Design a one-way slab for an exterior bay of a multi-story office building using the information specified below.

Assume partitions will not be damaged by deflections. Round slab thickness up to the nearest 1/4”.

- \( w^{SD} = 20 \text{ psf} \)
- \( w^{LL} = 80 \text{ psf} \)
- \( f_c = 4000 \text{ psi} \)
- \( f_y = 60,000 \text{ psi} \)
- \( t_{stab} = ? \)
- \( b_w \text{ of beam} = 16 \text{ in} \)
- span = 80 ft
- beam spacing = 16 ft

**Plan View of Floor System**
1) Slab Thickness, \( t \)

Use ACI Table 9.5(a): \( h_{\text{min}} = \frac{L}{28} \)

\( L \) = distance from center of support to center of support = beam spacing = 16 ft

\( h_{\text{min}} = \frac{(16' \times 12''/')}{28} = 6.857 '' \),

\( \text{use } h = 7.0'' \)

2) Design Flexure Reinforcement at each Section

--- Section @ Midspan ---

2.1 Flexural Strength

2.1.1 \( M_u \)

ACI moment coefficient = 16 (ACI 8.3.3)

\[
M_u = w_u \frac{l^2}{16}
\]

\[
w_u = 1.2(w_{\text{self}} + w_{\text{SD}}) + 1.6w'
\]

\[
w_{\text{self}} = (0.150k)\left(\frac{12''}{12''/'}\right)\left(\frac{7''}{12''/'}\right) = 0.0875\text{k}\text{l}/\text{f} \\
\]

\[
w_u = 1.2[0.0875\text{k} + (0.02k)\text{l}'] + 1.6(0.08k)\text{l}', \quad w_u = 0.257\text{k}\text{l}/\text{f} \\
\]

\( l_n = \text{clear span} = \text{beam spacing} - b_{\text{w of beam}} = 16' - \frac{16''}{12''/1} = 14.67 \text{ ft} \)

\[
M_u = (0.257k)\left(\frac{14.67'}{12''/1}\right)^2 = 3.46k\text{ft} \\
\]

2.1.2 As for \( \phi M_n > M_u \)

Using spreadsheet, can use:

\#4 @ 18'', \( A_s = 0.133 \text{ in}^2 / \text{ft} \)

\#3 @ 9'', \( A_s = 0.147 \text{ in}^2 / \text{ft} \)

Use \#3 @ 9'' (better distribution), \( A_s = 0.147 \text{ in}^2 / \text{ft} \)

Calc. \( \phi M_n \)

\( d_{\text{max}} = 7'' - (0.75'' + \frac{1}{2}(3''/8)) = 6.06'' \),

\( \text{use } d = 6.0'' \)

\[ \Sigma F_H = 0, \ C = T \]

0.85 \( f_c \ a \ b = A_s \ f_y \), \ Assume steel yields

0.85 (4 ksi) a (12'') = (0.147 in\(^2\)) (60 ksi),

\( a = 0.216'' \)
0.003 = \varepsilon_s + 0.003  \\
\frac{y_i}{d} \\
0.003 = \varepsilon_s + 0.003  \\
\frac{0.216''}{6.0''} = \varepsilon_s \\
\varepsilon_s = 0.0678

Therefore:

- Steel has yielded ($\varepsilon_s > \varepsilon_y = 0.002$)
- $\phi = 0.90$ ($\varepsilon_t > 0.005$)

\[ \phi_M = \phi A_s f_y (d - a/2) = (0.90)(0.147\text{ in}^2)(60 \text{ ksi}) \left( (6.0'' - 0.216''/2) \right) 1'/12'' \]
\[ \phi M_n = 3.89 \text{ k-ft} \]
\[ \phi M_n = 3.89 \text{ k-ft} > 3.46 \text{ k-ft} = M_u, \text{ OK} \]

### 2.2 Check for Ductile Failure

Under-reinforced if $A_s < A_{s\text{,min}}$

$A_{s\text{,min}} = 0.0018 b h$ (ACI 7.12.2.1)

$A_{s\text{,min}} = 0.0018 (12'')(7''), \quad A_{s\text{,min}} = 0.151 \text{ in}^2$

$A_s = 0.147 \text{ in}^2 < 0.151 \text{ in}^2 = A_{s\text{,min}}$, NG

Use #3 @ 8'', $A_s = 0.165 \text{ in}^2$

Over-reinforced if $\varepsilon_t < 0.004$ (ACI 10.3.5)

Re-compute $\varepsilon_t$ since $A_s$ has changed

\[ 0.003 = \frac{\varepsilon_t + 0.003}{d} \]
\[ a = 0.85 f_{y}^c ab = A_s f_y \]
\[ 0.85(4^{k_{y}}) a (12^{k_{in}}) = (0.165 in^2)(60 ksi), \quad a = 0.243 \text{ in} \]
\[ 0.003 = \frac{\varepsilon_t + 0.003}{6 \text{ in}}, \quad \varepsilon_t = 0.0600 \]
\[ \varepsilon_t = 0.0600 > 0.004, \text{ OK} \]

### 2.3 Check Distribution of Reinforcement

max spacing = min[ 3h, 18'' ] \quad ACI 7.12.2.2

max spacing = min[ 3 x 7'', 18''] = 18''

spacing = 8'' < 18'', \text{ OK}
Section @ Ext. Face of 1st Interior Support

2.1 Flexural Strength

2.1.1 $M_u$

$$M_u = \frac{w}{10} \left( \frac{0.257 \times \frac{1}{4}}{(14.67)^2} \right) = 5.53 \text{ k-ft}$$

2.1.2 As for $\phi M_n > M_u$

Carry $\frac{1}{2}$ of mid-span reinforcement full length of beam and through supports

$A_s'$: $\frac{1}{2}$ of #3 @ 8” = #3 @ 16”

Using spreadsheet, can use:

- #5 @ 18”, $A_s = 0.207 \text{ in}^2 / \text{ft}$
- #3 @ 6”, $A_s = 0.220 \text{ in}^2 / \text{ft}$

Use #3 @ 6” (better distribution), $A_s = 0.220 \text{ in}^2 / \text{ft}$

Calc. $\phi M_n$

$$d_{\text{max}} = 7” - (0.75” + \frac{1}{2}(3”/8)) = 6.06”$$

$$d' = 0.75” + \frac{1}{2}(3/8 \text{ in}) = 0.9378”$$

from spreadsheet: $y_t = 0.381”$

$a = b_1 y_t = 0.85 (0.381”) = 0.329”$

$$\frac{0.003}{y_t} = \frac{\varepsilon_s + 0.003}{d}$$

$$\frac{0.003}{y_t} = \frac{\varepsilon_s + 0.003}{6.0”}$$

$$\varepsilon_s = 0.0442$$

Therefore:

- Steel has yielded ($\varepsilon_s > \varepsilon_y = 0.002$)
- $\phi = 0.90$ ($\varepsilon_s > 0.005$)

$$\frac{0.003}{y_t} = \frac{\varepsilon_s'}{y_t - d'}$$

$$\varepsilon_s' = 0.00487$$

$$\varepsilon_s = 0.00415$$

Note: since $d' > y_t$, top steel is in tension
fs' = e's E_s = (0.00487)(29,000 ksi) = 141 ksi > 60 ksi, use fs' = 60 ksi

C_s = A_s' fs' = (0.083 in^2)(60 ksi) = 4.98 k

\[ \phi M_n = \phi [A_s f_y (d - a/2) + C_s(d' - a/2)] = 0.90[(0.220 \text{ in}^2)(60 \text{ ksi})(6.0'' - 0.446''/2) + (4.98^k)(1.0'' - 0.446''/2)] 1'/12'' \]

\[ \phi M_n = 6.01 \text{ k-ft} \]

\[ \phi M_n = 6.01 \text{ k-ft} > 5.53 \text{ k-ft} = M_{us}, \text{ OK} \]

2.2 Check for Ductile Failure

Under-reinforced if A_s < A_{s_{\text{min}}}

A_{s_{\text{min}}} = 0.0018 b h \ (ACI 7.12.2.1)

A_{s_{\text{min}}} = 0.0018 (12'')(7'') = 0.151 \text{ in}^2

A_s = 0.220 \text{ in}^2 < 0.151 \text{ in}^2 = A_{s_{\text{min}}}, \text{ OK}

Over-reinforced if \( \varepsilon_t < 0.004 \) (ACI 10.3.5)

\( \varepsilon_t = 0.0372 > 0.004, \text{ OK} \)

2.3 Check Distribution of Reinforcement

max spacing = min[ 3h, 18'' ] \ ACI 7.12.2.2

max spacing = min[ 3 x 7'', 18'' ] = 18''

spacing = 8'' < 18'', \text{ OK}

3. Temperature & Shrinkage Reinforcement

A_{s_{\text{temp}}} = 0.151 \text{ in}^2 \ (= A_{s_{\text{min}}} \text{ from pg 3/6})

max spacing = 18''

Use #3 @ 8'' (A_s = 0.165 \text{ in}^2) for Temp. & Shrink. Steel

(transverse to the flexural steel)

Sketch of Elevation View on following page.