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. $M_{n_{tx}}$ and $M_{n{ty}}$ are the maximum design moments in the $x$- and $y$-axis of the member.

- $P_u = 1.2P_d + 1.6P_L$
- $M_{n{tx}} = 1.2M_{Dx} + 1.6M_{Lx}$
- $M_{n{ty}} = 1.2M_{Dy} + 1.6M_{Ly}$

**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 $\phi P_n$, as

$$P_u + \frac{8\phi P_n}{9\phi_b M_{n,x}} M_{u,x} + \frac{8\phi P_n}{9\phi_b M_{n,y}} M_{u,y} \leq \phi P_n$$

or at the limit state,

$$P_u + \frac{8\phi P_n}{9\phi_b M_{n,x}} M_{u,x} + \frac{8\phi P_n}{9\phi_b M_{n,y}} M_{u,y} = \phi P_n$$

Multiplication of the third term by $M_{n,x}/M_{n,x}$ and letting

$$m = \frac{8\phi P_n}{9\phi_b M_{n,x}} \quad \text{and} \quad u = \frac{M_{n,x}}{M_{n,y}}$$

the equivalent load ($P_{ueq}$) is obtained

$$P_u + mM_{u,x} + muM_{u,y} = \phi P_n = P_{ueq}$$

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 \( \lambda_c \) 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:

\[
C_{mx} = 0.6 - 0.4 \left( \frac{M_1}{M_2} \right)_x
\]

(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:

\[
(M_1/M_2)_x > 0 \quad \text{for reverse curvature}
\]
\[
(M_1/M_2)_x \leq 0 \quad \text{for single curvature}
\]

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

\[
B_{1x} = \frac{C_{mx}}{1 - P_u/P_{e1x}} \geq 1
\]

(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:

\[
C_{my} = 0.6 - 0.4 \left( \frac{M_1}{M_2} \right)_y
\]  
(H1-4)

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

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

\[
P_{e1y} = \frac{\pi^2 EA_g}{K_y L_y} = \frac{F_y A_g}{2 \chi_{cy}^2}
\]

(f) **Interaction:**

If \( P_u / \phi_c P_n \geq 0.2 \) then

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

If \( P_u / \phi_c P_n < 0.2 \) then

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

(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:

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