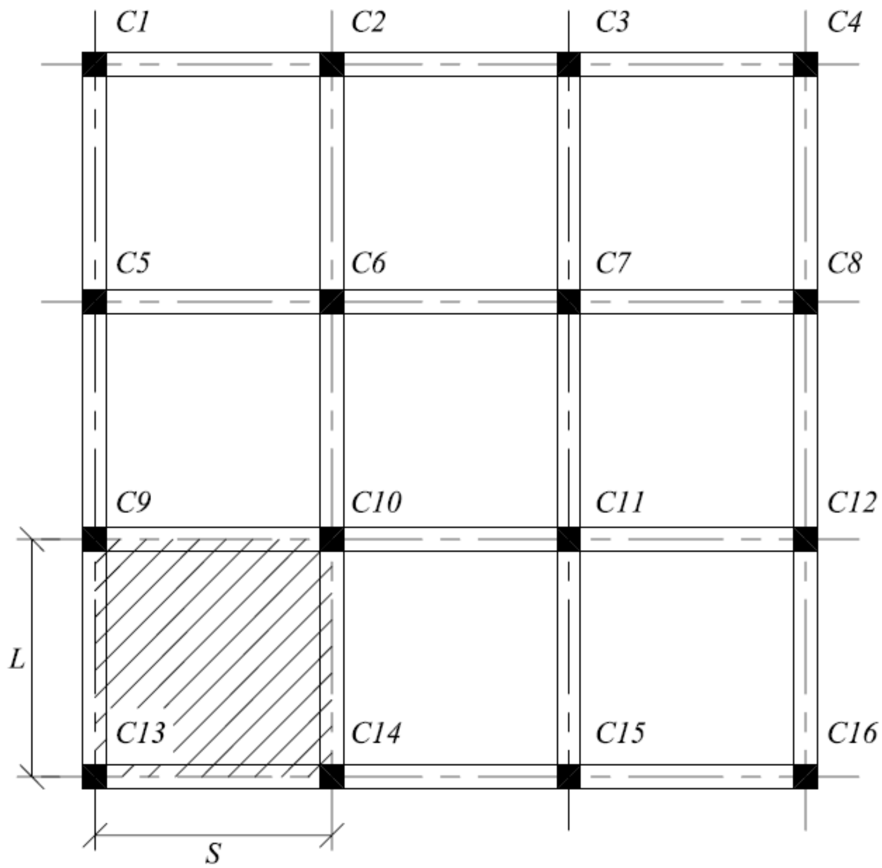
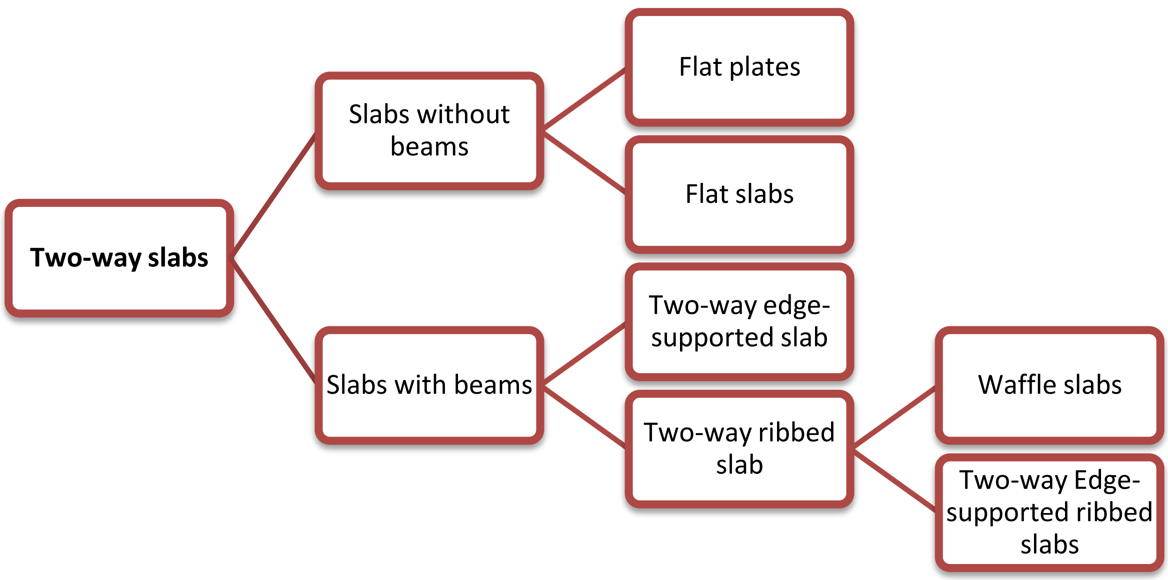
1. Inroduction

When the ratio (***L/S***) is less than 2.0, slab is called two-way slab, as shown in the fig. below. Bending will take place in the two directions in a dish-like form.

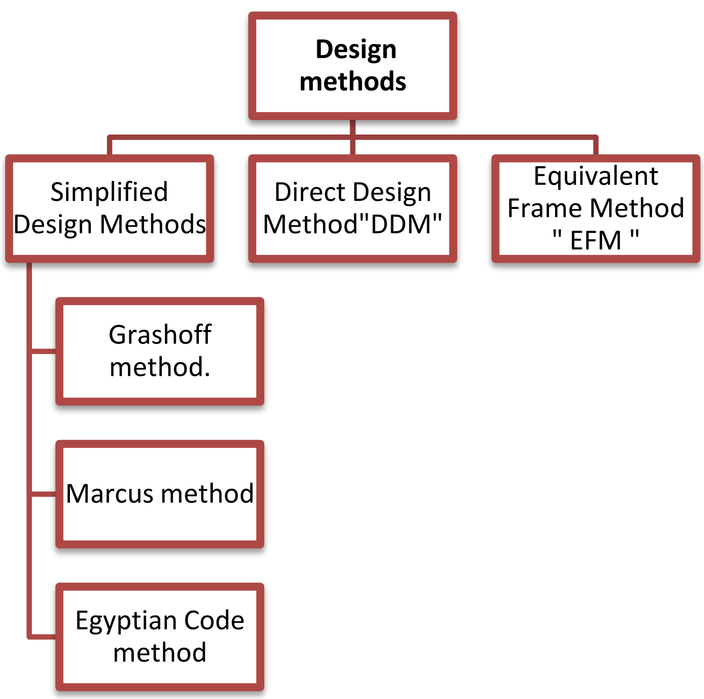
Accordingly, main reinforcement is required in the two directions.



2.Types Of Two Way Slabs



3. Design Methods



4. Direct Design Method "D.D.M"

Before Discussion Of this Method, we have to study some concepts:

1. Limitations:

1. Three or more spans in each direction.
2. Variation in successive spans$\ngtr$33% ($\frac{l_2-l_1}{l2} \times 100\% \ngtr 33\%$).
3. LL $\ngtr$2 DL
4. Column offset $\ngtr$ 10% in each direction.
5. L/B $\ngtr$2.
6. For slabs on beams, for one panel $\frac{\alpha_1 l_2^2}{\alpha_1 l_2^2} \nless 0.2$

$\ngtr 5.0.$

2. Determination of Two way slab thickness:

- **Case 1** : interior and edge beams are exist.

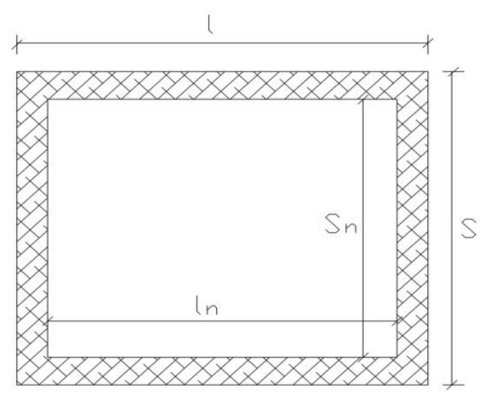
$h_{min}=\frac{l_n(0.8+ f_y/14000)}{36+5\beta(1+\beta_s)}$

$h_{max}=\frac{l_n(0.8+ f_y/14000)}{36}$

Where:

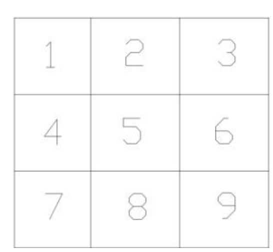
l_n : is the largest clear distance in the longest direction of panels.

S_n : is the clear distance in the short direction in the panel.



B = $\frac{l_n}{S_n}$

B_s = $\frac{length\ of\ continues\ edges\ in\ the\ panel}{Total\ perimeter\ of\ the\ panel}$



Example for finding B_s : for fig. shown:

For panel 1 ... $B_s = \frac{l+s}{2l+2s} = \frac{1}{2}$

For panel 5 ... $B_s = \frac{2l+2s}{2l+2s} = 1$

So **h** to be used should be : $h_{min} < h < h_{max}$

- **Case 2**: interior beams are not existing, thickness can be found according to table 8.8, page 339.

Table 8.8: Minimum thickness of slabs without interior beams*

Without drop panels			With drop panels		
Exterior panels		Interior panels	Exterior panels		Interior panels
Without edge beams	With edge beams		Without edge beams	With edge beams	
$l_n / 30$	$l_n / 33$	$l_n / 33$	$l_n / 33$	$l_n / 36$	$l_n / 36$

* $f_y = 4200\ kg/cm^2$

3. Estimating dimensions of interior and exterior beams sections:

Dimensions can be estimated from the following figures:

Where: b = beam width,

h = slab thickness,

a =beam thickness.

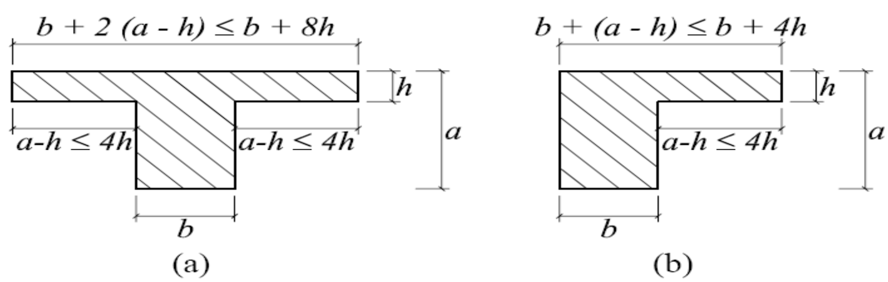
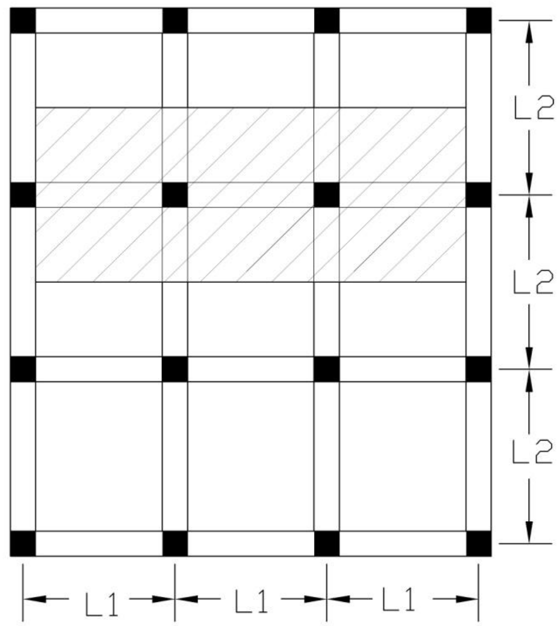


Figure 8.20: Effective beam section; (a) interior beam; (b) exterior beam

Design Procedures

Discussion will be done to one representative strip in the horizontal and vertical directions; the same procedure can be used for the other strips.



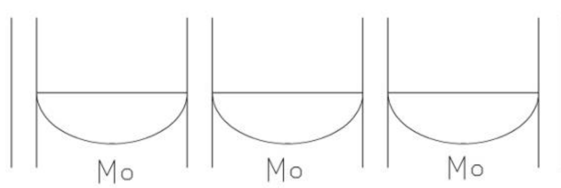
a- Determination of total factored Static Moment M_o :

$M_o = W_u \times \text{Strip width} \times l_n^2 / 8$

where:

W_u : total factored load in t/m^2 .

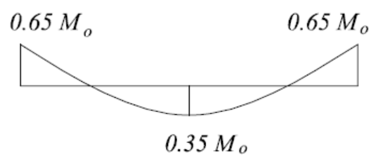
l_n= clear distance in the direction of strip, and not less than $0.65 l_1$.



b- Distribution of the total factored static moment to negative and positive moments:

I. For interior Spans:

According to the code, the moments can be distributed according to factores shown in the figure:

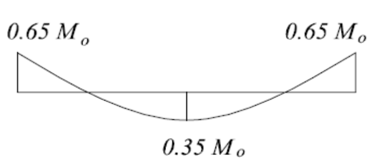


II. For Edge Spans :

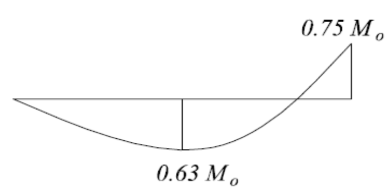
Table 8.9: Distribution of total static moment in end spans

	(1)	(2)	(3)		(4)
	Exterior edge unrestrained	Beams between all supports	No beams between interior supports		Exterior edge fully restrained
			Without edge beam	With edge beam	
Interior negative factored moment	0.75	0.70	0.70	0.70	0.65
Positive factored moment	0.63	0.57	0.52	0.50	0.35
Exterior negative factored moment	0.00	0.16	0.26	0.30	0.65

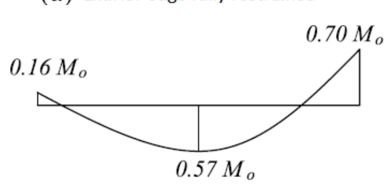
Static Mom. M_o can be distributed, according to factors given in the table 8.9, page 341.



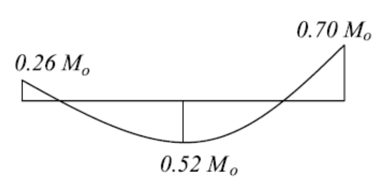
(a) Extirior edge fully restrained



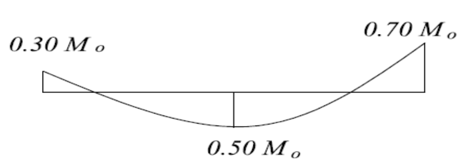
(b) Extirior edge unrestrained



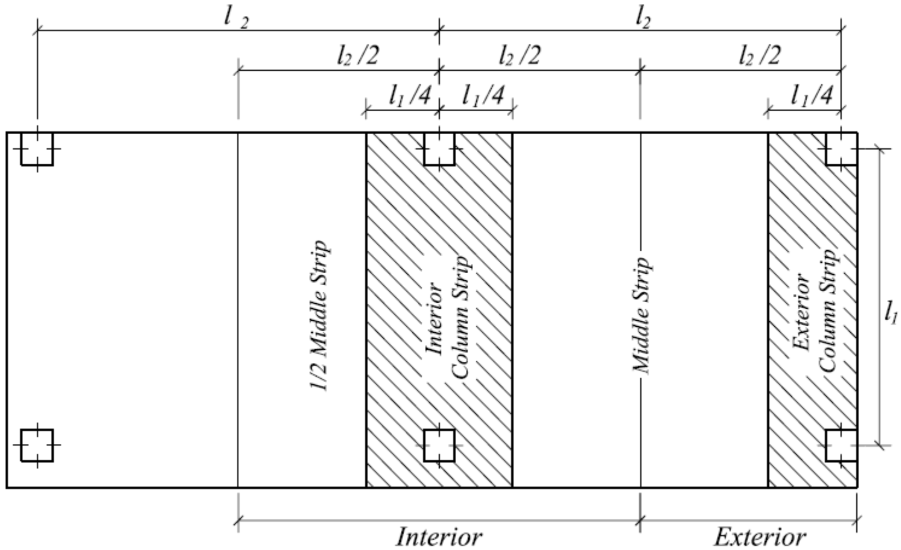
(c) beams between all supports



(d) No beams between intirior supports and without edge beams



(e) No beams between intirior supports and with edge beams c- **Distribution of the positive and negative factored moments to the Column and middle strips:**



Note: width of column strip is equal to $\mathbf{0.25}\boldsymbol{l_1}$ or $\mathbf{0.25}\boldsymbol{l_2}$ which is **smaller**.

l_1: length in the direction of strip, center to center between columns.

l_2: length in the direction perpendicular to l_1.

I. Determination of factored moments on column and middle strips:

- Finding α and β_t:

> **Note:** α is given only for **the beams in the direction** of the strip

- $\alpha = \frac{I_b}{I_s}$

α : is ratio of flexural stiffness .

I_b : Moment of inertia of the beam in the direction of strip… can be found from fig.8.14 and fig.8.15, pages 310 and 311.

I_s : Moment of inertia of slab = $\frac{1}{12} \times strip\ width \times h^3$, where h is slab thickness.

> **Note:** β_t is given only for **edge beams perpendicular** to the strip

- $\beta_t = \frac{E_{cb}C}{2E_{cs}\,I_s}$,

β_t: Ratio of torsional stiffness

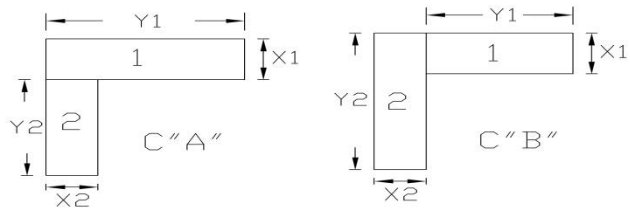
E_{cb} and E_{cs} are the modulus of elastisity of concrete for beam and slab.

C: Cross sectional constant defines torsional properties ➡ C = $\sum\left(1-0.63\frac{X}{Y}\right)\left(\frac{X^3Y}{3}\right)$

X: smallest dimension in the section of **edge beam**.

Y: Largest dimension in the section of **edge beam**.

Note: the C relation is applicable directly for rectangular section only, but when used for L-Shape beams, we should divide it to two rectangular sections and find C.



C "A" = $C_1 + C_2$ for A and C "B" = $C_1 + C_2$ for B.

C to be used = Max (C "A" , C "B").

When α and β_t are found, factors for moment can be found from table 8.10 page 343 for the column strip.

Table 8.10: Column strip factored moments

		l_2/l_1	0.50	1.0	2.0
Exterior negative factored moment	$\alpha_1 l_2/l_1 = 0$	$\beta_t = 0$	100	100	100
		$\beta_t \geq 2.5$	75	75	75
	$\alpha_1 l_2/l_1 \geq 1$	$\beta_t = 0$	100	100	100
		$\beta_t \geq 2.5$	90	75	45
Positive factored moment	$\alpha_1 l_2/l_1 = 0$		60	60	60
	$\alpha_1 l_2/l_1 \geq 1$		90	75	45
Interior negative factored moment	$\alpha_1 l_2/l_1 = 0$		75	75	75
	$\alpha_1 l_2/l_1 \geq 1$		90	75	45

Notes:

- α l_2/l_1 = 0.0 , when there is no interior beams in the direction of strip under consideration.
- β_t = 0.0 , when there is no extirior “edge” beams perpendicular to the strip under consideration.

After finding the moments on the column strip, Moments on the middle strip is the remain.

II. For the moment on the beam " if exist " :

If: $\alpha\, l_2/l_1 \geq 1$ … The beam moment is 85% of the moment of the column strip.

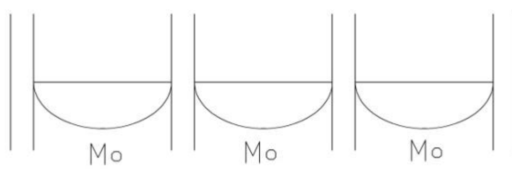
$\alpha\, l_2/l_1 = 0$ … there is no beam .. mom. = 0

$0 < \alpha\, l_2/l_1 < 1$ … Interpolation have to be done between 0 and 85% to find percentage of moment on the beam from that of the column strip.

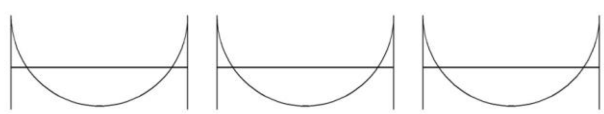
** The Mom. on the remain part of column strip = Tot. Mom. on the column strip – Mom. on the beam.

Summary:

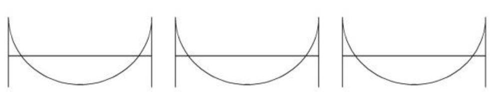
1- Find M_o :



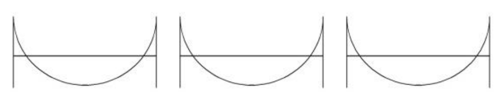
2- Distribute M_0 into +ve and –ve Mom.



3- Distribute Mom. Into column strip and Middle Strip.

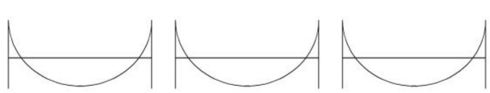


Column strip

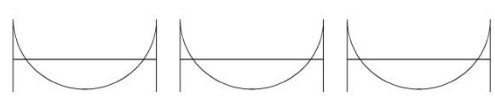


Middle Strip

4- Distribute Mom. In column strip into Mom. On beam and remained slab.



On beam



On remained Slab

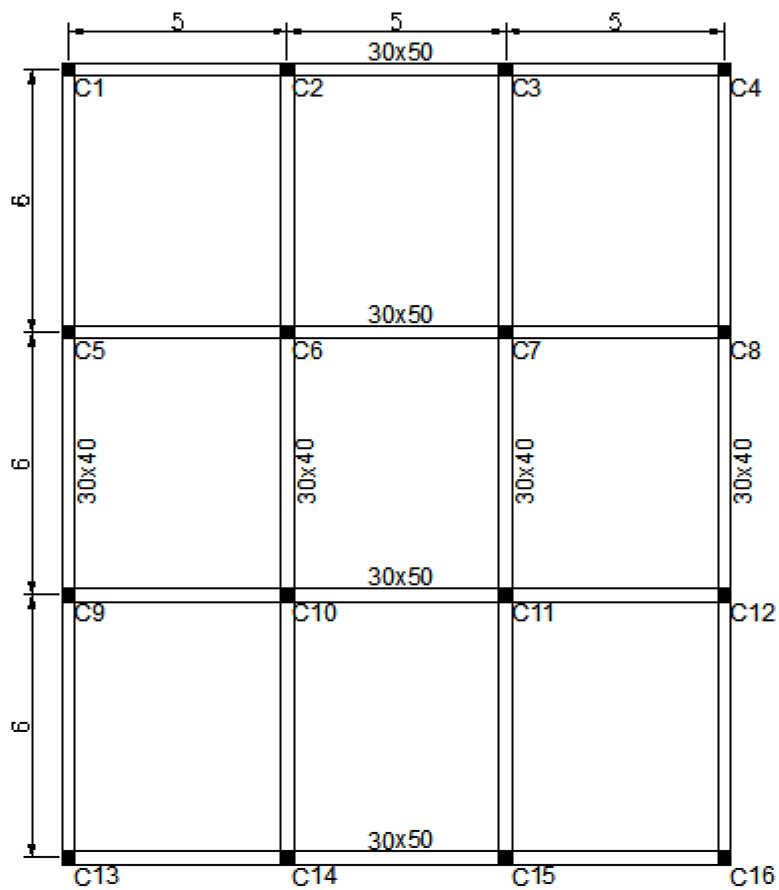
After calculating Moments, we can find the ρ, then A_{st} required

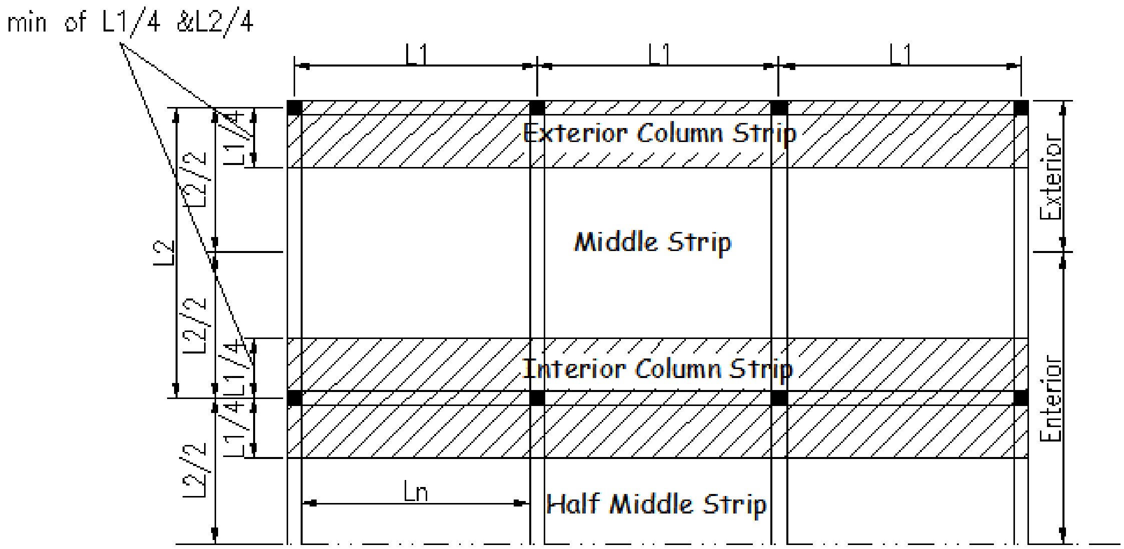
Example 1:

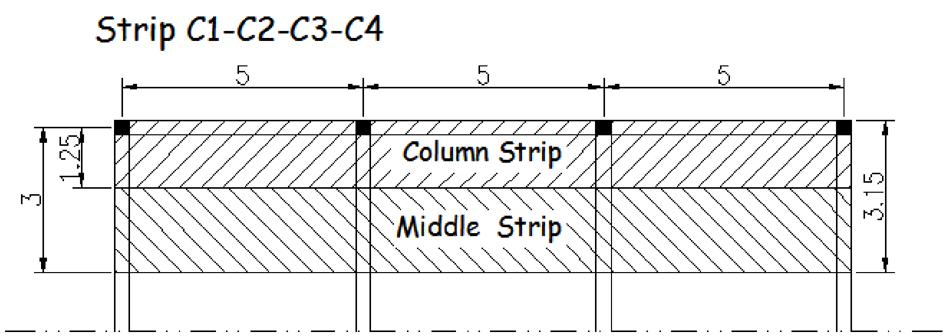
For the given data, design strip 1-2-3-4 of the two way slab for flexure.

Data:

Columns are 30cm X 30cm, Equivalent partitions load=250 Kg/m^2, Live Load = 400Kg/m^2, f_c' = 280 kg/cm^2 , f_y = 4200 Kg/cm^2, slab thickness = 16cm





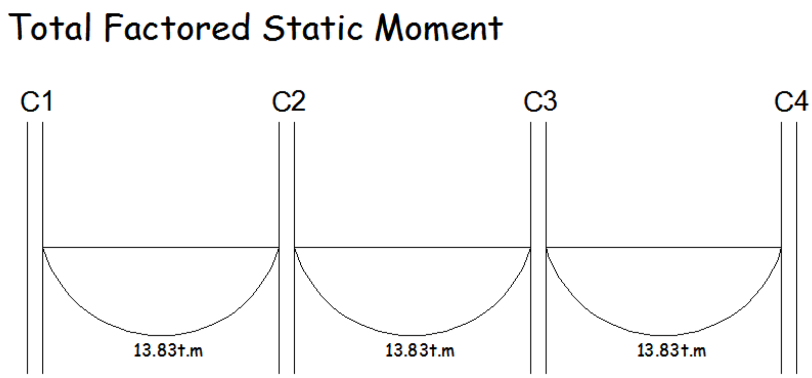


Solution:

Thickness is given 16cm, no need to be checked.

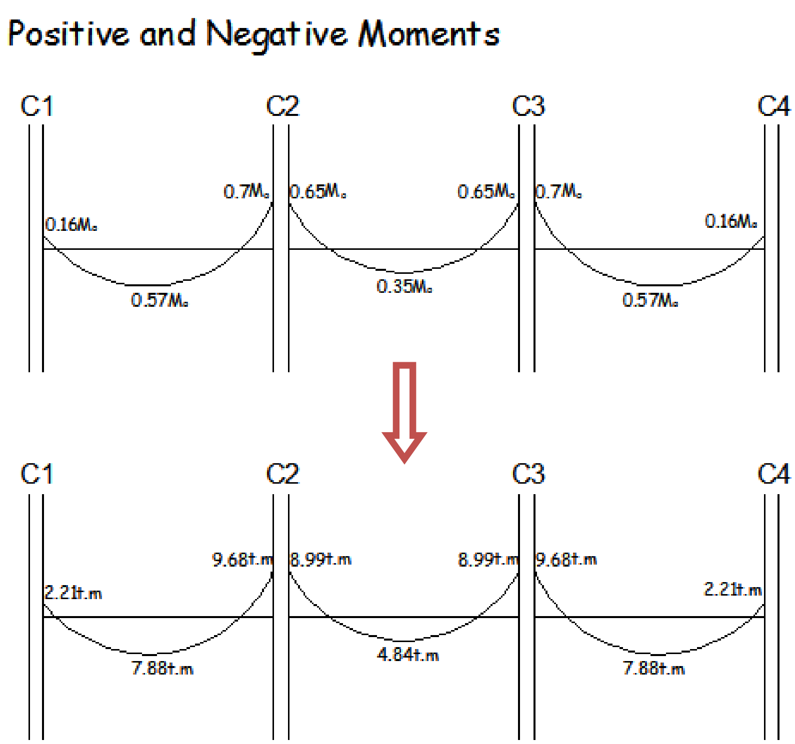
1- **Calculate total factored load W_u "t/m^2":**
   $W_u = 1.4\times(0.16\times2.5 + 0.25) + 1.7\times(0.4) = 1.59$ t/m^2.

2- **Determine The Total Factored Static Moment (M_o) :**
   $M_o = \frac{W_u \times strip\ width \times l_n^2}{8} = \frac{1.59\times\mathbf{3.15}\times4.7^2}{8} = 13.83$t.m



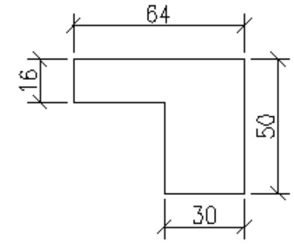
3- Distribute M_o into +ve and –ve moments :

The total factored static moment was distributed according to **T**able "8.9" in your text book as shown in the following **F**igure.



4- Moments on the column Strip :

Evaluate the constant α and β



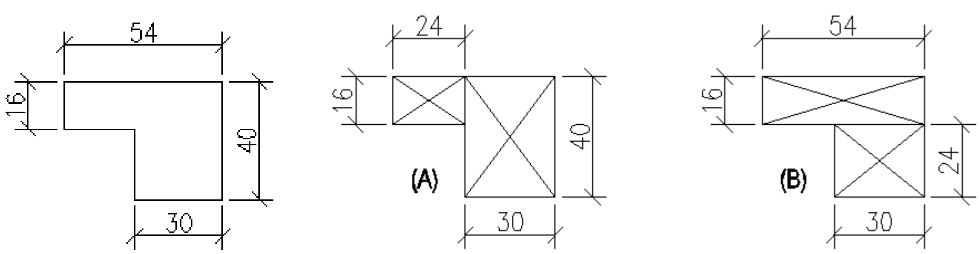
- Evaluation of α:

$\alpha = (\frac{b}{srtip\ width})\ (\frac{a}{h})^3 f$. "**For beam in direction of strip**"

For a/h=50/16=3.125 and b/h=30/16=1.875, f=1.4 (**F**ig. 8.14)

$\alpha = (\frac{0.3}{3.15})\ (3.125)^3 \times 1.4 = 4.07$

- Evaluation of β:



$\beta_t = \frac{C}{2I_s}$. " **For edge beam perpendicular to direction of strip**"

$C_A = \left(1 - 0.63 \times \frac{16}{24}\right)\left(\frac{16^3 \times 24}{3}\right) + \left(1 - 0.63 \times \frac{30}{40}\right)\left(\frac{30^3 \times 40}{3}\right) = 208{,}909.55 cm^4$

$C_B = \left(1 - 0.63 \times \frac{16}{54}\right)\left(\frac{16^3 \times 54}{3}\right) + \left(1 - 0.63 \times \frac{24}{30}\right)\left(\frac{24^3 \times 30}{3}\right) = 128{,}532.48 cm^4$

C = Max (C_A or C_B) = 207393.8

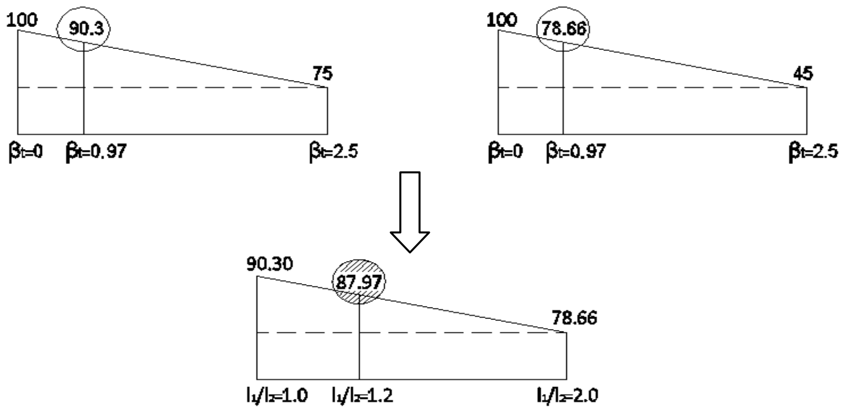
$\beta_t = \frac{208{,}909.55}{\frac{1}{12} \times 315 \times 16^3 \times 2} = 0.97$

After α and β_t are calculated, factors for the moment of column strip can be found from **T**able 8.10, page 343

$\alpha \frac{l_2}{l_1} = 4.07 \times \frac{6}{5} = 4.88 > 1$, β_t between 0 and 2.5 , $\frac{l_2}{l_1} = 1.2$

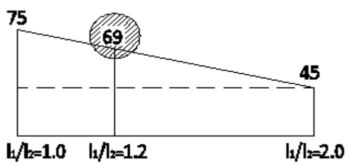
- *– Ve exterior moment Factor :*

	l_1/l_2=1	l_1/l_2=1.2	l_1/l_2=2
β_t = 0	100	100	100
β_t = 0.97	0.903	**0.8797**	0.7866
β_t = 2.5	75	69	45



- *+Ve interior moment Factor :*

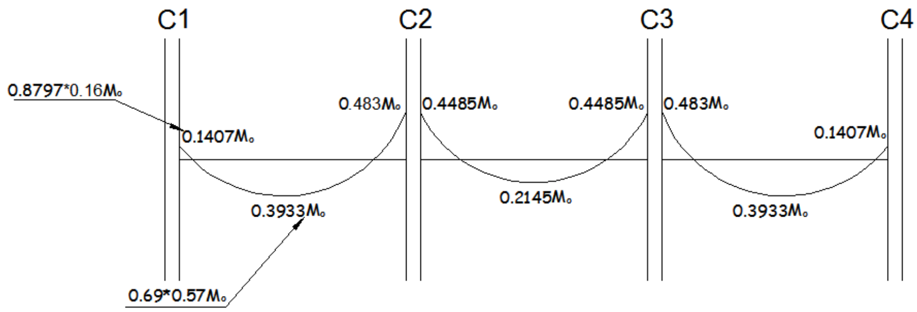
l_1/l_2=1	$l_1 l_2$=1.2	l_1/l_2=2
75	**69**	45



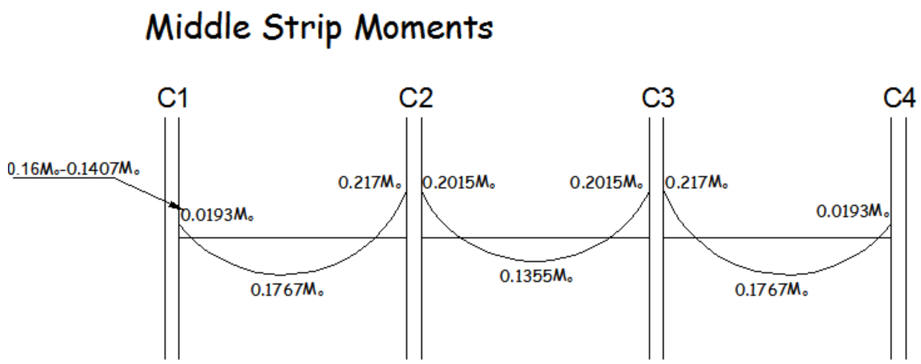
- *-Ve interior moment Factor :*

l_1/l_2=1	l_1/l_2=1.2	l_1/l_2=2
75	**69**	45

Column Strip Moments

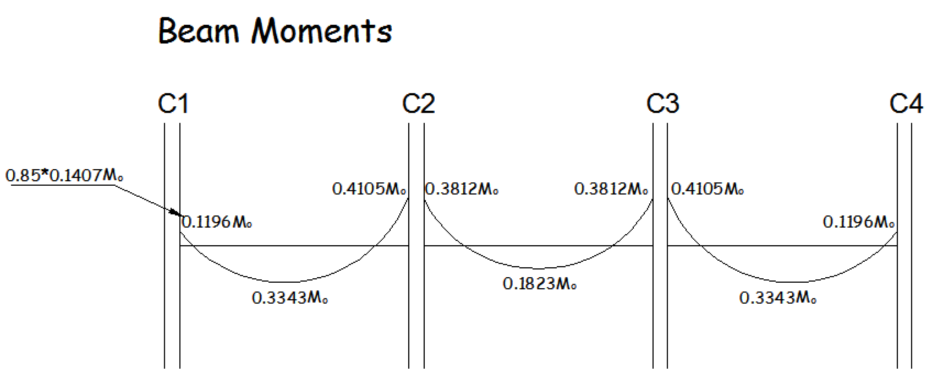


5- Moments on the Middle Strip: "The remain moment":

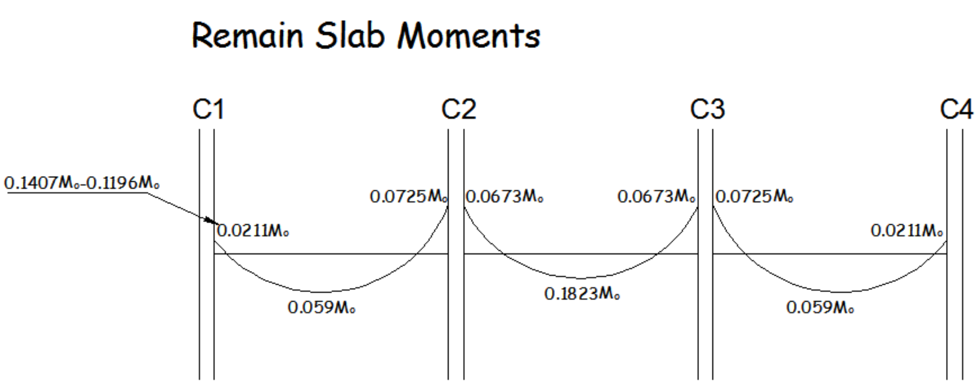


6- Moment On Beam :

As $\alpha \frac{l_2}{l_1} > 1$ …. Beam willl resist 85% of the column strip moment.



7- Moment On Remained Slab :



Notes:

- For each value of moment, ρ can be calculated, thenA_{st}.
- **Widths to used for design and ρ calculations are** :

For the remained slab of column strip: b = 1.25-0.3=0.95m

For half middle strip: b= 3.15-1.25=1.9m

Beam = 0.3m

- Beam should be designed for shear, according to specifications of code **ACI 318"13.6.8"**, and reported in page 344 of your text book.

By:

Eng. AbdUlla Taisir Al-Madhoun

Eng. Nour Nagi Al-Hindi

.