

# **Steel Column Design by ASD/LRFD Steel Construction Manual**

**An Online Continuing Education Course for Engineers**

**Course Number: C-2021**

**Credit: 2 Hours / 2 PDH / 2 CPD**

**Steel Column Design by  
ASD/LRFD Steel Construction Manual  
13<sup>th</sup> Edition**

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Compression members are commonly used in structures. *Columns* are a type of compression member used to support beams, girders, floors, roofs and other areas. Compression members are also used in trusses. Compression members can be subjected to axial compression, eccentric compression or combined axial compression and flexure. This tends to buckle the compression member.












*Camber*, is the bending of a beam to help compensate for deflection. You do not camber a column. That would make it tend to buckle and buckle in a certain direction.

Compressive strength depends on the axis of bending and the type of end connections. A W section has an x-axis and a y-axis. The x-axis is parallel to the flanges and the y-axis is parallel to and goes through the web. The x-axis is the strong axis and the y-axis is the weak axis. Bucking will occur about the weak axis.

The type of end connection determines the *effective length factor*, K. There are three basic types of end connections used in most buildings.

- Fixed-fixed
- Pinned-pinned
- Fixed-pinned

Recommended design K values are given in the following table and the recommended K values should be used instead of the theoretical K values.

| TABLE C-C2.2<br>Approximate Values of Effective Length Factor, $K$ |  |  |  |  |  |  |
|--|--|--|--|--|--|--|
| Buckled shape of column is shown by dashed line.                   | (a)<br>   | (b)<br> | (c)<br> | (d)<br> | (e)<br> | (f)<br> |
| 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   |  <ul style="list-style-type: none"> <li> Rotation fixed and translation fixed</li> <li> Rotation free and translation fixed</li> <li> Rotation fixed and translation free</li> <li> Rotation free and translation free</li> </ul> |  |  |  |  |  |

- Case (a) has fixed, fixed connections
- Case (b) has pinned, fixed connections
- Case (d) has pinned, pinned connections

If the column is used in a frame, we would use a different method to determine the  $K$  value. The *effective length* is  $KL$ .  $KL/r$  is the *slenderness ratio*. Section E2 of the specification says that  $KL/r$  should be less than 200.

Section E1 of the specification explains how to calculate the *design compressive strength* and the *allowable compressive strength*.

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 according to the *limit states* of *flexural buckling*, *torsional buckling* and *flexural-torsional buckling*.

- (a) For doubly symmetric and singly symmetric members the limit state of flexural buckling is applicable.
- (b) For singly symmetric and unsymmetric members, and certain doubly symmetric members, such as cruciform or built-up *columns*, the limit states of torsional or flexural-torsional buckling are also applicable.

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

A W section is *doubly symmetrical*.

Section B4 of the specification says that compression members are classified for local buckling as compact, non-compact or slender-elements. Most W sections are compact. Section E7 of the specification says there is a *reduction factor*, Q. It says that Q=1 for compact and non-compact but is less than 1 for slender-elements. Table B4.1, case 3 says a member is non-compact if

$$b/t = \lambda_r < 0.56 \sqrt{E/F_y} \text{ and case 10, if } h/t_w = \lambda_r < 1.49 \sqrt{E/F_y} .$$

Section E3 of the specification shows how to calculate the compressive strength of most compression members since most W sections are compact. The equations in section E3 are the basis of Table 4-22 in the Steel Manual. If you want to determine the available compressive strength of a section, use Table 4-22 and determine the available critical stress. Multiply the available critical stress by the gross area to calculate the available compressive stress.

The *nominal compressive strength*,  $P_n$ , shall be determined based on the *limit state of flexural buckling*.

$$P_n = F_{cr} A_g \quad (\text{E3-1})$$

The *flexural buckling stress*,  $F_{cr}$ , is determined as follows:

$$\text{(a) When } \frac{KL}{r} \leq 4.71 \sqrt{\frac{E}{F_y}} \quad (\text{or } F_e \geq 0.44F_y)$$

$$F_{cr} = \left[ 0.658 \frac{F_y}{F_e} \right] F_y \quad (\text{E3-2})$$

$$\text{(b) When } \frac{KL}{r} > 4.71 \sqrt{\frac{E}{F_y}} \quad (\text{or } F_e < 0.44F_y)$$

$$F_{cr} = 0.877 F_e \quad (\text{E3-3})$$

where

$F_e$  = elastic critical buckling stress determined according to Equation E3-4, Section E4, or the provisions of Section C2, as applicable, ksi (MPa)

$$F_e = \frac{\pi^2 E}{\left( \frac{KL}{r} \right)^2} \quad (\text{E3-4})$$

Design of columns by formulas involves trial-and-error. Table 4-1 helps with the design of W sections in axial compression. Table 4-22 also helps with the design of compression members with minimum yield strengths of 35 ksi, 36 ksi, 42 ksi, 46 ksi and 50 ksi. Most W sections would have a yield stress of 36 ksi or 50 ksi.

### Example 1

Select an ASTM A992 ( $F_y=50$  ksi) W section column to carry an axial dead load of 150 kips and live load of 400 kips. The column is 30" long and is pinned at the top and bottom. The limit is a 14" member.

#### LRFD

$$P_u = 1.2D + 1.6L = (1.2 \times 150 \text{ kips}) + (1.6 \times 400 \text{ k}) = 820 \text{ k}$$

#### ASD

$$P_a = D + L = 150 \text{ k} + 400 \text{ k} = 550 \text{ k}$$

Assume  $KL/r=50$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = 114 \text{ ksi}$$

$$F_{cr} = \left[ 0.658 \frac{F_y}{F_e} \right] F_y = 41.6 \text{ ksi}$$

LRFD

$\phi$

A

$22.0 \text{ in}^2$

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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Sh

|       |
|-------|
| W14   |
| W14   |
| W14   |
| W14   |
| W14X  |
| W14X  |
| W14X  |
| W14XE |
| W14X4 |
| W14X4 |
| W14X3 |
| W14X3 |
| W14X3 |

|   | $S_y$         |   |
|---|---------------|---|
|   | $\text{in}^3$ |   |
| 7 | 61.2          | 3 |
|   | 55.2          | 3 |
|   | 49.9          | 3 |
|   | 29.3          | 2 |
|   | 26.6          | 2 |
|   | 24.2          | 2 |
|   | 21.5          | 2 |
|   | 14.3          | 1 |
|   | 12.8          | 1 |
|   | 11.3          | 1 |
|   | 7.88          | 1 |
|   | 5.91          | 1 |
|   | 4.82          | 1 |

$A_g = 24$

$$\frac{6.05 \text{ in}}{0.1} = 59.5$$

$$\frac{KL}{r_y} = \frac{1.0(30 \text{ ft})(12 \text{ in / ft})}{2.48 \text{ in}} = 145.2 \quad \text{use larger}$$

$$F_e = \frac{\pi^2 E}{(145.2)^2} = 13.583 \text{ ksi}$$

$$F_{cr} = 0.877 F_e = 0.877 (13.583 \text{ ksi}) = 11.912 \text{ ksi}$$