Plain & Reinforced Concrete-1

Sixth Term
Civil Engineering

CE-314

Lecture # 19

Analysis and Design of Slabs

Two-Way Edge Supported Slabs

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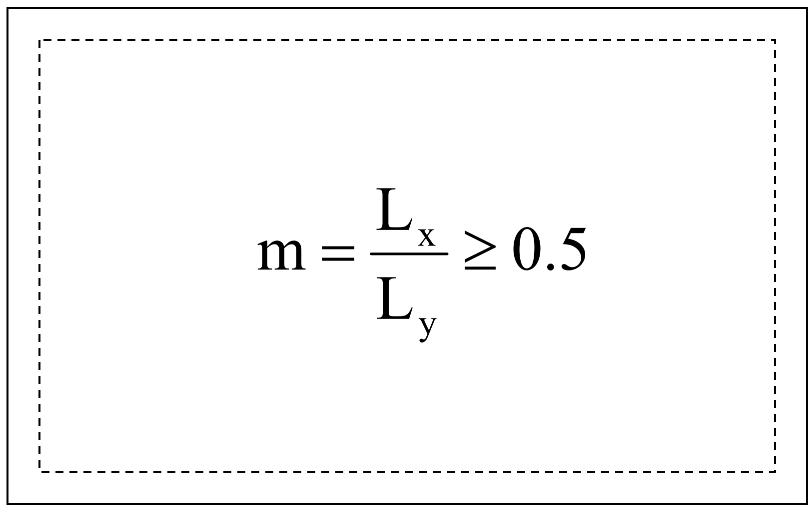
Two-Way Slabs

Slab resting on walls or sufficiently deep and rigid beams on all sides. Other options are column supported slab e.g. Flat slab, waffle slab.



$$m = \frac{L_x}{L_y} \geq 0.5$$

Two-way slabs have two way bending unlike one-way slab.

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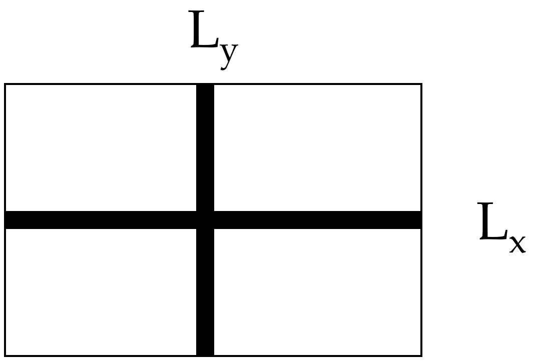
Design Methods

1. ACI co-efficient method
2. Direct design method
3. Equivalent frame method
4. Finite element method



Notes

1. In two-way slabs shorter direction strip carry greater %age of load.
2. Steel will be more in shorter direction.
3. Shorter direction steel will be placed near the outer edge to get more "d" means more lever arm to get more flexural capacity.

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ACI Co-efficient Method

Unit width strip is taken in both directions. The strip is designed separately for +ve and –ve moment.

$$M_u = C \times w_u \times L_n{}^2$$

C = ACI co-efficient

w_u = Slab load

"C" depends upon the end conditions of slab and the aspect ratio.

Three tables are available for "C"

- Dead load positive moment
- Live load positive moment
- Negative moment (both for dead and live loads)

M**+** coefficients are increased by 25 % and M**-** coefficients are reduced by 10 % to get the result more closer to accurate solution.

Table 6.4. ACI 1963 Coefficients For Dead Load Positive Moments In Slabs Increased by 25%.										
Ratio *m*		Case 2	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	C_x	0.045	0.023	0.023	0.034	0.034	0.041	0.034	0.025	0.029
	C_y	0.045	0.023	0.034	0.034	0.023	0.034	0.038	0.029	0.025
0.95	C_x	0.050	0.025	0.026	0.038	0.035	0.045	0.039	0.028	0.030
	C_y	0.041	0.020	0.031	0.030	0.019	0.030	0.039	0.026	0.021
0.90	C_x	0.056	0.028	0.031	0.041	0.036	0.049	0.044	0.031	0.033
	C_y	0.036	0.018	0.030	0.028	0.016	0.026	0.035	0.024	0.019
0.85	C_x	0.063	0.030	0.036	0.045	0.039	0.053	0.050	0.036	0.035
	C_y	0.033	0.015	0.028	0.024	0.014	0.021	0.031	0.021	0.016
0.80	C_x	0.070	0.033	0.043	0.049	0.040	0.056	0.056	0.040	0.036
	C_y	0.029	0.014	0.025	0.020	0.011	0.019	0.028	0.019	0.013
0.75	C_x	0.076	0.035	0.050	0.054	0.041	0.060	0.064	0.045	0.039
	C_y	0.024	0.011	0.023	0.016	0.009	0.015	0.025	0.016	0.009
0.70	C_x	0.085	0.038	0.058	0.058	0.044	0.064	0.073	0.050	0.041
	C_y	0.020	0.009	0.020	0.014	0.006	0.011	0.021	0.014	0.008
0.65	C_x	0.093	0.040	0.068	0.063	0.045	0.068	0.081	0.055	0.043
	C_y	0.016	0.008	0.018	0.011	0.005	0.009	0.018	0.011	0.006
0.60	C_x	0.101	0.043	0.078	0.066	0.046	0.070	0.091	0.060	0.045
	C_y	0.013	0.005	0.014	0.009	0.004	0.008	0.015	0.009	0.005
0.55	C_x	0.110	0.044	0.089	0.070	0.048	0.073	0.101	0.065	0.046
	C_y	0.010	0.004	0.011	0.006	0.003	0.005	0.011	0.006	0.004
0.5	C_x	0.119	0.046	0.100	0.074	0.049	0.076	0.111	0.070	0.048
	C_y	0.008	0.003	0.009	0.005	0.001	0.004	0.009	0.005	0.003

Table 6.5. ACI 1963 Coefficients For Live Load Positive Moments In Slabs Increased by 25%.

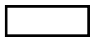
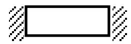
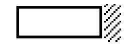
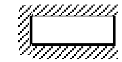
Ratio m		**Case 1** 	**Case 2** 	**Case 3** 	**Case 4** 	**Case 5** 	**Case 6** 	**Case 7** 	**Case 8** 	**Case 9** 
1.00	C_x	0.045	0.034	0.034	0.040	0.040	0.044	0.040	0.035	0.038
	C_y	0.045	0.034	0.040	0.040	0.034	0.040	0.044	0.038	0.035
0.95	C_x	0.050	0.038	0.039	0.044	0.043	0.048	0.045	0.039	0.040
	C_y	0.041	0.031	0.036	0.036	0.030	0.036	0.040	0.034	0.031
0.90	C_x	0.056	0.043	0.044	0.049	0.046	0.053	0.050	0.044	0.045
	C_y	0.036	0.028	0.034	0.033	0.026	0.031	0.036	0.030	0.028
0.85	C_x	0.063	0.046	0.050	0.054	0.051	0.058	0.056	0.050	0.049
	C_y	0.033	0.024	0.030	0.029	0.024	0.028	0.033	0.028	0.025
0.80	C_x	0.070	0.051	0.056	0.060	0.055	0.064	0.064	0.055	0.053
	C_y	0.029	0.021	0.028	0.025	0.020	0.024	0.029	0.024	0.021
0.75	C_x	0.076	0.056	0.064	0.065	0.059	0.069	0.070	0.061	0.058
	C_y	0.024	0.018	0.024	0.020	0.016	0.020	0.025	0.020	0.016
0.70	C_x	0.085	0.061	0.071	0.071	0.064	0.075	0.079	0.068	0.063
	C_y	0.020	0.015	0.020	0.018	0.014	0.016	0.021	0.018	0.014
0.65	C_x	0.093	0.066	0.080	0.078	0.069	0.080	0.088	0.074	0.068
	C_y	0.016	0.013	0.018	0.014	0.011	0.013	0.018	0.014	0.011
0.60	C_x	0.101	0.073	0.089	0.084	0.074	0.085	0.096	0.081	0.074
	C_y	0.013	0.009	0.014	0.011	0.009	0.010	0.014	0.011	0.009
0.55	C_x	0.110	0.078	0.100	0.090	0.079	0.091	0.106	0.088	0.079
	C_y	0.010	0.008	0.011	0.009	0.006	0.008	0.011	0.009	0.008
0.5	C_x	0.119	0.083	0.110	0.096	0.084	0.098	0.115	0.095	0.084
	C_y	0.008	0.005	0.009	0.006	0.005	0.006	0.009	0.063	0.005

Table 6.6. ACI 1963 Coefficients For Negative Moments In Slabs Decreased by 10%.

Ratio m		**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**	**Case 8**	**Case 9**
1.00	C_x	—	0.041	—	0.045	0.068	0.064	—	0.030	0.055
	C_y	—	0.041	0.068	0.045	—	—	0.064	0.055	0.030
0.95	C_x	—	0.045	—	0.050	0.071	0.068	—	0.034	0.059
	C_y	—	0.037	0.065	0.041	—	—	0.060	0.050	0.026
0.90	C_x	—	0.050	—	0.054	0.072	0.071	—	0.039	0.061
	C_y	—	0.033	0.063	0.036	—	—	0.056	0.047	0.023
0.85	C_x	—	0.054	—	0.059	0.074	0.075	—	0.044	0.065
	C_y	—	0.028	0.059	0.031	—	—	0.051	0.041	0.019
0.80	C_x	—	0.059	—	0.064	0.075	0.077	—	0.050	0.068
	C_y	—	0.024	0.055	0.026	—	—	0.046	0.037	0.015
0.75	C_x	—	0.062	—	0.068	0.077	0.079	—	0.055	0.070
	C_y	—	0.020	0.050	0.022	—	—	0.040	0.032	0.013
0.70	C_x	—	0.067	—	0.073	0.077	0.082	—	0.061	0.073
	C_y	—	0.015	0.045	0.017	—	—	0.034	0.026	0.010
0.65	C_x	—	0.069	—	0.077	0.078	0.084	—	0.067	0.075
	C_y	—	0.013	0.039	0.014	—	—	0.028	0.022	0.007
0.60	C_x	—	0.073	—	0.080	0.079	0.086	—	0.072	0.077
	C_y	—	0.009	0.032	0.010	—	—	0.022	0.016	0.005
0.55	C_x	—	0.076	—	0.083	0.080	0.086	—	0.077	0.077
	C_y	—	0.006	0.025	0.007	—	—	0.017	0.013	0.005
0.5	C_x	—	0.077	—	0.085	0.081	0.087	—	0.080	0.079
	C_y	—	0.005	0.020	0.005	—	—	0.013	0.009	0.003

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Minimum Depth of 2-Way Slab for Deflection Control

According to ACI-318-1963

h_{min} = (inner perimeter of slab panel)/180
≥ 90 mm

For f_y = 280 MPa $$h_{min} = \frac{2(L_x + L_y)}{180}$$

For f_y = 420 MPa $$h_{min} = \frac{2(L_x + L_y)}{165}$$

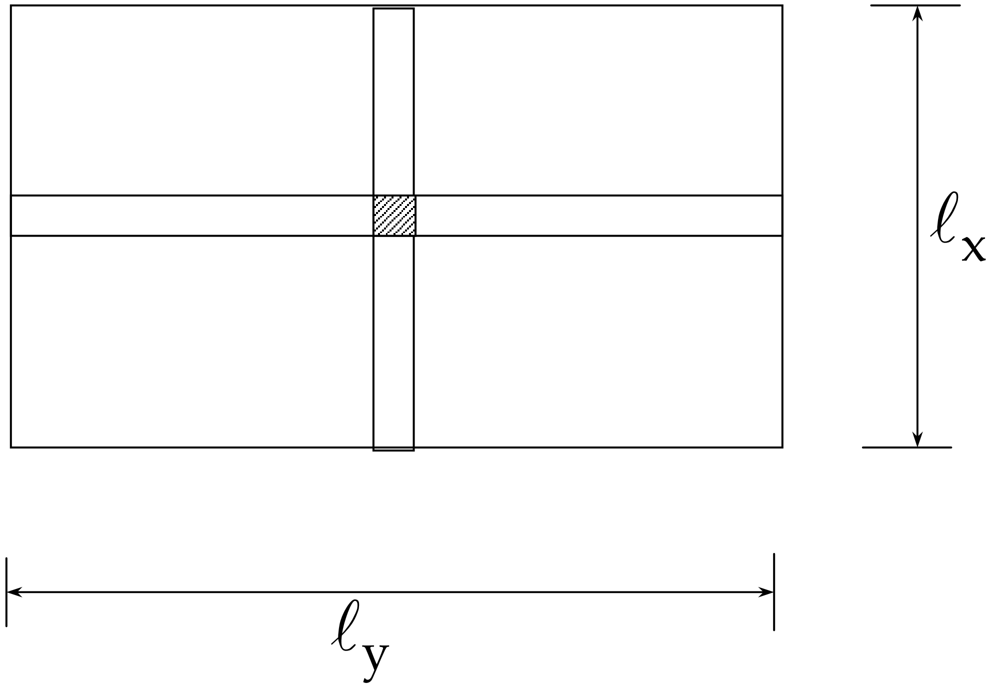
According to ACI-318-2005

$$h_{min} = \frac{L_n\left(0.8 + f_y/1400\right)}{\left(36 \times m + 9\right)}$$

$$m = \frac{L_x}{L_y}$$

L_n = clear span in short direction

Basic Behavior Of Two-Way Slabs



Design Strips in a Two-Way Slab.

- The shaded portion is jointly supported by both the strips.
- One of the simplest methods, which is the basis of similar coefficients in the British Standards is to find the deflections at the common point for both the strips and evaluating their contribution by equating these deflections.

Let q_x = load taken by shorter strip

q_y = load taken by longer strip

q_t = total load on the slab

$= q_x + q_y$

and $m = L_x / L_y$

$$\frac{5q_x\ell_x^4}{384EI} = \frac{5q_y\ell_y^4}{384EI} \qquad \Rightarrow \qquad \frac{q_x}{q_y} = \frac{\ell_y^4}{\ell_x^4}$$

$q_x \times m^4 = q_y$ or $q_x \times m^4 = q_t - q_x$

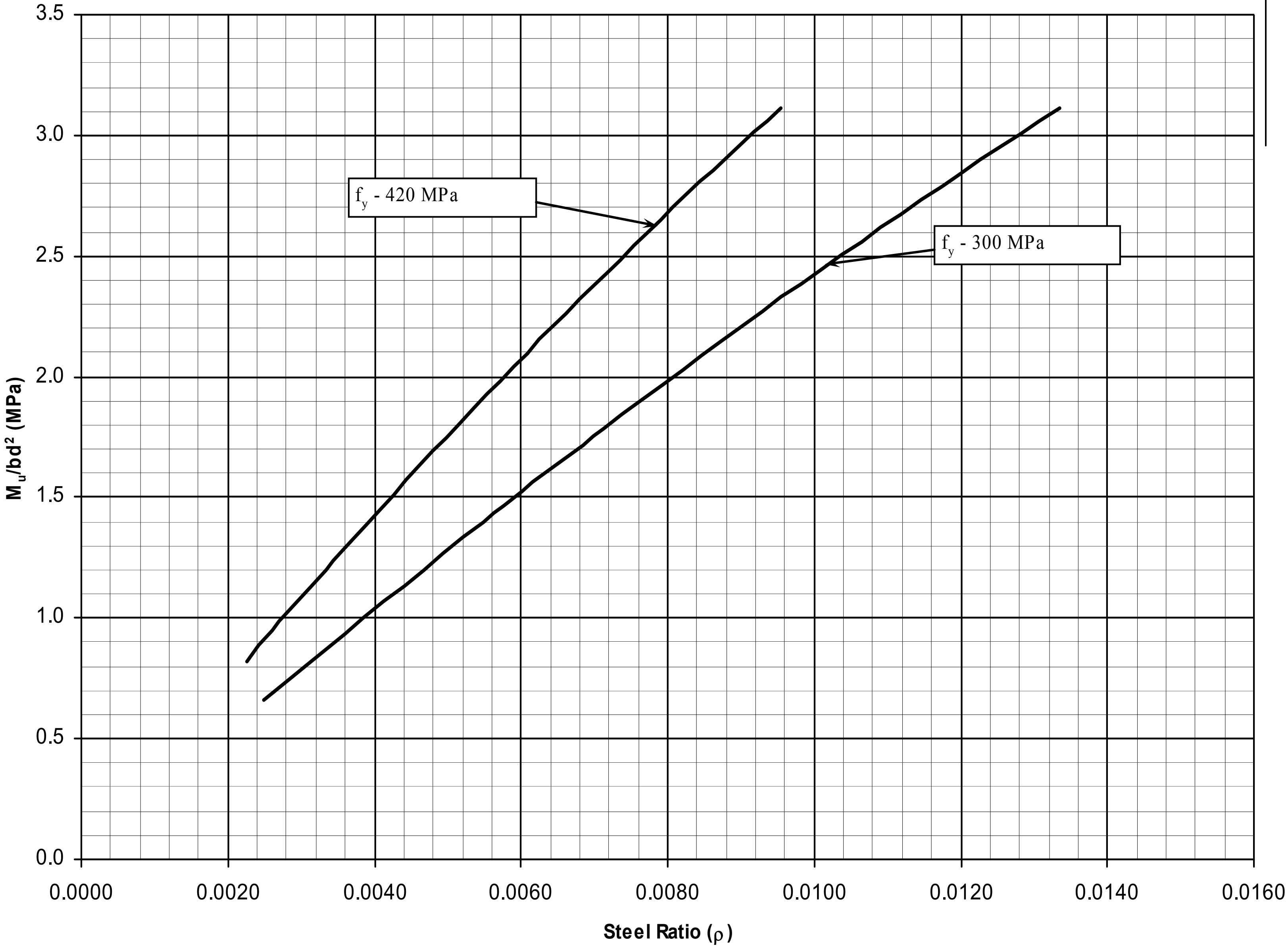
$$q_x = \frac{q_t}{1+m^4}$$

- For square panel, $m = 1$, $q_x = 0.5\, q_t$
- For $L_y = 2 \times L_x$, $m = 0.5$, $q_x = 0.941\, q_t$
- For $m = 1$, $M_x = q_x \times l_x^2 / 8 = 0.0625 \times q_t \times l_x^2$

  : $C_x = 0.0625$
- For $m = 0.5$, $M_x = q_x \times l_x^2 / 8 = 0.118 \times q_t \times l_x^2$

  : $C_x = 0.118$

$f_c' = 17.25$ MPa



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Mu/bd² (MPa)
0.0000
0.0020
0.0040
0.0060
0.0080
0.0100
0.0120
0.0140
0.0160
Steel Ratio (ρ)
fy - 420 MPa
fy - 300 MPa

Design Flow Chart Will Be Explained By Example

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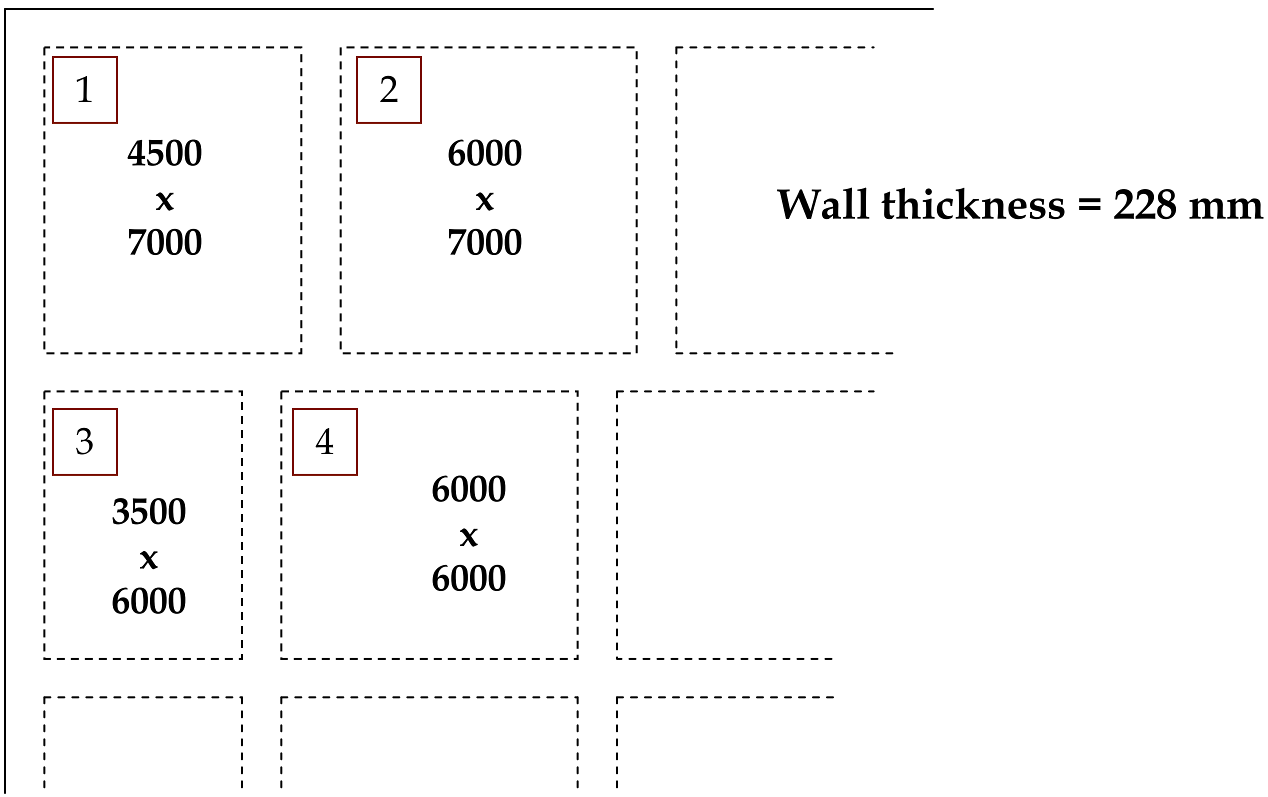
Example: Design the 4 marked slab panels of an ordinary house. Use US customary bars. $f_c' = 18$ MPa $f_y = 280$ MPa



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Solution: Panel Edge Conditions

Panel # 1

L_x = 4.5m , L_y = 7.0m

m = 0.64 > 0.5, 2-way slab

Panel # 2

L_x = 6.0m , L_y = 7.0m

m = 0.86> 0.5, 2-way slab

Panel # 3

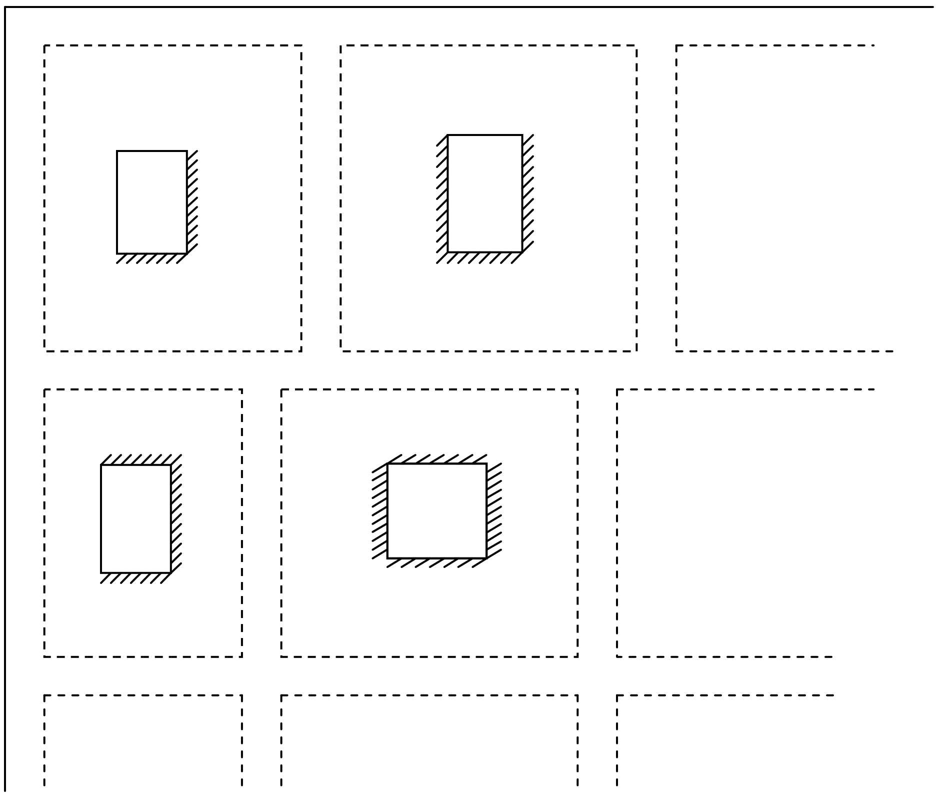
L_x = 3.5m , L_y = 6.0m

m = 0.58 > 0.5, 2-way slab

Panel # 4

L_x = 6.0m , L_y = 6.0m

m = 1 > 0.5, 2-way slab



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Solution: (contd…)

Slab Thickness

Generally same depth is preferred for one monolith slab. Calculate h_{min} for all the panels and select the largest value.

Panel # 1

$$h_{min} = \frac{L_n\left(0.8 + f_y/1400\right)}{36 \times m + 9}$$

$$h_{min} = \frac{4500\left(0.8 + 280/1400\right)}{36 \times 0.64 + 9} \cong 140mm$$

Panel # 2

$$h_{min} = \frac{6000\left(0.8 + 280/1400\right)}{36 \times 0.86 + 9} \cong 150mm$$

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Solution: (contd…)

Panel # 3

$$h_{\min} = \frac{3500(0.8 + 280/1400)}{36 \times 0.58 + 9} \cong 117mm$$

Panel # 4

$$h_{\min} = \frac{6000(0.8 + 280/1400)}{36 \times 1 + 9} \cong 133mm$$

$$\boxed{\text{h} = 150\text{mm}}$$

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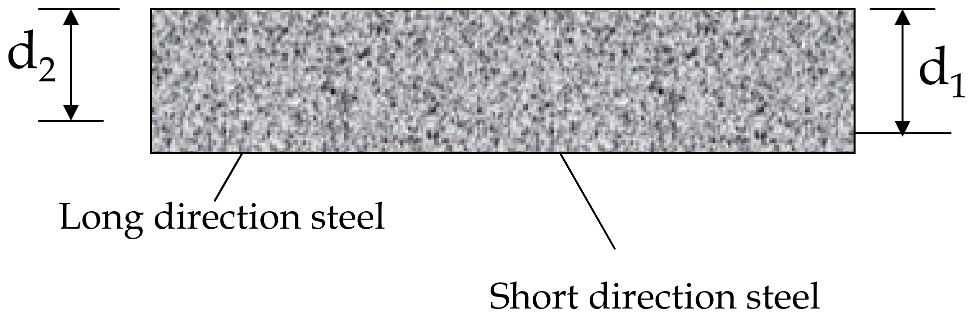
Solution: (contd…)

Effective depth



For short direction steel

$$d_1 = h - 27 = 123mm$$

For longer direction steel

$$d_2 = h - 20 - 13 - 10/2 = 112mm$$

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Solution: (contd…)

Slab Load

Self weight of slab $= \dfrac{150}{1000} \times 2400 = 360 \text{kg} / \text{m}^2$

75 mm brick ballast/ screed $= \dfrac{75}{1000} \times 1800 = 135 \text{kg} / \text{m}^2$

60 mm floor finishes $= \dfrac{60}{1000} \times 2300 = 138 \text{kg} / \text{m}^2$

Total dead load $= 360 + 135 + 138 = 633 \text{kg} / \text{m}^2$

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Solution: (contd…)

Slab Load

$$\text{Live Load} = 200\text{kg}/\text{m}^2$$

$$1.2\text{w}_\text{L} = (1.6 \times 200) \times \frac{9.81}{1000} = 3.14 kN/m^2$$

$$1.2\text{w}_\text{d} = (1.2 \times 633) \times \frac{9.81}{1000} = 7.45 kN/m^2$$

$$\text{w}_\text{u} = 7.45 + 3.14 = 10.59 kN/m^2$$

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Solution: (contd…)

Minimum Steel

$$A_{s\,min} = 0.002bh$$

$$A_{s\,min} = 0.002 \times 1000 \times 150$$

$$A_{s\,min} = 300mm^2$$ **For a unit strip**

Continued on next file