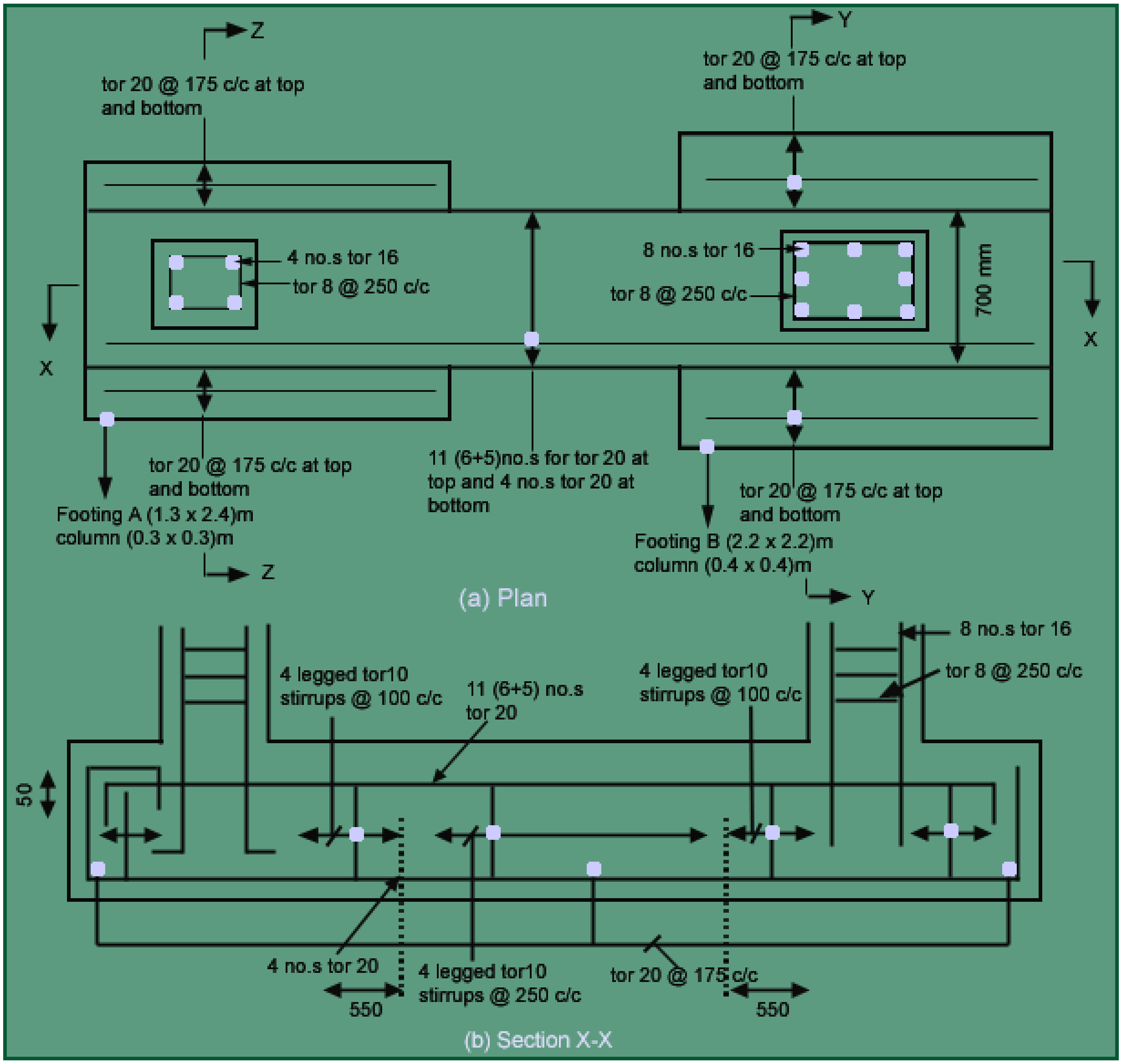
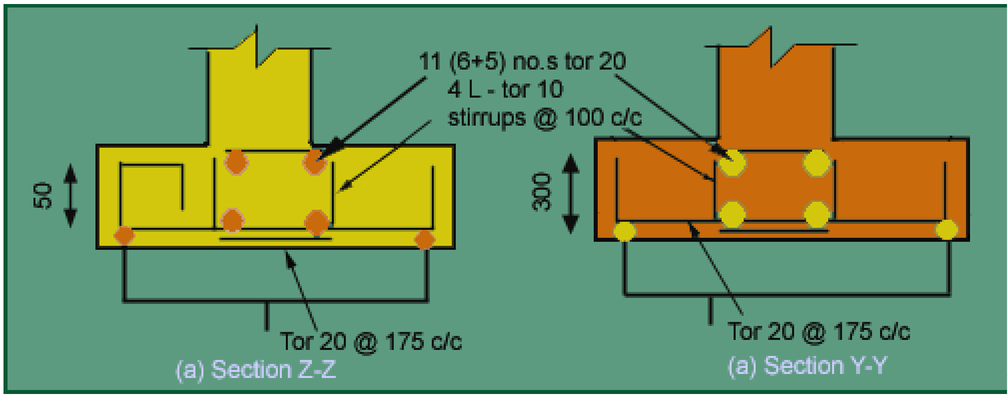
UNIT III
FOOTINGS AND RAFTS



(a) Plan

(b) Section X-X



Design of Combined Footing

P_1 =800kN

P_2 =1000kN

q_a =20 t/m^2,M15, f_y =415kN/m^2

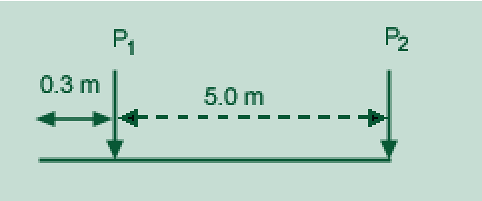


Fig. 4.51 Loading on combined footing

Column size: 400x400mm.

See Fig 4.54 for details of footing.

Column design

Let pt=0.8%

A_{sc} =.008A; A_c =0.992A

Clause.39.3 of IS 456-2000

A=146763.8mm^2

A_{sc} =1174.11 mm^2, A_c =145589.746mm^2

Provide footing of 400x400size for both columns.

Using 8-16 ϕas main reinforcement and 8 ϕ@250c/c as lateral tie

Design of Footing

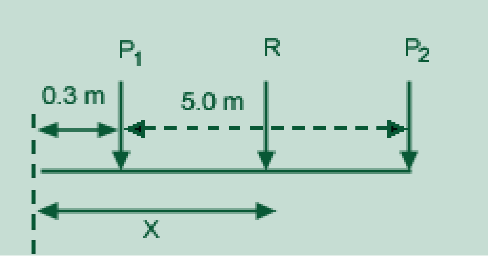


Fig. 4.52 Forces acting on the footing

Resultant of Column Load

R =1800 kN acting 3.08m from the boundary.

Area of the footing :

Taking length L=6m, Depth of footing D_f =0.9m, $\gamma_c = 2.5t/m^2$, $\gamma_s = 1.8t/m^2$

Width of footing, $B = \frac{P_1 + P_2}{L[q_a - (\gamma_c - \gamma_s)D_f}$ =1.549m.

Therefore, provide footing of dimension 6m x 1.6m

Soil Pressure q = $\frac{180}{6x1.6}$ =18.75 $t/m^2 < 20\ t/m^2$ OK.

q_u =28.125 t/m^2

Soil pressure intensity acting along the length =B x q_u =1.6x28.125 =45t/m.

R_B =119.88kN, R_C =150.12kN.

Thickness of Footing i. Wide beam shear:

Maximum shear force is on footing C,SF=115.02KN

$\tau_c \times B \times d = qu[2.556 - 0.2 - d]$

$\tau_c = 0.32 N/mm^2$ for percentage reinforcement P_t =0.2%

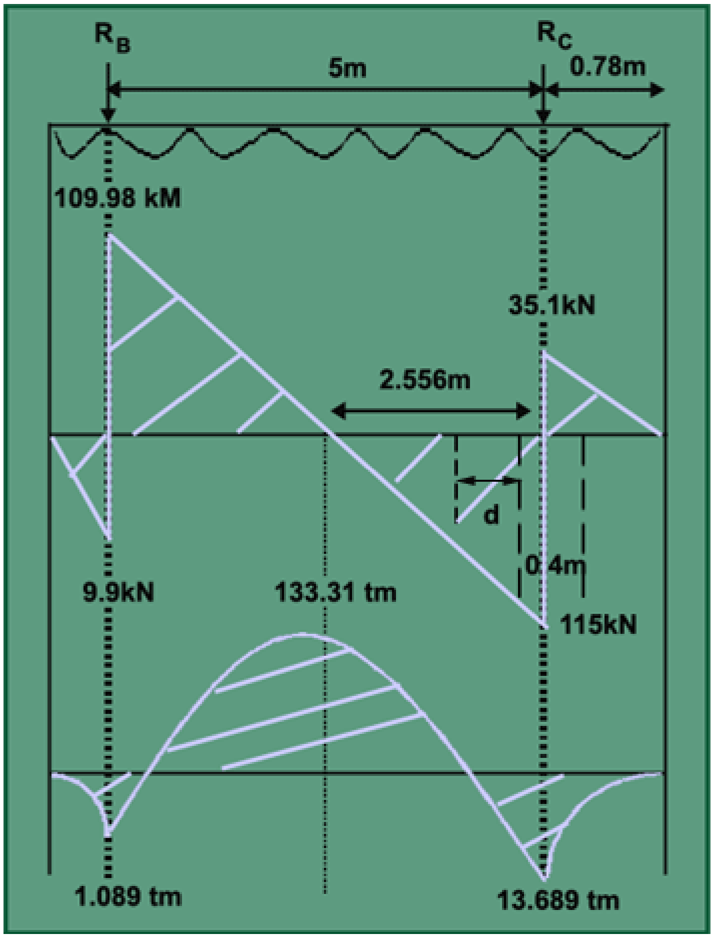
0.32 x d x 1.6=45 [2.556-0.2-d]

d=1.1m

$\tau_c = 0.5 N/mm^2$ for percentage reinforcement P_t=0.6%

0.6 x d x 1.6=45 [2.556-0.2-d]

d=0.847m.D=900mm.OK.



ii.Two way Shear **Thickness of Footing** i. Wide beam shear:

Maximum shear force is on footing C,SF=115.02KN

$\tau_c \times B \times d = qu[2.556 - 0.2 - d]$

$\tau_c = 0.32 N/mm^2$ for percentage reinforcement P_t=0.2%

0.32 x d x 1.6=45 [2.556-0.2-d]

d=1.1m

$\tau_c = 0.5 N/mm^2$ for percentage reinforcement P_t=0.6%

0.6 x d x 1.6=45 [2.556-0.2-d]

d=0.847m.D=900mm.OK.

$\beta_c = 1, k_s = 1.5 \Rightarrow 1,$

ii.Two way Shear $\tau_c' = k_s \tau_c = 96.8 t/m^2$

Column B

$4(0.4 + d)d \times 96.8 = 150 - 28.125(0.4 + d)^2$

d=0.415m.

Column A

2d[(0.4+d)+(0.42+d/2)] x 96.8=120-28.125[(0.4+d)(0.42+d/2)]

d=0.3906m

d_{reqd} =0.85mm

$D_{provided}$ =900mm, d_{reqd} =850mm.OK.

- **Flexural reinforcement**

Along Length Direction

$\frac{M_u}{bd^2} = \frac{133.31 \times 10^4}{1.6 \times 850^2}$ =1.15N/mm^2

Table 1of SP16

P_t =0.354%

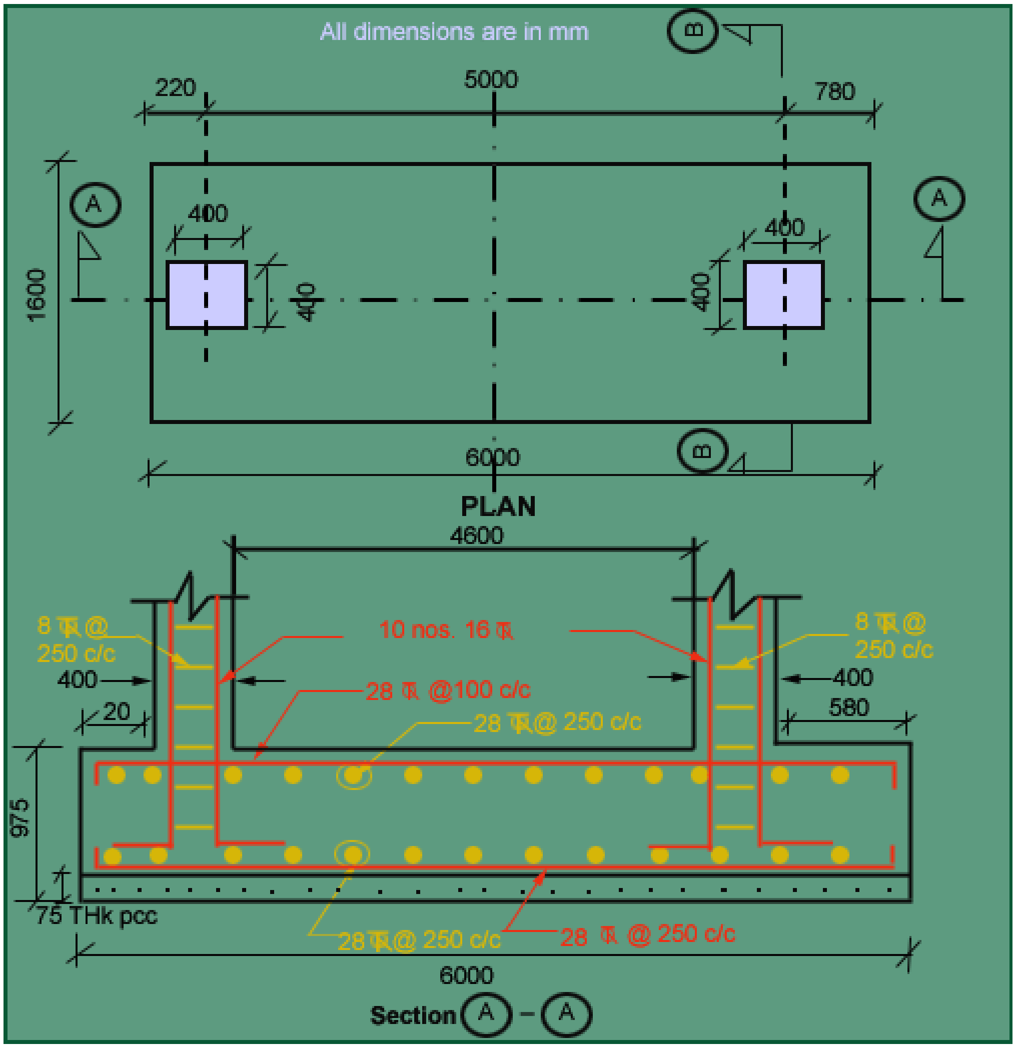
P_t provided=0.6%

A_{st} required=5100 mm^2/mm

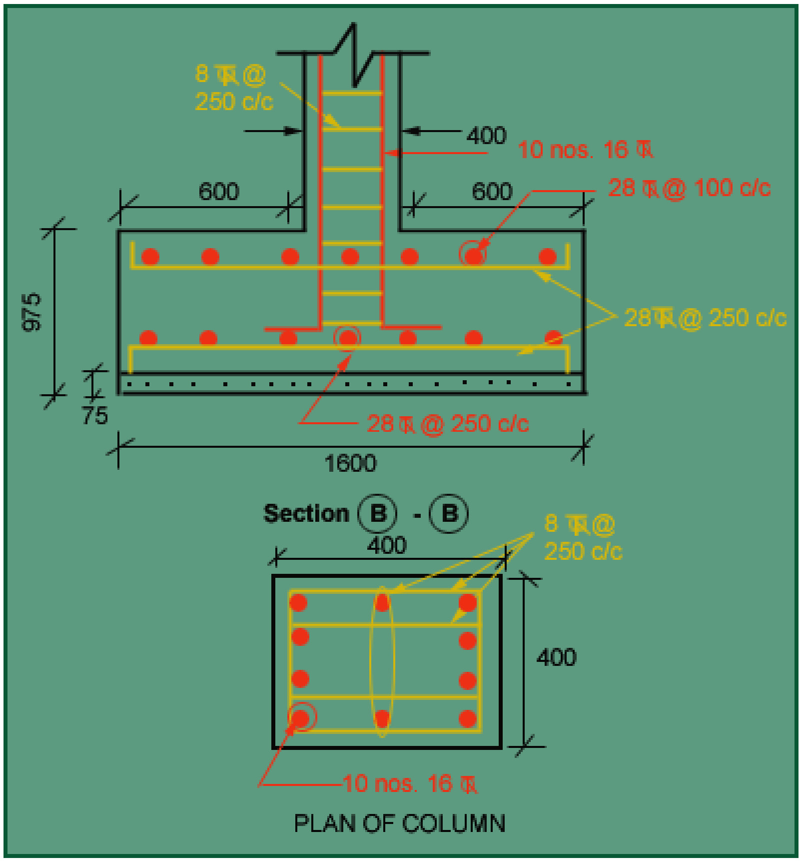
Provide 28 ϕ@120mmc/c at top and bottom of the footing

Along width direction

$$M_u = \frac{28.125\times1.6^2}{2} = 36tm$$



$$M_u = 0.073N/mm^2$$



Raft Footing Design the raft footing for the given loads on the columns and spacing between the columns as shown below.

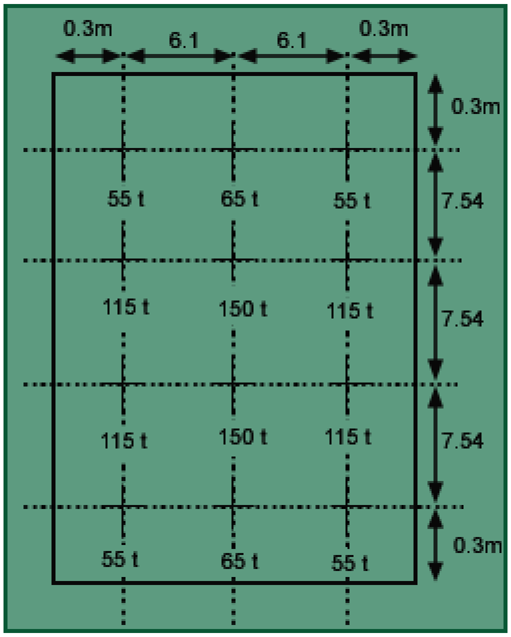


Fig 4.57 column locations and intensity of loads acting on the raft

a) Column sizes

Take size of the columns are as: 300*450 mm for load of less than 115 ton

450*450 mm for a load of greater than 115 ton

Thickness of raft

$$q_{us} = \frac{1110}{12.8 \times 23.22} * 1.5 = 5.607\, t/m^2$$

Two way shear

The shear should be checked for every column, but in this case because of symmetry property checking for 115 t, 150 t, and 55 t is enough.

For 150 t column

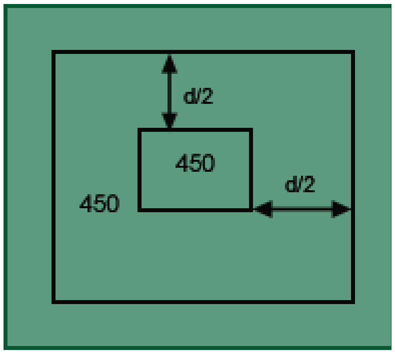


Fig 4.58 section for two way shear for 150 t column

IS: 456-1978, β_c =450/450=1.0

K_s =(0.5+ β_c)=1.0=1.0

Therefore K_s =1.0

$$\tau_c = 0.25\sqrt{f_{ck}} = 96.8\, t/m^2$$

$$\tau'_c = k_s \tau_c = 96.8\, t/m^2$$

$$\tau'_c = 96.8\, t/m^2$$

4(0.45+d)*d*96.8=150*1.5-5.607(0.45+d)2

Therefore d=0.562 m

For 115 t column

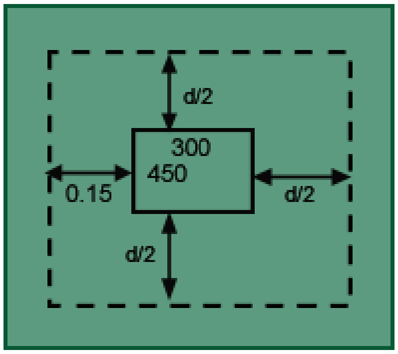


Fig 4.59 section for two way shear for 115 t column

2(0.45+d+0.15+0.3+d/2) d*96.8=115*1.5-5.607(0.45+d)(0.3+0.15+0.5d)

Therefore d=0.519 m

For 55 t column

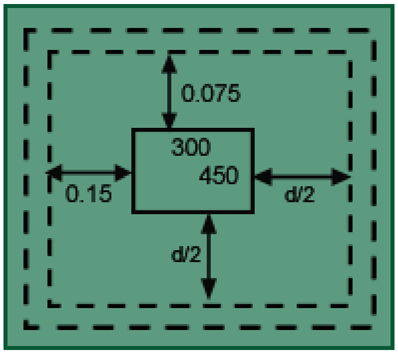


Fig 4.60 section for two way shear for 55 t column

2(0.45+0.075+0.5d+0.15+0.3+0.5d) d*96.8=55*1.5-5.607(0.45+0.5d+0.075)(0.3+0.5d+0.15)

Therefore d=0.32 m

The guiding thickness is 0.562m and code says that the minimum thickness should not be less than 1.0m.

let provide a overall depth of 1.1m=D

d_{prdv}=1100-75-20/2=1015mm.

To calculate k & λ-Stiffness factors

There are two criterions for checking the rigidity of the footing:
Plate size used is 300*300 mm.
For clays: μ_s =0.5,

$$k = B\frac{E_s}{1-\mu^2{}_s}$$

Take k=0.7 and B=30 cm

Es=15.75 kg/cm^2=1.575 N/mm^2

$$K = \frac{EI}{E_s b^3 a}, \qquad where \;\; I = \frac{ad^3}{12}$$

$$E = 5000\sqrt{f_{ck}}$$

$$= 5000\sqrt{15} = 19364.92\,N/mm^2$$

b=23.2*103 mm, a=12.8*103 mm 4 , d=1015 mm

$$K = \frac{19364.92\times 1015^3\times 12.8*10^3}{12\times 1.575\times(23.2*10^3)^3\times 12.8*10^3}$$

=0.085<0.5

Therefore it is acting as a flexible footing.

$$\lambda = \left(\frac{kB}{4E_c I}\right)^{\frac{1}{4}} = \frac{0.7\times 12.8*10^2\times 12}{4\times 19364.92\times 12.8*10^2\times 101.5^3}$$

=0.00179*10^{-3}

1.75/ λ =975.184=9.75m

If column spacing is less than 1.75/ λ, then the footing is said to be rigid.

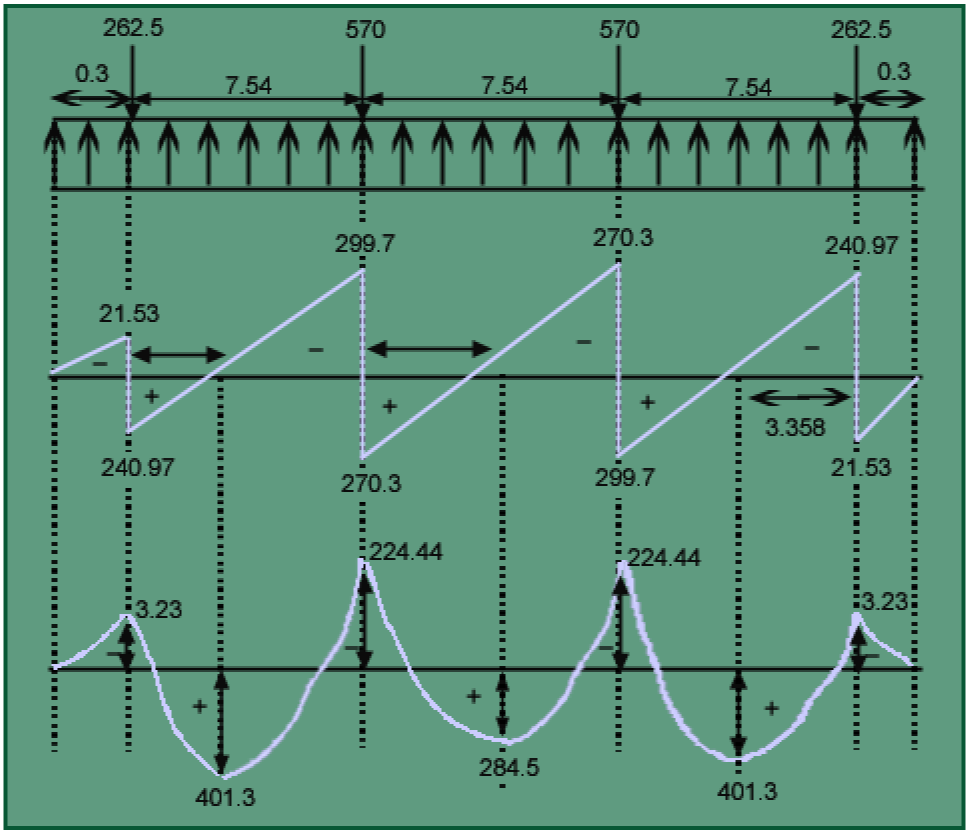
Therefore the given footing is rigid.

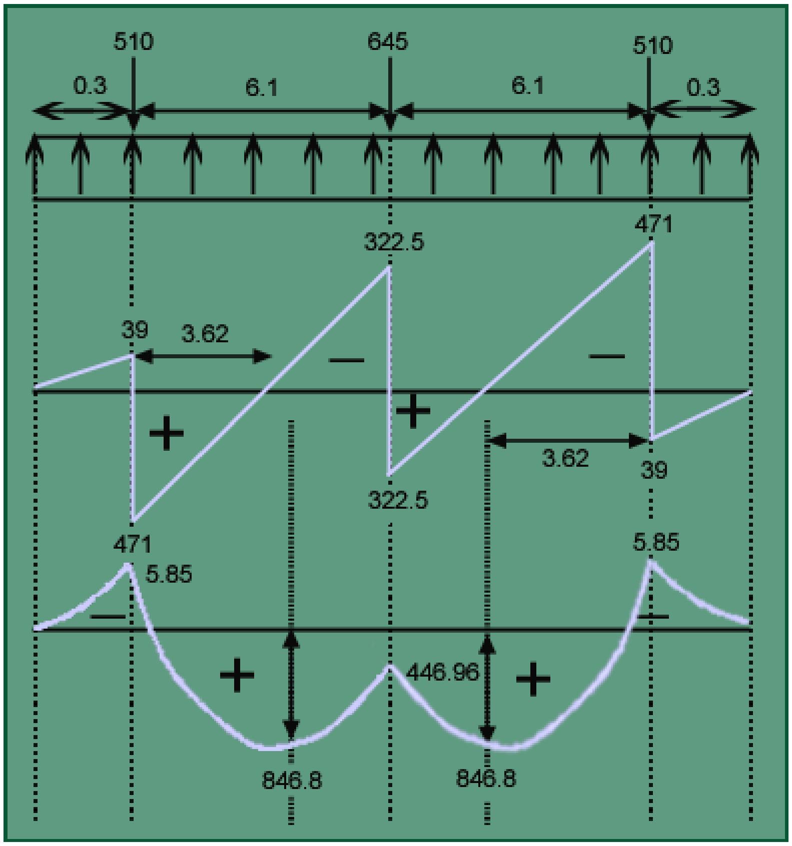
One criterion showing the footing is flexible and another showing that the given footing is rigid. Both are contradicting each other, so design the footing for both criterions.

$$q_{act} = \frac{1100}{12.8*23.2} = 3.738\,t/m^2$$

q_{us} =5.607 t/m^2

$$q = \frac{2*510+645}{6.1+6.1+0.6} = 130.08\,t/m^2$$


262.5
570
570
262.5
0.3
7.54
7.54
7.54
0.3
299.7
270.3
240.97
21.53
–
–
–
–
+
+
+
3.358
240.97
270.3
299.7
21.53
224.44
224.44
3.23
3.23
–
–
–
+
+
+
401.3
284.5
401.3


510
645
510
0.3
6.1
6.1
0.3
322.5
471
39
3.62
–
–
+
+
3.62
39
322.5
471
5.85
5.85
–
–
+
+
446.96
846.8
846.8

Reinforcement in width direction

$$\frac{M_u}{b\,d^2{}_x} = \frac{846.8\times10^7}{23.2\times10^3 * 1015^2} = 0.354$$

From SP-16 graphs

P_t =0.102%, but minimum is 0.12%.

A_{stx} =(0.12*1000*1015)/100=1218 mm^2

Provide 20 mm diameter bars @250 c/c along shorter direction in bottom.

- **Reinforcement in length direction**

$$\frac{M_u}{b\,d^2{}_y} = \frac{401.3\times10^7}{12.8\times10^3 * (1015-20)^2} = 0.316$$

Provide 20 mm diameter bars @250 c/c in longer direction.

Clause 33.3.1

$$A_{stx_{centralband}} = \frac{2}{\frac{23.2}{12.8}+1}(1218 * 23.2)\,mm^2$$

Provide 20 mm diameter bars @ 200 c/c in central band and 20 mm diameter bars @300 c/c at other parts along shorter direction at bottom.

Shear (wide beam shear criterion)

In width direction

$$\frac{V_u}{b\,d_x} = \frac{471\times10^4}{23.2\times10^3 * 1015}$$ 0.2 N/mm^2 < τ_v

Pt_{prov} =0.123%,

τ_c =0.27 N/mm 2 > τ_v (from table 61 of SP – 16 by extrapolation)

Therefore no shear reinforcement is required.

$$\frac{V_u}{b\,d_y} = \frac{229.7\times10^4}{12.8\times10^3 * (1013-20)} = 0.235\ \text{N/mm}^2 < \tau_c\,(0.27\ \text{N/mm}^2)$$

Therefore no shear reinforcement is required.

Along the width direction

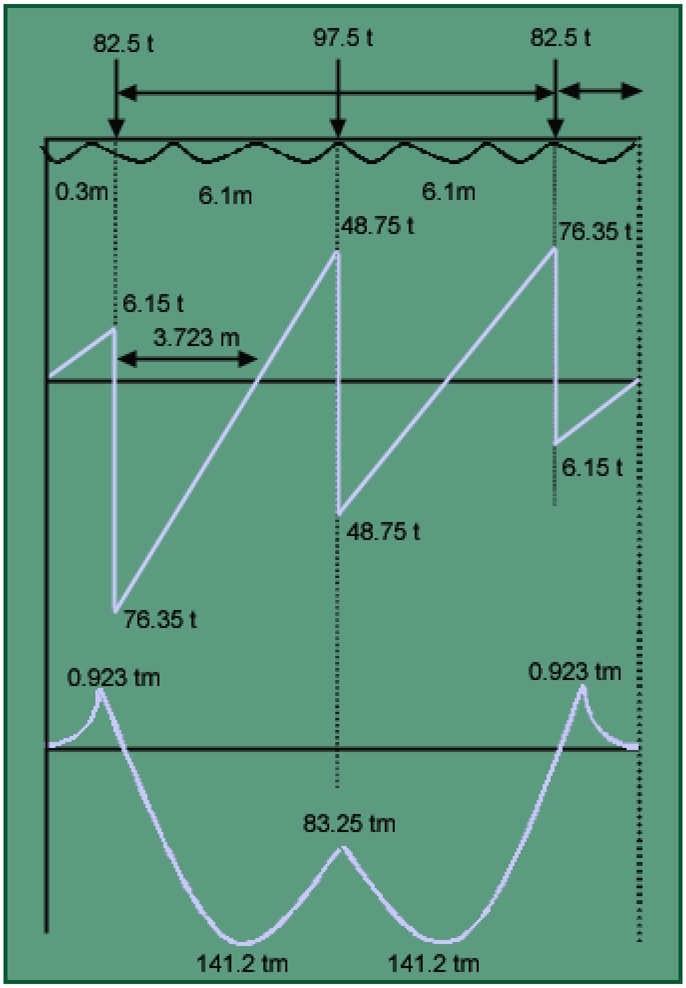


Fig. 4.63 Shear Force and Bending Moment Diagrams of strips 1 and 4

In width direction: Strip1/4:-

M_u =141.2tm

$$\frac{M_u}{bd^2} = \frac{141.2\times10^7}{4.067\times10^3\times(1015)^2} = 0.337\text{N/mm}^2$$

Strip2/3

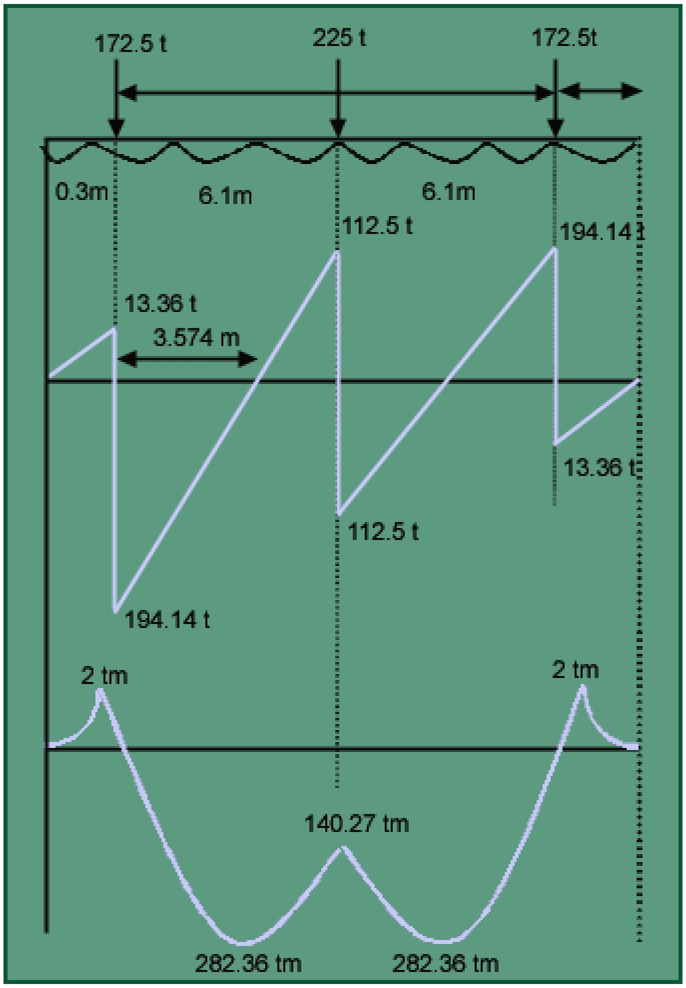


Fig. 4.64 Shear Force and Bending Moment Diagrams of strips 2 and 3

Strip 2/3

M_u =282.36tm

$\frac{M_u}{bd^2} = \frac{282.36\times10^7}{7.533\times10^3\times(1015)^2}$ =0.364N/mm^2

Minimum P_t =0.12%has to be provided.

Provide 20 ϕ@200c/c in centre band and 20 ϕ@300c/c at other parts along the shorter direction.

1. **Shear check**

Along width direction:-

For strip1/4:

V_u=76.35t

$\frac{V_u}{bd_x} = \frac{76.35\times10^4}{4.067\times10^3\times1015}$ =0.185N/mm^2< τ_c , OK.

For strip 2/3:

V_u=159.14 t

$\frac{V_u}{bd_x} = \frac{159.14\times10^4}{7.533\times10^3\times1015}$ =0.208N/mm^2< τ_c, OK.

Hence no shear reinforcement is required.

Development Length

$L_d = \frac{\phi\sigma_S}{4\tau_{bd}} = \frac{20\times0.87\times415}{4\times1\times1.6}$ =1128.3mm

At the ends, length of bar provided=150mm.
Extra length to be provided=1128.3-150-8x20=818.3mm.
Provide a Development length of 850mm

3. **Transfer of load at the base of the column:-**

For end column;

A_1 =2650X2725=7.22125x106mm^2

A_2 =300x450=135000mm^2

$\sqrt{\frac{A1}{A2}}$ = 7.31 But not greater than 2.0

$q_{prem} = \sqrt{\frac{A1}{A2}}\times0.45f_{ck}$ =13.5N/mm^2

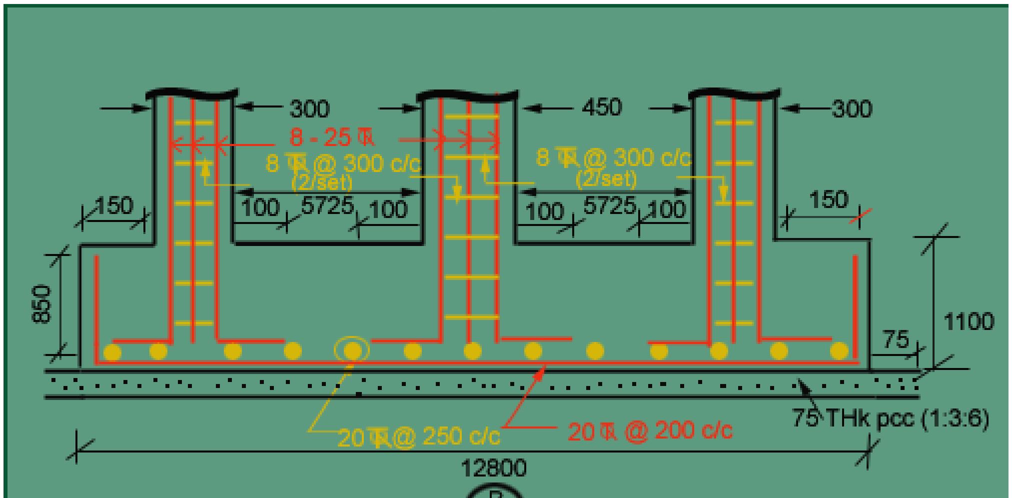
$q_{acting} = \frac{55\times10^4}{300\times450}$ =4.07N/mm^2< q_{prem} .OK.

For 150t columns

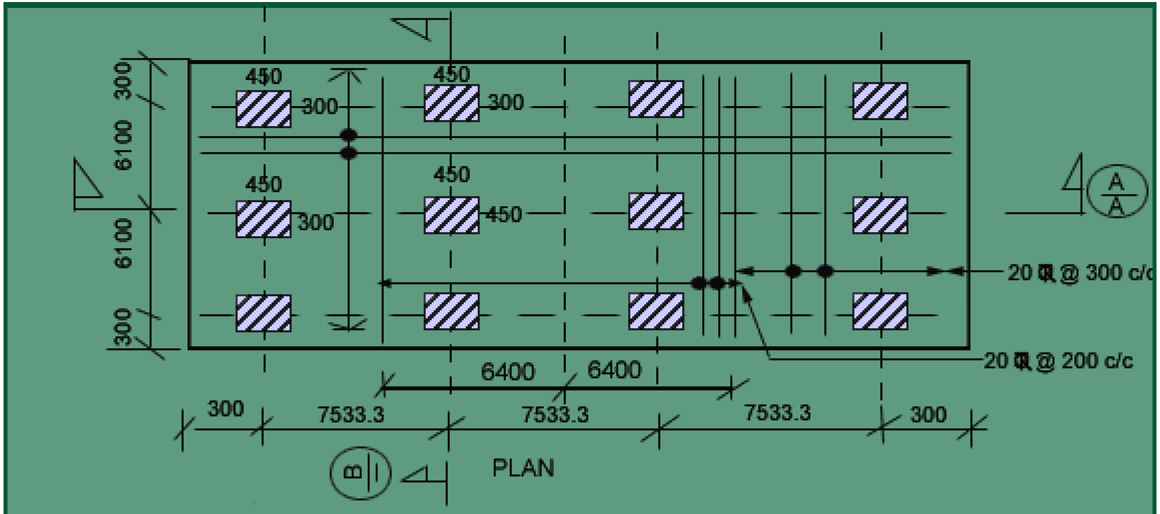
$q_{acting} = \frac{150\times10^4}{450^2}$ =7.41N/mm^2< q_{prem} .OK.

For 115t columns

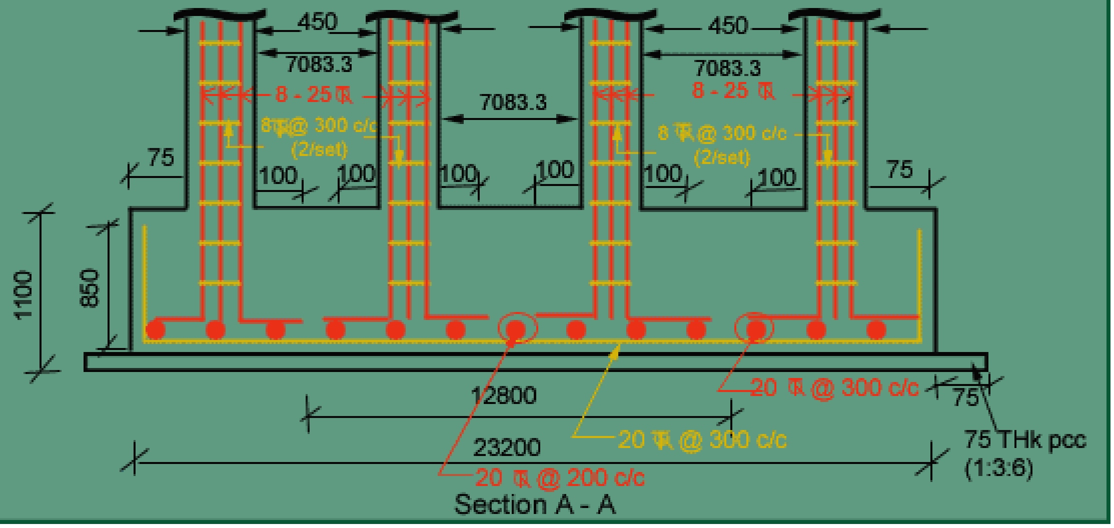
$\sqrt{\frac{A1}{A2}}$ = 2, q_{acting} = $\frac{115\times10^4}{300\times450}$ =8.52N/mm^2< q_{prem}.OK.



Section B



PLAN



Section A - A