4.8 One-Way Shear Strength

Stresses resulting from one-way shear are normally low, and usually do not control the design. One-way shear stresses must be resisted by concrete strength only and without any reinforcement contribution. The Egyptian code gives the following equation for one-way concrete shear strength:

$$q_{cu} = 0.16\sqrt{\frac{f_{cu}}{\gamma_c}} \qquad \text{.........(4.43)}$$

The critical section for one-way shear is taken at d/2 from the face of the column as shown in Fig. 4.22. The calculated shear stress should be less than concrete shear strength. For example, shear stresses for the interior column shown in Fig. 4.22 are given by

$$q_{u1} = \frac{w_u \times L_2 \times L_x}{L_2 \times d} \le q_{cu} \qquad \text{.........(4.44)}$$

$$q_{u2} = \frac{w_u \times L_1 \times L_y}{L_1 \times d} \le q_{cu} \qquad \text{.........(4.45)}$$

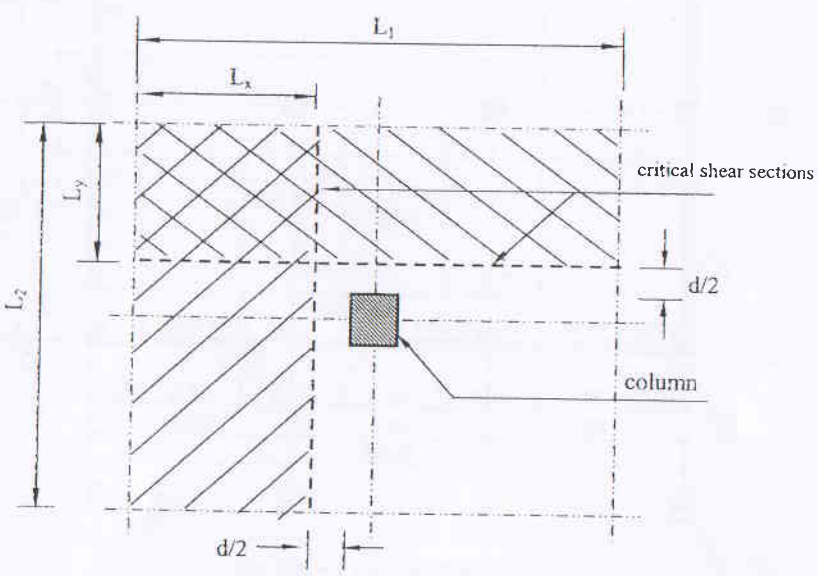


Fig. 4.22 Critical sections for one-way shear in interior columns

Example 4.1

It is required to design the Flat Slab Roof shown in Fig. EX4.1. Columns (500x 500 mm) are only allowed as shown. For architectural purposes, it is required that no drop panels or columns' heads to be used.

Data:-

Concrete Characteristic Strength	=	25	N/mm^2
Steel Yield Stress	=	360	N/mm^2
Live Load	=	4.0	kN/m^2
Flooring	=	2.0	kN/m^2
Equivalent wall loads	=	1.5	kN/m^2
Floor Height	=	3.50	m

Solution:

The floor consists of three equal spans in each direction, the span in the long direction equals $L_1 = 6.0$ m and the span in the short direction L_2=5.0 m

The system satisfies the requirements of the empirical method specified in the Code-article (6-2-5-5)

The average length L_{avg}=5.5 m

Step 1: Dimensioning

- **Slab thickness (t_s):-**

$$t_s = \text{bigger of} \begin{cases} 150\ mm \\ \frac{L_{long}}{32} = \frac{6000}{32} = 187.5\ mm \end{cases}$$

Take t_s = 200 mm

- **Column Dimensions (bxb)**

$$b = \text{bigger of} \begin{cases} 300\ mm \\ \frac{h_{clear}}{15} = \frac{(3500-200)}{15} = 220\ mm \\ \frac{L_1}{20} = \frac{6000}{20} = 300\ mm \end{cases}$$

Thus b=500 mm is satisfactory

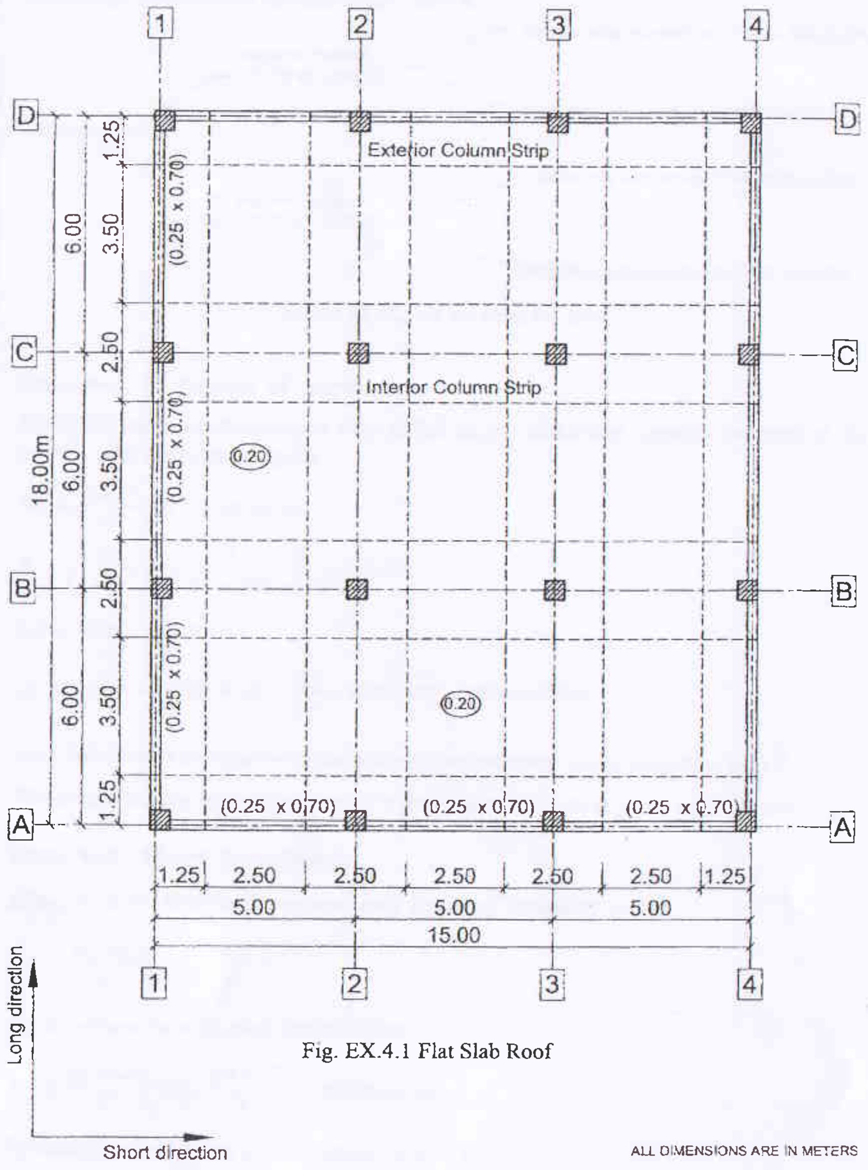


Fig. EX.4.1 Flat Slab Roof

ALL DIMENSIONS ARE IN METERS

- **Marginal Beams ($b_b x t_b$)**

Punching stresses are usually high in exterior and corner columns. Hence, a marginal beam is considered with thickness $t_b \geq 3t_s \geq 600$ mm

Take t_b = 700 mm & b_b = 250 mm

- **Column and Field Strips:-**

Assume that width of Column Strip = ½ Smaller side = 1/2x5.0 = 2.50 m .

Width of Field Strip:-

For short direction = 6.00-2.50 = 3.50 m

For long direction = 5.00-2.50 = 2.50 m

Step 2: Minimum steel requirements:-

For f_y = 360 N/mm^2

$$A_{s,min}(long) = \frac{0.6}{360} \times 1000 \times (200-20) = 300\ mm^2/m'$$

$$A_{s,min}(short) = \frac{0.6}{360} \times 1000 \times (200-30) = 283\ mm^2/m'$$

Step 3: Load calculations

Dead Load, g_s = Own weight + Flooring + Equivalent Wall Loads

$= 25 \times 0.20 + 2.0 + 1.5 = 8.5\ kN/m^2$

Live Load, p_s = 4.0 kN/m^2

Since the live loads is less than 0.75 the dead loads

w_{su} = 1.50 (g_s + p_s)

= 1.5 x (8.50 + 4.0)

= 18.75 kN/m^2

Step 4: Design of Strips

Step 4-a: Long Direction

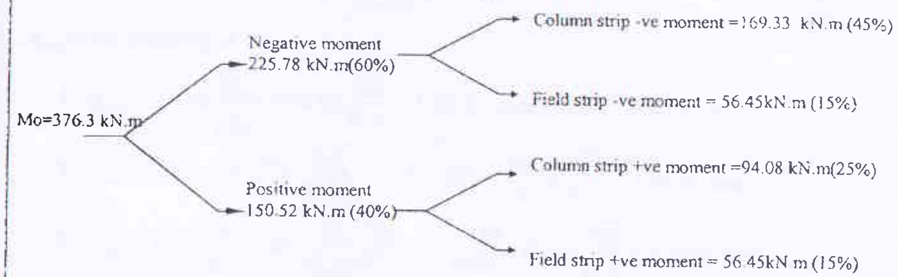
Step 4-a-i: Statical system and bending moment

$$M_o = \frac{w_{su} \times L_2}{8}\left(L_1 - \frac{2 \times D}{3}\right)^2$$

As no column head is used D=b=0.50 m

$$M_o = \frac{18.75 \times 5}{8}\left(6.0 - \frac{2 \times 0.5}{3}\right)^2 = 376.3\ kN.m$$

Percentage of moments is taken from Table 4.1



Distribution of M_o for an interior bay

Step 4-a-ii: Design of sections

Since the width of the column strip is 2.5 m, the maximum negative moment at the interior panel per meter equals

$$M_u = \frac{169.33}{2.5} = 67.73\ kN.m/m'$$

$$R = \frac{M_u}{f_{cu} \times b \times d^2} = \frac{67.73 \times 10^6}{25 \times 1000 \times 180^2} = 0.084$$

For α =0.0 ω=0.107

$$A_s = \omega \times \frac{f_{cu}}{f_y} \times b \times d = 0.107 \times \frac{25}{360} \times 1000 \times 180 = 1337\ mm^2/m'$$

use (9Φ 14 /m') as negative column strip reinforcement in the long direction

The design for the rest of the long direction critical section is given in the figure

Step 4-b: Short Direction:-

Step 4-b-i: Statical system and bending moment:-

$$M_o = \frac{w_{su} \times L_1}{8}\left(L_2 - \frac{2 \times D}{3}\right)^2$$

As no column head is used D=b=0.50 m

$$M_o = \frac{18.75 \times 6}{8}\left(5.0 - \frac{2 \times 0.5}{3}\right)^2 = 306.25\ kN.m$$

Percentage of moments is taken from Table 4.1

Step 4-b-ii: Design of sections

Since the width of the column strip is 2.5 m, the maximum negative moment at the interior panel per meter equals

$$M_u = \frac{137.81}{2.5} = 55.12\ kN.m/m'$$

since this is the secondary direction d=200-30=170 mm

$$R = \frac{M_u}{f_{cu} \times b \times d^2} = \frac{55.12 \times 10^6}{25 \times 1000 \times 170^2} = 0.076$$

For α =0.0 ω=0.097

$$A_s = \omega \times \frac{f_{cu}}{f_y} \times b \times d = 0.097 \times \frac{25}{360} \times 1000 \times 170 = 1144\ mm^2/m'$$

use (6Φ12/m'+3Φ14 /m') as negative column strip reinforcement of the short direction

The design for the rest of the short direction critical sections is given in the figure

Step 5: Design of edge column strip

Due to the presence of the marginal beam, the moment in the exterior strip/m' equal half the moment in the interior strip/m'.

So, the reinforcement in the exterior strip/m equals half the reinforcement in the interior strip/m'. (While considering the minimum steel requirements).

Step 6: Check for negative reinforcement in the field span

As g_s >2/3 p_s, no top reinforcement is required. However, since the slab thickness is greater than 160 mm, shrinkage top mat is needed (use 6 Φ 10/m' in the long direction and 5 Φ 10/m' in the short direction)

Step 7: Design for Punching Shear for Interior Column

Assume concrete cover of 20 mm

d = 200-20 = 180 mm

$a_1 = b_1$=500 +180 = 680 mm

Q_{up} = 18.75 × 5.0 × 6 – 18.75 × 0.68 × 0.68 = 554 kN

β =1.15 (case of interior column)

$b_o = 2 \times (680+680) = 2720$ mm

$$q_u = \frac{Q_{up}\,\beta}{b_o\,d} = \frac{554 \times 1000 \times 1.15}{2720 \times 180} = 1.3\ N/mm^2$$

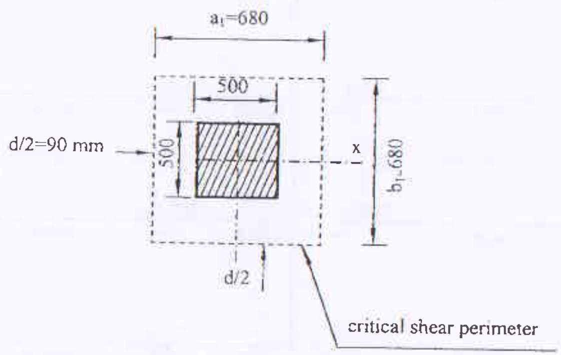
q_{cup} is the smallest of

1. $q_{cup} = 0.316\sqrt{\frac{f_{cu}}{\gamma_c}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2 < 1.6....o.k$
2. $q_{cup} = 0.316\,(0.5 + \frac{a}{b}) \times \sqrt{\frac{f_{cu}}{\gamma_c}} = 0.316\,(0.5 + \frac{500}{500}) \times \sqrt{\frac{25}{1.5}} = 1.93\ N/mm^2$
3. $q_{cup} = 0.8\,(\frac{\alpha\, d}{b_o} + 0.2) \times \sqrt{\frac{f_{cu}}{\gamma_c}} = 0.8\,(\frac{4 \times 180}{2720} + 0.2) \times \sqrt{\frac{25}{1.5}} = 1.51\ N/mm^2$

Note : α =4.0 for interior columns

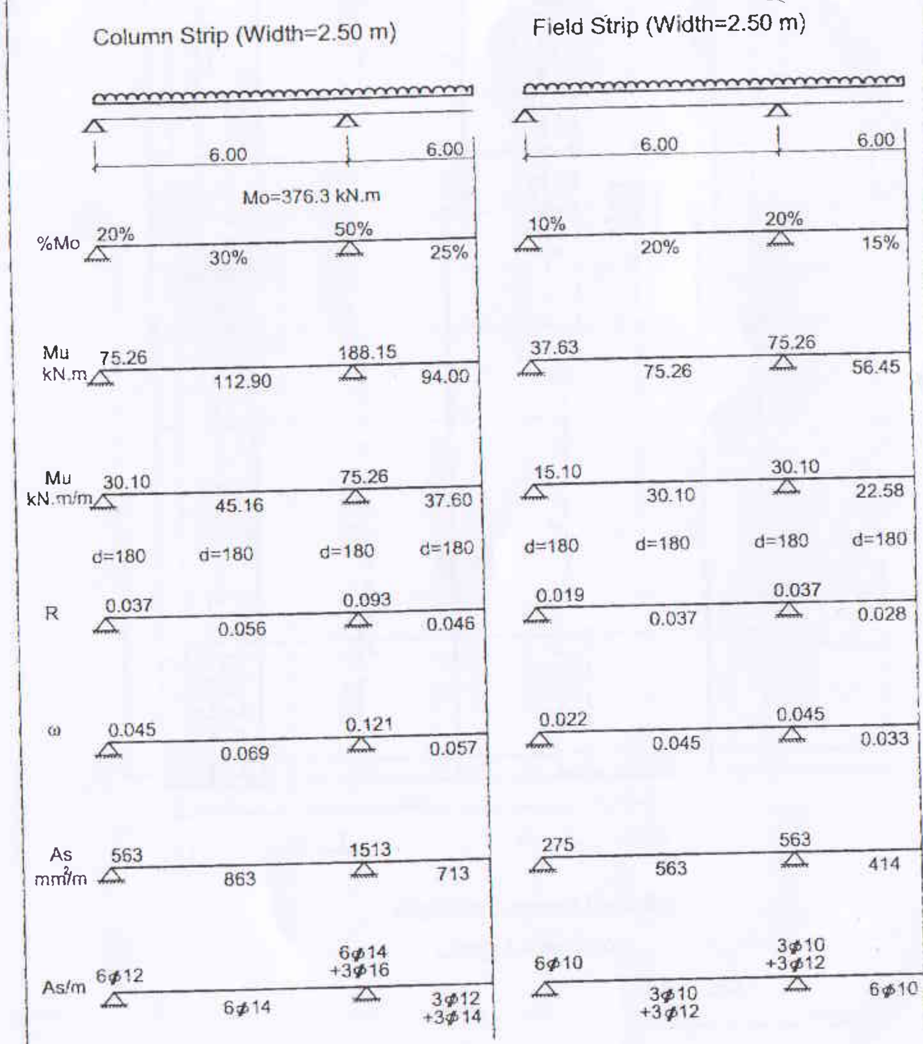
q_{cup}=1.29 N/mm^2

Since $q_u \cong q_{cup}$, the slab is considered safe regarding to punching



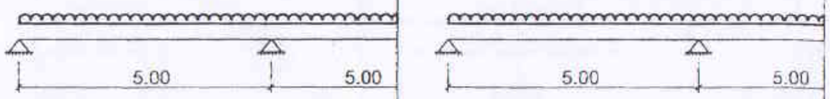
The punching strength of the exterior and corner columns can be checked in similar manner.

Design of Long Direction

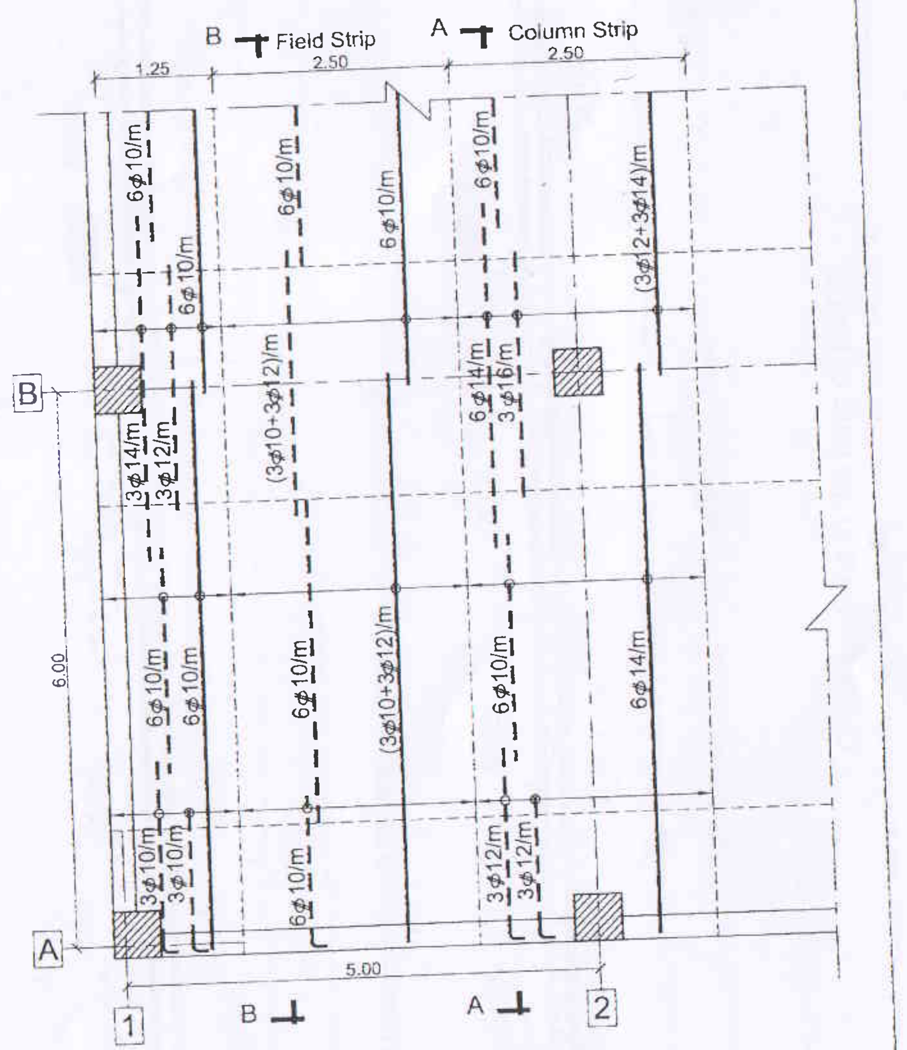


Design of Short Direction

Column Strip (Width=2.5m) — Field Strip (Width=3.50 m)

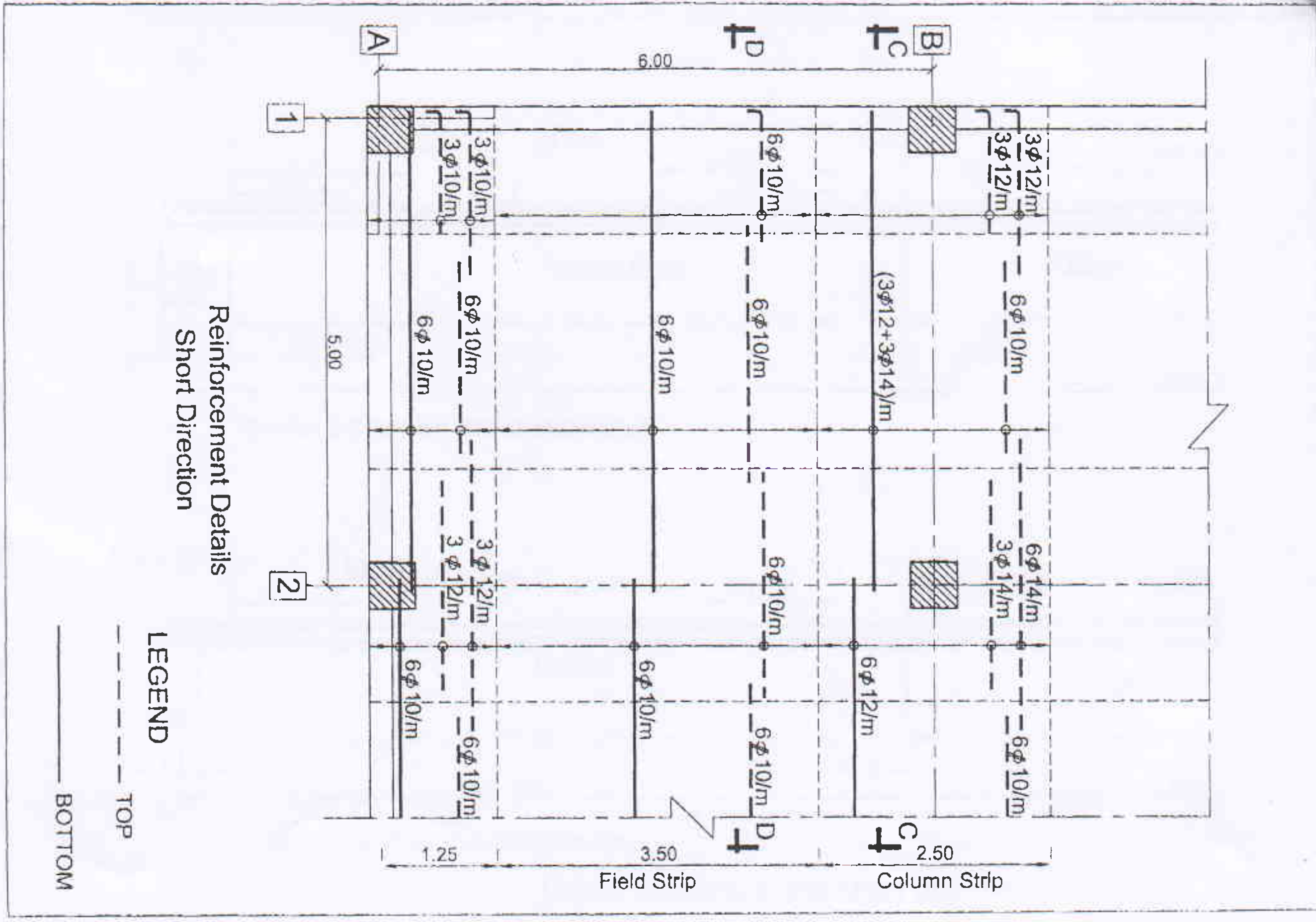


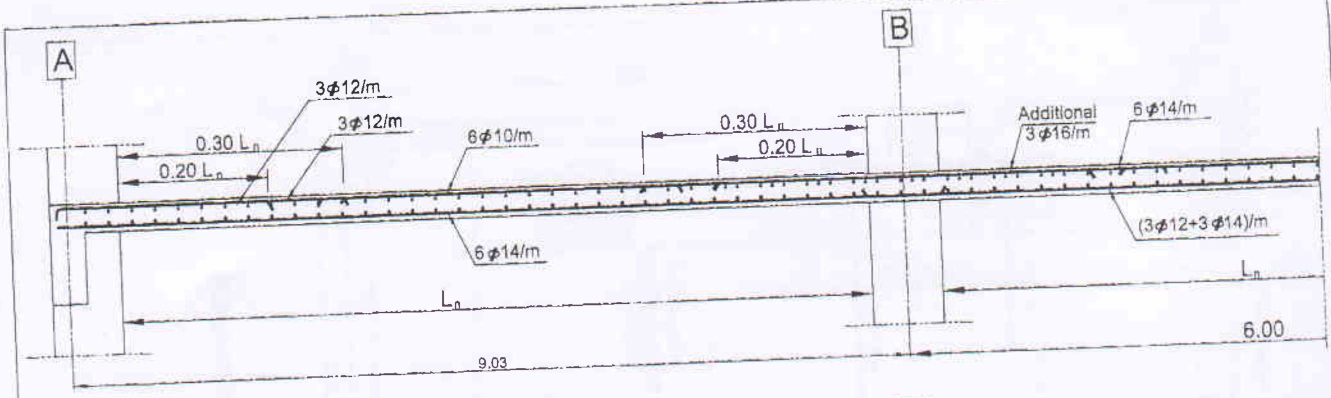
	Column Strip				Field Strip			
%Mo	20%	30%	50%	25%	10%	20%	20%	15%
Mu kN.m	61.25	91.88	153.13	76.56	30.63	61.25	61.25	45.94
Mu kN.m/m	24.50	36.75	61.25	30.62	8.75	17.50	17.50	13.13
	d=170	d=170	d=170	d=170	d=170	d=170	d=170	d=170
R	0.034	0.051	0.085	0.042	0.012	0.024	0.024	0.018
ω	0.041	0.062	0.109	0.051	0.014	0.028	0.028	0.021
As mm^2/m	481	737	1291	600	165	335	335	250
As/m	6ϕ12	3ϕ12 +3ϕ14	9ϕ14	6ϕ12	6ϕ10	6ϕ10	6ϕ10	6ϕ10



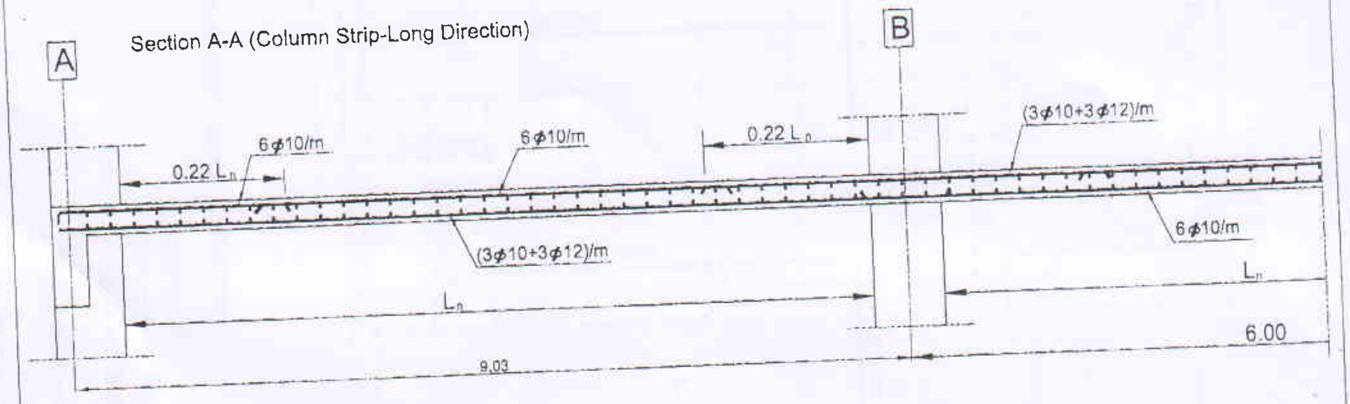
Reinforcement Details
Long Direction

LEGEND
- - - - - - TOP
———— BOTTOM





Section A-A (Column Strip-Long Direction)



Section B-B (Field Strip-Long Direction)

Cross sections in the long direction