

Steel Design - LRFD

AISC Steel Manual 14th edition

Column Design Tutorial

Professor Louie L. Yaw

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1 Introduction

According to the LRFD methodology columns must be selected such that the following basic equation is satisfied:

$$\phi P_n \geq P_u.$$

Therefore, column design requires the determination of ϕP_n . To do this, for a particular column, the slenderness, KL/r , of the column must be determined. This tutorial outlines the relevant information needed to obtain the column's governing slenderness and then subsequently determine ϕP_n .

2 Slenderness Ratio

Every column has a slenderness ratio calculated as KL/r where K is the effective length factor, L is the column length and r is the radius of gyration for the column cross-section about the axis that governs buckling. The slenderness ratio for compression members preferably should not exceed 200. The slenderness may need to be calculated for buckling about each axis of the column cross-section. The largest of the following values, $K_x L_x / r_x$, $K_y L_y / r_y$ or possibly $K_z L_z / r_z$, must be used.

2.1 Effective Length Factor

Depending on the type of building and column end conditions, the effective length factor, K , may be determined as follows:

(a.) Braced frames(Non-sway Frames)

i. Non-moment connections at the column joints.

$$K = 1.0$$

- ii. Moment connections at the column joints (in a braced frame this case is rare since it generally is not logical or economical to have a braced frame with moment connections).

For this case the value of K may be determined by using the non-sway nomograph (see Manual page 16.1-512). To do this a value of G must be calculated for the top and bottom of the column under consideration.

$$G = \frac{\sum(I/L)_{columns}}{\sum(I/L)_{beams}} \quad (1)$$

The value of G is taken as 10 for a “pinned” column base and taken as 1.0 for a “fixed” column base.

- (b.) Unbraced frames (Sway Frames)

For columns with moment connections the value of K may be found by using the sway nomograph (see Manual page 16.1-513). The values for G at the top and bottom of the column are calculated as given previously in equation (1). Again, G is taken as 10 or 1 for “pinned” or “fixed” base columns respectively.

- (c.) Modified Nomograph Values

When nomographs are used in any case above, G values as calculated by equation (1) may be modified by a stiffness reduction factor (SRF), τ_a , to get a more realistic value of K . This modification is only for columns in the inelastic range. The SRF τ_a is found by using Table 4-21 in the steel manual (see Manual page 4-321). The modified value of G is calculated as follows:

$$G_{modified} = \tau_a G_{initial} \quad (2)$$

The modified value of G is then used to obtain K from the nomograph.

2.2 Column Length

The column length L may have a different value for each axis about which buckling may occur. For example, the values for L_x and L_y may be different.

2.3 Radius of Gyration

The appropriate value of radius of gyration must be used. For example, the correct value of either r_x , r_y or possibly r_z must be used.

3 Determining ϕP_n

For $Q=1$ (i.e. no slender elements per Table B4.1a,b Manual p. 16.1-16 & 17), the value of ϕP_n is calculated as follows:

$$\phi P_n = \phi F_{cr} A_g \quad (3)$$

where, $\phi = 0.9$ and A_g is the gross cross-sectional area of the compression member. The flexural buckling stress F_{cr} is determined as follows:

(a.) When $\frac{KL}{r} \leq 4.71\sqrt{\frac{E}{F_y}}$

$$F_{cr} = \left[0.658 \frac{F_y}{F_e}\right] F_y \quad (4)$$

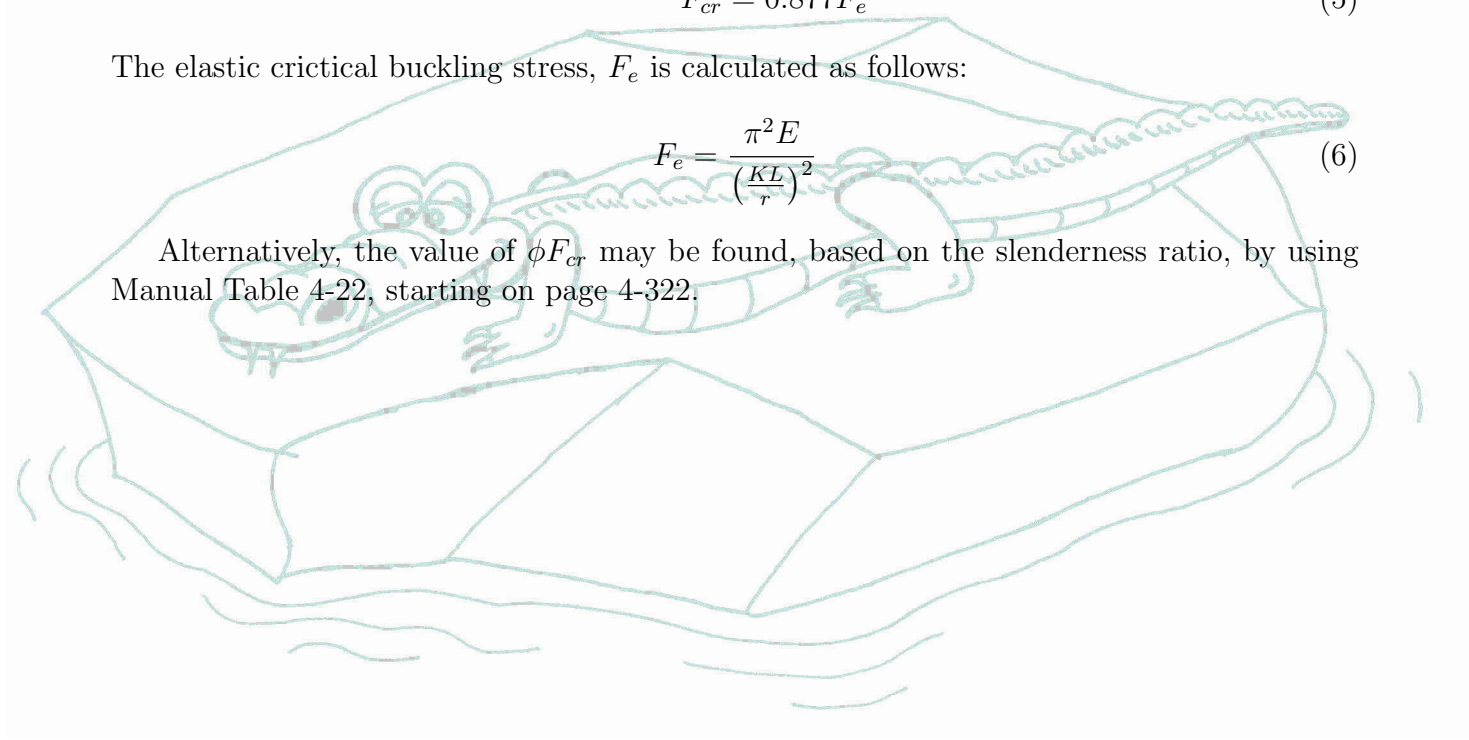
(b.) When $\frac{KL}{r} > 4.71\sqrt{\frac{E}{F_y}}$

$$F_{cr} = 0.877F_e \quad (5)$$

The elastic critical buckling stress, F_e is calculated as follows:

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} \quad (6)$$

Alternatively, the value of ϕF_{cr} may be found, based on the slenderness ratio, by using Manual Table 4-22, starting on page 4-322.



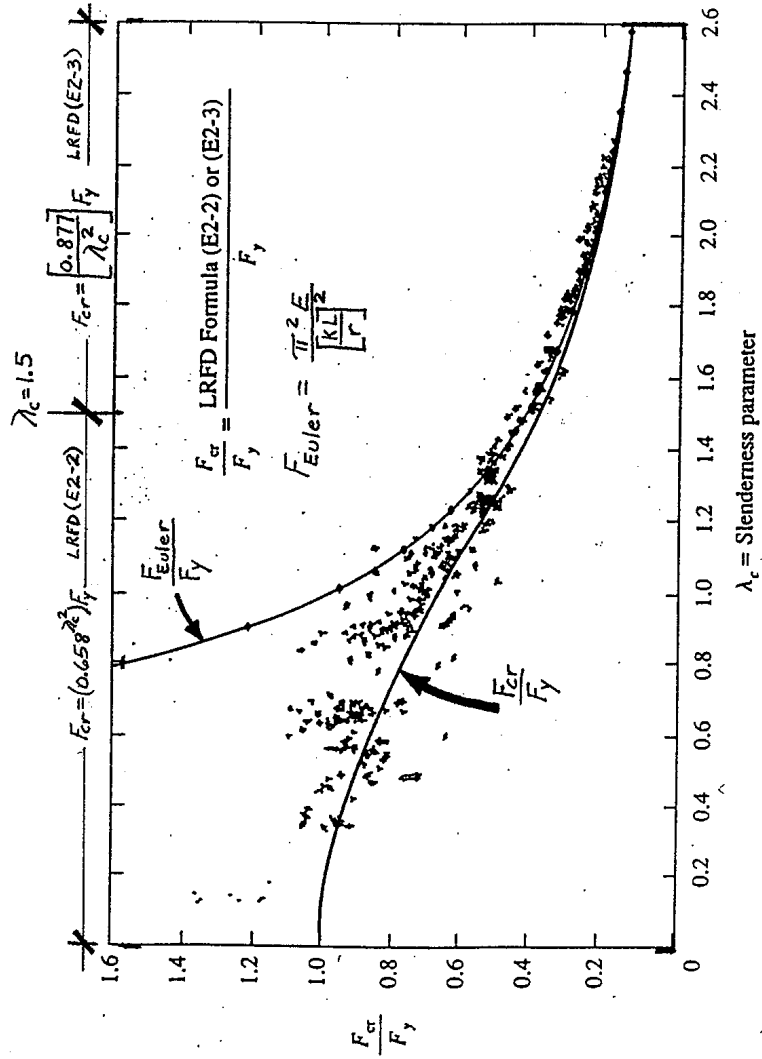


Figure 6.7.3 Comparison of LRFD equations for F_{cr} for columns with data from physical tests. (Test data from Hall [6.24])