Modern Steel Construction's monthly *Steel Quiz* allows you to test your knowledge of steel design and construction. All references to LRFD specifications pertain to the 2005 *Specification for Structural Steel Buildings*, available as a free download from AISC's web site:

www.aisc.org/2005spec

ASD references pertain to the 1989 *ASD Specification for Structural Steel Buildings*. Where appropriate, other industry standards are also referenced.

Anyone is welcome to submit questions for *Steel Quiz*—one question or 10! If you or your firm are interested in submitting a *Steel Quiz* question or column, contact ▶

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This month's Steel Quiz continues the development of a Flexural Strength Chart in relation to Chapter F of the 2005 AISC *Specification for Structural Steel Buildings* (a free download at **www.aisc.org/2005spec**). **There are only nine questions this month.**

Orientation references to the "chart" in these questions assume that the ordinate represents the flexural strength of a beam and the abscissa represents the unbraced length of the beam.

1. **True/False:** All hot-rolled W-shapes with F_y 50 ksi are classified as flexural compact shapes?

2. What is the nominal flexural strength of a doubly-symmetric I-shaped compact flexural member bent about the major axis, when $L_b < L_p$? What is the location and orientation of the line representing this capacity on the "chart"?

3. What is the nominal flexural strength of a doubly-symmetric I-shaped compact flexural member bent about the major axis, when $\boldsymbol{L_p} < L_b < \boldsymbol{L_r}$? What is the location and orientation of the line representing this capacity on the "chart"?

4. What is the nominal flexural strength of a doubly-symmetric I-shaped compact member bent about the major axis when $L_b > L_r$? What is the location and orientation of the line representing the capacity on the "chart"?

5. What is the relationship between the available flexural strength and the nominal flexural strength of a structural member?

6. What is the effect of using a noncompact section as a flexural member?

7. What is the effect of using a slender web section as a flexural member?

8. How are the nominal flexural strengths of members bent about their minor axes and shapes other than I-shaped determined?

9. What is the designation and purpose of the modification factor for non-uniform moment diagrams?

Turn page for answers

Answers

1. **False**—A handful of W-shapes have flexural non-compact flanges for F_y = 50 ksi, but all have flexural compact webs. Section F3 of the 2005 *Specification* includes a user note indicating ten W-shapes (and one M-shape) with flexural non-compact flanges at $F_y = 50$ ksi. One of those W-shapes and the one M-shape also have flexural non-compact flanges at $F_y = 36$ ksi. As indicated in last month's Steel Quiz, all elements of the section must be flexurally compact for the section to be considered compact to facilitate plastic yielding.

2. The nominal flexural strength of a doubly-symmetric I-shaped compact flexural member bent about the major axis, when $L_b < L_p$ is that value obtained according to the limit state of yielding (plastic moment) as stipulated in Equation (F2-1) of the 2005 *Specification*. $M_n = M_p = F_yZ_x$. The limit state of lateral-torsional buckling does not apply in this case. This nominal flexural strength in the region where $M_n = M_p$ (plastic capacity of the section), is represented by a straight line at level M_p that extends from the ordinate line ($L_b = 0$) horizontally and parallel to the abscissa line ($M_n = 0$) to L_p (limiting laterally unbraced length for the limit state of yielding).

3. The nominal flexural strength of a doubly-symmetric I-shaped compact flexural member bent about the major axis, when $L_p < L_b < L_r$ is the lower value obtained according to the limit states of yielding (plastic moment) and inelastic lateral-torsional buckling. This is the lower of Equat ions (F2-1) or (F2-2) of the 2005 *Specification*. This nominal flexural strength in the region is represented by a straight line of diminishing capacity, proportional to unbraced length, and extending between L_p and L_r on the abscissa. The nominal flexural strength cannot exceed the smaller of the capacities determined by (F2-1) or (F2-2), therefore the ordinate cannot be greater than the horizontal line representing M_p or the sloping line representing (F2-2). The astute observer will recognize that Equation F2-2 is simply a straight-line interpolation between M_p, L_p and M_r, L_r.

4. The nominal flexural strength of a doubly-symmetric I-shaped compact flexural member bent about the major axis, when $L_b > L_r$ is the lower value obtained according to the limit states of yielding (plastic moment) and elastic lateral-torsional buckling. This is the lower of Equations (F2-1) or (F2-3) of the 2005 *Specification*. The nominal flexural strength in the region is represented by a concave curve starting at L_r that diminishes in a decreasing manner as the unbraced length L_b increases.

5. For LRFD, the available flexural strength is obtained by multiplying the nominal flexural strength M_n by a resistance factor ϕ to result in a design flexural strength ϕM_n. For ASD, the available flexural strength is obtained by dividing M_n by a safety factor Ω to result in an allowable flexural strength M_n/Ω.

6. A flexurally noncompact section will be subjected to local buckling after initial yielding and the inability to achieve a fully plastic section. Thus, the nominal flexural strength M_n cannot reach $M_p = F_yZ_x$.

M_n for doubly symmetric I-shaped members with compact webs and noncompact or slender flanges is the lower value obtained according to the limit states of lateral-torsional buckling (F2-2) or (F2-3) based on the unbraced length, and compression flange local buckling (F3-1) for sections with non-compact flanges ($\lambda_p \leq \lambda_{rf} \leq \lambda_r$) or (F3-2) for sections with slender flanges ($\lambda_{rf} > \lambda_r$).

M_n for other I-shaped members with compact or noncompact webs bent about their major axes, is the lowest value obtained according to the limit states of compression flange yielding (F4-1), lateral-torsional buckling (F4-2) or (F4-3) depending on unbraced length L_b, compression flange local buckling (F4-12) for sections with noncompact flanges or (F4-13) for sections with slender flanges, and tension flange yielding (F4-14).

7. There are no hot-rolled structural shapes that have flexurally slender webs. Typically slender webs are associated with plate girders. Section F5 of the 2005 *Specification* covers doubly symmetric and singly symmetric I-shaped members with slender webs attached to the mid-width of the flanges, bent about their major axes. The nominal flexural strength, M_n, for such members is the lowest value obtained according to the limit states of compression flange yielding (F5-1), lateral-torsional buckling (F5-2), compression flange local buckling (F5-7), and tension flange yielding (F5-10).

8. The nominal flexural strength, M_n, of I-shaped members and channels bent about their minor axes is stipulated in Section F6, and that for various other sections in Sections F7 through F13 of the 2005 *Specification*. It is important to note that lateral torsional buckling does not apply to a member bent about the weak axis. ★

9. C_b is a lateral-torsional buckling factor used to account for non-uniform moment diagrams of the flexural member when both ends of the unsupported segment are braced. The nominal flexural strength as defined by M_n based on C_b=1.0 corresponds to a uniform moment in the braced segment and can be used conservatively for all moment diagram shapes. However, when there is a moment gradient, C_b>1 can be determined by Equation (F1-1) based on the moment diagram of the applied load and support conditions, and is permitted to be used to modify M_n in the applicable capacity equation involving lateral-torsional buckling. Note that C_b cannot be used to increase the nominal flexural strength in excess of M_p, however. ★

Do you have an idea for *Steel Quiz*? Send it to:

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