1. Calculate unfactored axial forces and moments for the columns in the frame due to DL, LL and WL. Use as a minimum the following two load combinations:

   LC I: 1.2D + 1.6L + 0.5L_r  (ACI 9-2) (largest total gravity load)
   LC II: 1.2D + 1.01L + 0.5L_r + 1.62W  (ACI 9-4) (largest gravity load and sidesway loads)

2. Determine the preliminary column size using the load combination with the largest factored gravity loads.

   \[ A_g \approx \frac{P_u}{.45(f'_c + \rho f_y)} \]

   let \( \rho = 1.5\% \), round up each column dimension to the nearest even number

3. Determine if the frame is sway or non-sway.

   Method 1, computer analysis: the column is slender if the increase in column-end moments due to second-order effects (P-\(\Delta\)) is \( > 0.05 \)

   Method 2, hand calculations: the frame is a sway frame if \( Q = \sum \frac{P_u \Delta_o}{V_u l_c} > 0.05 \)

   \( P_u \) = the total factored vertical load on a story
   \( V_u \) = the factored horizontal shear on a story
   \( \Delta_o \) = the relative story deflection due to \( V_u \)
   \( l_c \) = the column height, measured from center-of-joint to center-of-joint

   In modeling the frame, use:

   \( I_g \approx 2b_wh^3/12 \) for T-beams

   \( I_{beams} = 0.35 I_g \)

   \( A_{beam} = 2b_wh \)

   \( I_{col} = 0.7 I_g \)

   \( A_{col} = A_g \)

4. Determine if the column is slender

   a. For non-sway frames, the column is slender if \( \frac{k l_u}{r} > 34 - 12 \left( \frac{M_1}{M_2} \right) \leq 40 \)

   \( k = \) the effective length factor. \( k \) is a function of the rotational restraint at the column ends. Column ends with large rotational restraint \( \rightarrow \) small \( \psi \) \( \rightarrow \) small effective length factor.

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1 May be reduced to 0.5 except for garages, places of public assembly and when \( L > 100 \) psf
2 May be reduced to 1.3 if wind directionality factor has not been applied
\[ \psi = \frac{\sum EI_{\text{col}}}{l_c} \frac{1}{\sum EI_{\text{beam}}} \]

where \( l_c \) and \( l \) are the lengths of the column and beam, respectively, measured center-of-joint to center-of-joint.

\( k \) is calculated using the alignment chart on pg 127 in ACI.

\( l_u \) = the unsupported length of the compression member in inches

\( r = \) the radius of gyration \( \approx 0.3h \) for rectangular columns

\( M_2 \) is the larger between \( M_1 \) and \( M_2 \)

\( \frac{M_1}{M_2} \) is positive if the column is in single curvature, and negative if the column is in double curvature

b. For sway frames, the column is slender if \( \frac{k l_u}{r} > 22 \).

5. Calculate the factored moments (\( M_u \)) for each load combination. If the column is slender and it is part of a

a. non-sway frame then:

\[ M_u = M_c = \delta_{ns} M_2, \text{ where} \]

\( \delta_{ns} \) = moment magnification factor for frames braced against sidesway to reflect effects of member curvature between ends of compression member

\[ \delta_{ns} = \frac{C_m}{1 - \frac{P_u}{0.75P_c}}, \quad P_c = \frac{\pi^2 EI}{(kl_u)^2}, \quad EI = \frac{0.4E_c I_g}{1 + \beta_d}, \quad \beta_d \]

\( \beta_d \) reflects the increased lateral deflections of a column due to creep

\[ \beta_d = \frac{\text{factored sustained axial load}}{\text{factored total axial load}} \]

\[ C_m = 0.6 + 0.4 \frac{M_1}{M_2} \geq 0.4, \quad C_m = 1.0 \text{ for columns with transverse loads} \]

the min. \( M_2 \) in the equation for \( M_c \) above = \( P_u(0.6 + 0.03h) \)
b. sway frame then:

\[ M_u = \text{larger of the moments at the column ends, } = \max[M_1, M_2] \] where:

\[ M_1 = M_{1ns} + \delta_s M_{1s} \]
\[ M_2 = M_{2ns} + \delta_s M_{2s} \]

where \( M_{ns} \) = the factored moment due to loads that cause no appreciable sidesway
calculated by a first-order analysis

i) \( \delta_s M_s \) can be calculated three different ways according to ACI, two of which are
shown below.

Method 1: \( \delta_s M_s \) can be calculated by a computer program using a second-order (P-\( \Delta \))
analysis

Method 2 (Method 3 in ACI): \( \delta_s \) can be calculated by hand using ACI Eqn 10-18

\[ \delta_s = \frac{1}{1 - \frac{\sum P_u}{0.75 \sum P_c}} \geq 1.0, \]

where \( \sum P_u = \text{the sum of } P_u \text{ for the story and} \)
\( \sum P_c = \text{the sum of } P_c \text{ for all the sway–resisting columns in a story} \)

ii) The maximum moment occurs between the column ends if

\[ \frac{l_u}{r} \geq \frac{35}{f'c A_g} \]

If the max. moment occurs between the column ends, then

\[ M_u = \delta_{ns} M_2 = \delta_{ns}(M_{2ns} + \delta_s M_{2s}) \]

where \( \delta_{ns} \) is calculated following the procedure for columns in non-sway frames

iii) check for instability under gravity loads alone

iv) If the magnified moments were calculated using a computer program (ACI 10.14.4.1), then

\( \Delta_{LC}^{I + \text{any Lat}} \text{ from 2}^{\text{nd}}-\text{order analysis} \text{ must be } < 2.5 \Delta_{LC}^{I + \text{any Lat}} \text{ from 1}^{\text{st}}-\text{order analysis. Any lateral load may be used to cause the sidesway.} \)

v) If the magnified moments were calculated using hand calculations (ACI 10.13.4.3)

the moment magnifier (\( \delta_s \)) must be < 2.5