The nominal strength is

$$P_n = F_{cr}A_g = 25.21(21.8) = 549.6 \text{ kips}$$

LRFD SOLUTION The design strength is

$$\phi_c P_n = 0.90(549.6) = 495 \text{ kips}$$

ASD SOLUTION From Equation 4.7, the allowable stress is

$$F_a = 0.6F_{cr} = 0.6(25.21) = 15.13 \text{ ksi}$$

The allowable strength is

$$F_a A_g = 15.13(21.8) = 330 \text{ kips}$$

ANSWER Design compressive strength = 495 kips. Allowable compressive strength = 330 kips.

In Example 4.2, $r_y < r_x$, and there is excess strength in the x-direction. Square structural tubes (HSS) are efficient shapes for compression members because $r_y = r_x$ and the strength is the same for both axes. Hollow circular shapes are sometimes used as compression members for the same reason.

The mode of failure considered so far is referred to as *flexural* buckling, as the member is subjected to flexure, or bending, when it becomes unstable. For some cross-sectional configurations, the member will fail by twisting (torsional buckling) or by a combination of twisting and bending (flexural-torsional buckling). We consider these infrequent cases in Section 4.8.

4.4 LOCAL STABILITY

The strength corresponding to any *overall* buckling mode, however, such as flexural buckling, cannot be developed if the elements of the cross section are so thin that *local* buckling occurs. This type of instability is a localized buckling or wrinkling at an isolated location. If it occurs, the cross section is no longer fully effective, and the member has failed. I-shaped cross sections with thin flanges or webs are susceptible to this phenomenon, and their use should be avoided whenever possible. Otherwise, the compressive strength given by AISC Equations E3-2 and E3-3 must be reduced. The measure of this susceptibility is the width-to-thickness ratio of each cross-sectional element. Two types of elements must be considered: unstiffened elements, which are unsupported along one edge parallel to the direction of load, and stiffened elements, which are supported along both edges.

Limiting values of width-to-thickness ratios are given in AISC B4.1, "Classification of Sections for Local Buckling." For compression members, shapes are classified as *slender* or *nonslender.* If a shape is slender, its strength limit state is local buckling, and the corresponding reduced strength must be computed. The width-to-thickness ratio is given the generic symbol λ. Depending on the particular cross-sectional element, λ for I shapes is either the ratio b/t or h/t_w, both of which are defined presently. If λ is greater than the specified limit (denoted λ_r), the shape is slender.

AISC Table B4.1a shows the upper limit, λ_r, for nonslender members of various cross-sectional shapes. If $\lambda \leq \lambda_r$, the shape is nonslender. Otherwise, the shape is slender. The table is divided into two parts: unstiffened elements and stiffened elements. (For beams, a shape can be *compact, noncompact,* or *slender,* and the limiting values of λ are given in AISC Table B4.1b. We cover beams in Chapter 5.) For I shapes, the projecting flange is considered to be an unstiffened element, and its width can be taken as half of the full nominal width. Using AISC notation gives

$$= \frac{b}{t} = \frac{b_f/2}{t_f} = \frac{b_f}{2t_f}$$

where b_f and t_f are the width and thickness of the flange. The upper limit is

$$_r = 0.56\sqrt{\frac{E}{F_y}}$$

The webs of I shapes are stiffened elements, and the stiffened width is the distance between the roots of the flanges. The width-to-thickness parameter is

$$= \frac{h}{t_w}$$

where h is the distance between the roots of the flanges, and t_w is the web thickness. The upper limit is

$$_r = 1.49\sqrt{\frac{E}{F_y}}$$

Stiffened and unstiffened elements of various cross-sectional shapes are illustrated in Figure 4.9. The appropriate compression member limit, λ_r, from AISC B4.1 is given for each case.