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Question 1: What is the buckling resistance of a compression member when only one flange is laterally braced?

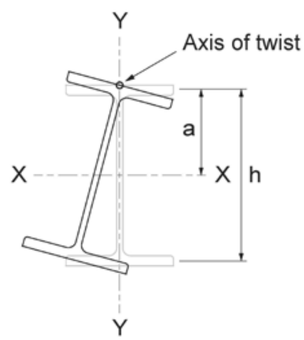

FIGURE 1
Torsional-Flexural Buckling About a Constrained Axis

Answer: Although this condition is not covered in CSA S16-14, it occurs mainly in two situations: (1) exterior columns in single-storey buildings, and (2) beams in braced frames supporting a steel deck. In case (1), the outside flange of the column is laterally braced by girts while the inside flange is unsupported. In case (2), the top flange of a roof beam, for example, is continuously braced by the deck while the bottom flange is unsupported. In both cases, torsional-flexural buckling under axial loading occurs about a constrained axis of twist located near the braced flange, as shown in Figure 1.

Ziemian (2010) provides a formula for the elastic buckling load:

$$P_{eyz} = \frac{P_{ey}\left(\frac{h^2}{4} + a^2\right) + GJ}{a^2 + r_x^2 + r_y^2}, \quad P_{ey} = \left(\frac{\pi}{L_y}\right)^2 E I_y$$

where:
a = Distance between the constrained axis and the shear centre of the member
G = Shear modulus
h = Distance between the flange centroids
I_y = Weak-axis moment of inertia
J = St. Venant torsional constant
L_y = Unsupported member length between points of zero twist
P_{ey} = Euler (flexural) buckling load about the weak axis
r_x , r_y = Principal radii of gyration

This buckling mode is also referred to as "constrained-axis torsional buckling" in ANSI/AISC (2016). Due to the finite stiffness of the lateral bracing, it is recommended to limit P_{eyz} to 90% of the calculated value.

In case (1), since the girts provide discrete rather than continuous bracing, flexural buckling of the column about the weak axis should also be checked separately using S16-14 Clause 13.3.1 with the unsupported length taken as the girt spacing.

References:

ANSI/AISC. 2016. Specification for Structural Steel Buildings. American Institute of Steel Construction, Chicago, Illinois.
Ziemian, R. D. 2010. Guide to Stability Design Criteria for Metal Structures, 6th Edition. John Wiley and Sons

Question 2: How is the formula for M_u in S16-14 Clause 13.6(e) applied to a WT-section in bending with the stem in compression? And what value of β_x should be used?

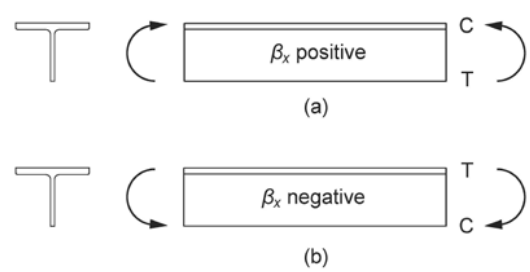

FIGURE 2
Laterally Unsupported WT-Section

Answer: The same formula for the elastic buckling moment, M_u, is used whether the WT stem is in compression or tension. The only difference is that the asymmetry parameter, β_x, is taken to be (a) positive when the flange is in flexural compression, and (b) negative otherwise (i.e. when the stem is in flexural compression), as shown in Figure 2. In case (b), the WT-section is less stable, and M_u will therefore be smaller than in case (a).

The values of βx listed in Part 6 of the Handbook of Steel Construction were calculated for WT-sections using the exact expression given in Part 2 (CISC Commentary on CSA S16-14). The formula for βx in Clause 13.6(e), on the other hand, is an approximation for singly-symmetric beams that is not valid for T-sections (according to the new CSA S16-19). AS

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