

# Summary of post - Comprehension

Solved Problems 13.28A Iqbal's book  
13.3 F.E. Exam

a) Problem 13.28A  
Multiple choice selection Preparation

✓ - Value of available strength in kips  
or  $\phi_c P_n$  F.E Handbook 10-4

Value For the given End Condition

Guided rollers  
Fixed supports

b) Problem 13-30

Prepared by Eng. Maged Kamel.

Question 13.28 - A ~~W14x50~~ is used as a column as shown in Fig. 13.13.

A ~~W14x50~~  $W14 \times 16$

$F_y = 50 \text{ k/s}$

The available strength in axial compression

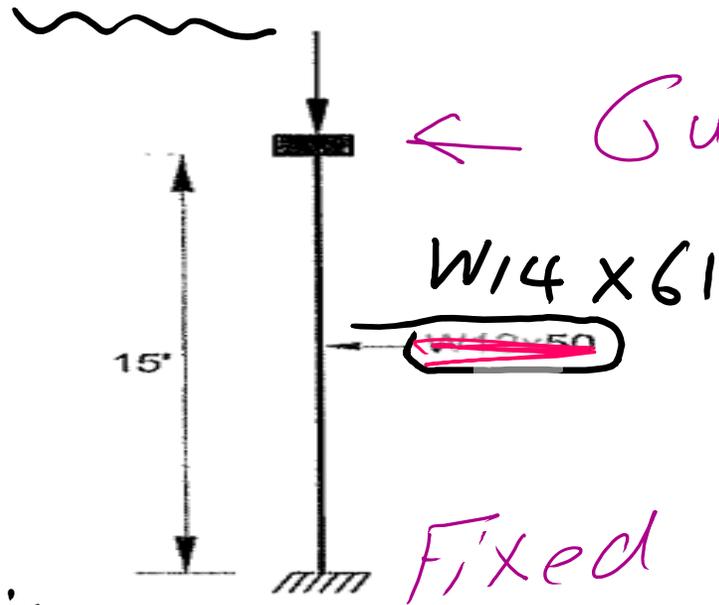


Fig. 13.13

Case C  
in Table  
Table C-A-7.1

- A) 500 kips
  - B) 460 kips
  - C) 580 kips
  - D) 600 kips
- is most nearly

Solution: The support at the top is a Guided support

- The critical buckling load  $P_{cr}$  for columns is theoretically given by Equation (3.1)

$$P_{cr} = \frac{\pi^2 E I}{(K L)^2} \quad (3.1)$$

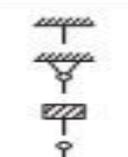
where,  $I$  = moment of inertia about axis of buckling

$K$  = effective length factor based on end boundary conditions

- Effective length factors are given on page 16.1-189 of the AISC manual.

### Civil Engineering

TABLE C-A-7.1  
AISC APPROXIMATE VALUES OF EFFECTIVE LENGTH FACTOR,  $K$

BUCKLED SHAPE OF COLUMN IS SHOWN BY DASHED LINE.	(a)	(b)	(c)	(d)	(e)	(f)
THEORETICAL $K$ VALUE	0.5	0.7	1.0	1.0	2.0	2.0
AISC-RECOMMENDED DESIGN VALUE WHEN IDEAL CONDITIONS ARE APPROXIMATED	0.65	0.80	1.2	1.0	2.10	2.0
END CONDITION CODE	 ROTATION FIXED AND TRANSLATION FIXED ROTATION FREE AND TRANSLATION FIXED ROTATION FIXED AND TRANSLATION FREE ROTATION FREE AND TRANSLATION FREE					

Based on Case C

$$K_x = K_y = 1$$

Both x & y has a Guided support at Top and a Fixed support at bottom

But it is recommended to have

$$K_x = K_y = 1.2, \quad h = 15'$$

$$L_{e_x} = L_{e_y} = (KL) = 1.2(15) = 18'$$

Use Table 4-1 For the available strength

**Prepared by Eng. Maged Kamel.**

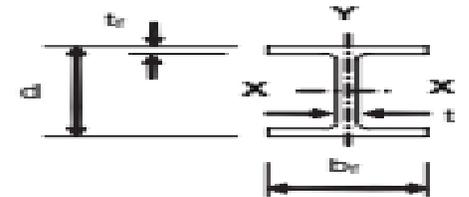
Design of Steel Components  
(ANSI/AISC 360-16) LRFD, ASD

E = 29,000 ksi

Part - 1

Table 1-1: W Shapes Dimensions and Properties

Shape	Area	Depth d	Web t <sub>w</sub>	Flange		Axis X-X				Axis Y-Y	
	A			b <sub>f</sub>	t <sub>f</sub>	I	S	r	Z	I	r
	In. <sup>2</sup>	In.	In.	In.	In.	In. <sup>4</sup>	In. <sup>3</sup>	In.	In. <sup>3</sup>	In. <sup>4</sup>	In.
W24X68 <sup>C</sup>	20.1	23.7	0.415	8.97	0.585	1830	154	9.55	177	70.4	1.87
W24X62 <sup>C</sup>	18.2	23.7	0.430	7.04	0.590	1550	131	9.23	153	34.5	1.38
W24X55 <sup>C,V</sup>	16.3	23.6	0.395	7.01	0.505	1350	114	9.11	134	29.1	1.34
W21X73 <sup>C</sup>	21.5	21.2	0.455	8.30	0.740	1600	151	8.64	172	70.6	1.81
W21X68 <sup>C</sup>	20.0	21.1	0.430	8.27	0.685	1480	140	8.60	160	64.7	1.80
W21X62 <sup>C</sup>	18.3	21.0	0.400	8.24	0.615	1330	127	8.54	144	57.5	1.77
W21X55 <sup>C</sup>	16.2	20.8	0.375	8.22	0.522	1140	110	8.40	126	48.4	1.73
W21X57 <sup>C</sup>	16.7	21.1	0.405	6.56	0.650	1170	111	8.36	129	30.6	1.35
W21X50 <sup>C</sup>	14.7	20.8	0.380	6.53	0.535	984	94.5	8.18	110	24.9	1.30
W21X48 <sup>C,F</sup>	14.1	20.6	0.350	8.14	0.430	959	93.0	8.24	107	38.7	1.66
W21X44 <sup>C</sup>	13.0	20.7	0.350	6.50	0.450	843	81.6	8.06	95.4	20.7	1.26
W18X71	20.8	18.5	0.495	7.64	0.810	1170	127	7.50	146	60.3	1.70
W18X65	19.1	18.4	0.450	7.59	0.750	1070	117	7.49	133	54.8	1.69
W18X60 <sup>C</sup>	17.6	18.2	0.415	7.56	0.695	984	108	7.47	123	50.1	1.68
W18X55 <sup>C</sup>	16.2	18.1	0.390	7.53	0.630	890	98.3	7.41	112	44.9	1.67
W18X50 <sup>C</sup>	14.7	18.0	0.355	7.50	0.570	800	88.9	7.38	101	40.1	1.65
W18X46 <sup>C</sup>	13.5	18.1	0.360	6.06	0.605	712	78.8	7.25	90.7	22.5	1.29
W18X40 <sup>C</sup>	11.8	17.9	0.315	6.02	0.525	612	68.4	7.21	78.4	19.1	1.27
W16X67 <sup>C</sup>	19.7	16.3	0.395	10.2	0.67	954	117	6.96	130	119	2.46
W16X57	16.8	16.4	0.430	7.12	0.715	758	92.2	6.72	105	43.1	1.60
W16X50 <sup>C</sup>	14.7	16.3	0.380	7.07	0.630	659	81.0	6.68	92.0	37.2	1.59
W16X45 <sup>C</sup>	13.3	16.1	0.345	7.04	0.565	586	72.7	6.65	82.3	32.8	1.57
W16X40 <sup>C</sup>	11.8	16.0	0.305	7.00	0.505	518	64.7	6.63	73.0	28.9	1.57
W16X36 <sup>C</sup>	10.6	15.9	0.295	6.99	0.430	448	56.5	6.51	64.0	24.5	1.52



Part - 2

W14x61

is not slender Column

Table 1-1: W Shapes Dimensions and Properties

Shape	Area	Depth	Web	Flange		Axis X-X				Axis Y-Y	
	A	d	t <sub>w</sub>	b <sub>f</sub>	t <sub>f</sub>	I	S	r	Z	I	r
	In. <sup>2</sup>	In.	In.	In.	In.	In. <sup>4</sup>	In. <sup>3</sup>	In.	In. <sup>3</sup>	In. <sup>4</sup>	In.
W14x74	21.8	14.2	0.450	10.1	0.785	795	112	6.04	126	134	2.48
W14x68	20.0	14.0	0.415	10.0	0.720	722	103	6.01	115	121	2.46
W14x61	17.9	13.9	0.375	9.99	0.645	640	92.1	5.98	102	107	2.45
W14x53	15.6	13.9	0.370	8.06	0.660	541	77.8	5.89	87.1	57.7	1.92
W14x48	14.1	13.8	0.340	8.03	0.595	484	70.2	5.85	78.4	51.4	1.91

→ No  
C  
Foot  
note

←

Notes:

c Shape is slender for compression with  $F_y = 50$  ksi.

r Shape exceeds compact limit for flexure with  $F_y = 50$  ksi.

v Shape does not meet the  $h/t_w$  limit for shear in AISC Specifications Section G2.1(a) with  $F_y = 50$  ksi.

C For Slender Column (Local buckling  
Parameter)

$$r_x = 5.98''$$

W14x61

$$r_y = 2.45''$$

$$A_g = 17.90 \text{ inch}^2$$

# To Use Table 4-1 Consider

The tabulated values are given for the effective length with respect to the y-axis,  $L_{cy}$ . However, the effective length with respect to the x-axis,  $L_{cx}$ , must also be investigated. To determine the available strength in axial compression, the table should be entered at the larger of  $L_{cy}$  and  $L_{cy\ eq}$ , where

$$L_{cy\ eq} = \frac{L_{cx}}{\frac{r_x}{r_y}}$$

$$L_{cy\ eq} = \left( \frac{L_{cx}}{\frac{r_x}{r_y}} \right)$$

$$\Rightarrow P_{cr_x} = P_{cr_y}$$
$$\frac{\pi^2 E I_x}{(L_{cx})^2} = \frac{\pi^2 E I_y}{L_{cy}^2}$$
$$L_{cy} = \sqrt{\frac{I_y}{I_x}} L_{cx}$$

$$L_{cx} = (K L)_x = 1.2(15) = 18'$$
$$r_x = 5.98''$$
$$r_y = 2.45'' = \frac{L_{cx}}{\frac{r_x}{r_y}} = \frac{18}{\left( \frac{5.98}{2.45} \right)} = 7.37'$$

$$L_{cy} = L_{cx} \left( \frac{r_y}{r_x} \right)$$
$$L_{cy} = \frac{L_{cx}}{\frac{r_x}{r_y}}$$

$$L_{cy} = 1.2(15) = 18'$$

Choose max value of  $(7.37', 18') = 18'$

Table 4-1 in the F.E Handbook

will give  $\phi P_n$  LRFD value

LOG in  $L_{cy} = 18'$

W14x61

Select the available strength value at the intersection.

$$\phi_c P_n = 457 \text{ kips}$$

W14 x 61

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

$$\phi_c = 0.9$$

Shape wt/ft	W14					W12					W10				
	74	68	61	53	48	58	53	50	45	40	60	54	49	45	39

Effective length KL (ft) with respect to least radius of gyration $r_y$	AISC Table 4-1 Available Strength in Axial Compression, kips—W shapes LRFD: $\phi P_n$															
	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	
797	728	652	497	449	627	569	471	422	375	655	586	533	435	373		
766	700	626	465	420	603	547	443	396	351	631	565	513	410	351		
734	670	599	433	391	578	525	413	370	328	606	543	493	384	328		
701	639	572	401	361	553	501	384	343	304	581	520	471	358	305		
667	608	543	369	332	527	477	354	317	280	555	496	450	332	282		
632	576	515	338	304	500	452	326	291	257	528	472	428	306	260		
598	544	486	308	276	473	427	297	265	234	501	448	405	281	238		
563	512	457	278	250	446	402	270	241	212	474	423	383	256	216		
528	480	428	250	224	420	378	244	217	191	447	399	360	233	195		
494	448	400	226	202	393	353	220	196	172	420	375	338	210	176		
428	387	345	186	167	342	306	182	162	142	367	327	295	174	146		
365	329	293	157	140	293	261	153	136	120	317	282	254	146	122		
311	281	250	133	120	249	222	130	116	102	270	241	216	124	104		
268	242	215	115	103	215	192	112	99.8	88.0	233	208	186	107	90.0		
234	211	187	100	89.9	187	167	97.7	87.0	76.6	203	181	162	93.4	78.4		

$$L_{cy} = 18'$$

Option (B) is correct most nearly 457 kips

## GENERAL PROVISIONS

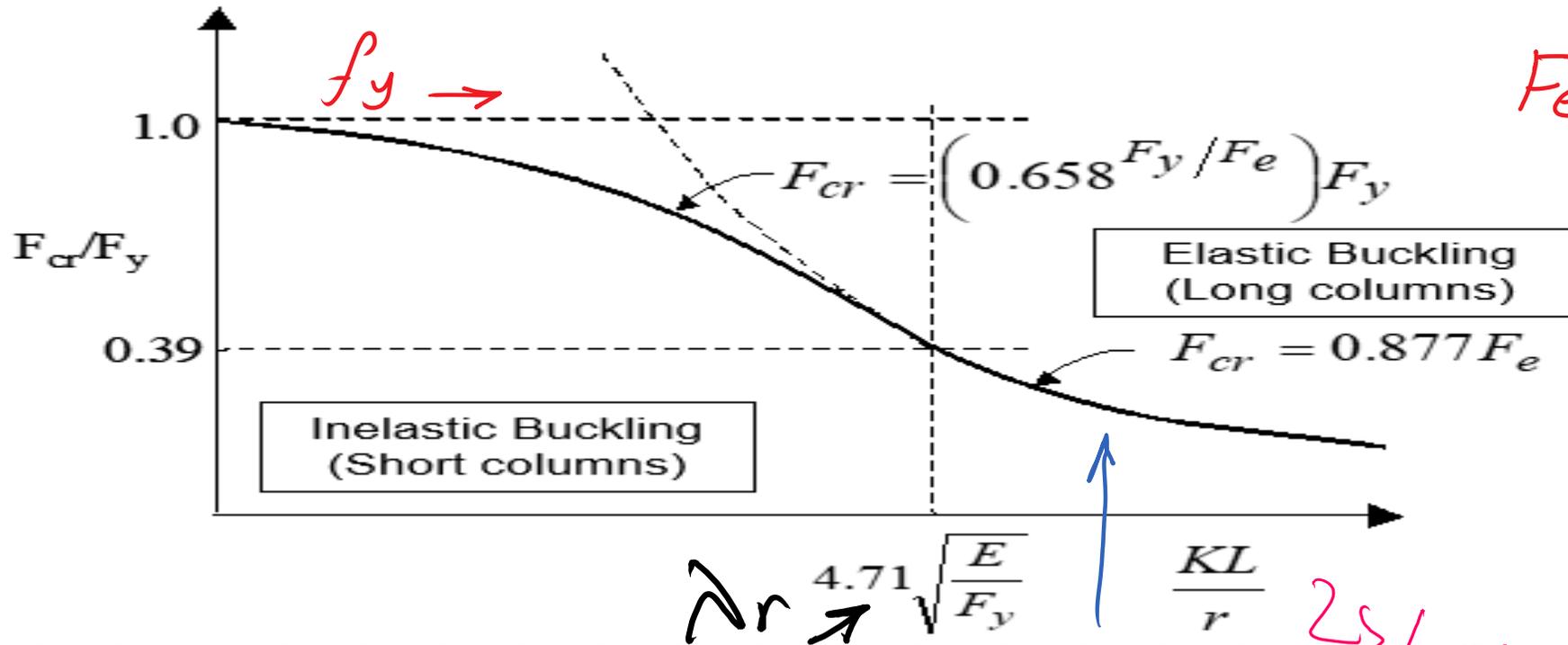
The *design compressive strength*,  $\phi_c P_n$ , and the *allowable compressive strength*,  $P_n / \Omega_c$ , are determined as follows.

The *nominal compressive strength*,  $P_n$ , shall be the lowest value obtained based on the applicable *limit states of flexural buckling, torsional buckling, and flexural-torsional buckling*.

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)}$$

AIISC-E-1

Global buckling



$$F_e = \frac{P_e}{A_g} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}_{\min.}$$

Prepared by Eng. Maged Kamel.

$\left(\frac{L_e}{r}\right)$

if you wish to check your answer from

AISC. E-1 equations  $h=15'$ ,  $k=1.2$

① check whether  $[W_{14} \times 61]$  is Long or short

$$\lambda_r = 4.71 \sqrt{\frac{E}{F_y}} = 4.71 \left( \frac{29000}{50} \right)^{1/2} = 113.43$$

$$L_{cx} = \frac{(KL)}{r_x} = \frac{1.2(15)(12)}{(5.98)} = 36.12$$

$$r_x = 5.98''$$
$$r_y = 2.45''$$

Bigger than

$$L_{cy} = \left( \frac{KL}{r_y} \right) = \frac{1.2(15)(12)}{2.45} = 88.16 \Rightarrow y \text{ direction governs}$$

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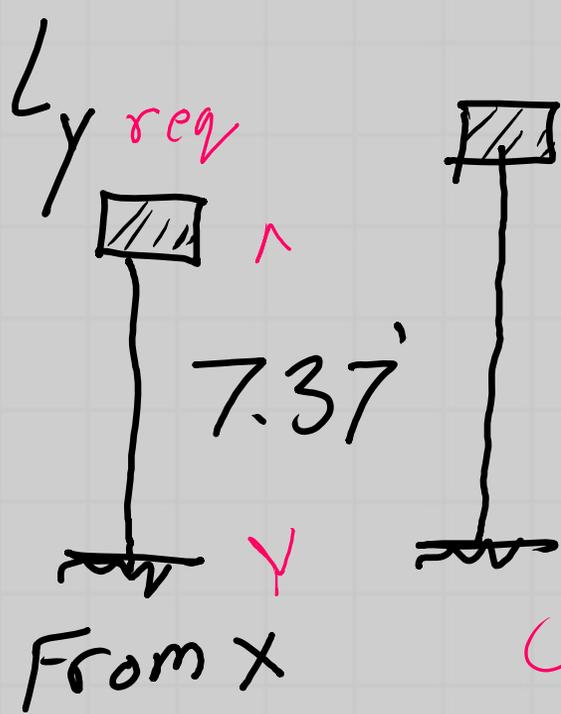
(Hint)  $L_{cy}$  <sup>Final</sup> which we use For Table

4-1 Equals W16 x 41

max of  $\left[ \left( \frac{KL}{r_{yL}} \right) r_y \right] = 36.12 \left( \frac{2.45}{12} \right)$

$\left( \frac{KL}{r_y} \right) (r_y) = \underline{7.37}$

$= \frac{88.16}{12} (2.45) = 18'$



18' original  $\Rightarrow$  Bigger Height  
 y-direction

Column is short  $\left(\frac{L_c}{r_y}\right)$   
W14x61  $88.16 < 113.43$

$$A_g = 17.90 \text{ inch}^2$$

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

$$F_{cr} = 0.658^{r_c^2} F_y \quad \text{where } r_c^2 = \frac{F_y}{F_e}$$

$$F_e = \frac{\pi^2 E}{\left(\frac{L_e}{r}\right)^2} = \frac{(3.14159)^2 (29000)}{(88.16)^2} = 36.83 \text{ ksi}$$

$$F_{cr} = 0.658 \left(\frac{50}{36.83}\right) (50) = 28.33 \text{ ksi}$$

$$\phi_c F_{cr} A_g = 0.90 (28.33) (17.9) = 456.40 \text{ kips}$$

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most nearly 460 kips

■ ■  
**Question 13.30** – A  $W10 \times 49$  column is carrying 100 kips of service dead load. Its controlling slenderness ratio is 120 and the yield stress is 50 ksi. The service live load capacity of column (kips) is most nearly:

- A. 225
- B. 150
- C. 100
- D. 65

solution

$W10 \times 49$

$D = 100$  kips

$F_y = 50$  ksi

$L = ?$

Find service L-L

$\left(\frac{L}{r}\right) = 120$

$$\lambda_r = 4.71 \sqrt{\frac{E}{F_y}} = 113.43 \quad \left(\frac{L}{r}\right) > 113.43 \quad \text{short column}$$

Use Table 1-1

Table 1-1: W Shapes Dimensions and Properties

Shape	Area	Depth	Web	Flange		Axis X-X				Axis Y-Y	
	A	d	t <sub>w</sub>	b <sub>f</sub>	t <sub>f</sub>	I	S	r	Z	I	r
	In. <sup>2</sup>	In.	In.	In.	In.	In. <sup>4</sup>	In. <sup>3</sup>	In.	In. <sup>3</sup>	In. <sup>4</sup>	In.
W10x60	17.6	10.2	0.420	10.1	0.680	341	66.7	4.38	74.6	116	2.57
W10x54	15.8	10.1	0.370	10.0	0.615	303	60.0	4.37	66.6	103	2.56
W10x49	14.4	10.0	0.340	10.0	0.560	272	54.6	4.35	60.4	93.4	2.54
W10x45	13.3	10.1	0.350	8.02	0.620	248	49.1	4.32	54.9	53.4	2.01
W10x39	11.5	9.92	0.315	7.99	0.530	209	42.1	4.27	46.8	45.0	1.98

W10 x 49

$$r_x = 4.35 \text{ in}$$

$$r_y = 2.54 \text{ in}$$

$$A = 14.40$$

Notes:

c Shape is slender for compression with  $F_y = 50$  ksi.

f Shape exceeds compact limit for flexure with  $F_y = 50$  ksi.

v Shape does not meet the  $h/t_w$  limit for shear in AISC Specifications Section G2.1(a) with  $F_y = 50$  ksi.

Use Table 4-14  $F.E$  10.40  
 Gives only  $\phi_c F_{cr}$  For

$F_y = 50 \text{ ksi}$

Civil Engineering

AISC Table 4-14

Available Critical Stress  $\phi_c F_{cr}$  for Compression Members

$F_y = 50 \text{ ksi}$

$\phi_c = 0.90$

$\frac{KL}{r}$	$\phi F_{cr}$ ksi								
35	41.2	75	29.8	115	17.1	155	9.40	195	5.94
36	40.9	76	29.5	116	16.8	156	9.28	196	5.88
37	40.7	77	29.2	117	16.5	157	9.17	197	5.82
38	40.5	78	28.8	118	16.2	158	9.05	198	5.76
39	40.3	79	28.5	119	16.0	159	8.94	199	5.70
40	40.0	80	28.2	120	15.7	160	8.82	200	5.65

From Table 4-14  $W_{10 \times 49} \Rightarrow 14.40 \text{ inch}^2$

$$\phi_c F_{cr} = 15.70 \text{ ksi}$$

$$P_{ult} = 1.2 D + 1.4 L$$

$$\phi_c P_n \geq P_{ult} \quad \phi_c P_n = (\phi_c F_{cr}) A_g = 15.7 (14.4)$$

$$P_{ult} = 226.08 = 1.2(100) + 1.6 L = 226.08 \text{ kips}$$

$$1.6 L = 226.08 - 120 = 106.08 \text{ kips}$$

$$L = 66.3 \approx 66 \text{ k most nearly } 65 \text{ kips}$$

Select option D