Design of two way slab:

Design a slab panel 20 ft by 25 ft to support a uniform live load of 125 psf. The panel is a corner panel of a group. A 3000 psi concrete and steel with fy 60000 psi are used in connection with USD method. Design the slab, following the provisions of the ACI code.

Answer:

Given,

(i) $f_c' = 3000$ psi

(ii) $f_y = 60000$ psi

Shorter direction length, $l_x = 20$ ft

longer direction length, $l_y = 25$ ft

Now, $\frac{l_y}{l_x} = \frac{25}{20} = 1.25 < 2$; Hence, it is a two way slab.

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Step-1: Calculation of minimum thickness of slab

f_y = 60000 psi = 414 MPa

for, f_y = 420 MPa

minimum thickness, $h_{min} = \frac{2(L_x+L_y)}{165} = \frac{2(20+25)}{165}$

= 6.55 inch

= 7 in (considered)

Step-2: Calculating factored load for 1ft wide strip

Unit weight of concrete, γ = 150 pcf

$\therefore$ Dead load = $\frac{h_{min}}{12} \times \gamma = \frac{7}{12} \times 150 = 87.5$ psf

$\therefore$ factored dead load, $W_{DL} = 1.2 \times 87.5 = 105$ psf

Live load = 125 psf

$\therefore$ factored live load, $W_{LL} = 1.6 \times 125 = 200$ psf

$\therefore$ Total factored load, $W_u = 105 + 200 = 305$ psf

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Step-3: Calculation of factored moments at critical sections

$$m = \frac{l_x}{l_y} = \frac{20}{25} = 0.8$$

Here,
$M_a = C_a W l_a^2$
$M_b = C_b W l_b^2$

from the ACI moment coefficient table, for $m = 0.8$ and corner panel, case = 4,

(a) At continuous edge, negative moment,

$M_A(-) = 0.071 \times 305 \times 20^2 = 8662$ ft-lb

$M_B(-) = 0.029 \times 305 \times 25^2 = 5528$ ft-lb

(b) At middle strip, positive moment,

$M_A(+) = C_a \times W_{DL} \times l_a^2 + C_a \times W_{LL} \times l_a^2$

$= 0.039 \times 105 \times 20^2 + 0.048 \times 200 \times 20^2$

$= 5478$ ft-lb

$M_B(+) = C_b \times W_{DL} \times l_b^2 + C_b \times W_{LL} \times l_b^2$

$= 0.016 \times 105 \times 25^2 + 0.020 \times 200 \times 25^2$

$= 3550$ ft-lb

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(c) At discontinuous edges, negative moment,

$M_A(-) = 1/3 \times 5478 = 1826$ ft-lb

$M_B(-) = 1/3 \times 3550 = 1183$ ft-lb

Step-4: Determination of reinforcement ratio (ρ)

The maximum practical reinforcement ratio is, $\rho_{0.005} = 0.85\beta_1 \frac{f_c'}{f_y} \frac{\epsilon_u}{\epsilon_u + 0.005}$

$= 0.85 \times 0.85 \times \frac{3000}{60000} \times \frac{0.003}{0.003+0.005}$

$= 0.0135$

Step-5: Calculation of minimum effective depth

$$d^2 = \frac{Mu}{\phi \rho f_y b (1 - 0.59 \rho f_y / f_c')}$$

$$= \frac{8662 \times 12}{0.9 \times 0.0135 \times 60000 \times 12 \times \left(1 - 0.59 \times 0.0135 \times \frac{60000}{3000}\right)}$$

$\therefore d_{req} = 3.76$ inch

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Clear cover = 1 inch

$\therefore d = h_{min} - cc = 7 - 1 = 6$ inch

$d_{req} < d \rightarrow$ OK

Step-6 : Calculation of As for interior, mid and exterior section in both direction

@ for shorter direction, Let a = 1 inch

at continuous edge, Mu = 8662 ft-lb

$$A_s = \frac{M_u}{\phi f_y (d - a/2)} = \frac{8662 \times 12}{0.9 \times 60000 (6 - 1/2)} = 0.35 \text{ in}^2/\text{ft}$$

$$\therefore a = \frac{A_s f_y}{0.85 f_c' b} = \frac{0.35 \times 60000}{0.85 \times 3000 \times 12} = 0.7''$$

Second trial, $A_s = \frac{8662 \times 12}{0.9 \times 60000 \times (6 - \frac{0.7}{2})} = 0.34 \text{ in}^2/\text{ft}$

$$\therefore a = 0.7 \times \frac{0.35}{0.34} = 0.72''$$

at middle strip, Mu = 5478 ft-lb

$$A_s = \frac{5478 \times 12}{0.9 \times 60000 \times (6 - 1/2)} = 0.221 \text{ in}^2/\text{ft}$$

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$$a = \frac{0.221 \times 60000}{0.85 \times 3000 \times 12} = 0.434''$$

Second trial, $A_s = \frac{5478 \times 12}{0.9 \times 60000 \times \left(6 - \frac{0.434}{2}\right)} = 0.21 \text{ in}^2/\text{ft}$

$$\therefore a = 0.434 \times \frac{0.221}{0.21} = 0.457''$$

at discontinuous edge, $M_u = 1826$ ft-lb

$$A_s = \frac{1826 \times 12}{0.9 \times 60000 \times (6 - 1/2)} = 0.0737 \text{ in}^2/\text{ft}$$

$$\therefore a = \frac{0.0737 \times 60000}{0.85 \times 3000 \times 12} = 0.1446''$$

Second trial, $A_s = \frac{1826 \times 12}{0.9 \times 60000 \left(1 - \frac{0.1446}{2}\right)} = 0.0684 \text{ in}^2/\text{ft}$

$$\therefore a = \frac{0.1446 \times 0.0737}{0.0684} = 0.155''$$

(b) for longer direction,

at continuous edge, $M_u = 5528$ ft-lb

$$A_s = \frac{5528 \times 12}{0.9 \times 60000 \times (6 - 1/2)} = 0.223 \text{ in}^2/\text{ft}$$

$$a = \frac{0.223 \times 60000}{0.85 \times 3000 \times 12} = 0.438''$$

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Second trial, $A_s = \frac{5528 \times 12}{0.9 \times 60000 (6 - \frac{0.438}{2})} = 0.212$ in²/ft

$\therefore a = 0.438 \times \frac{0.223}{0.212} = 0.461''$

at middle strip, $M_u = 3550$ ft-lb

$A_s = \frac{3550 \times 12}{0.9 \times 60000 \times (6 - 1/2)} = 0.143$ in²/ft

$a = \frac{0.143 \times 60000}{0.85 \times 3000 \times 12} = 0.281''$

Second trial, $A_s = \frac{3550 \times 12}{0.9 \times 60000 \times (6 - \frac{0.143}{2})} = 0.135$ in²/ft

$\therefore a = 0.281 \times \frac{0.143}{0.135} = 0.297''$

at discontinuous edge, $M_u = 1183$ ft-lb

$A_s = \frac{1183 \times 12}{0.9 \times 60000 \times (6 - 1/2)} = 0.048$ in²/ft

$\therefore a = \frac{0.048 \times 60000}{0.85 \times 3000 \times 12} = 0.094''$

Second trial, $A_s = \frac{1183 \times 12}{0.9 \times 60000 \times (6 - \frac{0.094}{2})} = 0.044$ in²/ft

$\therefore a = 0.094 \times \frac{0.048}{0.044} = 0.1025''$

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Step-7: Calculation of factored shear force

factored shear force of interior support,

$$V_u = C\frac{W_u l_x}{2} - W_u d$$

$$= 1.15 \times \frac{305 \times 20}{2} - 305 \times \frac{6}{12}$$

$$= 3355 \text{ lb}$$

$W_u = 305$ psf
$l_x = 20$ ft
$d = 6''$
$C = 1.15$

The nominal shear strength of the concrete slab is,

$$V_n = V_c = 2\lambda\sqrt{f_c'}\, bd$$

$$= 2 \times 1 \times \sqrt{3000} \times 12 \times 6 = 7887 \text{ lb}$$

Thus the design shear strength of the concrete slab,

$$\phi V_c = 0.75 \times 7887 = 5915 \text{ lb} > 3355 \text{ lb}$$

$\therefore \phi V_c > V_u$

The design is <u>ok</u>.

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Step-8: Reinforcement detailing

Maximum spacing of the lateral bars should not exceed 3h or 18"

$3h = 3 \times 7 = 21"$ So, 18" should be taken.

Bar size:

At shorter direction,

for positive moment,

required $A_s = 0.21 \text{ in}^2/\text{ft}$

Using #4 bars,

$$\therefore \text{Spacing of bar} = \frac{\text{Area of bar used} \times \text{width of strip}}{\text{Required } A_s}$$

$$= \frac{0.20 \times 12}{0.21} = 11.43" \sim 11"$$

Crank 50% of bar to negative zone.

for negative moment,

Required $A_s = 0.34 \text{ in}^2/\text{ft}$

$$\text{Already provided, } A_s = \frac{\text{Area of bar used} \times \text{width of strip}}{2 \times \text{spacing of the bar}}$$

$= \frac{0.20 \times 12}{2 \times 11} = 0.11 \text{ in}^2/\text{ft}$

Required for extra top $= (0.34 - 0.11) \text{ in}^2/\text{ft}$

$= 0.23 \text{ in}^2/\text{ft}$

$\therefore$ Spacing of the bar $= \frac{0.20 \times 12}{0.23} = 10.43''$

$\sim 10''$

At longer direction,

for positive moment,

Required $A_s = 0.135 \text{ in}^2/\text{ft}$

Using #4 bars,

$\therefore$ Spacing of the bar $= \frac{0.20 \times 12}{0.135} = 17.78'' \sim 17''$

Crank 50% bar to negative area,

for negative moment,

Required $A_s = 0.212 \text{ in}^2/\text{ft}$

Already provided $A_s = \frac{0.20 \times 12}{2 \times 17} = 0.0706 \text{ in}^2/\text{ft}$

$\therefore$ Required extra top $= 0.212 - 0.0706$

$= 0.1414 \text{ in}^2/\text{ft}$

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$\therefore$ Spacing of the bars $= \dfrac{0.20 \times 12}{0.1414}$

$= 16.97'' \sim 16''$

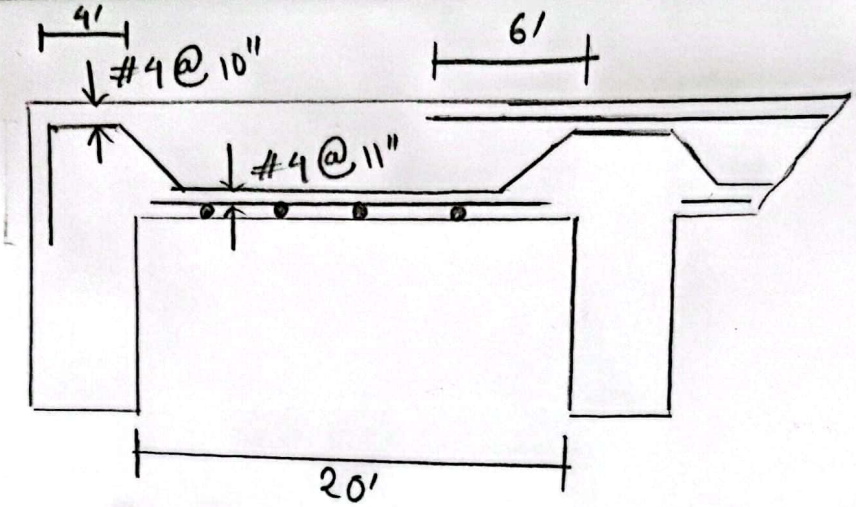
For the corner reinforcement,

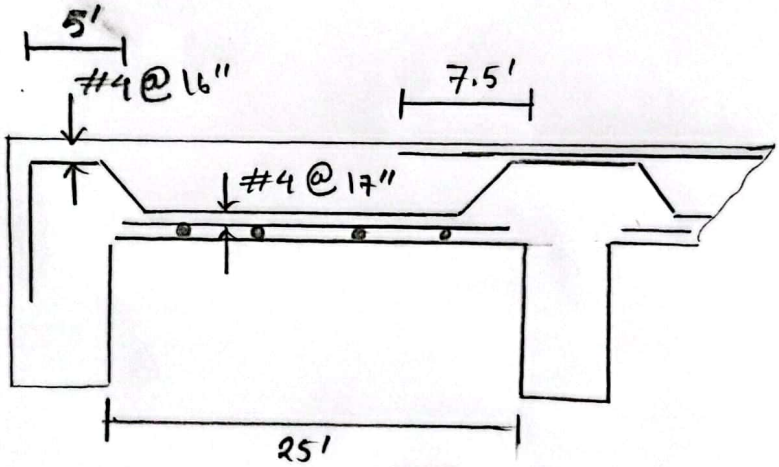
the bars should extend at least 1/5 of the longer span from the corner.

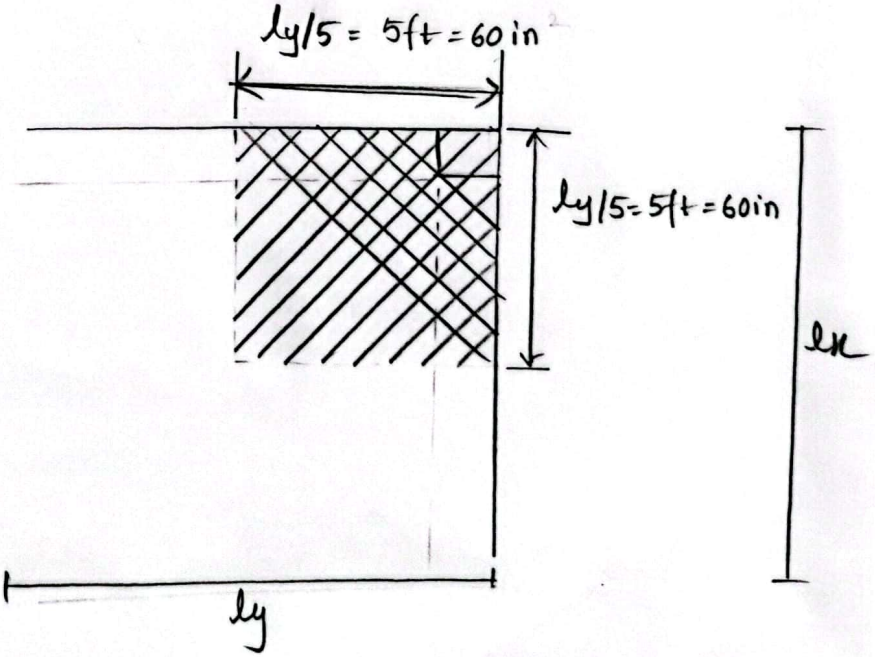
$l_y = 25\,ft \Rightarrow \dfrac{l_y}{5} = \dfrac{25}{5} = 5\,ft = 60\,inch$

Therefore, the bars should extend 60 inch from the corner.

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4'
#4@10"
6'
#4@11"
20'


5'
#4@16"
7.5'
#4@17"
25'


ly/5 = 5ft = 60 in
ly/5 = 5ft = 60in
lx
ly