STRUCTURAL STEEL DESIGN

Compression Members

-7-

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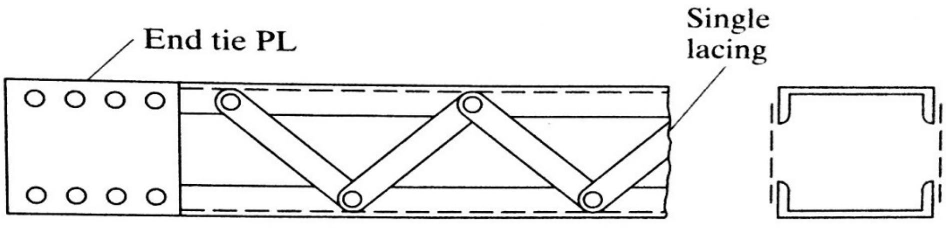
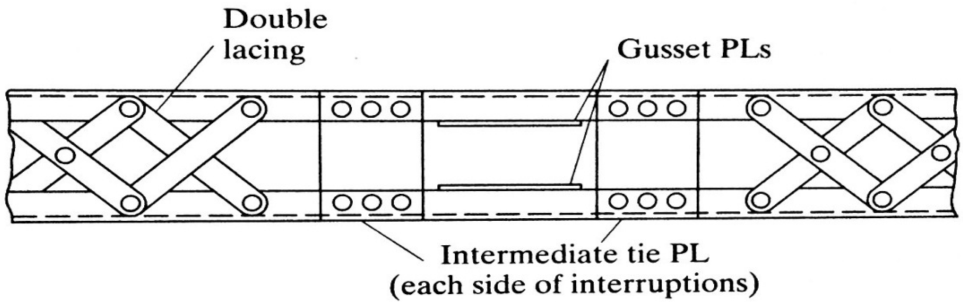
Design of The Connection For Built-Up Columns

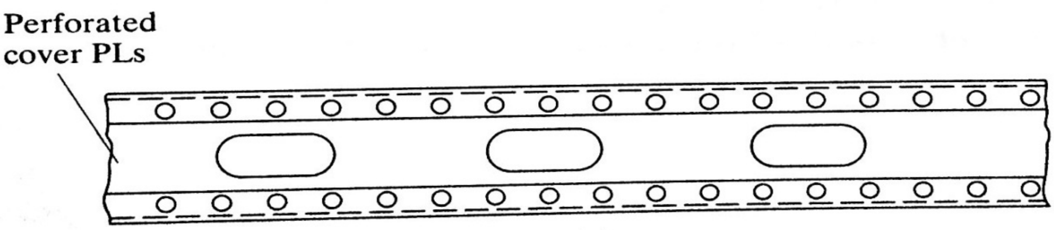
The open side of compression members that are built up from plates or shapes may be connected together with continuous cover plates with perforated holes or they may be connected together with lacing and tie plates .The purposes of the perforated cover plates and the lacing are to hold the various parts parallel and equalize the stress distribution between the various parts .Figures shown below arrangements of tie plates and lacing .



(a)



(b)



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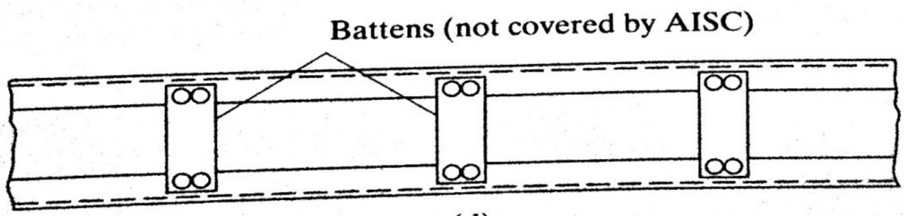
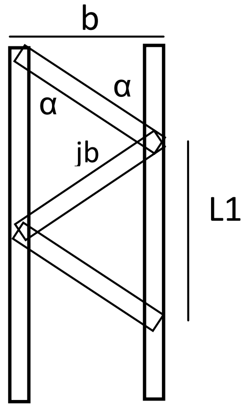


(d)

Design Lacing Bar

1. Find (b) as :
   - If b ≤ 15" …… Design single lacing , α = 60'
   - If b > 15" …… Design double lacing , α = 45'



2. Check limitation of interior column length

$$\frac{KL_1}{r_{min}} \leq \frac{3}{4}\left(\frac{KL}{r}\right)$$

   - K = 1.0 for single lacing
   - K = 0.7 for double lacing

3. Find dimensions of lacing bar :

$$\frac{L_b}{r_b} \leq 140 \text{ for single lacing}$$

$$\leq 200 \text{ for double lacing}$$

4. The shear resisted by lacing

   V = 2% Pu (compression force)

5. Connection the lacing bar at column using welding or bolts

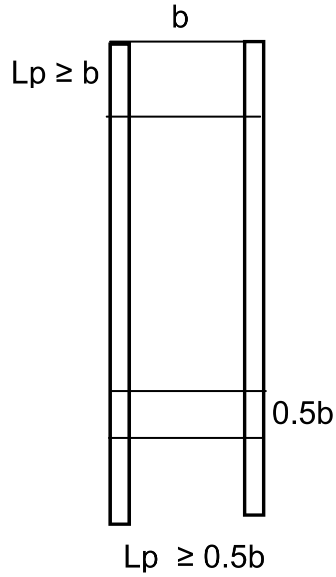
Design of Tie Plates

1. tp = thickness = b/ 50
2. Lp = length of plate ≥ b for ends

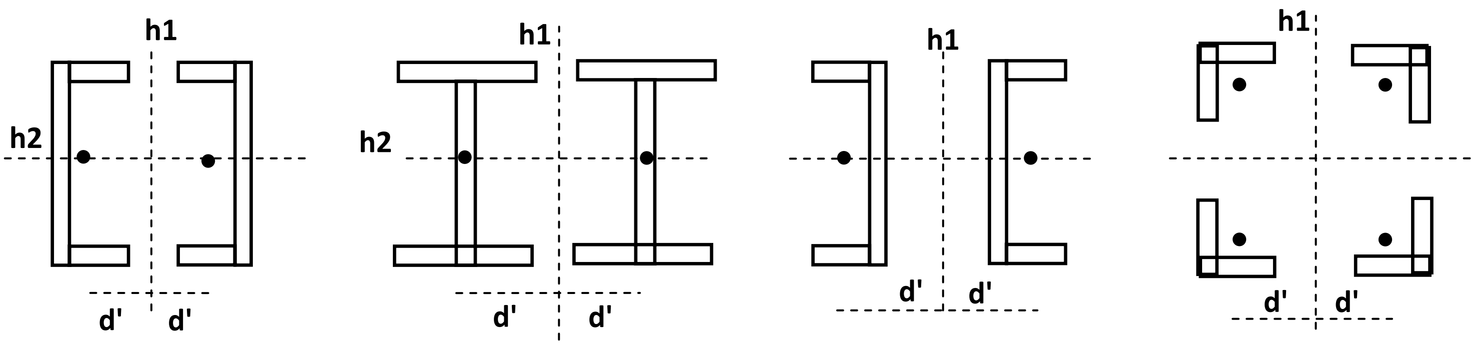
   ≥ b/2 for mid-end

3. Connections

   Length of welding ≥ 1/3 Lp



The properties of Built-Up Columns



(1) (2) (3) (4)

For shapes (1) , (2) & (3)

$Ix = 2Ix$

$Iy = 2Iy + 2\ A.\ d'^2$

For shapes (4)

$Ix = 4Ix + 4\ A.\ d'^2$

$Iy = 4Iy + 4\ A.\ d'^2$

$rx = 0.42\ h2$

$ry = 0.42\ h2$

$rx = 0.36\ h2$

$ry = 0.45\ h2$

For area (1)

$rx = 0.36\ h2$

$ry = 0.52\ h2$

For area (2)

Where:

$$r = \sqrt{\frac{I}{A}}$$

$rx = 0.36\ h2$

$ry = 0.60\ h2$

For area (3)

Example: Using the AISC Specification and 36 ksi steel ,design bolted single lacing for the column of previous example .Assume that 3/4-in bolts are us

Solution. Distance between lines of bolts is 8.5 in < 15 in; therefore, single lacing is OK.

Assume that lacing bars are inclined at 60° with axis of member. Length of channels between lacing connections is 8.5/cos 30° = 9.8 in, and L/r of 1 channel between connections is 9.8/0.762 = 12.9 < 3/4 × 55.94, which is L/r of main member previously determined in Example 6-5. Only the LRFD solution is shown.

Force on lacing bar:

$$V_u = 0.02 \text{ times available design compressive strength of member (from Example 6–5)}$$

$$V_u = (0.02)(631) = 12.62 \text{ k}$$

$$\frac{1}{2}V_u = 6.31 \text{ k} = \text{shearing force on each plane of lacing}$$

Force in bar (with reference to bar dimensions in Fig. 6.10):

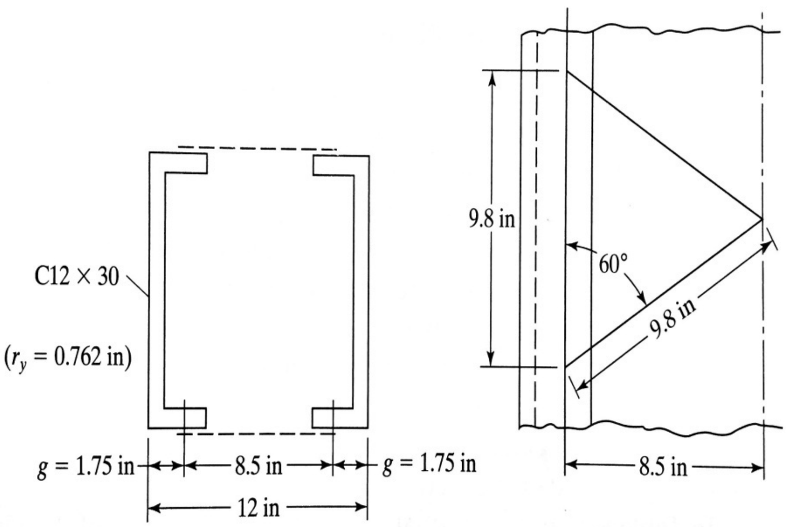
$$\left(\frac{9.8}{8.5}\right)(6.31) = 7.28 \text{ k}$$

Properties of flat bar:

$$I = \tfrac{1}{12}bt^3$$

$$A = bt$$

$$r = \sqrt{\frac{\frac{1}{12}bt^3}{bt}} = 0.289t$$



$$\text{Assume } \frac{L}{r} = \text{maximum value of } 140$$

$$\frac{9.8}{0.289t} = 140$$

$$t = 0.242 \text{ in (try } \tfrac{1}{4}\text{-in flat bar)}$$

$$\frac{L}{r} = \frac{9.8}{(0.289)(0.250)} = 136$$

$$\phi_c F_{cr} = 12.2 \text{ ksi}$$

$$\text{Area reqd} = \frac{7.28}{12.2} = 0.597 \text{ in}^2 \left(2.39 \times \tfrac{1}{4} \text{ needed}\right)$$

Minimum edge distance if $\frac{3}{4}$-in bolt used $= 1\frac{1}{4}$ in — AISC Table J3.4

$\therefore$ Minimum length of bar $= 9.8 + (2)\left(1\frac{1}{4}\right) = 12.3$ in, say, 14 in

Use $\frac{1}{4} \times 2\frac{1}{2} \times$ 1-ft 2-in bars $F_y = 36$ ksi.

Design of end tie plates:

Minimum length $= 8.5$ in

Minimum $t = \left(\frac{1}{50}\right)(8.5) = 0.17$ in

Minimum width $= 8.5 + (2)\left(1\frac{1}{4}\right) = 11$ in

Use $\frac{3}{16} \times 8\frac{1}{2} \times$ 0-ft 12-in end tie plates.

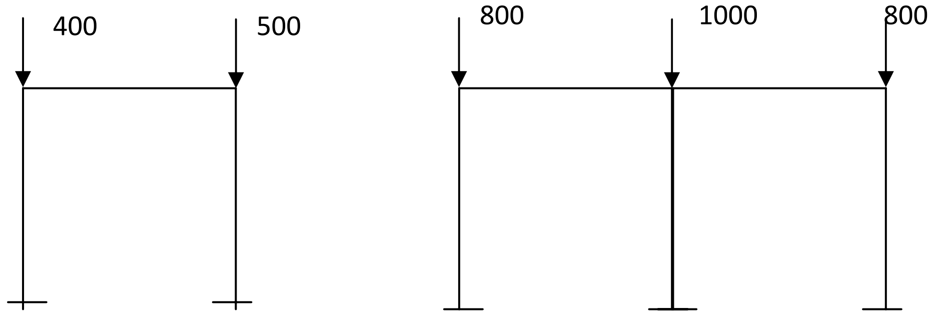
Columns Leaning on Each Other for In-Plane Design

When we have an unbraced frame with beams rigidly attached to columns , it is safe to design each column individually using the sidesway uninhibited alignment chart to obtain the K larger than 1.0 .

A column cannot buckle by sidesway unless all of the columns on that story buckle by sidesway .In some situations ,columns in a frame have some excess buckling strength .If the buckling loads of the exterior columns of the unbraced frame of Figure shown below , have not been reached when the bucking loads of the interior columns are reached , the frame will not buckle (Leaner column theory) .

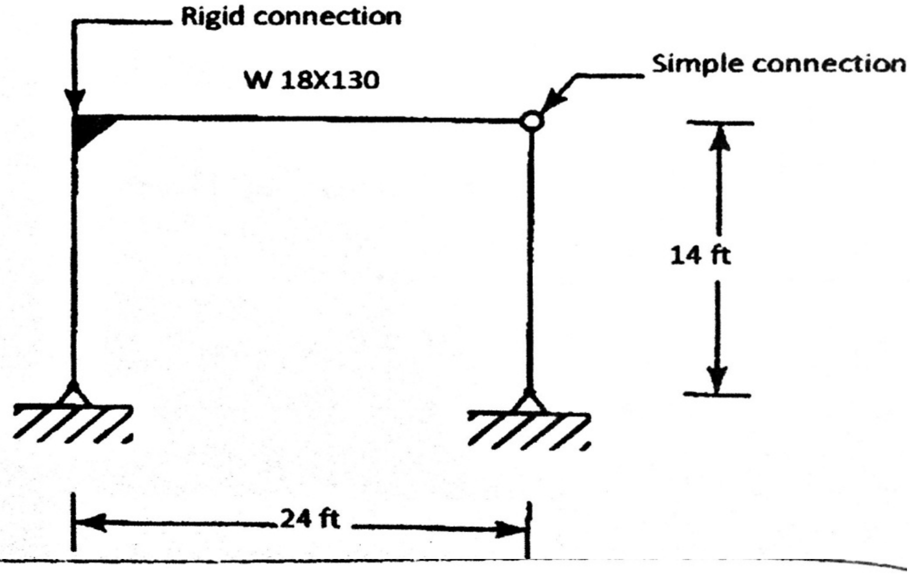
The exterior columns will braced the interior ones against sidesway , the K factor for those interior columns are approaching 1 .But the K factors for the exterior columns are determined with the sidesway uninhibited chart , and they are each designed for column loads equal to ∑loads as shown below :

∑400+500

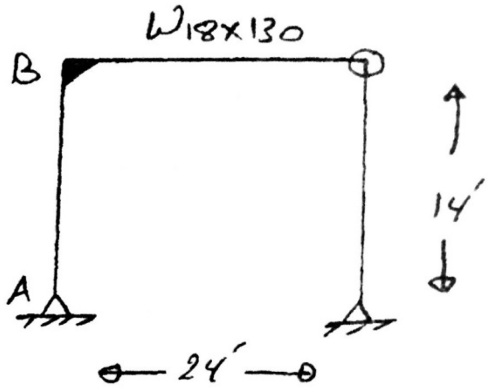


∑800+1000/2

Design W 14 column for the bent shown in the accompanying illustration, with 50 ksi steel, using the inelastic K factor procedure. The columns are braced top and bottom against sidesway out of the plane of the frame so that K=1.0 in that direction. Sidesway is possible in the plane of the frame. Design the right hand column by using K = 1.0, and the left hand column with k as determined from the alignment chart. Note that PD = 200 k and PL = 350, for each column. The beam is rigidly connected to the left column, but has only a simple connection to the right column.



Problem 7.7



Use W14 section, $F_y = 50$ ksi

No sidesway out of Plane.

Sidesway is possible in Plane.

$P_D = 200$ k , $P_L = 350$ k

Solution

The right column

$P_u = 1.2\,P_D + 1.6\,P_L$

$= 1.2 \times 200 + 1.6 \times 350 = 800$ k

$K_y = K_x = 1 \Rightarrow (KL)_y = 14$ ft

Try W14x90

$\phi_c P_n = 1030\ k > P_u = 800\ k$ ✓ ∴ ok

Equivelent K_yL_y of $K_xL_x = \dfrac{14}{(6.14/3.70)} = 8.436\ ft < 14\ ft$

∴ $K_yL_y = 14\ ft$ ← controls

Use W 14X90 ✓

The left column

* out of plane

$K_y = 1.0 \Longrightarrow K_yL_y = 14\ ft$

∴ W14X90 will work

$\phi_c P_n = 1030\ k > P_u = 800\ k$ ∴ OK

* in plane

$P_u = 800 + 800 = 1600\ k$ ✓

Try W14X145

$A = 42.7\ in^2$, $I_x = 1710\ in^4$, $r_x = 6.33\ in$

$\dfrac{P_u}{A} = \dfrac{1600}{42.7} = 37.471$

$\tau = 0.75116$

P_u/A	τ
37	0.770
37.471	0.75116
38	0.730

$G_A = 10$ (Pin)

$G_B = \dfrac{1710/14\times12}{(2460/24\times12)0.5} \times 0.75116 = 1.790$

$K_x = 2.08$

$(\frac{KL}{r})_x = 55.204$

(KL/r)	$\phi_c F_{cr}$ (ksi)
55	36.1
55.204	36.0388
56	35.8

$\phi_c F_{cr} = 36.0388$ ksi

$\phi_c P_n = \phi_c F_{cr} A_g$

$= 36.0388 \times 42.7$

$\phi_c P_n = 1538.857\,k < P_u = 1600\,k$ ∴ N.G

Try W14 X 159

$A = 46.7\ in^2$ $I_x = 1900\ in^4$, $r_x = 6.38\ in$

$\frac{P_u}{A} = 34.261$

P_u/A	τ
34	0.870
34.261	0.8622
35	0.840

$\tau = 0.8622$

$G_A = 10$ (Pin)

$G_B = \frac{1900/14 \times 12}{(2460/24 \times 12)0.5} * 0.8622 = 2.283$

$K_x = 2.18$

$(\frac{KL}{r})_x = \frac{2.18 \times 14 \times 12}{6.38} = 57.404$

(KL/r)	$\phi_c F_{cr}$
57	35.5
57.404	35.3788
58	35.2

$\phi_c F_{cr} = 35.3788$ ksi

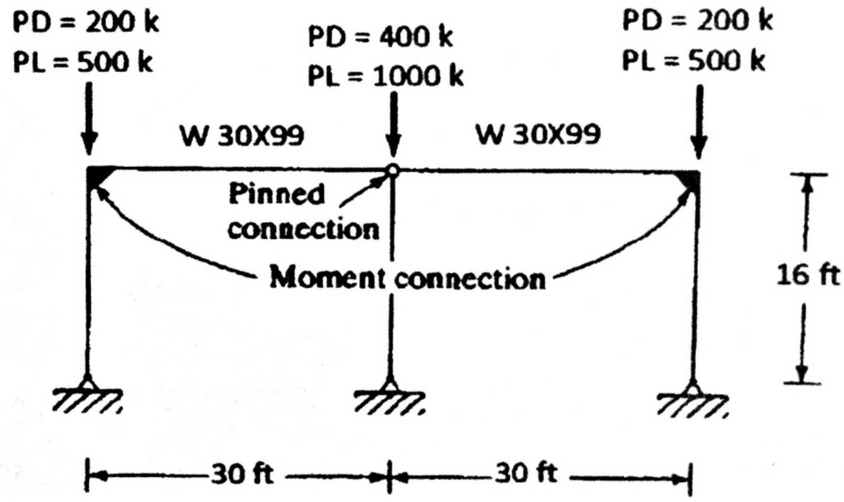
$\phi_c P_n = \phi_c F_{cr} \times A_g$

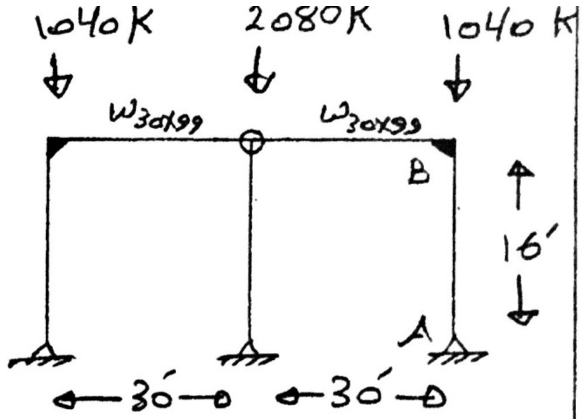
$= 35.3788 \times 46.7$

$\phi_c P_n = 1652.19\,k > P_u = 1600\,k$ ∴

Use W14 X 159

The columns for the frame shown in the accompanying illustration are braced top and bottom against sidesway out of the plane of the frame so that K=1.0 in that direction. Sidesway is possible in the plane of the frame. Design the interior column, assuming that K = 1.0, and the exterior columns with K as determined from the alignment chart. Use Fy = 50 ksi and a W 14 section.





No sidysawy out of plane,

Sidesway Possible in plane.

$F_y = 50$ ksi , Use W14 section,

$W30 \times 99 \quad I_x = 3990 \text{ in}^4$

Solution:-

$Pu_{int} = 1.2 \times 400 + 1.6 \times 1000 = 2080K$

$Pu_{ext.} = 1.2 \times 200 + 1.6 \times 500 = 1040 K$

Interior column Design:-

$Pu = 2080 \ K$

$k_x = k_y = 1.0 \Rightarrow (KL)_y = 1.0 \times 16 = 16 \text{ ft}$ } from table 4.1

Try W14x193

$\phi_c P_n = 2170\,k > P_u = 2080\,k$ ∴ ok

Equivalent K_yL_y of $K_xL_x = \frac{16}{(6.50/4.05)} = 9.97\ ft < 16\ ft$

∴ $K_yL_y = 16\ ft$ ← controls

Use W14x193 for interior column.

Exterior column Design

Out of plane $K_y = 1.0$

$K_yL_y = 1.0 * 16 = 16\ ft$, $P_u = 1040\ k$

from table 4.1 W14x99 will work

$\phi_c P_n = 1080\,k > P_u = 1040\,k$ ∴ ok

in plane

$P_u = 1040 + (2080/2) = 2080\,k$

Try W14x211

$A = 62.0\ in^2$ $I_x = 2660\ in^4$, $r_x = 6.55\ in$

$G_A = 10$ (Pin)

$$G_B = \frac{2660/16\times12}{(3990/30\times12)0.5} = 2.5$$

$K_x = 2.2$

$$\left(\frac{KL}{r}\right)_x = \frac{2.2 * 16 \times 12}{6.55} = 64.4885$$

$\phi_c F_{cr} = 33.2046\ ksi$

∴ $\phi_c P_n = 33.2046 * 62.0$

$= 2058\,K < P_u = 2080\,K$

N.G

(KL/r)	$\phi_c F_{cr}$
64	33.4
64.4885	33.2046
65	33.0

Try W14X233

$A = 68.5\ in^2$ $I_x = 3010\ in^4$, $r_x = 6.63\ in$

$G_A = 10$

$$G_B = \frac{3010/16\times12}{(3990/30\times12)0.5} = 2.829$$

$K_x = 2.208$

$$\left(\frac{KL}{r}\right)_x = \frac{2.208\times16\times12}{6.63} = 63.942$$

$\phi_c F_{cr} = 33.4174\ ksi$

$\phi_c P_n = 33.4174 * 68.5$

$= 2289.0919\ k > P_u = 2080\ k$ ∴ ok

Use W14X233 for Exterior column

7-1. Using the Jackson and Moreland charts, determine the effective length factors for columns EF, FG, and KL of the frame shown in the accompanying illustration, assuming that the frame is subject to sidesway and that all of the assumptions on which the alignment charts were developed are met. (*Ans.* 1.84, 1.26, and 1.44)

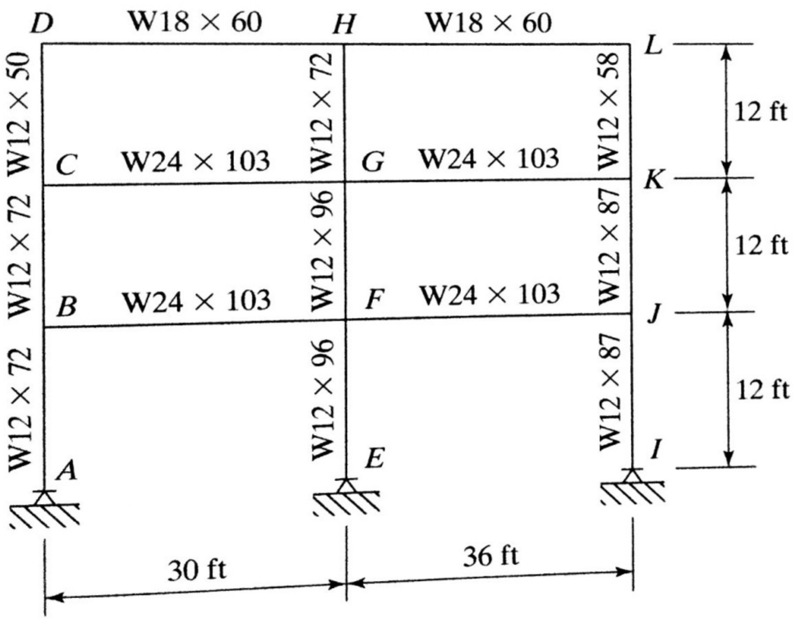


FIGURE P7-1

7-2. Determine the effective length factors for all the columns of the frame shown in the accompanying illustration. Note that the columns on the upper level are subject to sidesway, while the ones on the lower level are braced against sidesway. Assume that all of the assumptions on which the alignment charts were developed are met.

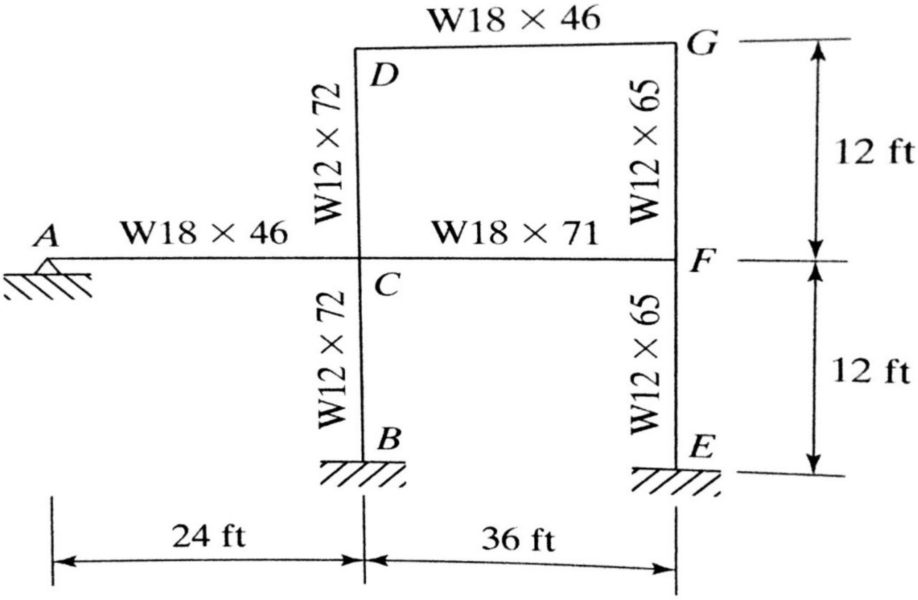
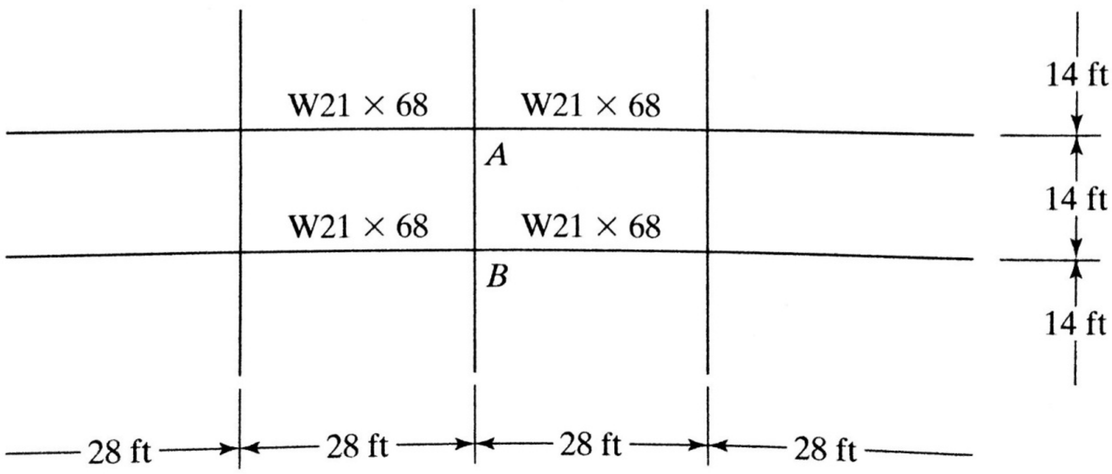


FIGURE P7-2

Use both LRFD and ASD methods.

7-3. a. Select a W14 section for column AB in the frame shown if $P_D = 250$ k, $P_L = 500$ k, and $F_y = 50$ ksi, and only in-plane behavior is considered. Furthermore, assume that the columns immediately above and below AB are approximately the same size as AB, and also that all the other assumptions on which the alignment charts were developed are met. (*Ans.* W14 × 90 LRFD & ASD)

b. Repeat part (a) if inelastic behavior is considered. (*Ans.* W14 × 90 LRFD & W14 × 99 ASD)



7-4. Repeat Prob. 7-3 if the beams are W24 × 62 and P_D = 300 k and P_L = 500 k. Select W12 sections.

7-5. Repeat Prob. 7-3 if a W12 is used. (*Ans.* (a) W12 × 96 LRFD & ASD (b) W12 × 96 LRFD, W12 × 106 ASD)

7-6. We desire to select a W14 section for column *CD* in the frame shown for which P_D = 300 k, P_L = 600 k, and F_y = 50 ksi. Otherwise, the conditions are exactly as those described for Prob. 7-3.

a. Assume elastic behavior.
b. Assume inelastic behavior.

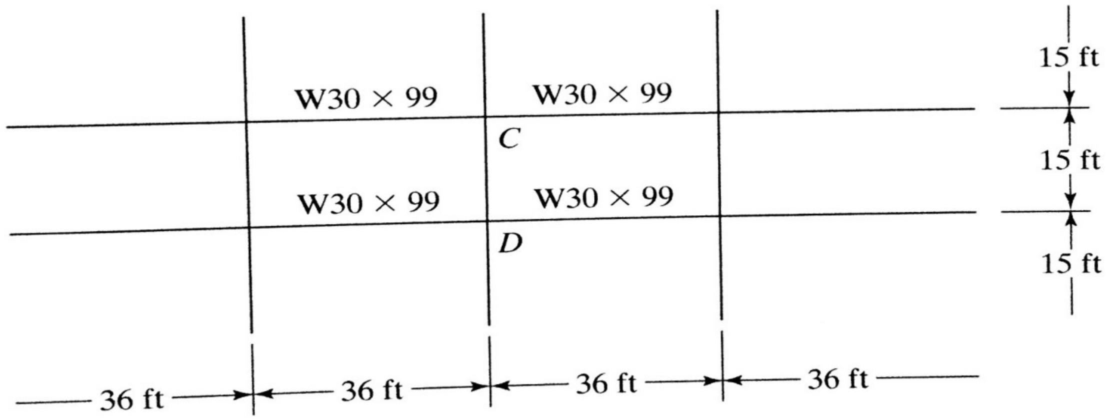
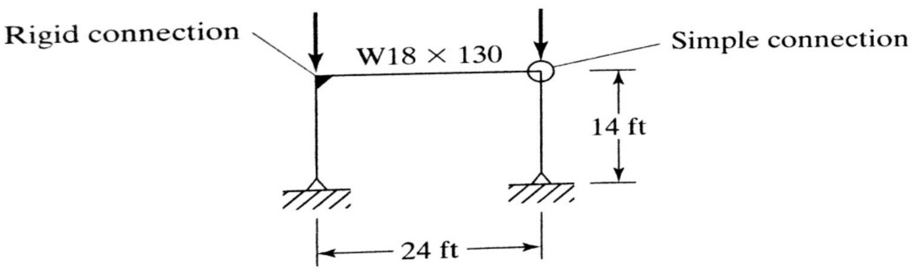


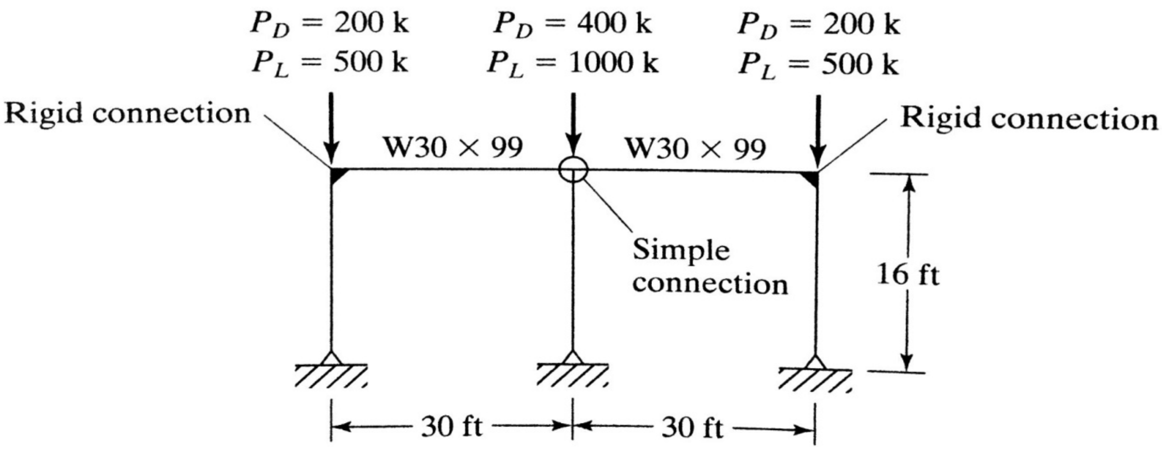
FIGURE P7-6

7-7. Design W14 columns for the bent shown in the accompanying illustration, with 50 ksi steel, using the inelastic *K*-factor procedure. The columns are braced top and bottom against sidesway out of the plane of the frame so that *K* = 1.0 in that direction. Sidesway is possible in the plane of the frame. Design the right-hand column by using *K* = 1.0, and the left-hand column with *K* as determined from the alignment chart. Note that P_D = 200 k and P_L = 350 k, for each column. The beam is rigidly connected to the left column, but has only a simple connection to the right column. (*Ans.* W14 × 211 LRFD and ASD)



7-8. Repeat Prob. 7-7 if the loads on each column are $P_D = 550$ k and $P_L = 300$ k, and use $F_y = 50$ ksi.

7-9. The columns for the frames shown in the accompanying illustration are braced top and bottom against sidesway out of the plane of the frame so that $K = 1.0$ in that direction. Sidesway is possible in the plane of the frame. Design the interior column, assuming that $K = 1.0$, and the exterior columns with K as determined from the alignment chart. Use $F_y = 50$ ksi and a W14 section. (*Ans.* W14 × 211 LRFD & ASD for interior column. W14 × 193 LRFD, W14 × 233 ASD for exterior columns)



7-10. Repeat Prob. 7-9, assuming that the outside column bases are fixed.

7-11. For the frame shown in the accompanying illustration, the beams are rigidly connected to the exterior columns, while all other connections are simple. The columns are braced top and bottom against sidesway out of the plane of the frame so that $K = 1.0$ in that direction. Sidesway is possible in the plane of the frame. Design W14 interior columns of 50 ksi steel, assuming $K = 1.0$, and W14 exterior columns with K as determined from the alignment chart. (*Ans.* For LRFD & ASD W14 × 90 interior columns, W14 × 176 exterior columns)

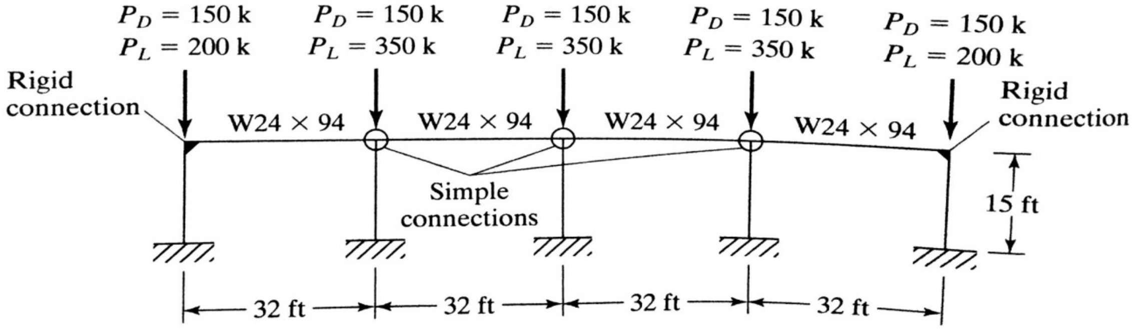


FIGURE P7-11