Toppersnotes
Unleash the topper in you

IES/GATE

CIVIL ENGINEERING

VOLUME – VI

RCC – II & Highway Eng.

SIERRA INNOVATIONS

Index

RCC – II & Highway Engineering

Highway Engineering

Chapter 1 - Design of Footing

→ Various types of footing are ;

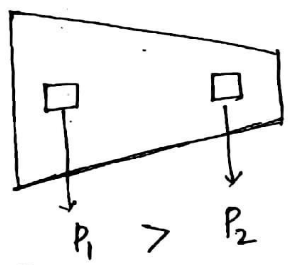
a) <u>Isolated footing</u> ;

→ Provided under a single Column.

b) <u>Combined footing</u> ;

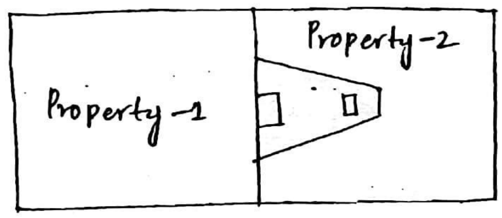
→ when isolated footing of one column overlaps with other, we provide combined footing.

→



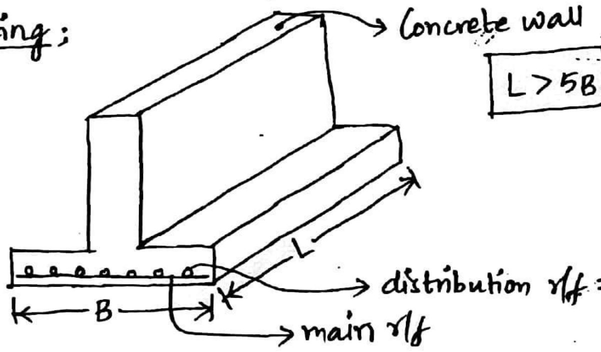
[Trapezoidal Combined footing]

→



→ [In case of Property line constraint, we can provide trapezoidal Combined footing.]

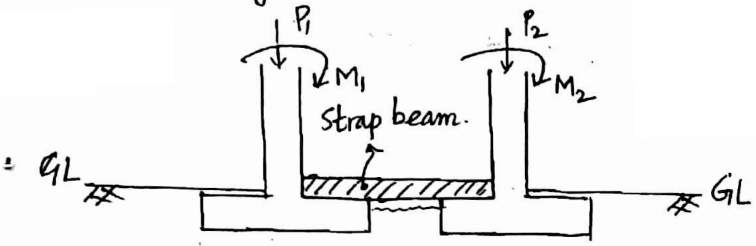
c) <u>Strip footing</u> ;



$\boxed{L > 5B}$

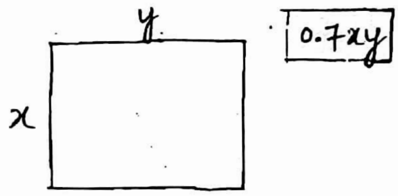
distribution r/f ⇒ [Provided to take care of differential settlement along the length]

d) Strap footing;



→ Strap footing controls the differential settlement by making the two footing as a single unit and distributes the B.M., Generally strap beam is not designed to transfer any vertical load directly to the soil

e) Raft footing;



→ when the load is very heavy and the bearing capacity available is less, we Provide Raft footing (or) Mat footing.

• Generally when the plan area of Isolated footing (or) Combined footing exceeds 70% of plan area of building, we provide a raft footing. In case of Raft footing differential settlement is very less.

• Criteria for Design;

a) Depth of footing:

• All foundation should be located at a minimum depth of 0.5m below the ground surface.

The depth is primarily governed by availability of bearing capacity, minimum seasonal variation like swelling and shrinkage of soil.

For a preliminary estimate, minimum depth of foundation is given by Rankine's formula;

$$\boxed{D_f = \frac{q}{\gamma}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]^2}$$

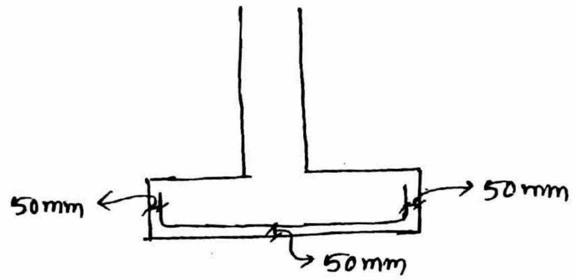
where; $q \rightarrow$ gross safe bearing capacity

$\gamma \rightarrow$ unit wt. of soil

$\phi \rightarrow$ Angle of friction

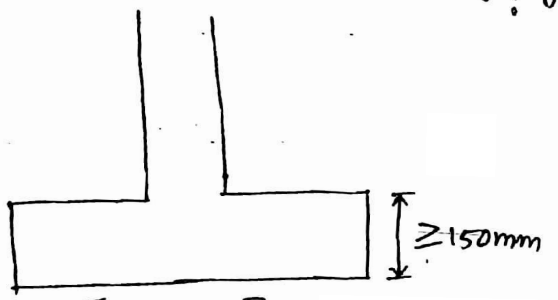
b) **Minimum clear cover ;**

→ A minimum clear cover of 50mm is provided to all r/f in footing.

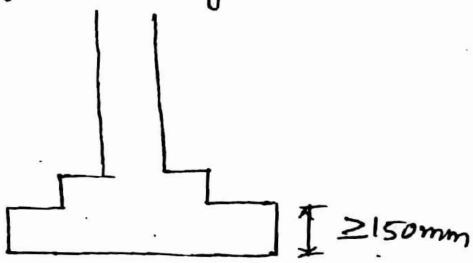


c) **Minimum thickness ;**

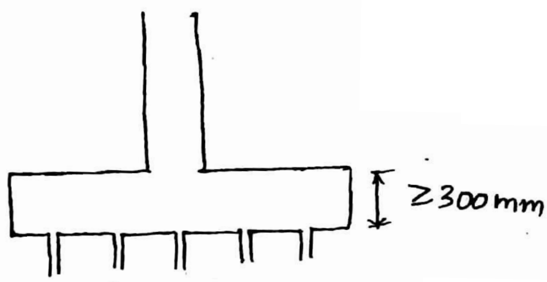
→ Thickness at edge of footing is 150mm minimum for footing on soil and 300mm minimum for footing on Piles, To ensure rigidity of the footing.



[Above soil]



[Above soil]



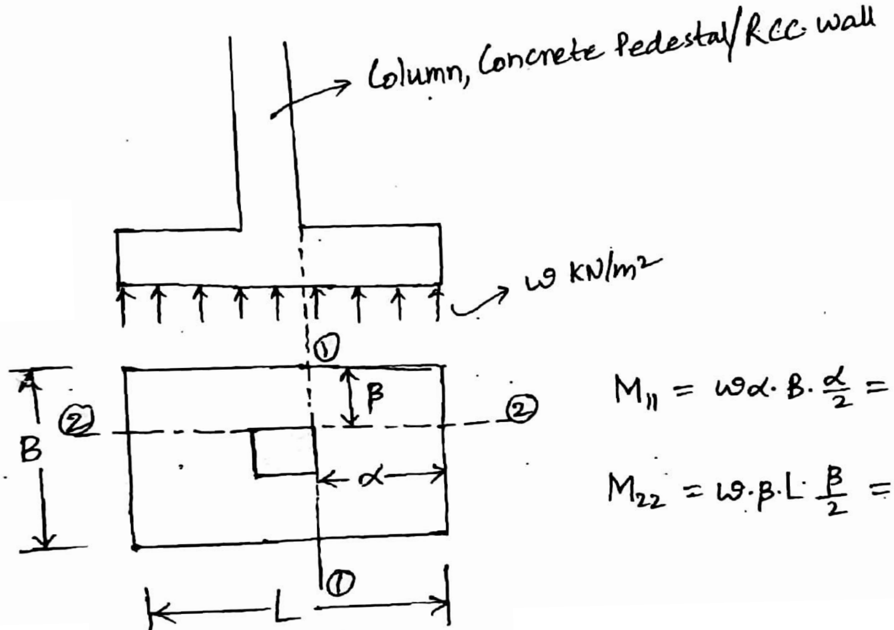
[Above piles]

1) **Critical Section for bending ;**

→ Critical section for bending for isolated concrete footing which supports column, Pedestal (or) wall shall be ;

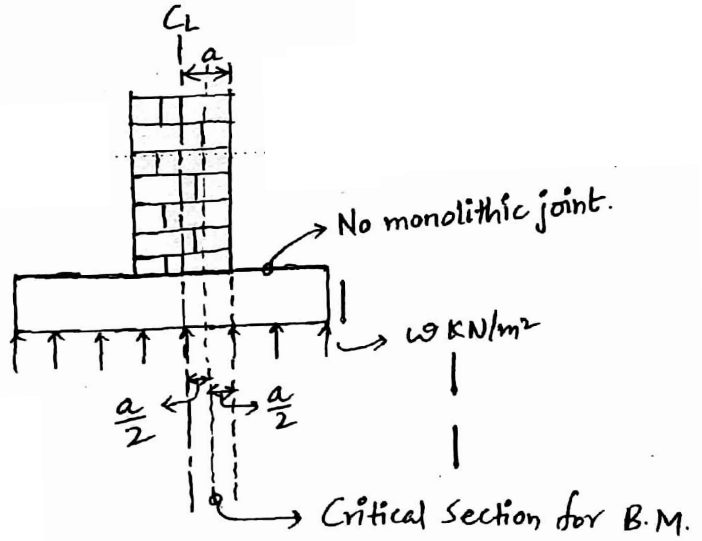
a) At the face of column, Pedestal (or) wall for footing supporting concrete - column, concrete Pedestal (or) RCC wall.

b) Half way between the centreline and edge of wall for footing supporting mansonary wall.



$$M_{11} = w\alpha \cdot B \cdot \frac{\alpha}{2} = \frac{wB\alpha^2}{2} \; (\text{r/f along } L)$$

$$M_{22} = w \cdot \beta \cdot L \cdot \frac{\beta}{2} = \frac{wL\beta^2}{2} \; (\text{r/f along } B)$$



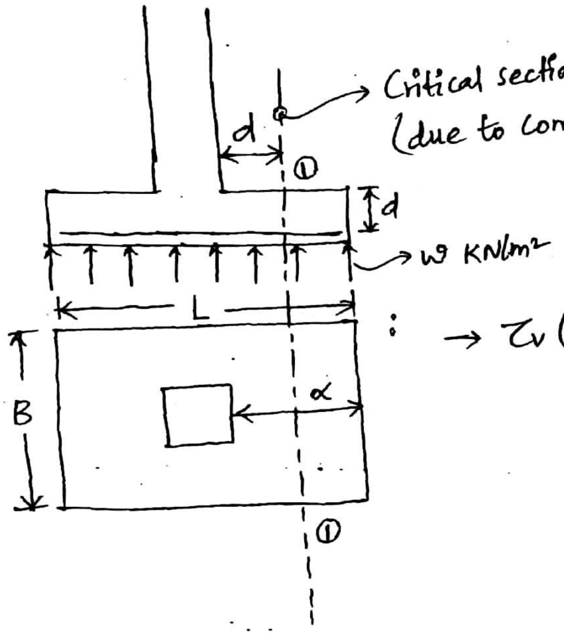
e) Critical Section for shear ;

→ In case of footing, shear governs the thickness of footing. The type of shear considered are oneway shear and Twoway shear [Punching shear].

→ In oneway shear, the critical section for shear is ;

a) At a distance 'd' from the face of wall or column when the footing is supported on soil.

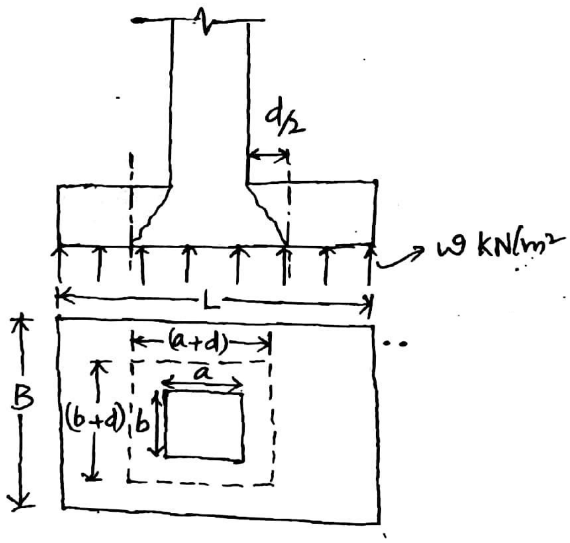
b) At a distance '$d/2$' from the face of wall or column if the footing slab is on piles



→ τ_v (Nominal shear stress in oneway condition)

$$= \frac{w(\alpha-d)B}{B \cdot d}$$

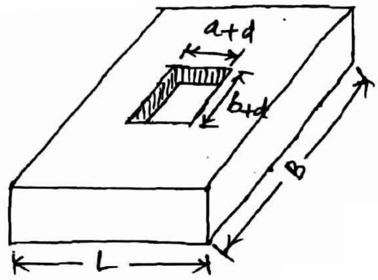
→ Twoway shear (Punching shear) ;



$$\tau_{v,\text{twoway}} = \frac{w\left[L\times B-(a+d)(b+d)\right]}{2\times\left[(a+d)+(b+d)\right]\times d}$$

Twoway shear capacity $= k_s \tau_c'$

$$\boxed{\underbrace{\tau_c'}_{MPa} = 0.25\sqrt{\underbrace{f_{ck}}_{MPa}}}$$

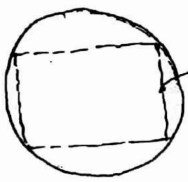


$k_s = 0.5+\beta \not> 1.0$; $\beta = \dfrac{\text{Shorter dimension of Column}}{\text{Longer dimension of Column}}$

→ Twoway (or) Punching shear shall be checked around the Column on a perimeter half the effective depth of footing slab away from the face of column (or) Pedestal.

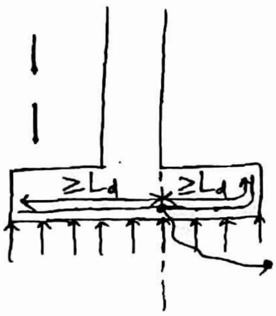
Note:

→ For the purpose of Calculating stresses in footing which support a circular (or) octagonal concrete Column (or) Pedestal, the face of column (or) Pedestal shall be taken as the side of a square inscribed with in the Perimeter of the Circular (or) Octagonal Column (or) Pedestal.



:) Bond ;

→ critical section for checking development Length of r/f in the footing is at the face of Column, Pedestal (or) RCC wall.

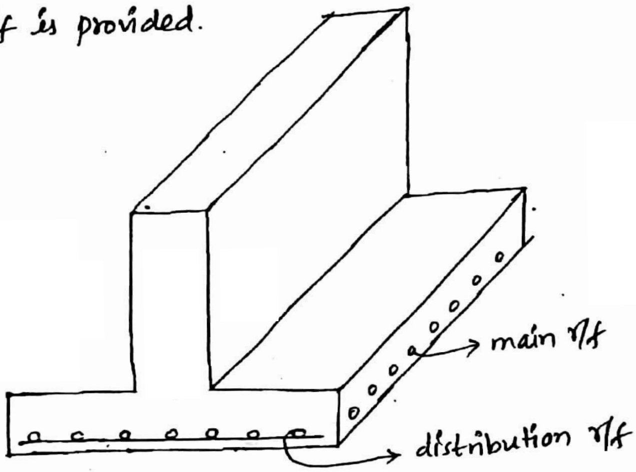


g) Tensile r/f ;

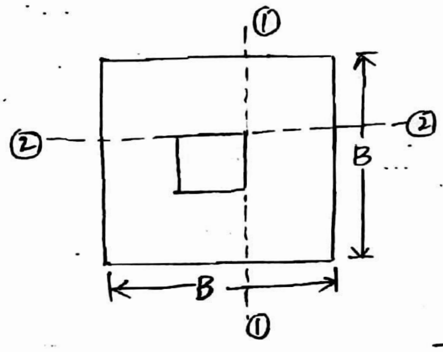
→ Tensile r/f is provided in the footing slab similar to that of solid slab.

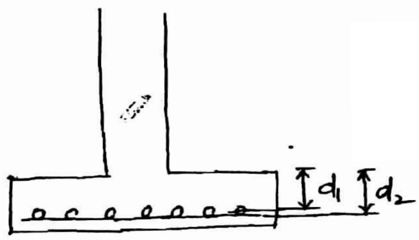
→ In one way bending condition, main r/f is provided in the direction of bending and nominal r/f is provided in the Transverse direction. [differential settlement, shrinkage and Temp.]

→ In oneway reinforced footing slab, r/f is distributed uniformly across the full length of the footing as in the case of wall footing and in the Transverse direction distribution r/f is provided.



→ In case of twoway reinforced square footing slab, r/f extending in each direction shall be distributed uniformly across the full length and width of the footing.





→ Consider $\boxed{d_1}$ here for A_{st} calculation

→ $M = 0.87 f_y A_{st} \left(d \;\; \frac{f_y A_{st}}{f_{ck} b}\right)$

→ In Twoway reinforced rectangular footing slab, r/f in the longer direction is distributed uniformly across the full width. In the shorter direction the total length is divided into central band of width B and edge band.

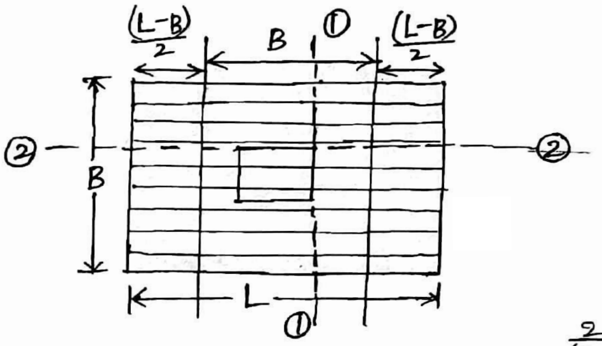
→ R/f in the central band is equal to;

$$= \boxed{A_{st,short} \times \frac{2}{\beta+1}}$$

$$\beta = \frac{\text{longer dimension of footing}}{\text{Shorter dimension of footing}}$$

$\Rightarrow \frac{A_{st,short}}{L} \times B \longrightarrow ①$

$\Rightarrow A_{st,short} \times \frac{2}{\frac{L}{B}+1} \longrightarrow ②$



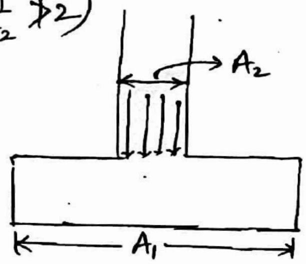
r/f along B = $A_{st,short}$ $\frac{2}{(\beta+1)}$

In the two edge strip = $A_{st,short} - A_{st,short} \times \frac{2}{(\beta+1)}$

→ Transfer of Load at the base of Column;

→ Permissible bearing stress of concrete in footing is given by;

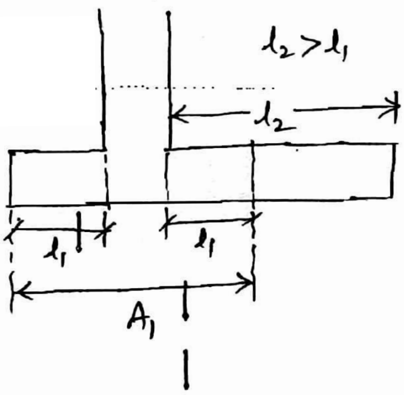
$$\boxed{\sigma_{br} = 0.45 f_{ck} \sqrt{\frac{A_1}{A_2}}} \quad \left(\sqrt{\frac{A_1}{A_2}} \not> 2\right)$$

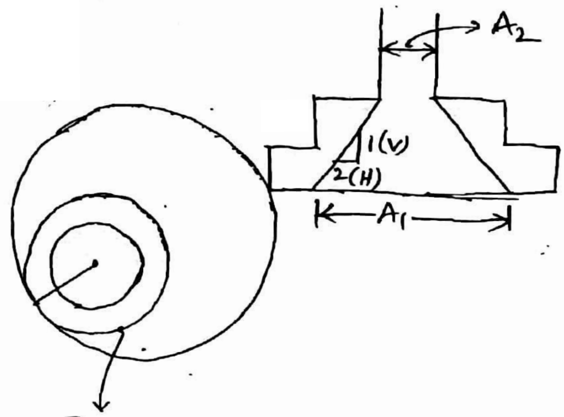


where ; A_1 = maximum supporting area of footing, geometrically similar and concentric with loaded area A_2.

→ In case of stepped or sloped footing, the area A_1 shall be taken below.

→





A_1 [geometrically similar and concentric with column]

A_2 = The loaded area at the base of column.

→ At the junction of column and footing, In the column side the permissible bearing stress is taken as $0.45 f_{ck}$ [as $A_1 = A_2$] —

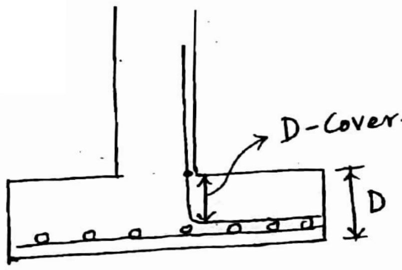
→ If the permissible bearing stress in concrete either in column (or) in the footing is exceeded, extra r/f is provided to resist the additional force.

→ The additional r/f is either in the form of Longitudinal r/f of column (or) additional dowel bar.

→ Dowel bars may be provided either alone (or) in-combination with the longitudinal bar of column.

→ Sufficient development length shall be available for transfering the additional load both above and below the junction of column and footing.

→ If Pedestal is provided, then sufficient development length shall be available beyond the junction of column and Pedestal.



$0.87 f_y$ stress in the Tension $= 47\phi$ (Fe415, M20)

$0.87 f_y$ stress in Compression $= 47 \times 0.8 \phi$

→ For $0.67 f_y$ in Compression $= \frac{47 \times 0.8}{0.87} \times 0.67 \phi$

→ Minimum Area of longitudinal r/f (or) Dowel [Combination of column bars & dowels] shall be 0.5% of the supported column (or) Pedestal.

→ Minimum of 4 bars shall be provided [Column bar + Dowel]

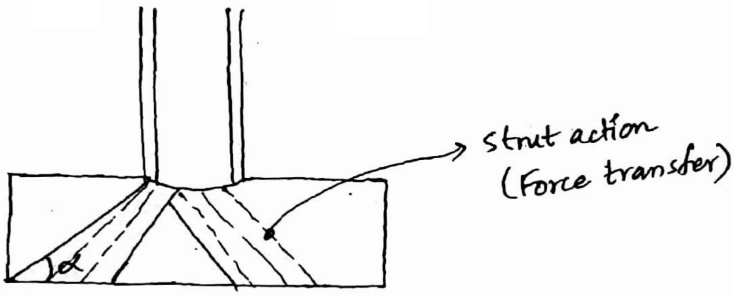
→ The dowel bar dia. shall not exceed the dia. of column by a more than 3mm

→ Column bars of dia. greater than 36 mm in compression can only be dowelled with bars of smaller dia. with equivalent area. The Dowel shall extend into the column a distance equal to the development Length of column bar and into th footing, a distance equal to the development length of the dowel bar.

→ **Plain Concrete Footing** :

→ When the column is lightly loaded [without any bars in Tension] and the base area of footing is relatively low, sometimes plain footing can be provided.

→ Also σ_{br} criteria shall satisfy at the column and footing junction.



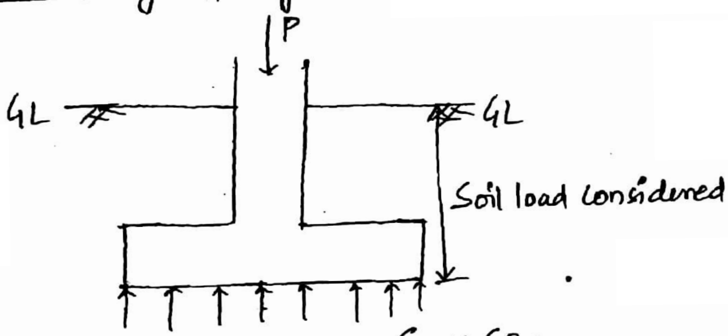
(**) $\boxed{\tan\alpha > 0.9\sqrt{\frac{100 q_a}{f_{ck}} + 1}}$ (**) [$\tan\alpha$ is greater (>) ✓
(Not greater than equal ≥) ✗]

q_a → bearing pressure in soil in service load condition.

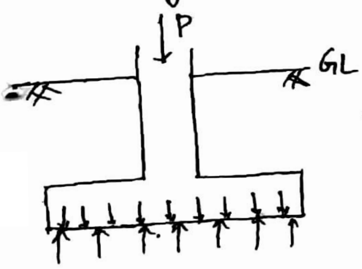
Note :-

› **Gross bearing Capacity** ;

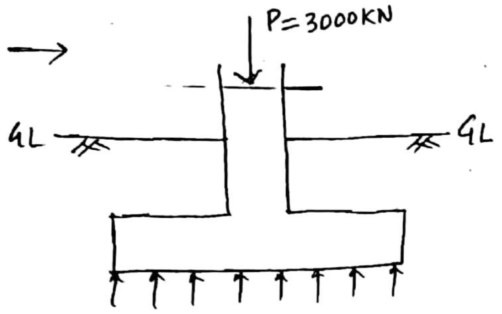
→



› When gross SBC is given increase service load of column by 10% to calculate the footing area.

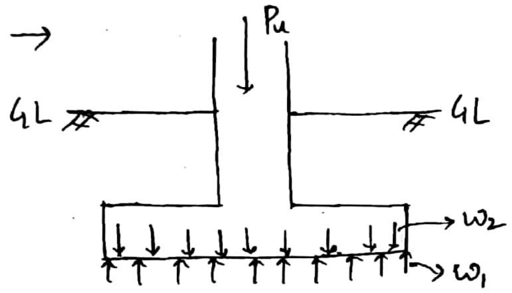


→ when Net SBC is given increase service load in column by 5% to calculate the footing area.



SBC = 300 kN/m²

- To calculate the footing area consider the Service load in column.
- To design all the structural component like [Footing thickness, r/f] we consider factored load.



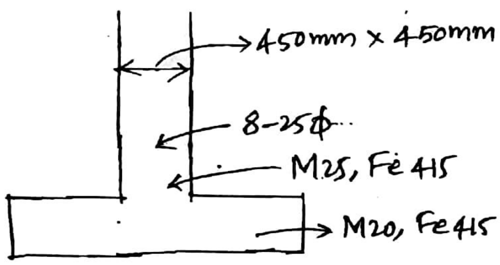
- The slab shall be designed for Net upward Pressure, i.e, Factored load in the Column divided by Area of footing.

Q:- Design a isolated square footing for column of size 450mm × 450mm reinforced with 8 no. of 25mm dia. bars and carrying a service load of 2300 KN. The gross bearing capacity of soil is 300 KN/m² at a depth of 1.5m below the ground surface, Grade of Concrete M20 for footing & M25 for column, Grade of steel is Fe415, Also check the Force Transfer at the junction of Column and Footing?

depth

beam → कोटरा
column → criteria
slab → like bending flex...

Sol:-



$P = 2300\,KN$

Gross SBC $= 300\,KN/m^2$

→ Calculation of Area of footing;

Gross SBC $= 300\,KN/m^2$

Load $= 2300 \times 1.1 = 2530\,KN$ [Considering the soil load above the footing level]

↑ +10%

$$\text{Area of footing} = \frac{2530}{300} = 8.43\,m^2$$

Design a square footing and hence $L = B = \sqrt{8.43} = 2.9m$

Consider the size of square footing as $3m \times 3m$

$$\text{Net bearing pressure} = \frac{2300 \times 1.5}{9} = 383.33\ KN/m^2$$

→ Calculation of thickness of footing from shear Criteria ;

→ From oneway shear ;

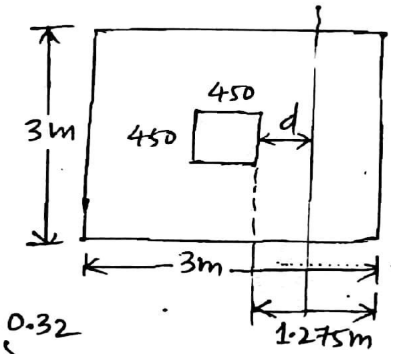
$$\tau_v \leq K\tau_c$$

In case of footing, the % tensile r/f varies between 0.15−0.3%, we can consider $P_t = 0.2\%$ for Calculation of τ_c

P_t	τ_c (MPa)
≤ 0.15	0.28
0.25	0.36

$\therefore$ for $P_t = 0.2\% \Rightarrow \tau_c = 0.32\,MPa$

Assuming the overall thickness of footing $\geq 300mm$, take, $K=1$

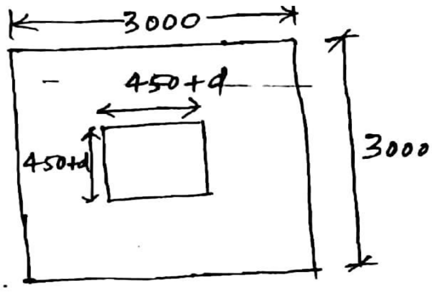


$$\therefore \underbrace{\tau_v}_{\leq 0.32} = \frac{3000 \times (1275 - d) \times 383.33 \times 10^3 \times 10^{-6}}{3000 \times d}$$

$\therefore d \geq 694mm$

→ From Twoway shear ;

$$\tau_{v,\,twoway} = \frac{383.33 \times 10^{-3} \times \left[3000^2 - (450+d)^2\right]}{4 \times (450+d) \times d}$$



∴ Permissible Two way shear $= K_s \tau_c'$

$\because \tau_c' = 0.25\sqrt{f_{ck}}$

$= 0.25 \times \sqrt{20}$

$= 1.118$ MPa

$K_s = 0.5 + \beta = 1.5$
$\not> 1$

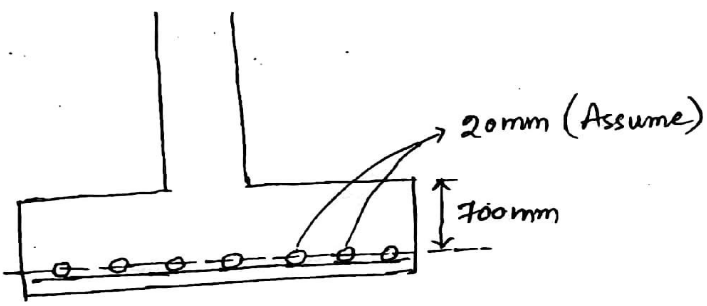
$\therefore K_s = 1$

$$\rightarrow \frac{383.33 \times 10^{-3}\left[3000^2 - (450+d)^2\right]}{4 \times (450+d) \times d} \le 1.118$$

$\therefore d \ge 625.26$ mm

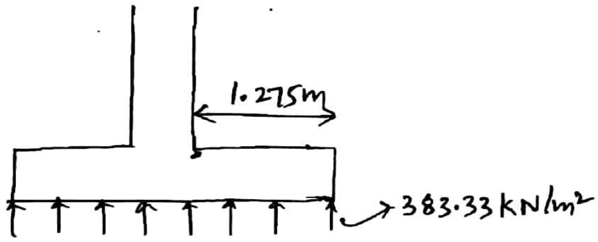
⇒ Consider $d = 700$ mm

→ <u>Calculation of overall depth</u> ;



$\therefore D = 700 + \frac{20}{2} + 20 + 50 = 780$ mm

→ <u>Calculation of M_f</u> ;



B.M. at critical Section $= 383.33 \times 1.275 \times 3 \times \frac{1.275}{2} = 934.73$ KNm.

The assumed value of K is correct as D>300mm

$\rightarrow M = 0.87 f_y A_{st}\left(d - \frac{f_y A_{st}}{f_{ck} b}\right)$

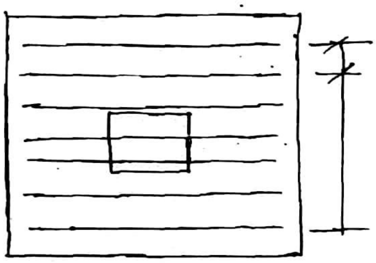
$\rightarrow 934.73\times10^6 = 0.87\times415\times A_{st}\times\left(700 - \frac{415\times A_{st}}{20\times3000}\right)$

$\therefore A_{st} = 3844.5\,mm^2$

$\rightarrow p_t = \frac{3844.5}{bd}\times100 = \frac{3844.5}{3000\times700}\times100 = 0.183\%$

→ The r/f required is less than that assumed for τ_c calculation and to take the thickness as calculated we need to provide atleast 0.2% r/f. i.e $p_t = 0.2\%$

$\therefore A_{st} = \frac{0.2}{100}\times bd = \frac{0.2}{100}\times3000\times700 = 4200\,mm^2$



$= \frac{3000 - 2\times50 - 2\times\frac{20}{2}}{13} = 221\,mm$

∴ Provide 14 no. of 20mm dia. on each side at equal spaing.

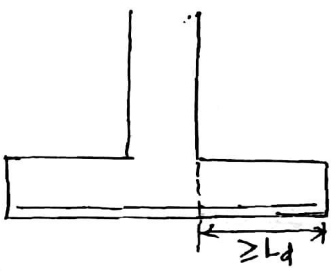
∴ Spaing = 221mm

Spaing $\not>$ 300mm

$\not>$ 3d = 3×700 = 2100mm

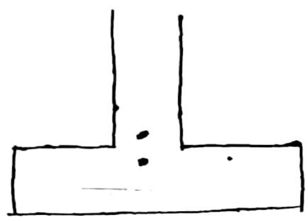
∴ O.K

→ Check for development Length;



$L_d = 47\phi = 47\times20 = 940\,mm$, O.K

→ Check of force transfer at Junction of Column and Footing;



load to be transferred from Column to footing $= 2300 \times 1.5 = 3450$ KN

Permissible bearing in Concrete on the column side $= 0.45 f_{ck} \sqrt{\frac{A_1}{A_2}}$

$= 0.45 \times 25 \times \sqrt{1}$

$= 11.25$ MPa.

on the footing side $= 0.45 f_{ck} \sqrt{\frac{A_1}{A_2}}$

$= 0.45 \times 20 \times \sqrt{\frac{3000 \times 3000}{450 \times 450}} \not> 2.0$

$= 18$ MPa.

→ for force transfer the governing side is the column side.

⇒ Maximum load that can be transferred through bearing $= 11.25 \times 450^2 \times 10^{-3}$

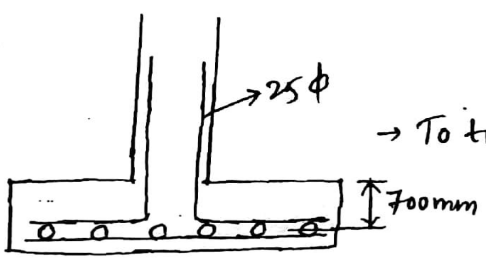
$= 2278.12$ KN

⇒ Additional load that needs to be transferred through development length

$= 3450 - 2278.12$

$= 1171.88$ KN.

→



→ To transfer $0.67 f_y$ in compression

$= \frac{47 \times 0.8 \times 0.67}{0.87} \phi$

$= \frac{47 \times 0.8 \times 0.67}{0.87} \times 25$

$\therefore = 723.9$ mm.

∵ Development length available $= 700 - \frac{20}{2} = 690$ mm.

→ Stress that can be developed in 690mm length $= \frac{0.67 f_y \times 600}{723.9} = 0.63 f_y$

$= 0.63 \times 415$

$= 265.02$ MPa

⇒ Load that can be transferred in one bar $= 265.02 \times 490 \times 10^{-3}$

$= 129.86$ KN.

⇒ Load than can be transferred through 8 no's $= 8 \times 129.86 = 1038.88$ KN

⇒ Force that needs to be transferred through additional dowels $= 1171.88 - 1038.88$

$= 133$ KN.

∴ Provide 2 no.s of 25mm dia. additional dowel bars.

⇒ Total bars $= 8 + 2 = 10 > 4$. O.K.

→ Percentage r/f $= \frac{10 \times 490}{D^2} \times 100$

$= \frac{10 \times 490}{450^2} \times 100$

$= 2.4\% > 0.5\%$

Note: