

Designing Concrete Structures:

Reinforced Rectangular Concrete Column Interaction Diagram Example



Photograph courtesy of Dan Mullins with Martin and Martin

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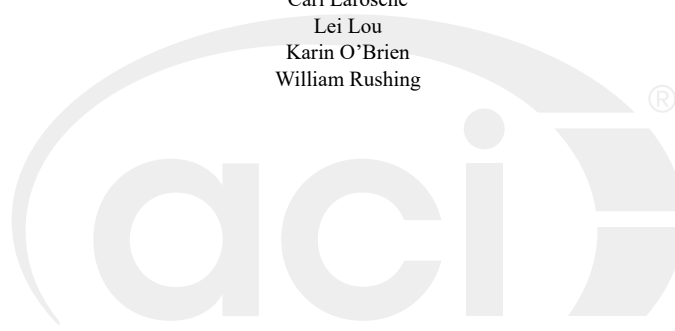
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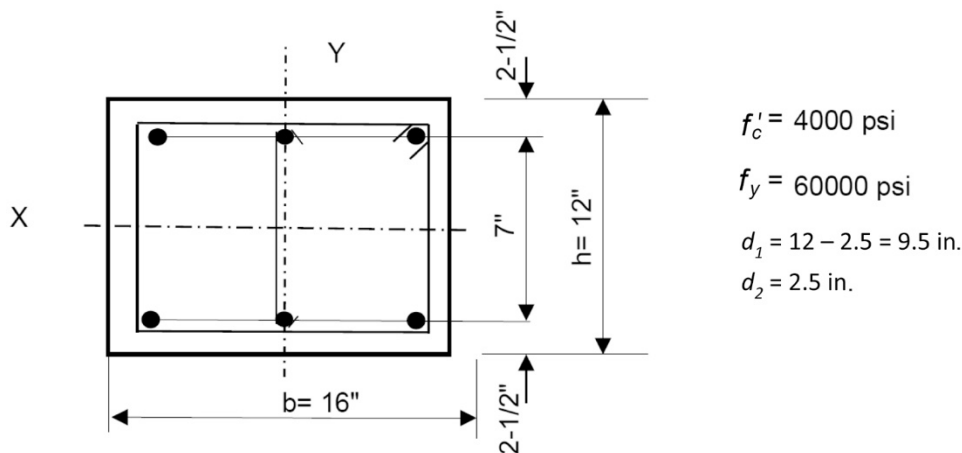
ACI E702.9-22 Designing Concrete Structures:
Reinforced Rectangular Concrete Column Interaction
Diagram Example.

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Problem Statement: Draw an interaction diagram for 16 x 12 in. nonslender tied column reinforced with six No. 8 vertical bars and No. 3 ties at 12 in. on center bending around its x-axis.



Notes		ACI 318-19 Reference
Calculate ϕP_{nmax}	Because concrete structures placed monolithically are continuous, a minimum eccentricity or minimum moment is assumed in this calculation. The Code reduces the maximum axial load by 20% to account for this minimum moment. $\max. P_n = 0.80 P_0$ $\phi P_n = 0.8 \phi \left[0.85 f'_c (A_g - A_{st}) + A_{st} f_y \right] \quad \text{Eq. (1-1)}$ $A_g = b \times h = 16 \text{ in.} \times 12 \text{ in.}$ $A_g = 192 \text{ in.}^2$ (Area of 1 - #8 bar = 0.79 in.²) $A_{st} = (6 \times 0.79) = 4.74 \text{ in.}^2$ $\phi = 0.65$	10.4, 22.4 22.4.2.1(a) 22.4.2.1, 22.4.2.2 Eq. (22.4.2.2) Appendix A
Find ϕ	$\phi P_n = 0.8(0.65) \left[0.85(4 \text{ ksi})(192 \text{ in.}^2 - 4.74 \text{ in.}^2) + 4.74 \text{ in.}^2 (60 \text{ ksi}) \right]$ $\phi P_{nmax} = 479.0 \text{ kip}$ A concrete column interaction diagram consists of numerous points corresponding to different strains in the reinforcement. To calculate each point, the designer must calculate the axial load (P_n) and moment (M_n) corresponding to each specific strain.	21.2.2

	Each steel strain is selected by multiplying an arbitrary “Z” factor and the yield strain of your steel. $\epsilon_{s1} = Z \times \epsilon_y \quad \text{Eq. (1-2)}$ The Z factors can range from 1 to -1000 and increments between Z depend on the required detail of diagram—the smaller the increment, the more detailed the diagram will be. For this example, points will be calculated in the compression-controlled zone (one with the column entirely in compression), the tension-controlled zone, and the transition zone. With the wide range of possible Z factors, four major points are calculated to determine an interaction diagram. These four-point Z factors are 0, -0.5, -1.0, and -2.5. $Z = 0(\epsilon_{s1} = 0)$: Strain $\epsilon_t = 0$ in extreme layer in tension. This point may change from compression lap splice being allowed on all longitudinal steel a tension lap splice. $Z = -0.5(f_{si} = -0.5f_y, \epsilon_{s1} = -0.5\epsilon_y)$: This strain distribution affects the length of the tension lap splice in a column and is customarily plotted on an interaction diagram. $Z = -1.0(f_{si} = -f_y, \epsilon_{s1} = -\epsilon_y)$: This is the point of balanced failure. This strain distribution marks the change from compression failures originating by crushing of the compression surface of the section to tension failures initiated by the longitudinal reinforcement. $\epsilon_{s1} = -\epsilon_y$ marks the beginning of transition zone for ϕ for columns in which the strength reduction factor increases from 0.65 or 0.70 for spirally tied columns up to 0.90. $Z = -2.5(f_{si} = -f_y, \epsilon_{s1} = -0.005 \text{ for } 60 \text{ ksi steel})$: This point corresponds to the tension strain limit of 0.005.	
Compression controlled zone	For this example, points will be calculated in the compression-controlled zone, (one with the column entirely in compression) ($Z = 0.9, -0.5$), the tension-controlled zone ($Z = -5.0$) and the transition zone ($Z = -1.1$). $\epsilon_{s1} \geq \epsilon_y$ $\epsilon_y = \frac{f_y}{E_s} \quad \text{Eq. (1-3)}$ Strain in reinforcement and concrete shall be assumed directly proportional to the distance from the neutral axis C.	21.2.2 22.2.1.2

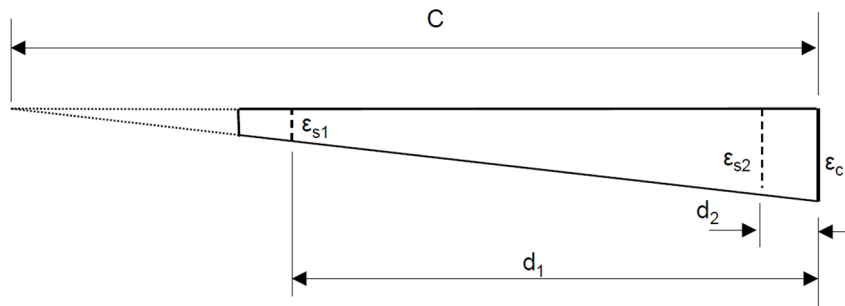


Figure 1.1 - Strain curve for a column entirely in compression

Calculate ϕP_n and ϕM_n for point in compression-controlled zone and column entirely in compression.

Given:

$$d_1 = 9.50 \text{ in.} \quad E_s = 29,000 \text{ ksi}$$

$$d_2 = 2.50 \text{ in.} \quad A_{s1} = (3)(0.79 \text{ in.}^2) = 2.37 \text{ in.}^2$$

$$A_{s2} = (3)(0.79 \text{ in.}^2) = 2.37 \text{ in.}^2$$

$$Z = 0.9$$

$$\varepsilon_c = 0.003$$

22.2.2.1

Calculate ε_y and ε_{s1} , using Eq. (1-2) and (1-3).

Calculate ε_{s1} strain in first row of steel.

$$f_y = E_s \varepsilon_y \therefore \varepsilon_y = \frac{f_y}{E_s} = \frac{60 \text{ ksi}}{29,000 \text{ ksi}}$$

20.2.2.1

$$\varepsilon_y = 0.00207$$

20.2.2.2

$$\varepsilon_{s1} = 0.9(0.00207)$$

$$\varepsilon_{s1} = 0.00186$$

As shown in Fig. 1.1: c (distance from extreme compression fiber to neutral axis) can be calculated using similar triangles.

Calculate c

$$c = 0.003 \left(\frac{d_1}{0.003 - \varepsilon_{s1}} \right) = 0.003 \left(\frac{9.5 \text{ in.}}{0.003 - 0.00186} \right) \quad \text{Eq. (1-4)}$$

22.2.2.1

$$c = 25.05 \text{ in.}$$