The requirements for design of structures for stability using the Direct Analysis Method are specified in Chapter C of the AISC Specification for Structural Steel Buildings (p 16.1-20). Most of the provisions pertain to calculation of the required strength (e.g. $M_u$). Calculation of the available strength (e.g. $\phi M_n$) is as specified in Chapters D through K with the exception that the effective length factor ($K$) is taken as unity.

The bending moments from factored loads, $M_u$, must include secondary moments which arise through the interaction of compressive forces and bending moments on a member. Secondary moments arise due to axial forces acting on member deflections. Secondary moments associated with member deflections between brace points are called P-$\delta$ effects (P-“little delta” effects), and secondary moments associated with joint displacements due to frame sidesway are called P-$\Delta$ effects (P-“big delta” effects).

Various procedures are presented by AISC for considering secondary moments. The Direct Analysis Method is presented in Chapter C and the alternate methods (the Effective Length Method and the First-Order Analysis Method) are presented in the appendix. Key features of the Direct Analysis Method include:

- A computer structural analysis program capable of performing a second-order analysis that considers both P-$\Delta$ and P-$\delta$ effects is required.
- The flexural stiffness, $EI$, and the axial stiffness, $EA$, of all members that contribute to the lateral stability of the structure are reduced to account for the effects of residual stresses.

$$EI^* = 0.8 \, t_b \, EI$$

$$EA^* = 0.8 \, EA$$

where: $t_b = 1.0$ if $P_u / P_Y \leq 0.5$, else $t_b = 4 \left( P_u / P_Y \right) \left[ 1 - P_u / P_Y \right]$ alternatively, $t_b$ can = 1.0 always if an additional notional load = 0.001 $Y$, to the notional load specified in the paragraph below.
- Notional ("imaginary) lateral loads equal to 0.002 times the gravity loads are added to account for "out of plumbness" of columns (top of column is not directly over the bottom) and curvature of columns (column is not completely straight).

\[ N_i = 0.002 Y_i, \quad Y_i = \text{factored gravity load for Level } i \text{ of frame} \]

![Diagram showing out-of-plumbness tolerance](image)

**Figure 2.** AISC construction out-of-plumbness tolerance

The origin of the 0.002 \( Y_i \) notional loads are demonstrated below.

\[
\begin{align*}
\sum M_{base} &= 0 \\
P \cdot \Delta &= V \cdot L \\
V &= \frac{P \Delta}{L} = \frac{PL}{500L} = \frac{P}{500} = 0.002P
\end{align*}
\]

Notional loads need not be applied to load combinations with lateral loads if the ratio of the second-order story drift to the first-order story drift is less than 1.7 (C2.2b (4), p 16.1-23).

We will use the structural analysis program RISA3D to help us analyze steel frames using the Direct Analysis procedure. RISA3D can perform a P-\( \Delta \) analysis (based on nodal deflections) but not a P-\( \delta \) analysis (based on member deflections). We will add intermediate nodes (typically three) to columns to approximate a rigorous P-\( \delta \) analysis. RISA will reduce the flexural and axial stiffnesses of appropriate members, including iterative calculation of \( \tau_b \), to calculate secondary moments. Notional lateral loads equal to 0.002 times the total factored gravity load will need to be added for load combinations with no lateral loads or with second-order drift / first-order drift > 1.7.