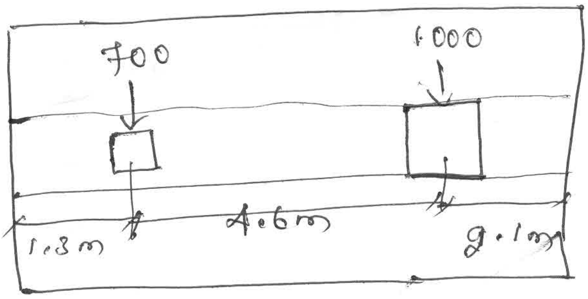
IAT - I[st] SOLUTION - DDRCC 31/08/17

(2) Two Interior column A&B carrying 700 kN & 1000 kN Respectively.
column A is 350 mm × 350 mm column B 400 × 400 mm at a Section Centre to Centre Spacing is 4.6 m, The Soil on which the footing Rest capable of providing Resistance to 130 kN/m². Design a combined footing providing Central beam use M_{20} grade and Fe415 Steel.

Soln



Area of footing = $\frac{\text{Total load}}{\text{SBC}}$

Total load = 700 + 1000 + 10% ($w_1 + w_2$)

Total load = 1870 kN

Area of footing = $\frac{1870}{130}$ = 14.38 m²

L × B = 14.38 m² B = 1.8 m

L = $\frac{14.38}{1.8}$

~~L = 7.98 m~~ ≈ L = 10 m

$L = 7.98\ m \simeq 8\ m$

$M_A = W \times \bar{x} = W_2 \times 4.6$

$$\bar{x} = \frac{1000 \times 4.6}{700 + 1000}$$

$$\boxed{\bar{x} = 2.70\ m}$$

$a_1 = L/2 - \bar{x}$

$a_1 = \frac{8}{2} - 2.70$

$\boxed{a_1 = 1.3\ m}$

$a_2 = L - (a_1 + 4.6)$

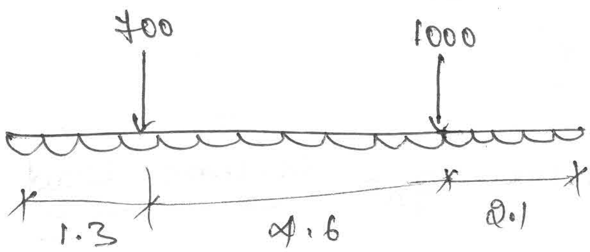
$a_2 = 8 - (1.3 + 4.6)$

$\boxed{a_2 = 2.1\ m}$

$$\text{Net upword pressure} = \frac{W}{\text{Area}} = \frac{1000 + 700}{8 \times 1.8}$$

$$\boxed{q_a = 118.05\ kN/m^2}$$

Design of footing slab :-



$M = \frac{wl^2}{2} = 118.05 \times$

Soln

Data = SBC = 130 kN/m²

concrete = M_{25} grade

Steel = Fe_{415} grade

Design

Step 1 Size of footing.

Total column load = 700 + 1000 = 1700 kN

Self wt of footing = 10% of total load

$= \frac{10}{100} \times 1700 = 170$ kN

Total = 1870 kN

Area of footing = L × B = $\frac{\text{Total load}}{SBC} = \frac{1870}{130}$

L × B = 14.38

L × 1.8 = 14.38

L = 7.99 ≃ 8m

A = 8 × 1.8 = 14.4 m²

up load Soil pressure $q_0 = \frac{\text{Column load}}{\text{Area}}$

$= \frac{~~2000~~}{~~14.4~~} = \frac{1700}{14.4} = 118.05$ kN/m²

Step 2 :- projections :

The projections P_1 & P_2 should be such that the centre of gravity of column load should coincide with the CG of the footing

$$\therefore \quad P_1 + \bar{x} = l/2$$

$$\bar{x} = \frac{w_1 x_1 + w_2 x_2}{w_1 + w_2}$$

$$\bar{x} = \frac{700 \times 0 + 1000 \times 4.6}{700 + 1000}$$

$$\boxed{\bar{x} = 2.70\ m}$$

$$P_1 + \bar{x} = l/2$$

$$P_1 + 2.7 = 8/2$$

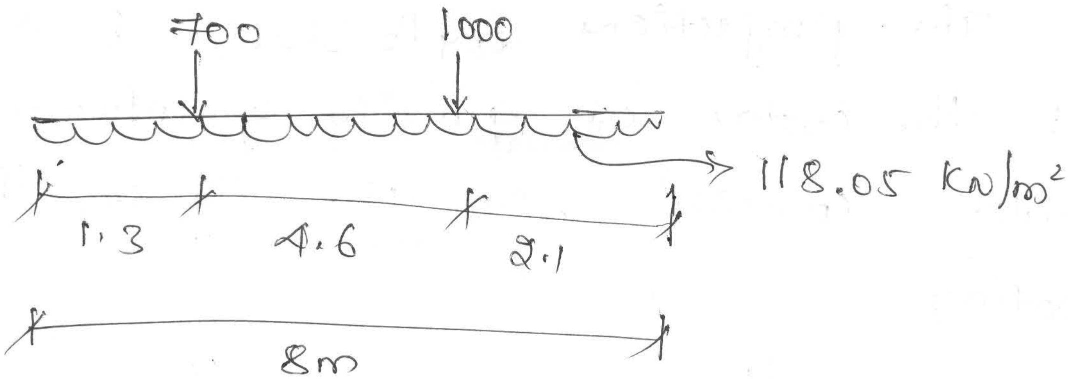
$$P_1 = 1.3\ m$$

$$P_1 + 4.6 + P_2 = 8$$

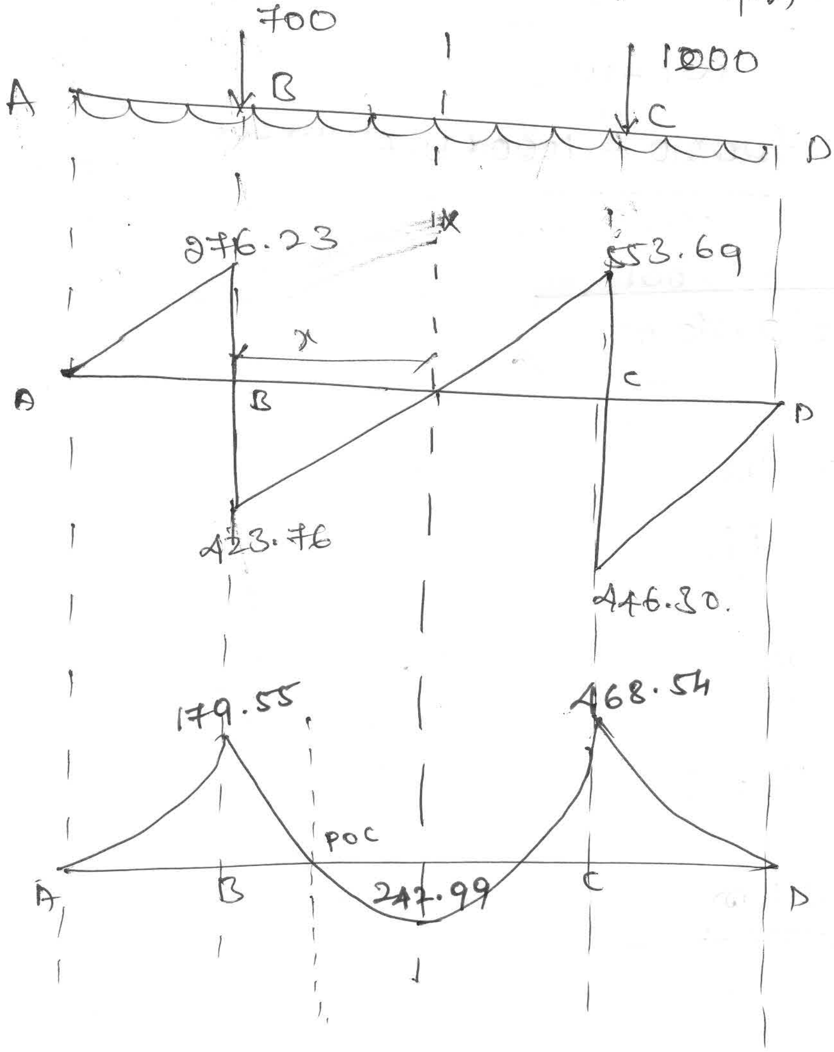
$$P_2 = 2.1\ m$$

Step 3

BMD & SFD



$q_0 = 118.05 \times 1.8 = 212.49$ KN/m



SF @ A = 0

SF @ B (Just left of Section) = 212.49 × 1.3 = 276.23 kN

SF @ B (Right of Section) = 276.23 − 700 = −423.76 kN

SF @ C (Just left of Section) = −423.76 + (212.49 × 4.6) = 553.69 kN

SF @ C (Right of Section) = 553.69 − 1000 = −446.30 kN

SF @ D = 0

BMD

$M_A = 0$

$M_B = 212.49 \times 1.3 \times \frac{1.3}{2} = 179.55$ kN-m

Max - location of zero shear force i.e x as shown in fig.

$$\frac{276.23}{1.3} = \frac{423.76}{x}$$

x = 1.994m ≈ 2m

BM is max @ a distance of 1.99m from point B where the SF is zero

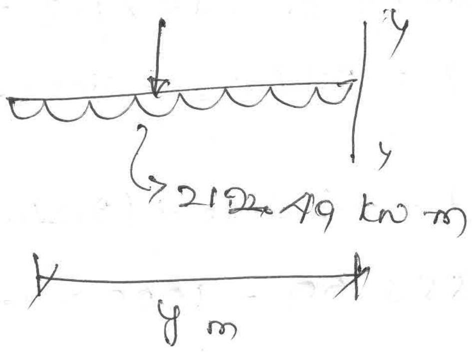
∴ Max BM $M_{xx} = 212.49 \times 3.3 \times \frac{3.3}{2} - 700 \times 2$

= −242.99 kN-m

$M_C = 212.49 \times 2.1 \times \frac{2.1}{2} = 468.54$ kN-m

(8)

Location of point of contraflexure (point @ which BM = 0)



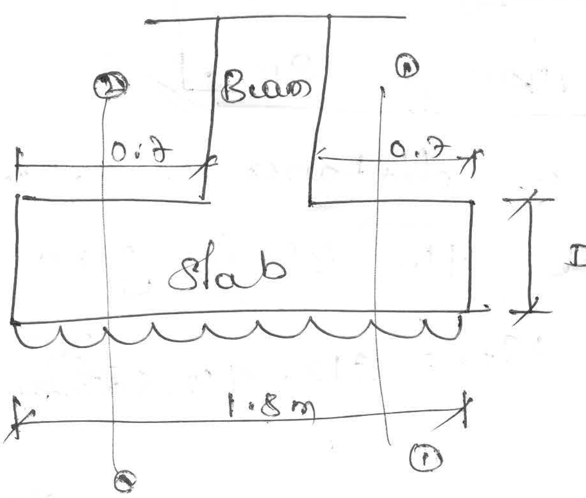
Consider a Section y-y @ a distance of y a shown fig ∴ BM @ y-y.

$$M_{yy} = 212.49 \times y \times y/2 - 700 \times (y - 1.3)$$

$$= 106.245 y^2 - 700y + 910$$

$y_2 = 4.80 m$ $y_1 = 1.78 m$

Step 4 Design of footing slab



Assuming beam width = 0.4m Same as bigger column size Consider a Section ①-① as shown in fig as a Critical Section for calculating BM

$$M_{①-①} = \frac{118.05 \times 0.7 \times 0.7}{2} = 28.92 \text{ kN-m}$$

ultimate moment $M_u = 1.5 \times 28.92 = 43.38$ kN m

using M_u limit $= 0.138 f_{ck} b d^2$

$$43.38 \times 10^6 = 0.138 \times 25 \times 1000 \times d^2$$

$$d = 112.13 \text{ mm}$$

using 60mm as effective cover

Overall depth $D = 112 + 60 = 172$ mm ≃ 180mm

∴ effective depth $d = 180 - 60 = 120$ mm

Area of Steel :-

$$M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{f_{ck} b d}\right]$$

$$43.38 \times 10^6 = 0.87 \times 415 \times A_{st} \times 120 \left[1 - \frac{A_{st} \times 415}{25 \times 1000 \times 120}\right]$$

$$43.38 \times 10^6 = 43326 A_{st} - 5.99 A_{st}^2$$

$$A_{st} = 1200.49 \text{ mm}^2$$

provide 12mm ϕ hence

$$\text{spacing} = \frac{\pi/4 \times 12^2}{1200.49} \times 1000 = 94.20 \text{mm}$$

provide 12mm ϕ main # @ 90 mm c/c

Distribution steel :-

Area of distribution steel =

$$= \frac{0.12}{100} \times 1000 \times 180 = 216 \text{ mm}^2$$

$$\text{Spacing of 10mm } \phi = \frac{\pi/4 \times d^2}{A_{st}} \times 1000$$

$$= \frac{\pi/4 \times 10^2}{216} \times 1000 = 363.61 \text{ mm c/c}$$

∴ provide 10mm ϕ # @ 350 mm c/c Distribution Steel

Check for shear :-

The critical section for shear force is @ a distance of 140mm from the face of the beam

ultimate SF @ critical section

$V_u = 1.5\,[118.09 \times 0.56]$

$V_u = 99.19$ kN

$\tau_v = \frac{V_u}{bd} = \frac{99.19 \times 10^3}{1000 \times 120} = 0.82\ N/mm^2$

From table 19 of IS456 pg 73

$\frac{100 A_{st}}{bd} = \frac{100 \times 1200.49}{1000 \times 120} = 1.00$

∴ $\tau_c = 0.62\ N/mm^2$

Comparing τ_c & τ_v $\tau_c < \tau_v$

it is unsafe

Hence increase the slab depth

$\tau_v = \frac{V_u}{bd}$

$0.62 = \frac{99.19 \times 10^3}{1000 \times d}$

$d = 159.98$ mm $d = 160$ mm

Step 5 Design of beam

provide width of the beam ∴ Size of bigger column $b = 400mm$

Max Bm from the BM diagram

$M_{max} = 468.54$ kN-m

ultimate Bm $M_u = 1.5 \times 468.54$

$M_u = 702.81$ kN-m

To design the depth of beam

$M_{u\,lim} = 0.138 f_{ck} b d^2$

$702.81 \times 10^6 = 0.138 \times 25 \times 400 \times d^2$

$d = 713.64\,mm \simeq 720mm$

$D = 720 + 60 = 780mm$

Area of Steel :-

AB and CD portion is designed as Rectangular beam & BC portion is designed as T-beam

Area of Steel for AB portion

$M = 179.55$ kN-m

$M_u = 1.5 \times 179.55 = 269.32$ kN-m

using

$$M_{u\,lim} = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{f_{ck} b d}\right]$$

$$269.32 \times 10^6 = 0.87 \times 415 \times A_{st} \times 720 \left[1 - \frac{A_{st} \times 415}{25 \times 400 \times 720}\right]$$

$269.32 \times 10^6 = 259956\, A_{st} - 14.98\, A_{st}^2$

$A_{st} = 1106.58\ mm^2$

Assume 20mm ϕ

No of 20mm ϕ # = $\frac{A_{st}}{\text{dia of bar}}$

$= \frac{1106.58}{\pi/4 \times 20^2} = 3.52 \simeq 4$ #

provide 20 mm ϕ # of 4 No for AB portion

Design for CD portion :-

$M = 468.54$ kN-m

$M_u = 468.54 \times 1.5 = 702.81$ kN-m

using $M_{ulim} = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{f_{ck} b d}\right]$

$702.81 \times 10^6 = 0.87 \times 415 \times A_{st} \times 720 \left[1 - \frac{A_{st} \times 415}{25 \times 400 \times 720}\right]$

$702.81 \times 10^6 = 259956\, A_{st} - 14.98\, A_{st}^2$

$A_{st} = 3350.44\ mm^2$

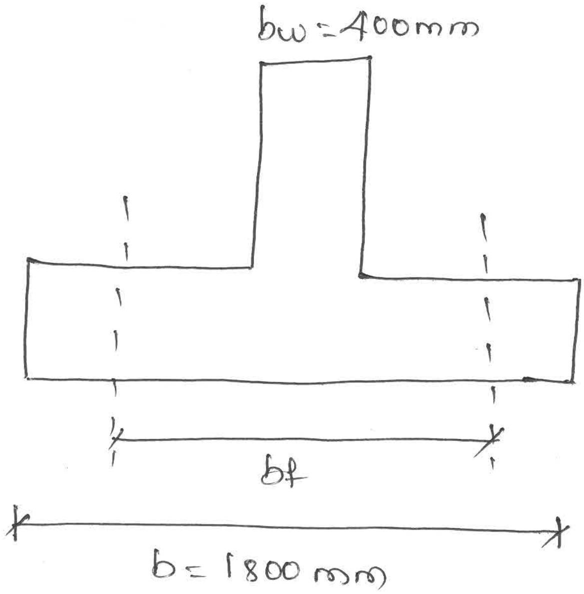
No of # = $\frac{3350.44}{\pi/4 \times 20^2} = 10.66 \simeq 11$ #

provide 20 mm ϕ # of 11 Nos for C portion Beam

Area of Steel for BC portion :-

This position is designed as T- beam

∴ b = breadth of flanges i.e effective flange width from PG 37 of IS 456



b = bf

bw = 400mm

$$b_f = \frac{l_o}{\left(\frac{l_o}{b} + 4\right)} + b_w$$

l_o = distance b/w zero moments

i.e $x_2 - x_1$ from BMD

l_o = [illegible]

b_f =

$$l_o = 4.80 - 1.78$$

$$l_o = \underline{3.02\,m}$$

$$b_f = \frac{3020}{\left(\frac{3020}{1800} + 4\right)} + 400$$

$$b_f = 931.89 \simeq \underline{932\,mm}$$

$M = 242.99$ kN-m

$M_u = 1.5 \times 242.99 = 364.48$ kN-m

$M_{ulim} = 0.87 \times f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$

$364.48 \times 10^6 = 0.87 \times 415 \times A_{st} \times 720 \left[1 - \frac{A_{st} \times 415}{25 \times 932 \times 720}\right]$

$364.48 \times 10^6 = 259956 A_{st} - 6.43 A_{st}^2$

$A_{st} = 1454.40 \text{ mm}^2$

Assume 20mm dia bars

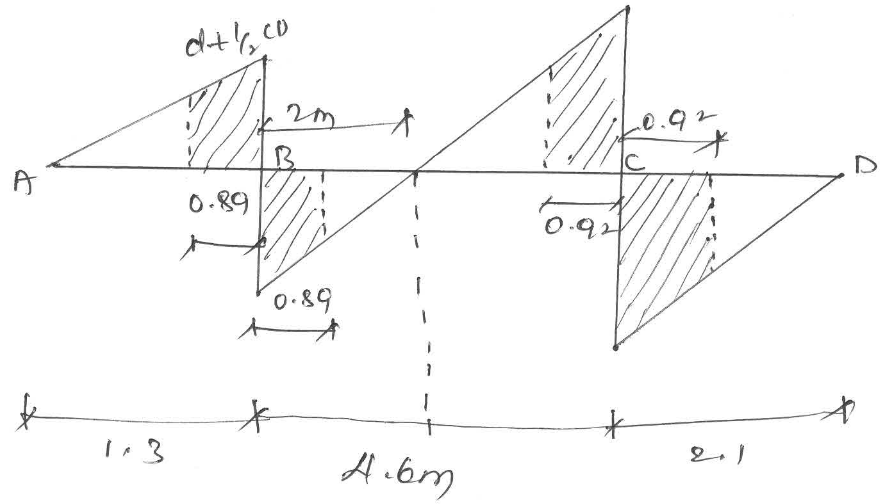
$\#$ 20mm ϕ $\# = \frac{1454.40}{\pi/4 \times 20^2} = 4.62 \simeq 5\#$

Provide 20mm ϕ # of 5 No for BC portion Beam

Shear design for beam

b = 400mm   d = 720mm   D = 780mm M_{15}, Fe_{415}

Critical section for shear force is @ a distance of effective depth d = 720mm from face of the column



$$\frac{x_1}{(1.3 - 0.895)} = \frac{276.23}{1.3}$$

$x_1 = 86.05$ kN

$$\frac{x_2}{1.105} = \frac{423.76}{2} = 234.12 \text{ kN}$$

$$\frac{x_3}{1.68} = \frac{553.69}{2.6} = x_3 = 357.76 \text{ kN.}$$

$$\frac{x_4}{1.175} = \frac{446.30}{2.1} \qquad x_4 = 249.71 \text{ kN.}$$

the Maximum Value is $x_3 = 357.76$ kN

$V_a = 357.76$ kN

$V_u = 357.76 \times 1.5$

$V_u = 536.64$ kN

$$A_{st\,pro} \text{ (BC portion)} = \frac{5 \times \pi \times 20^2}{4} = 1570.79 \text{mm}^2$$

Nominal Shear Stress $\tau_v = \frac{V_u}{bd} = \frac{536.64 \times 10^3}{400 \times 720}$

$\tau_v = 1.86$ N/mm²

$P_t = \frac{100 A_{st}}{bd}$

$P_t = \frac{100 \times 1570.79}{400 \times 720}$

$P_t = 0.5$

$\tau_c = 0.48 \ N/mm^2$

comparing $\tau_v > \tau_c$

hence provide shear Reinforcement

$V_{us} = \frac{0.87 \ f_y A_{sv} d}{S_v}$

using 4-legged 8mm ϕ Vertical Stirrups

$A_{sv} = 4 \times \pi \times \frac{8^2}{4} = 201.6 mm^2$

$V_{us} = V_u - \tau_c bd$

$V_{us} = 586.64 - 0.48 \times 400 \times 720$

$V_{us} = 398.40 \ kN$

$S_v = \frac{0.87 \times 415 \times 201.06 \times 720}{398.40}$

$S_v = 131.19 mm \simeq 130 mm$

From pg 48 of IS 456 Minimum shear Reinforcement

$\frac{A_{sv}}{b S_v} = \frac{0.4}{0.87 f_y}$

$$S_v = \frac{201.06 \times 0.89 \times 415}{400 \times 0.4}$$

$S_v = 453.1$ mm c/c.

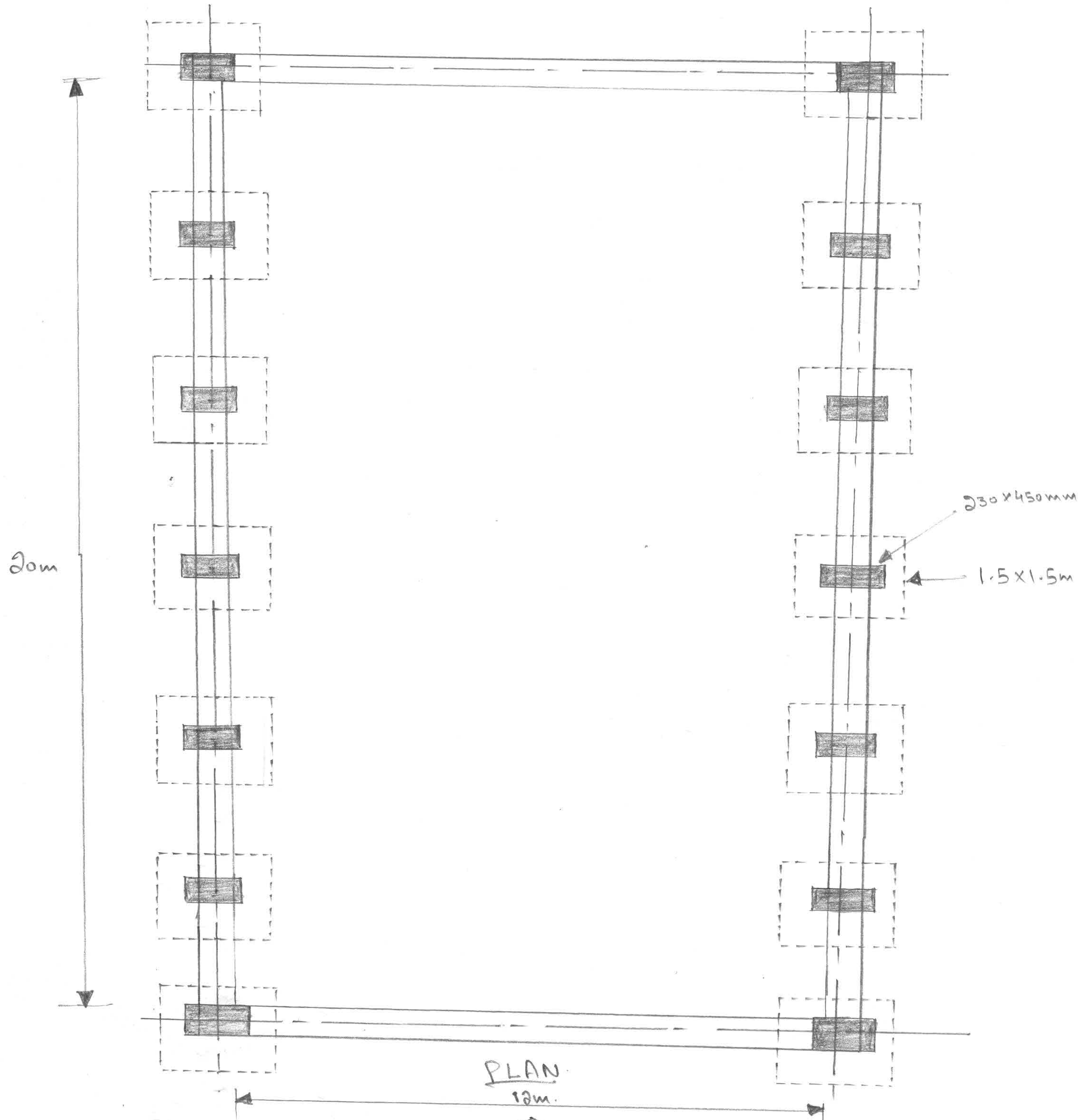
But max spacing $0.75 \times d$ @ 300mm

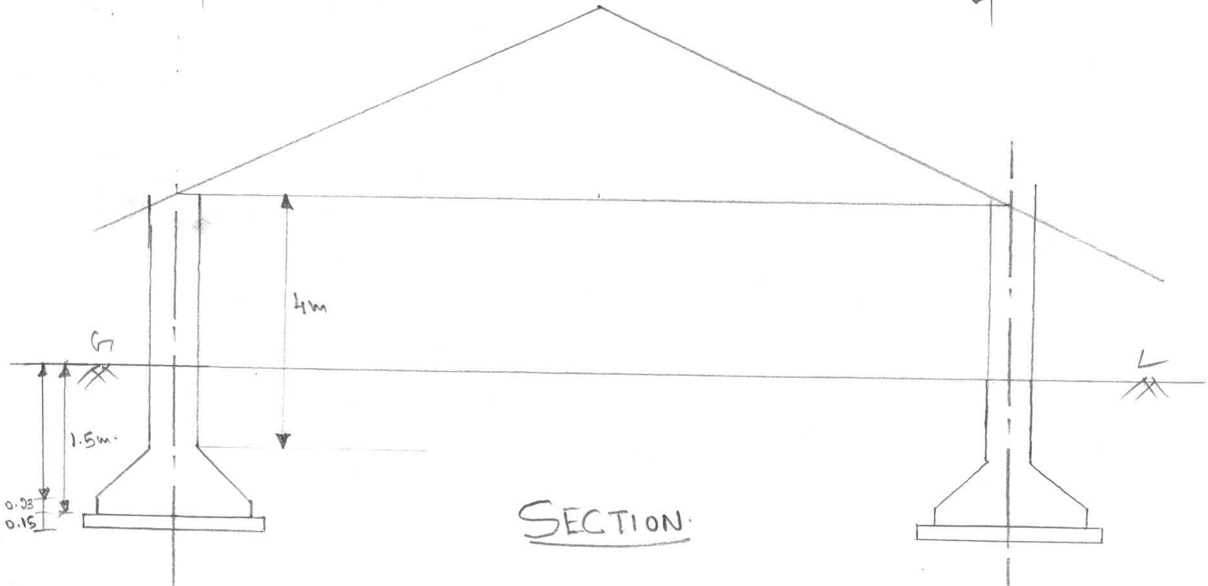
Provide 4 legged vertical stirups of 8mm dia @ 300mm c/c

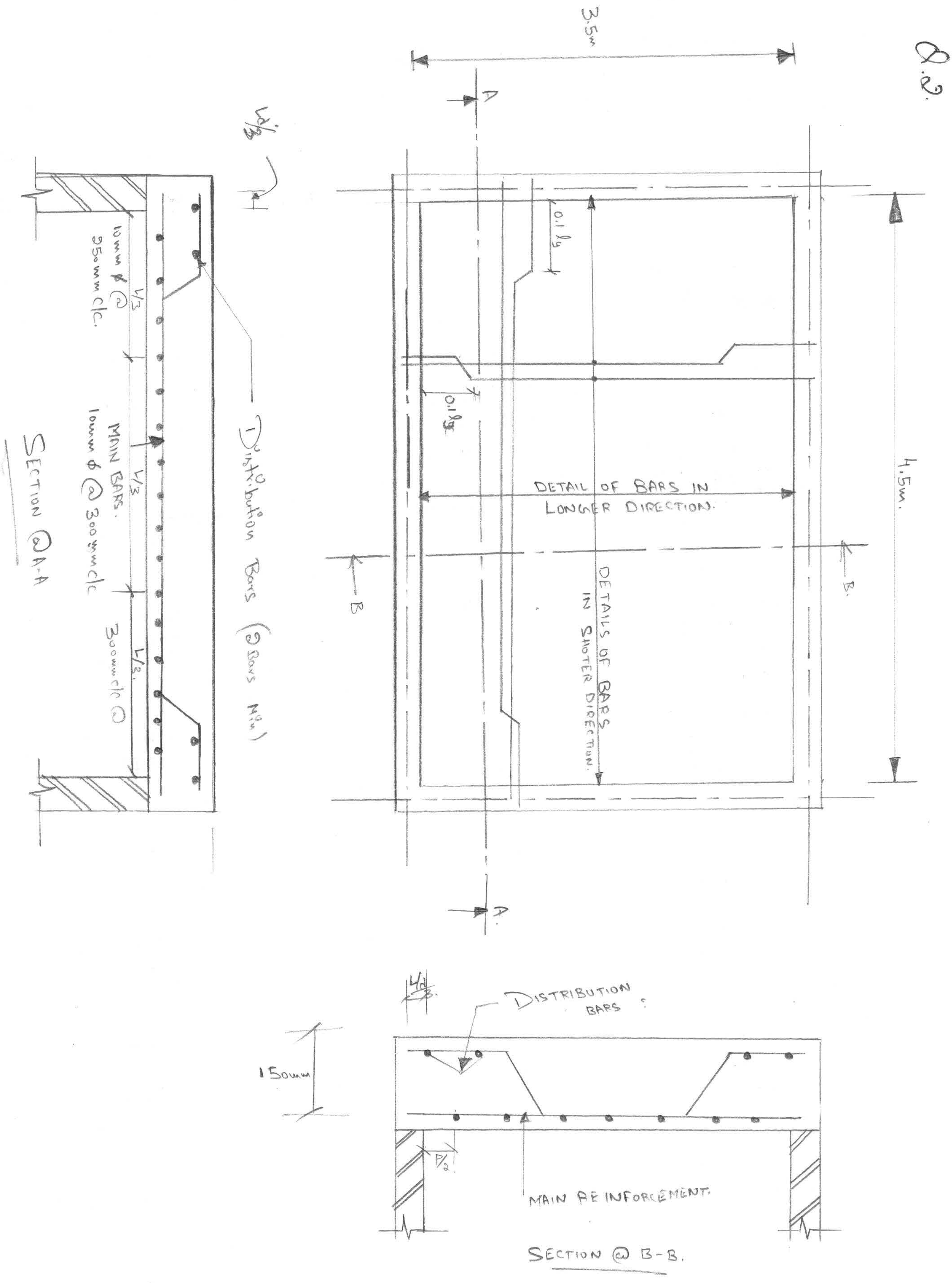
~~Ans~~ -

Part-B

1)







Q.2.
3.5m
4.5m
A
A
B
B
0.1 ly
0.1 ly
DETAIL OF BARS IN LONGER DIRECTION.
DETAILS OF BARS IN SHOTER DIRECTION.
Ld/3
10mm ϕ @ 250mm c/c.
L/3
L/3
L/2.
MAIN BARS. 10mm ϕ @ 300mm c/c
300mm c/c @
Distribution Bars (2 Bars Min)
SECTION @A-A
Ld/3
DISTRIBUTION BARS
150mm
P/2
MAIN REINFORCEMENT.
SECTION @ B-B.