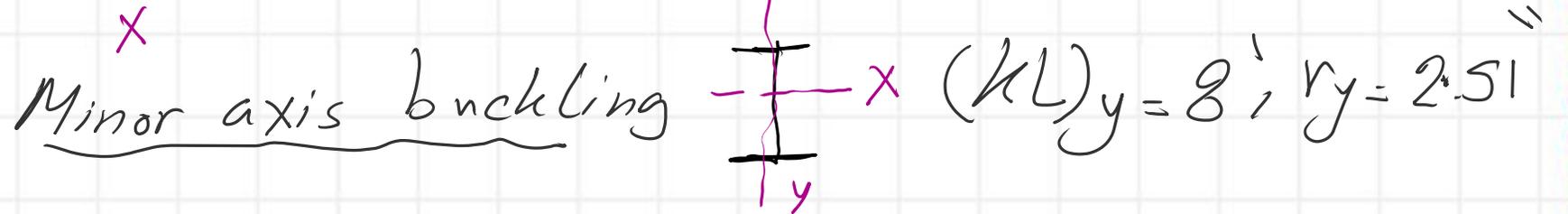
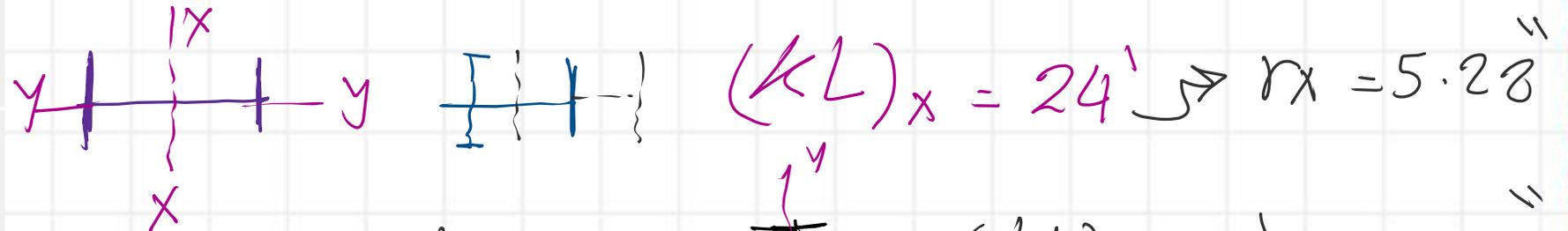


4-9 CM # 14

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.



Strong axis buckling



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Available Compressive strength can be evaluated from the following three options:

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

$$4.71 \sqrt{\frac{E}{f_y}} \begin{cases} \rightarrow 0.877 f_e (A) \rightarrow < 4.71 \sqrt{\frac{E}{F_y}} \\ \rightarrow 0.658 \frac{F_e}{F_y} (F_y) A \rightarrow \text{if } > 4.71 \sqrt{\frac{E}{F_y}} \end{cases}$$

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

check $(KL)_x \rightarrow (KL)_r = \frac{(KL)_x}{\frac{r_x}{r_y}}$
or $(KL)_y$

select the bigger value

2-4-1a → Manual - 15 $F_y = 50 \text{ ksi}$

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

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

Which direction control deflection:

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

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

Convert $(KL)_x \rightarrow$ Fake value $(\frac{KL}{r_x})$ and compare
with existing $(KL)_y \rightarrow$ select $\frac{r_x}{r_y}$ the bigger value

For a Column under Load $P \rightarrow F_e = P/A \Rightarrow$ To Convert

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

From x
↓
y

Take square root of both and Equate

$$KL/r_x = KL/r_y$$

Derive
Expression

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

$$(KL)_y \text{ Fake} = \frac{(KL)_x}{\left(\frac{r_x}{r_y}\right)}$$

} For general Expression
and Table 4-1

$$\left(\frac{KL}{r_y}\right)_{\text{fake}} = \left(\frac{KL}{r_x}\right) \text{ For table}$$

4-22 \rightarrow manual - 14
4-21a manual - 15

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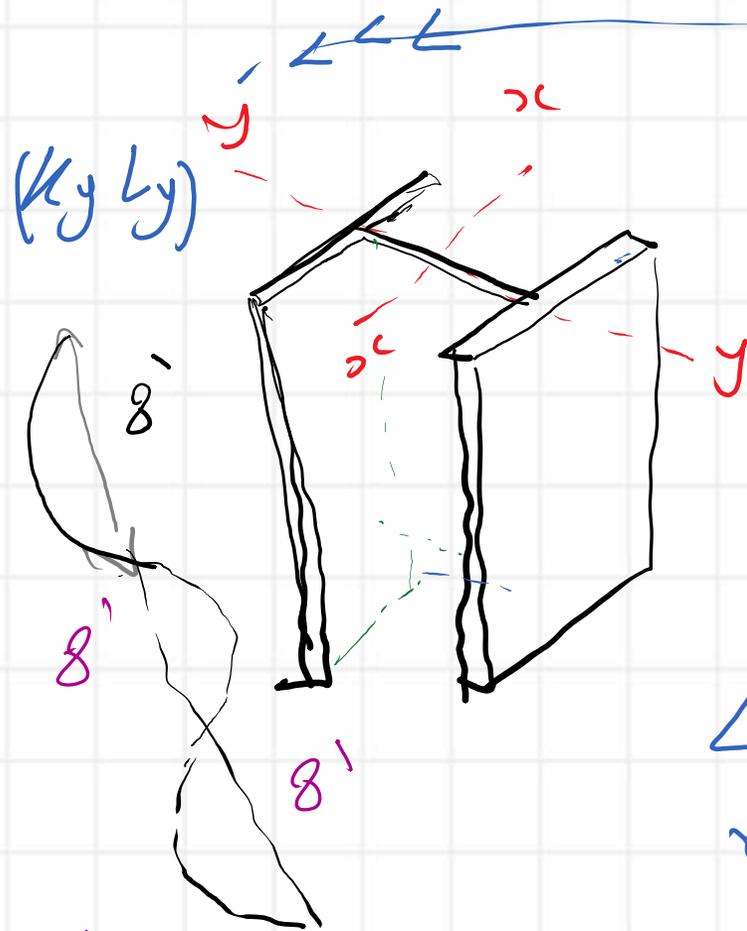
Available strengths in axial compression are given for W-shapes with $F_y = 50$ ksi (ASTM A992). The tabulated values are given for the effective length with respect to the y-axis $(KL)_y$. However, the effective length with respect to the x-axis $(KL)_x$ must also be investigated. To determine the available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

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

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 $(KL)_x = 24'$ \Rightarrow $(KL)_y = \frac{24}{\frac{5.28}{2.51}} = 11.409'$
 $(KL)_y = 8'$

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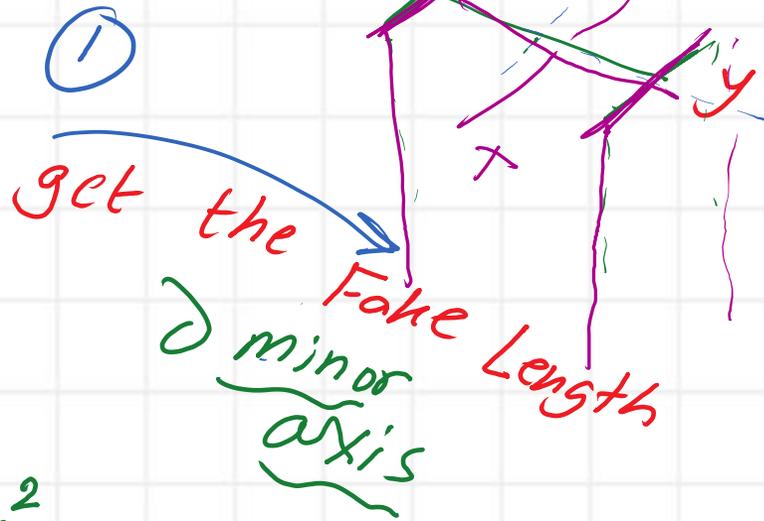


$L_x = 24'$
 $r_x = 5.28 \text{ inch}^2$
 major axis

given
 y-direction
 $L_y = 8'$
 $r_y = 2.51$

② Compare with

to be compared
 to $(k_y L_y)$



Fake Length
 $\left(\frac{k_x L_x}{r_x} \right)$
 $\frac{r_y}{r_y}$

mini map
 Converted to $\Rightarrow \frac{24}{\left(\frac{5.28}{2.51} \right)} = 11.41'$
 reduced

Example 4-9

CM # 14

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A W12 x 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.

Solution

W12 X 58
 $A_g = 17 \text{ inch}^2$
 $I_x = 475 \text{ inch}^4$

$I_y = 107 \text{ inch}^4$
 $r_y = 2.51 \text{ inch}$
 $r_x = 5.28 \text{ inch}$

Pg 1-26
27

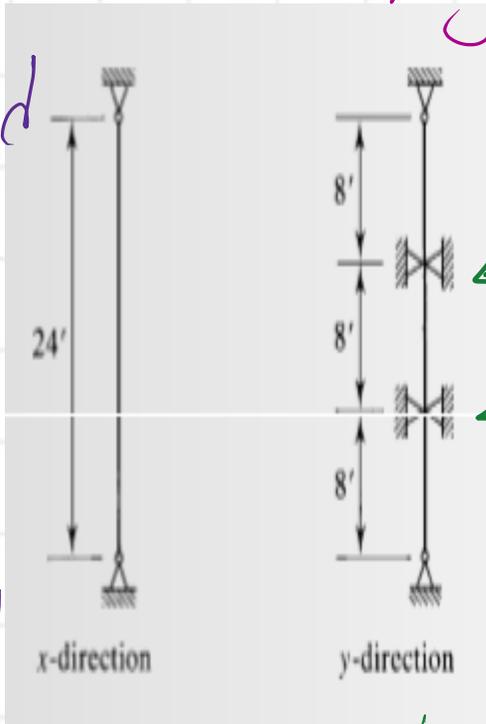
Table 4-1
 $f_y = 50 \text{ ksi}$

$L_x = 24'$

Pinned

X-

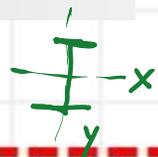
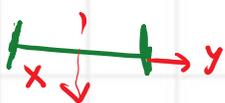
Pinned



← weak
y

← weak
y

y



Select bigger value
 $= 54.55$

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

$$= 54.55$$

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

$$= 38.25$$

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Limiting ratio

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

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

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

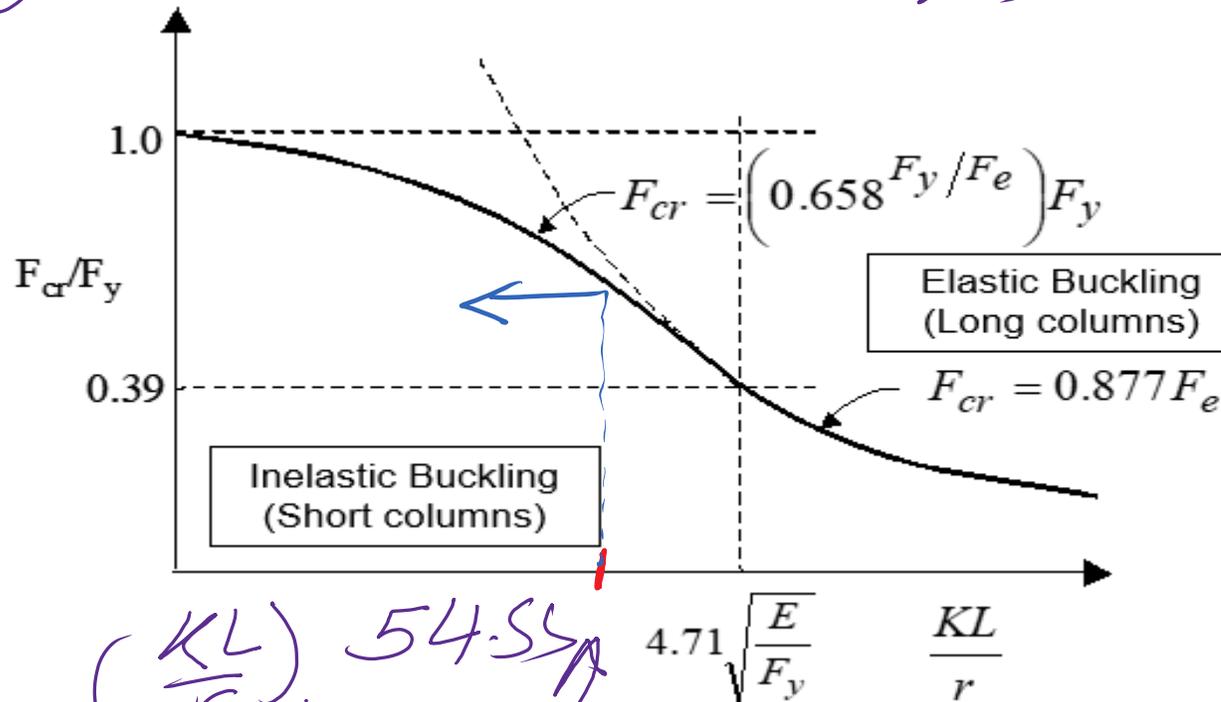
$$= 4.71 \sqrt{\frac{29000}{50}} = 113.43$$

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

Column is in Elastic

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

$$A_g = 17 \text{ inch}^2, F_e = 96.19 \text{ ksi} \Rightarrow F_{cr} = 0.658 \left(\frac{50}{96.19} \right) (50) = 40.22 \text{ ksi}$$



$$= 40.22 \text{ ksi}$$

LRFD $\phi_c F_{cr}$
 $\phi_c = 0.90 = 36.201 \text{ ksi}$

$$\phi_c P_n = 36.201(17) = 615.40 \text{ Kips}$$

$\left(\frac{KL}{r} \right)_{\times} = 54.55$
 113.43

ASD $\frac{P_n}{\Omega_c} = \frac{40.22(17)}{1.67} = 409.43 \text{ Kips}$

2nd option.

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



W12

W12x58

W-Shapes

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

$F_y = 50$ ksi

Shape	W12x									
	58		53		50		45		40	
lb/ft	P_n/Ω_c	$\phi_c P_n$								
Design	ASD	LRFD								
	0	509	765	467	702	437	657	392	589	350
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

effective length, r_y

least radius of gyration, r_y

$(KL)_y$

$(KL)_r = 11.409$

$\phi_c P_n = 625$ kips

for $(KL)_r = 11$

For $(KL)_r = 12$

$\phi_c P_n = 601$ kips

By interpolation

$\phi_c P_n = 625 - (625 - 601) \frac{0.409}{1}$
 $= 615.18$

$\phi_c P_n \approx 616$ kips

2nd option

$P_n/\Omega_c \Rightarrow$ from table 4-1



W12

W12x58

W-Shapes

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

$F_y = 50$ ksi

Shape		W12x									
lb/ft		58		53		50		45		40	
Design		P_n/Ω_c	$\phi_c P_n$								
		ASD	LRFD								
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

$(KL)_r = 11.409$

$\frac{P_n}{\Omega_c} = 416$ kips

for $(KL)_r = 11$

For $(KL)_r = 12$

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

By interpolation

$\frac{P_n}{\Omega_c} = \left[416 - \left(\frac{16}{1} \right) (0.409) \right]$
 $= 409.45$

≈ 410 kips

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

$F_y = 50 \text{ ksi}$
↓

$F_y = 35 \text{ ksi}$			$F_y = 36 \text{ ksi}$			$F_y = 42 \text{ ksi}$			$F_y = 46 \text{ ksi}$			$F_y = 50 \text{ ksi}$		
$\frac{KL}{r}$	F_{cr}/Ω_c	$\phi_c F_{cr}$												
	ksi	ksi												
	ASD	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
↓
 $\frac{KL}{r}$

$$\left. \begin{array}{l} \frac{KL}{r} = 54 \rightarrow \phi_c F_{cr} = 36.4 \text{ ksi} \\ \phantom{\frac{KL}{r}} = 55 \rightarrow \phi_c F_{cr} = 36.10 \text{ ksi} \end{array} \right\} \Rightarrow 36.4 - 0.30(0.55) = 36.24 \text{ ksi}$$

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

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Third option

Use Table 4-22

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

$$A_g = 17.0 \text{ inch}^2$$

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

(b) ASD

$F_y = 50 \text{ ksi}$
↓

$F_y = 35 \text{ ksi}$			$F_y = 36 \text{ ksi}$			$F_y = 42 \text{ ksi}$			$F_y = 46 \text{ ksi}$			$F_y = 50 \text{ ksi}$		
$\frac{KL}{r}$	F_{cr}/Ω_c	$\phi_c F_{cr}$												
	ksi	ksi												
	ASD	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
↓
 $\frac{KL}{r}$

$$\frac{KL}{r} = 54 \rightarrow \frac{1}{\Omega_c} F_{cr} = 24.2 \text{ ksi}$$

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

$$\Rightarrow 24.2 - (0.2) = 24.0 \text{ ksi}$$

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

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