1 Design Parameters

1.1 Design Load

$$M_u = 100.0 \text{ k-ft}$$

1.2 Design Parameters

Steel Properties		
f_y (ksi)	ϵ_y	E_s (ksi)
60.0	0.002	29000.0

Concrete Properties		
f'_c (ksi)	ϵ_c	β
6.0	0.003	0.75

Section Properties		
b (in)	h (in)	d (in)
12.0	18.0	16.0

2 Calculate Balanced Reinforcement Ratio

2.1 Balanced Reinforcement Ratio

$$\xi_b = \frac{\epsilon_c}{\epsilon_c + \epsilon_y} = \frac{0.003}{0.003 + 0.002} = 0.6$$

$$\rho_b = 0.85 \cdot \beta \frac{f'_c}{f_y} \cdot \xi_b = 0.85 \cdot 0.75 \frac{6.0 \text{ ksi}}{60 \text{ ksi}} \cdot 0.6 = 0.03825$$

2.2 Ensure Tension Controlled Section

$$\xi_{lim} = \frac{\epsilon_c}{\epsilon_c + 0.005} = \frac{0.003}{0.003 + 0.005} = 0.375$$

$$\rho_{lim} = 0.85 \cdot \beta \frac{f'_c}{f_y} \cdot \xi_{lim}$$
$$\rho_{lim} = 0.85 \cdot 0.75 \frac{6.0 \text{ ksi}}{60 \text{ ksi}} \cdot 0.375 = 0.02390625$$

$$x_{lim} = \xi_{lim} \cdot d = 0.375 \cdot 16.0 \text{ in} = 6.0 \text{ in}$$

3 Determine Required Reinforcement

3.1 Find Maximum Strength of Singly Reinforced Section

$$M_{u,lim} = \phi \cdot 0.85 \cdot f'_c \beta \text{ b} x_{lim} \left(\text{d} - \beta \frac{x_{lim}}{2} \right)$$

$$M_{u,lim} = 0.9 \cdot 0.85 \cdot (6.0\text{ksi})(0.75)(12.0 \text{ in})(6.0 \text{ in}) \left(16.0 \text{ in} - 0.75 \frac{6.0 \text{ in}}{2} \right) \cdot \frac{12 \text{ in}}{\text{ft}}$$

$$M_{u,lim} = 284.0 \text{ k-ft}$$

3.2 Calculate Required Reinforcement

$M_u \leq M_{u,lim} \Rightarrow$ Positive Reinforcement Required

$$A_s = \frac{0.85 f'_c \beta x_{na} b}{\sigma_s} = \frac{0.85(6.0 \text{ ksi}) 0.75 (1.9 \text{ in})(12.0 \text{ in})}{(60 \text{ ksi})}$$

$$A_s = 1.45 \text{ in}^2$$

Required Reinforcement by Bar Size

Bar No.	A_b(in^2)	No. Pos. Bars	No. Neg. Bars	Pos. Bar Spacing (in)	Neg. Bar Spacing (in)
3.0	0.11	14.0	0.0	0.86	0.0
4.0	0.20	8.0	0.0	1.50	0.0
5.0	0.31	5.0	0.0	2.40	0.0
6.0	0.44	4.0	0.0	3.00	0.0
7.0	0.60	3.0	0.0	4.00	0.0
8.0	0.79	2.0	0.0	6.00	0.0
9.0	0.99	2.0	0.0	6.00	0.0
10.0	1.23	2.0	0.0	6.00	0.0
11.0	1.48	1.0	0.0	12.00	0.0
14.0	2.41	1.0	0.0	12.00	0.0
18.0	3.98	1.0	0.0	12.00	0.0