FlowChart for Determining Column Slenderness Effects

1st Order Analysis

1st order analysis
10.14.1.1

Sidesway Consideration

Sway or Nonsway?

Nonsway if:

$$Q = \frac{\Sigma P_f \times \Delta_o}{V_f \times l_c} \leq 0.05 \qquad 10.14.4$$

Sway

Nonsway

Slenderness Consideration

Neglect Slenderness?

All columns in sway frames should be designed for slenderness.

No

Yes

Only 1st order analysis required
10.14.1.1

Neglect Slenderness?

Neglect slenderness if:

$$\frac{kl_u}{r} \leq \frac{25 - 10(M_1/M_2)}{\sqrt{P_f/(f_c' A_g)}} \quad \text{Eq. 10.16}$$

$$M_1/M_2 \geq -0.5$$

No

Slenderness Effects at Column Ends

Slenderness Effects at Column Ends

1. Moment Magnification Method:

$$M_1 = M_{1ns} + \delta_s M_{1s} \qquad \text{Eq. 10.22}$$

$$M_2 = M_{2ns} + \delta_s M_{2s} \qquad \text{Eq. 10.23}$$

$$\delta_s = \left\{ \begin{matrix} \frac{1}{1 - 1.2Q} \\ \frac{1}{1 - \frac{\Sigma P_f}{\phi_m \Sigma P_c}} \end{matrix} \right\} \qquad 10.16.3$$

$$Q = \frac{\Sigma P_f \times \Delta_o}{V_f \times l_c} \qquad 10.14.4$$

$$P_c = \frac{\pi^2 EI}{(kl_u)^2} \qquad \text{Eq. 10.18}$$

$$EI = \left\{ \begin{matrix} \frac{0.2E_c I_g + E_s I_{st}}{1 + \beta_d} & \text{Eq. 10.19} \\ \frac{0.4E_c I_g}{1 + \beta_d} & \text{Eq. 10.20} \end{matrix} \right\}$$

$$\beta_d = \frac{V_{f,sustained}}{V_f} \qquad 3.2$$

2. Elastic 2nd Order Analysis 10.16.3.1

3. Nonlinear 2nd Order Analysis 10.13.1

Slenderness Effects at Column Ends

Not Applicable

$M_1 = lesser\ first\ order\ factored\ end\ moment$

$M_2 = greater\ first\ order\ factored\ end\ moment$

$M_{2,min} = P_f(15 + 0.03h)$

$M_1/M_2 in\ Eq.10.16\ shall\ be\ taken\ as\ 1.0\ if\ M_2 < M_{2,min}$

Slenderness Effects along Column Length

Neglect Slenderness?

Neglect if:

$$\frac{l_u}{r} \leq \frac{35}{\sqrt{P_f/(f_c' A_g)}} \qquad \text{Eq. 10.26}$$

No

Yes

Slenderness Effects along Column Length

1. Moment Magnification Method:

$$M_c = \frac{C_m M_2}{1 - \frac{P_f}{\phi_m P_c}} \geq M_2 \qquad \text{Eq. 10.17}$$

$Where\ M_2 \geq M_{2,min}$

$$P_c = \frac{\pi^2 (EI)_{eff}}{(kl_u)^2} \qquad \text{Eq. 10.18}$$

$$(EI)_{eff} = \left\{ \begin{matrix} \frac{0.2E_c I_g + E_s I_{st}}{1 + \beta_d} & \text{Eq. 10.19} \\ \frac{0.4E_c I_g}{1 + \beta_d} & \text{Eq. 10.20} \end{matrix} \right\}$$

$$\beta_d = \frac{P_{f,sustained}}{P_f} \qquad 10.15.3.1$$

$$C_m = \left\{ \begin{matrix} 0.6 - 0.4\frac{M_1}{M_2} \geq 0.4 \\ 1 \end{matrix} \right\} \qquad \begin{matrix} \text{Eq. 10.21} \\ 10.15.3.3 \end{matrix}$$

$C_m\ in\ Eq.10.21\ shall\ be\ taken\ as\ 1.0\ if\ M_2 < M_{2,min}$

2. Elastic 2nd Order Analysis 10.16.3.1

3. Nonlinear 2nd Order Analysis 10.13.1

Lateral Stability

Laterally Stable?

The column is laterally stable if:

$$\frac{\Delta_{2nd}}{\Delta_{1st}} \leq 2.5 \quad 10.16.5\ a$$

$$\delta_s \leq 2.5 \quad 10.16.5\ b$$

Yes

Design Column for 2nd Order Moment

No

Revise Structural System

Reference: CSA A23.3-19