G. Design Equations and Procedure for Beam-Columns (Braced Frame)

There is no *standard* set of design steps but the following procedure may be suggested.

Step 1: Design Load

Moments should be computed at both the top and bottom of the column. M_{ntx} and M_{nty} are the maximum design moments in the x- and y-axis of the member.

$$\begin{aligned} P_u &= 1.2P_D + 1.6P_L \\ M_{ntx} &= 1.2M_{Dx} + 1.6M_{Lx} \\ M_{nty} &= 1.2M_{Dy} + 1.6M_{Ly} \end{aligned}$$

Step 2: Initial Member Selection. (Equivalent Axial Load Method)

Beam-column design is a trial and error process in which a trial section is checked for compliance with the AISC interaction equations (H1-1a) and (H1-1b). Initial guess of the member is made by using AISC Table 3-2 and the Column Tables. AISC/LRFD Specification (H1-a) can be rewritten, by multiplying each term by ϕP_n, as

$$P_u + \frac{8\phi P_n}{9\phi_b M_{nx}} M_{ux} + \frac{8\phi P_n}{9\phi_b M_{ny}} M_{uy} \le \phi P_n$$

or at the limit state,

$$P_u + \frac{8\phi P_n}{9\phi_b M_{nx}} M_{ux} + \frac{8\phi P_n}{9\phi_b M_{ny}} M_{uy} = \phi P_n$$

Multiplication of the third term by M_{nx}/M_{nx} and letting

$$m = \frac{8\phi P_n}{9\phi_b M_{nx}} \qquad \text{and} \qquad u = \frac{M_{nx}}{M_{ny}}$$

the equivalent load (P_{ueq}) is obtained

$$P_u + mM_{ux} + muM_{uy} = \phi P_n = P_{ueq}$$

where the values m (bending factor) are found in the AISC Table 3-2 and u are obtained by guessing from the Column Tables.

Step 3: Check member.

(a) **Column Effect:** Calculate the axial strength = $\phi_c P_n$. It is useful to compute the slenderness parameter λ_c for both the x- and y-axis for steps (d) and (e):

$$\lambda_{cx} = \frac{K_x L_x}{r_x}\sqrt{\frac{F_y}{\pi^2 E}}$$

$$\lambda_{cy} = \frac{K_y L_y}{r_y}\sqrt{\frac{F_y}{\pi^2 E}}$$

(b) **Beam Effect** (x-direction): Calculate the bending design strength = $\phi_b M_{nx}$ for the x-axis. Check both LB and LTB.

(c) **Beam Effect** (y-direction): Calculate the bending design strength = $\phi_b M_{ny}$ for the y-axis. This analysis is similar to step (b) except that y-axis properties (S_y and Z_y) are used. Consider only LB in the flange since there will be no LTB in the y-axis.

(d) **Moment Magnification** (x-axis direction): Calculate C_{mx} for the x-axis moments using:

$$C_{mx} = 0.6 - 0.4\left(\frac{M_1}{M_2}\right)_x \qquad \text{(H1-4)}$$

Here, M_1 and M_2 are the end moments with the condition $|M_1| \leq |M_2|$ and the sign of the value M_1/M_2 is:

$$\left(M_1/M_2\right)_x > 0 \qquad \text{for reverse curvature}$$

$$\left(M_1/M_2\right)_x \leq 0 \qquad \text{for single curvature}$$

Calculate B_{1x} for the x-axis using the formula:

$$B_{1x} = \frac{C_{mx}}{1 - P_u/P_{e1x}} \geq 1 \qquad \text{(H1-3)}$$

The Euler buckling load, P_{e1x}, is calculated using the x-axis properties regardless of which axis is weaker:

$$P_{e1x} = \frac{\pi^2 E A_g}{K_x L_x} = \frac{F_y A_g}{\lambda_{cx}^2}$$

(e) **Moment Magnification** (y-axis direction): Repeat step (d) for the y-axis using the formulas:

$$C_{my} = 0.6 - 0.4 \left(\frac{M_1}{M_2} \right)_y \qquad \text{(H1-4)}$$

$$B_{1y} = \frac{C_{my}}{1 - P_u / P_{e1y}} \geq 1 \qquad \text{(H1-3)}$$

The Euler buckling load, P_{e1y}, is calculated using the y-axis properties regardless of which axis is weaker:

$$P_{e1y} = \frac{\pi^2 E A_g}{K_y L_y} = \frac{F_y A_g}{\lambda_{cy}^2}$$

(f) **Interaction:**
If $P_u / \phi_c P_n \geq 0.2$ then

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9} \left(\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}} \right) = \text{interaction ratio} \leq 1 \qquad \text{(H1-1a)}$$

If $P_u / \phi_c P_n < 0.2$ then

$$\frac{P_u}{2 \phi_c P_n} + \left(\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}} \right) = \text{interaction ratio} \leq 1 \qquad \text{(H1-1a)}$$

(g) **Redesign:** If the interaction ratio falls in the range between 0.95 and 1.0, then no redesign may be necessary. Otherwise, it is necessary to check a new section using the general formula:

$$\text{New Weight} = \text{Old Weight} \times \frac{\text{Load}}{\text{Capacity}} = \text{Old Weight} \times \text{Interaction}$$