Structural Steel Design
LRFD Method

Third Edition

CHAPTER

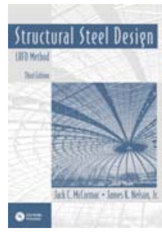
DESIGN OF AXIALLY LOADED COMPRESSION MEMBERS

A. J. Clark School of Engineering •Department of Civil and Environmental Engineering

Part II – Structural Steel Design and Analysis

6b

FALL 2002



By
Dr. Ibrahim. Assakkaf

ENCE 355 - Introduction to Structural Design

Department of Civil and Environmental Engineering

University of Maryland, College Park

Prentice Hall

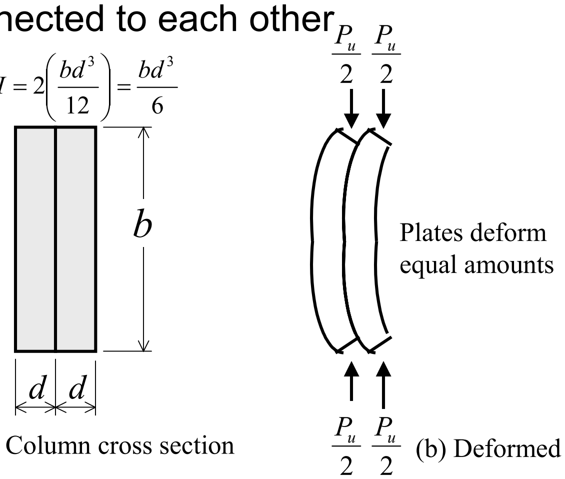
Built-Up Columns with Components in Contact with Each Other

- If a column consists of two equal size plates as shown in Fig. 1, and if those plates are not connected together, each plate will act as a separate column, and each will resist approximately half of the total column load.
- This means that the total moment of inertia of the column will equal two times the moment of inertia of one plate.

Built-Up Columns with Components in Contact with Each Other

Figure 1. Column consisting of two plates not connected to each other

$$I = 2\left(\frac{bd^3}{12}\right) = \frac{bd^3}{6}$$



(a) Column cross section

(b) Deformed shape of Columns

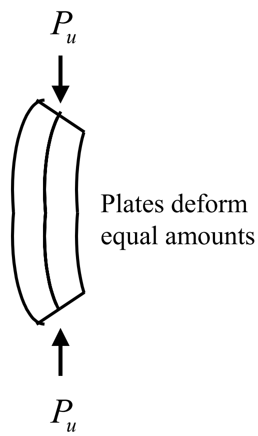
Built-Up Columns with Components in Contact with Each Other

- The two “columns” will act the same and have equal deformation, as shown in part (b) of Fig. 1.
- If the two plates are connected together sufficiently to prevent slippage on each other, they will act as a unit as shown in Fig. 2.
- Their moment of inertia may be computed for the whole built-up section.

Built-Up Columns with Components in Contact with Each Other

Figure 2. Column consisting of two plates fully connected to each other

$$I = \frac{b(2d)^3}{12} = \frac{b(8d^3)}{12} = \frac{4}{6}bd^3$$



Built-Up Columns with Components in Contact with Each Other

- The moment of inertia for this built-up section will be four times as large as it was for the column of Fig 1, where slipping between plates was possible.
- Also, the column of Fig 2 will deform different amounts as the column bends laterally.

Built-Up Columns with Components in Contact with Each Other

- Should the plates be connected in a few places, the strength of the resulting column would be somewhere in between the two cases just described.
- The greatest displacement between the two plates in Fig 1 tend to occur at the ends and the least displacement tends to occur at middle depth.

Built-Up Columns with Components in Contact with Each Other

- Greatest Strength of Built-up Column

As a result, connections placed at column ends which will prevent slipping between the parts have the greatest strengthening effect, while those at middepth have the least effect

Built-Up Columns with Components Not in Contact with Each Other

- The following example presents the design of member built up from two channels that are not in contact with each other.
- The parts of such members need to be connected or laced together across their open sides.

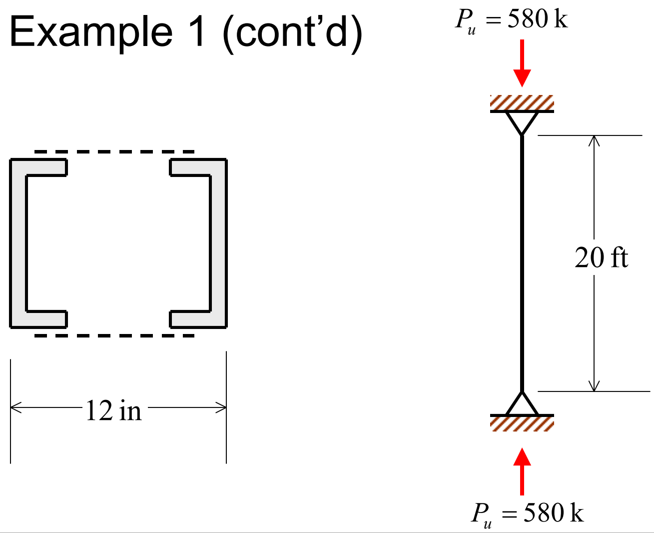
Built-Up Columns with Components Not in Contact with Each Other

- Example 1

  Select a pair of 12-in standard channels for the column and load shown using F_y = 50 ksi. For connection purposes, the back-to-back distance of the channels is to be 12 in.

Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)



Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)

$$\text{Assume } \frac{KL}{r} = 50$$

Then from Table 3.50 of the LRFD Manual,

$$\phi_c F_{cr} = 35.40 \text{ ksi}$$

$$A_{\text{required}} = \frac{P_u}{\phi_c F_{cr}} = \frac{580}{35.40} = 16.38 \text{ in}^2$$

Try 2C12 $\times$ 30's (for each channel, A = 8.81 in^2, I_x = 162 in^4, I_y = 5.12 in^4, $\bar{x} = 0.674$ in)

Built-Up Columns with Components Not in Contact with Each Other

- LRFD Manual Design Tables (P. 16.I-145)

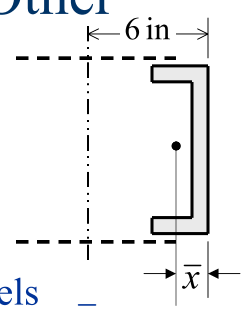
TABLE 3-50

Design Stress for Compression Members of 50 ksi Specified Yield Stress Steel, $\phi_c = 0.85$[a]

$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi
42.5	41	37.6	81	26.3	121	14.6	161	8.23
42.5	42	37.4	82	26.0	122	14.3	162	8.13
42.5	43	37.1	83	25.7	123	14.1	163	8.03
42.5	44	36.9	84	25.4	124	13.9	164	7.93
42.4	45	36.7	85	25.1	125	13.7	165	7.84
42.4	46	36.4	86	24.8	126	13.4	166	7.74
42.4	47	36.2	87	24.4	127	13.2	167	7.65
42.3	48	35.9	88	24.1	128	13.0	168	7.56
42.3	49	35.7	89	23.8	129	12.8	169	7.47
42.2	50	35.4	90	23.5	130	12.6	170	7.38

Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)



$$I_x = 2 \times 162 = 324 \text{ in}^2$$

$$I_y = 2\left[5.12 + 8.81(5.326)^2\right] = 510 \text{ in}^4$$

$$\text{Note that } 5.326 = \frac{\text{distance of channels}}{2} - \bar{x}$$

$$= \frac{12}{2} - 0.674 = 5.326 \text{ in}$$

Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)

$$r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{324}{(2 \times 8.81)}} = 4.29 \text{ in} \longleftarrow \text{Controls}$$

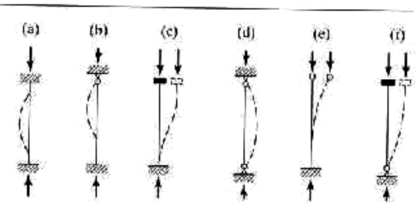
$$r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{510}{(2 \times 8.81)}} = 5.38 \text{ in}$$

$$\therefore r_x = 4.29 \text{ in to be used}$$

$$K = 1.0 (\text{From Table 1, pinned ends})$$

Built-Up Columns with Components Not in Contact with Each Other

Table 1



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
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

Source: *Load and Resistance Factor Design Specification for Structural Steel Buildings*, December 27, 1999 (Chicago: AISC)

Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)

$$KL = (1.0)(20) = 20 \text{ ft}$$

$$\frac{KL}{r} = \frac{KL}{r_x} = \frac{12 \times 20}{4.29} = 55.94$$

From Table 3.50 of the Manual and by interpolation:

$$\phi_c F_{cr} = 33.82 \text{ ksi}$$

$$\text{Therefore, } \phi_c P_n = \phi_c F_{cr} A_g = 33.82(2 \times 8.81) = 596 \text{ k} > 580 \text{ k} \quad \text{OK}$$

Thus, $\boxed{\text{USE 2C}12 \times 30}$

Built-Up Columns with Components Not in Contact with Each Other

- LRFD Manual Design Tables (P. 16.I-145)

TABLE 3-50

Design Stress for Compression Members of 50 ksi Specified Yield Stress Steel, $\phi_c = 0.85$[a]

$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi	$\frac{Kl}{r}$	$\phi_c F_{cr}$ ksi
41.8	55	34.1	95	22.0	135	11.7	175	6.97
41.7	56	33.8	96	21.7	136	11.5	176	6.89
41.6	57	33.5	97	21.4	137	11.4	177	6.81
41.5	58	33.2	98	21.1	138	11.2	178	6.73
41.4	59	33.0	99	20.8	139	11.0	179	6.66
41.3	60	32.7	100	20.5	140	10.9	180	6.59
41.2	61	32.4	101	20.2	141	10.7	181	6.51
41.0	62	32.1	102	19.9	142	10.6	182	6.44
40.9	63	31.8	103	19.6	143	10.4	183	6.37
40.8	64	31.5	104	19.3	144	10.3	184	6.30

Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)

Checking width/thickness ratios:

$$C12\times 30 \begin{pmatrix} d = 12.0\text{ in}, b_f = 3.17\text{ in}, t_f = 5.12\text{ in} \\ t_w = 0.51\text{ in}, k = 1\frac{1}{8}\text{ in} = 1.125\text{ in} \end{pmatrix}$$

Built-Up Columns with Components Not in Contact with Each Other

- Example 1 (cont'd)

$$\frac{b_f}{t_f} = \frac{3.17}{0.501} = 6.33 < 0.56\sqrt{\frac{E}{F_y}} = \sqrt{\frac{29\times 10^3}{50}} = 13.49 \quad \text{OK}$$

$$\frac{h}{t_w} = \frac{12.0 - 2(1.125)}{0.510} = 19.12 < 1.49\sqrt{\frac{E}{F_y}} = 1.49\sqrt{\frac{29\times 10^3}{50}} = 35.88 \quad \text{OK}$$

$$\boxed{\therefore \text{USE } 2C12\times 30, F_y = 50\text{ ksi}}$$

Built-Up Columns

- Figure 4. Limiting Width-Thickness Ratios for Compression Elements

	Description of Element	Width Thickness Ratio	Limiting Width-Thickness Ratios λ_p (compact)	Limiting Width-Thickness Ratios λ_r (noncompact)
Unstiffened Elements	Flanges of I-shaped rolled beams and channels in flexure	b/t	$0.38\sqrt{E/F_y}$ [c]	$0.83\sqrt{E/F_L}$ [e]
	Flanges of I-shaped hybrid or welded beams in flexure	b/t	$0.38\sqrt{E/F_{yf}}$	$0.95\sqrt{E/(F_L/k_c)}$ [e], [f]
	Flanges projecting from built-up compression members	b/t	NA	$0.64\sqrt{E/(F_y/k_c)}$ [f]
	Flanges of I-shaped sections in pure compression, plates projecting from compression elements; outstanding legs of pairs of angles in continuous contact; flanges of channels in pure compression	b/t	NA	$0.56\sqrt{E/F_y}$
	Legs of single angle struts; legs of double angle struts with separators; unstiffened elements, i.e., supported along one edge	b/t	NA	$0.45\sqrt{E/F_y}$
	Stems of tees	d/t	NA	$0.75\sqrt{E/F_y}$

Built-Up Columns

- Figure 4. (cont'd) Limiting Width-Thickness Ratios for Compression Elements

Stiffened Elements	Webs in combined flexural and axial compression	h/t_w	for $P_u/\phi_b P_y \le 0.125$ [c], [g] $3.76\sqrt{\frac{E}{F_y}}\left(1 - \frac{2.75P_u}{\phi_b P_y}\right)$ for $P_u/\phi_b P_y > 0.125$ [c], [g] $1.12\sqrt{\frac{E}{F_y}}\left(2.33 - \frac{P_u}{\phi_b P_y}\right) \ge 1.49\sqrt{\frac{E}{F_y}}$	[h] $5.70\sqrt{\frac{E}{F_y}}\left(1 - 0.74\frac{P_u}{\phi_b P_y}\right)$
	All other uniformly compressed stiffened elements, i.e., supported along two edges	b/t h/t_w	NA	$1.49\sqrt{E/F_y}$
	Circular hollow sections In axial compression In flexure	D/t	[d] NA $0.07E/F_y$	$0.11E/F_y$ $0.31E/F_y$