Faculty of Engineering

Er. Kalpana Patel

Branch - Civil Engineering

Sem - 6^{th}

Sub - Design of concrete structres - II

[CE-604]

Isolated Rectangular Footing-

Design Steps for Isolated Rectangular footing ⇒

Given data → load on column (w_c), Safe Bearing Capacity of soil (q_0), Grade of Concrete and steel, column dimensions (a & b)

Find out → Dimensions of Rectangular footing like Length, (Y) (X) width, depth (D) and reinforcement in footing.

Step-1 → Find Horizontal dimensions of footing:-

(A) Find weight of footing (w_f) by assuming it as 10% of load on column (w_c).

$$w_f = \frac{10}{100} \times w_c = 0.1 \times w_c$$

(B) Calculate Area of footing (A)

$$\boxed{A = \frac{w_c + w_f}{q_0}}$$

$$A = \frac{w_c + 0.1\, w_c}{q_0}$$

$$\boxed{A = \frac{1.1\, w_c}{q_0}}$$

(C) Calculate the size of footing. Here there are two methods -

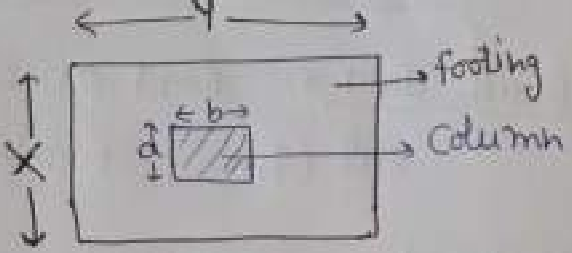
a → Assume one dimention (say X) and find other dimension (say Y) $Y = \frac{A}{X}$.

b → Assume $\frac{Y}{X}$ ratio between 1.5 to 3. Find Both dimensions (X & Y).

Note → You can provide roundoff higher values for X & Y.

(D) Calculate the soil pressure (p_u) due to factored column load only.

$$p_u = \frac{1.5\, w_c}{X \cdot Y}$$



Step-2 → Depth of footing calculation-

Depth of footing is calculated by the following three criteria and highest value so calculated is adopted in the design.

(A) Depth calculation by Bending Moment criteria-

The critical section for Bending moment is at the face of the column.

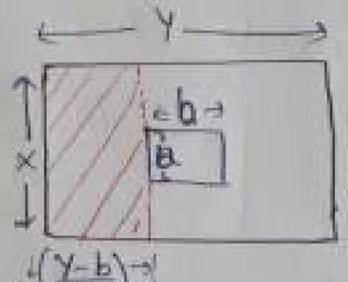
a → ~~$M_{u_1} = p_u$~~

$$UDL = \frac{p_u \times XY}{Y} = p_u X$$

BM_1 at Critical Section

$$BM_1 = p_u X \left(\frac{Y-b}{2}\right)\left(\frac{Y-b}{4}\right)$$

$$BM_1 = \frac{p_u \cdot X \cdot (Y-b)^2}{8} \quad \text{——— (1)}$$



find d by
$M_u = K b d^2$
where $b = X$
$d = d_1$

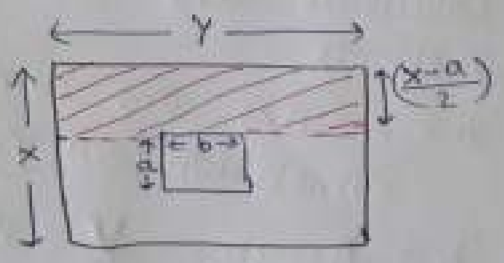
b →

$$UDL = \frac{p_u \times Y}{X} = p_u Y$$

BM_2 at Critical Section

$$BM_2 = p_u Y \left(\frac{X-a}{2}\right)\left(\frac{X-a}{4}\right)$$

$$BM_2 = \frac{p_u Y (X-a)^2}{8} \quad \text{——— (2)}$$



find d by
$M_u = K b d^2$
where $b = Y$, $d = d_2$

Note → Value of K would depend upon f_{ck}, f_y.

① find $\frac{x_{umax}}{d}$

$$\frac{x_{umax}}{d} = \frac{700}{1100 + 0.87 f_y}$$

where f_y = Yield Strength of steel in N/mm^2

② find value of K

$$M_{u\,lim} = 0.36\, \sigma_{ck}\, b\, x_u (d - 0.42\, x_u)$$

Put value of x_{umax} in terms of d and compare it with

$$M_{u\,lim} = K\, b d^2$$

find value of K

③ Table for $\frac{x_{max}}{b}$ →

Grade of Steel	$f_y \left(\frac{N}{mm^2}\right)$	$\frac{x_{umax}}{d}$
Mild Steel (Fe250)	250	0.53
Fe 415	415	0.48
Fe 500	500	0.46

④ for M20, Fe415, K = 2.76

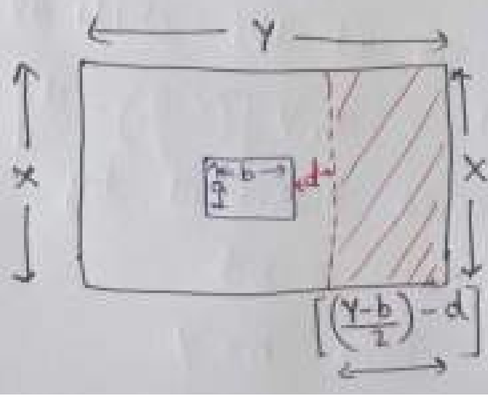
(B) Depth Calculation by One way shear criteria -

The critical section for one way shear is taken at a distance d (effective depth) from the column's face.

a →

$$UDL = \frac{p_u \times Y}{Y} = p_u X$$

$$SF_1 = p_u X \left[\left(\frac{Y-b}{2}\right) - d\right]$$



As exact % of reinforcement to be provided is not known yet, τ_c may be assumed as that corresponding to minimum reinforcement i.e. 0.12%

Note→ If we take min r/f as 0.12% the value of d obtained will be highest d, although that much depth is not required. It would be oversafe case but not wrong case.

If we assume min. r/f 0.2% the value of d obtained will be safe but always keep in mind that when we would check min Ast then we would use $0.2\% bD = A_{st\,min}$

Shear force resisted by concrete = $\tau_c bd$

in this case $b = X$

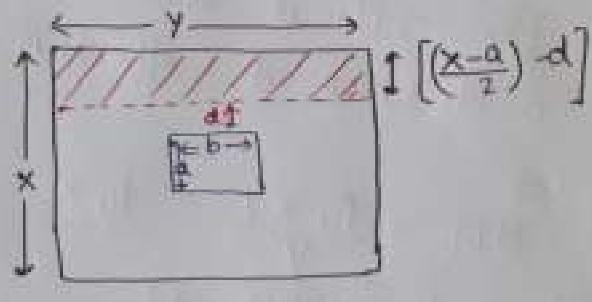
Shear force at the critical section = Shear force resisted by concrete

$$p_u \times \left[\left(\frac{Y-b}{2}\right) - d\right] = \tau_c \times d$$

find the value of d

$$d = d_3$$

b→ $UDL = \frac{p_u \times Y}{X} = p_u Y$



Shear force at the critical section $= p_u Y \left[\left(\frac{X-a}{2}\right) - d\right]$

Shear force resisted by concrete $= \tau_c bd$

here $b = Y$

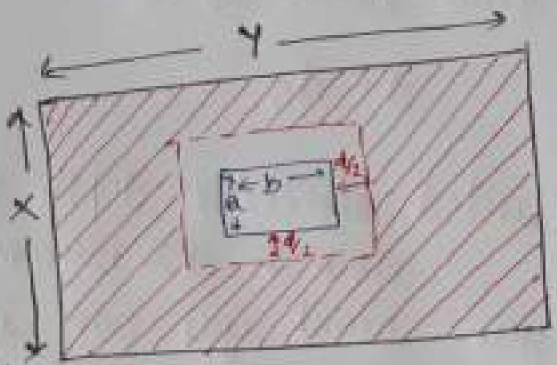
$$p_u Y \left[\left(\frac{X-a}{2}\right) - d\right] = \tau_c Y d$$

find the value of d

$d = d_4$

© Depth Calculation by Two way shear Criteria –

Critical ~~shear~~ section for two way shear (or punching shear) is at a distance $\frac{d}{2}$ from the face of the column.



Perimeter of the critical Section

$$= 2\left[\left(a + \frac{d}{2} + \frac{d}{2}\right) + \left(b + \frac{d}{2} + \frac{d}{2}\right)\right] = 2[a + b + 2d]$$

Area of concrete resisting punching shear

$$A = 2(a+b+2d)\,d$$

Punching shear resisted by the section

$$= \tau_c' \times A$$

$$= \tau_c' \times 2(a+b+2d)d$$

where value of $\tau_c' = \tau_c \times k_s$

$k_s = 0.5 + \beta_c$ but $k_s \not> 1$

$$\beta_c = \frac{\text{Short dimension of column}}{\text{Long dimension of column}}$$

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

Punching shear on critical Section

$$= p_u \left[XY - (a+d)(b+d)\right]$$

Punching shear on critical section = Punching shear resisted by the section

$$p_u[XY - (a+d)(b+d)] = \tau_c' \times 2(a+b+2d)\,d$$

find value of d

$$d = d_5$$

Provided effective depth d = highest value from (d_1, d_2, d_3, d_4, d_5)

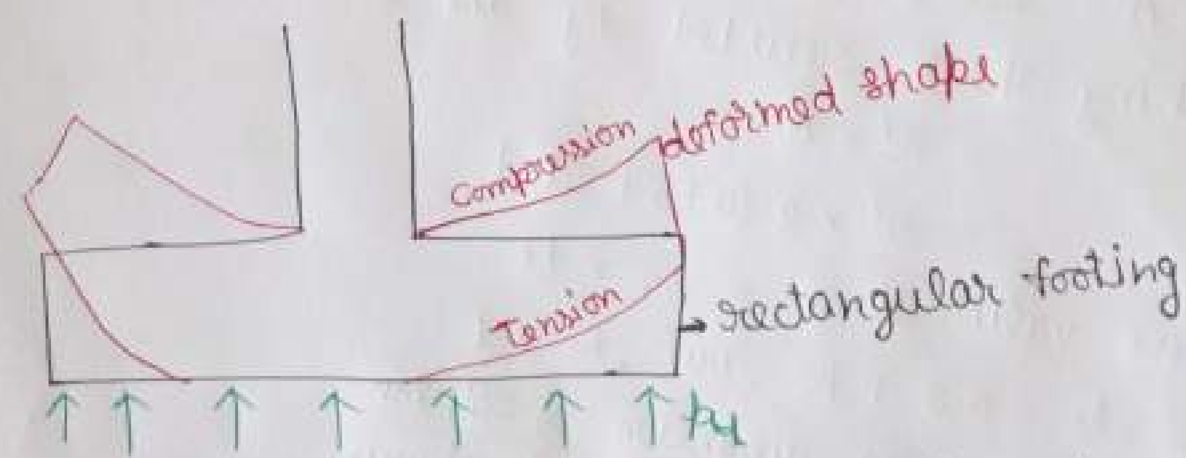
check → $d > 150$ mm

→ If you want you can increase the effective depth d for safety purpose.

→ provide effective cover of 50mm or 60mm.

→ Total depth of footing D = d + 50mm (or 60mm) + dia of r/f

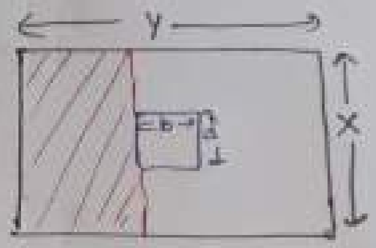
Step-3 → Area of reinforcement Calculation.



uplift pressure tries to deform the footing upward side, it creates tension on lower phase so on that portion steel reinforcement should be provided.

a) In step (2A) we have already calculated BM for longer ~~shorter~~ direction so $Mu = BM_1$

$$Mu = 0.87\ fy\ Ast\ d\left[1 - \frac{Ast\ fy}{bd\ fck}\right].$$



$b = X$

find Ast = ?

suppose Ast = Ast1

→ check for Astmin

$$Astmin = \frac{0.12}{100} \cdot bD$$ where D = Total Depth

Note: If you have taken 0.2% Astmin at the time of τ_c calculation in depth in one way shear then we that taken % as Astmin.

if $Ast_1 > Astmin$ provide Ast_1

if $Ast_1 < Astmin$ provide Astmin as r/f

→ Provide spacing

Select appropiate dia of r/f bar and calculate spacing

$$spacing = \frac{c/s \text{ of one bar} \cdot \text{width i.e. } X}{c/s \text{ of whole r/f i.e. } Ast_1}$$

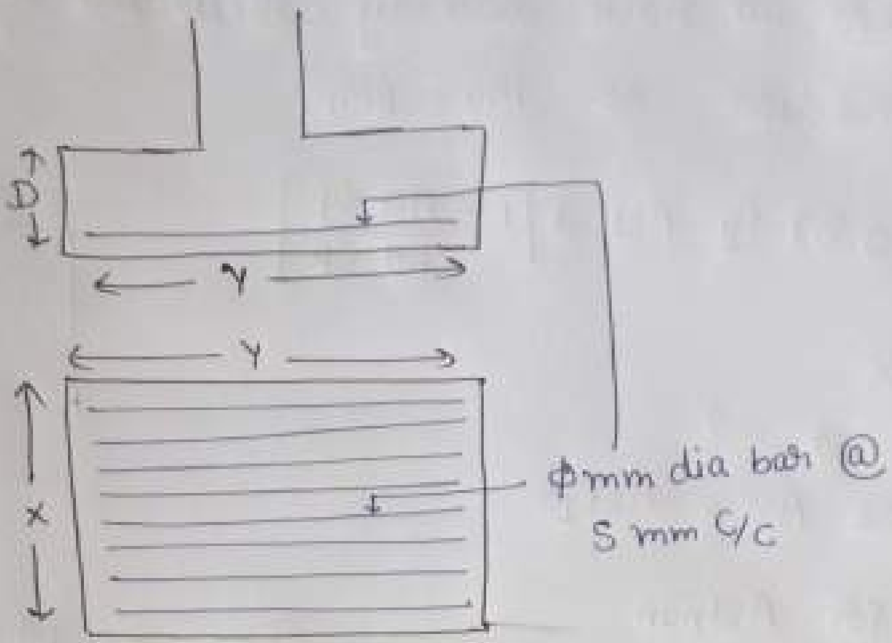
Min Spacing = 100 mm

max spacing = 300 mm or d whichever is less

check → min Spacing < spacing (S) < Max spacing

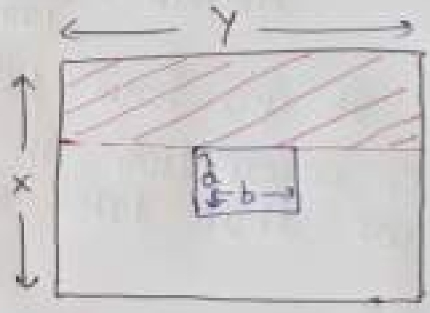
if Yes → OK

No → change dia of bar (Φ)



b → In step (2Ab)

we have already calculated BM for ~~longer~~ shorter direction. So $M_u = BM_2$



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

here $b = Y$

find $A_{st} = ?$

suppose $A_{st} = A_{st2}$

→ check for $A_{st min}$

$$A_{st min} = \frac{0.12}{100} b D$$

$A_{st provided} > A_{st min}$ → provide A_{st2}

$A_{st2} < A_{st min}$ → provide $A_{st min}$

→ band division -

As per IS code 456 in Page no- 65, clause no 34.3.1 (c) →

For r/f in short direction, a central band equal to the width of the footing shall be marked along the length of the footing and portion of r/f determined in accordance with the eq. –

$$\frac{\text{R/f in the central band width}}{\text{Total r/f in short direction}} = \frac{2}{\beta + 1}$$

$$\beta = \frac{\text{Long Side of footing}}{\text{Short Side of footing}}$$

The remainder of the reinforcement shall be uniformly distributed in the outer portions of footing.

$$\frac{Ast_{2\,center}}{Ast_1} = \frac{2}{\beta + 1}$$

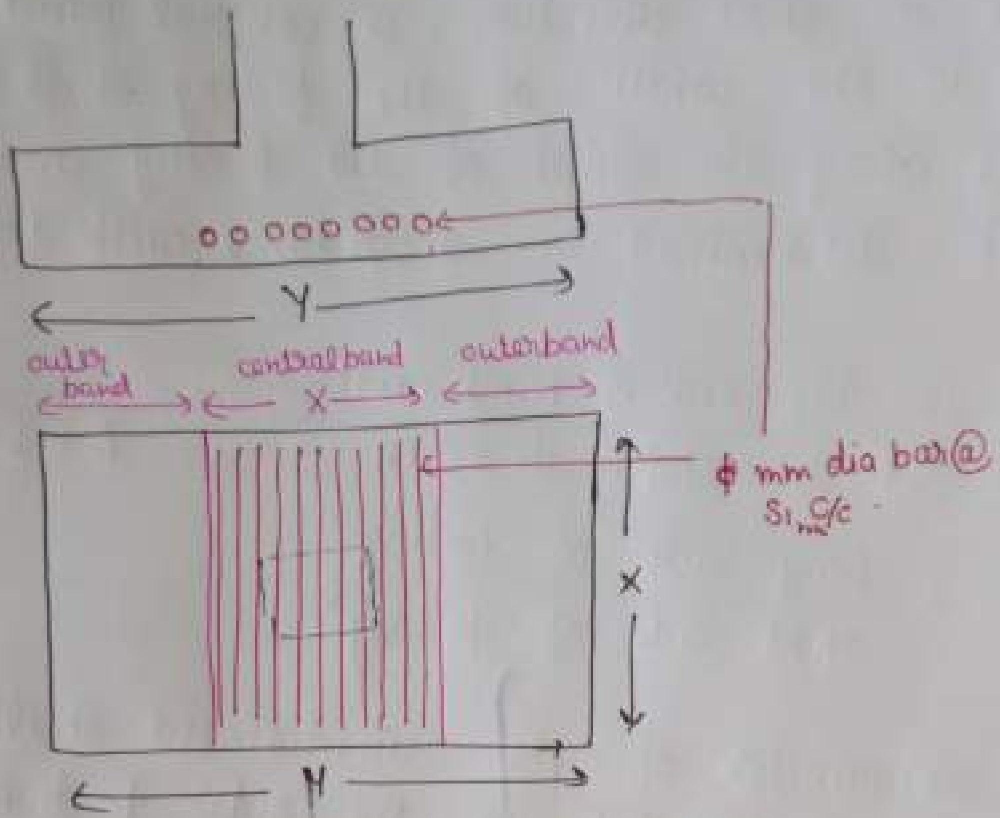
$$\beta = \frac{Y}{X}$$

Find $Ast_{2\,center}$ = ?

→ Select dia of bar ϕ

→ provide spacing (S_1) $= \dfrac{\text{c/s Area of one bar} \times \text{length of central band or X}}{Ast_{2\,center}}$

min Spacing (100 mm) $< S_1 <$ max spacing (300mm or d)

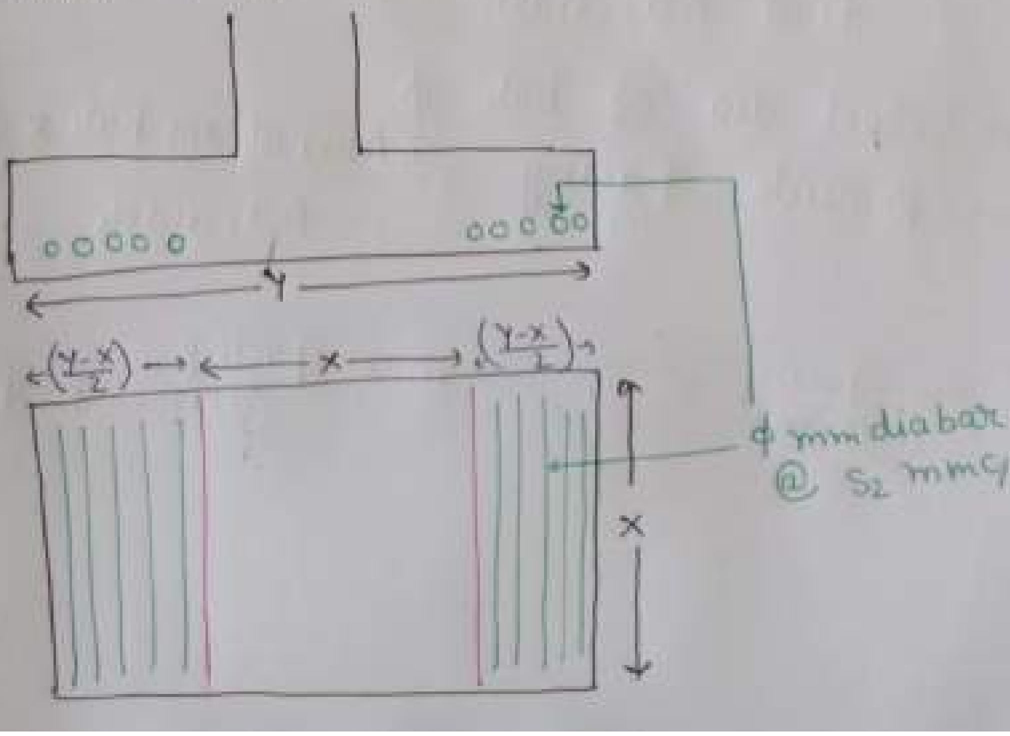


$Ast_{2outer} = Ast_2 - Ast_{2center}$

Select a dia for Ast_{2outer} bars and calculate spacing

$$S_2 = \frac{\text{c/s area of one bar} \times (\text{length of outer band or } (Y-X))}{Ast_{2outer}}$$

$100mm < S_2 < 300mm$ or d



Step-4 → Check for development length -

find τ_{bd} → design bond stress

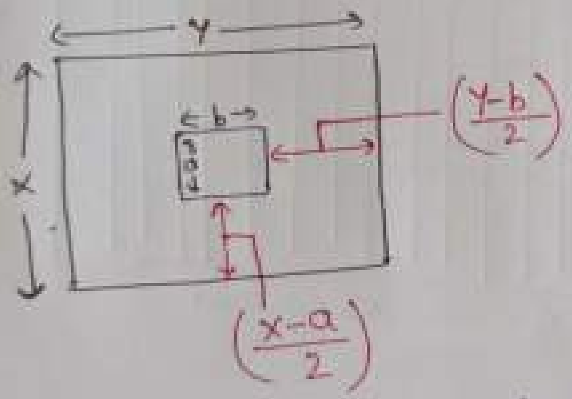
As per IS456:2000 code, Page no - 43, clause no - 26.2.1.1

Grade of concrete	M20	M25	M30	M35	M40 & above
τ_{bd} in N/mm^2	1.2	1.4	1.5	1.7	1.9

for deformed bars

$$\tau_{bd}' = 1.6\ \tau_{bd}$$

find development length $L_d = \dfrac{0.87 f_y \phi}{4 \tau_{bd}}$



use corresponding dia of bar and find Ld

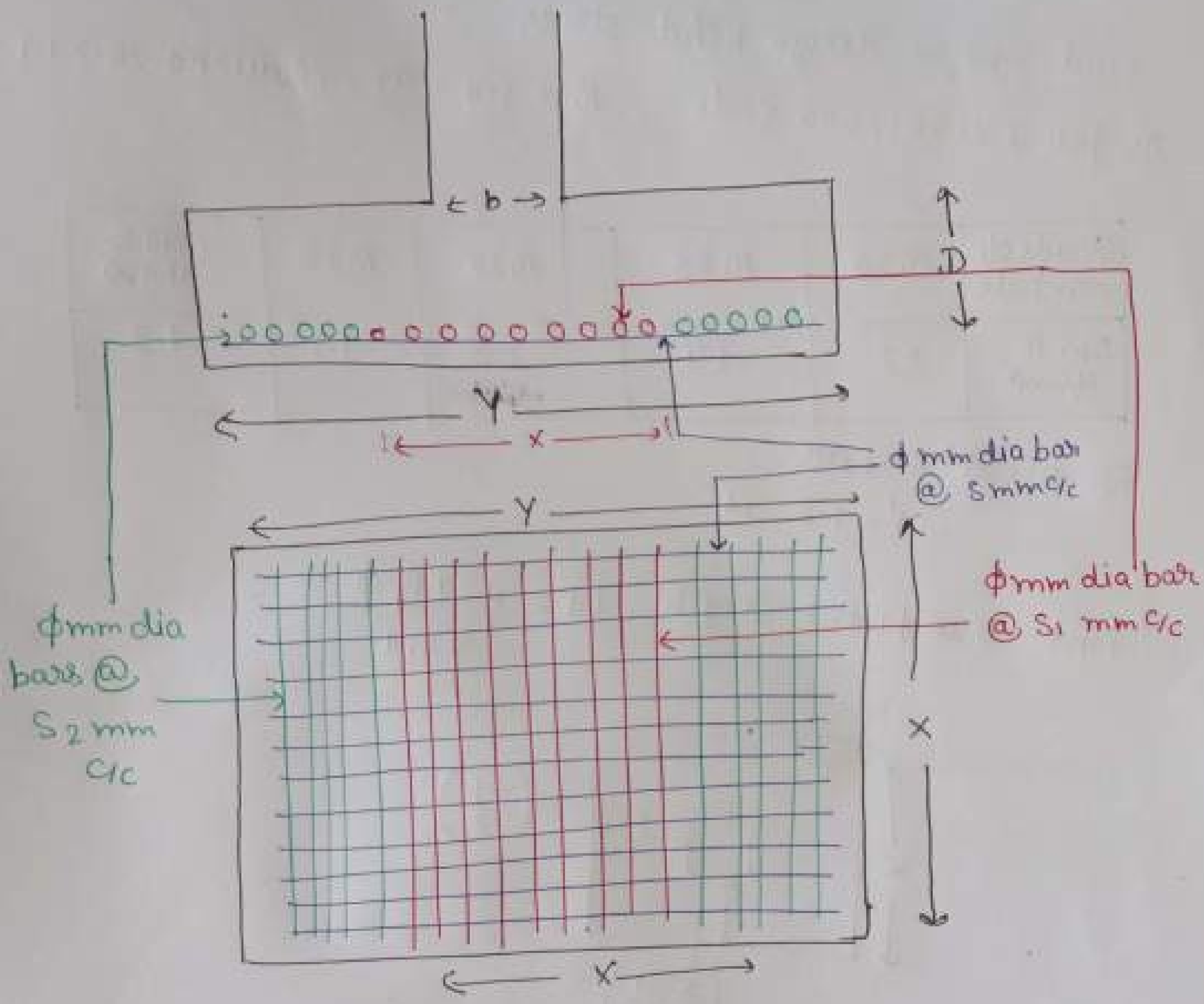
for Safety $L_d < \left(\dfrac{y-b}{2}\right)$

$L_d < \left(\dfrac{x-a}{2}\right)$

then OK

otherwise we have to anchor the bars.

As per IS 456, page no 43, clause no - 26.2.2.1


b
D
Y
x
ϕ mm dia bar @ s mm c/c
Y
ϕ mm dia bar @ S1 mm c/c
ϕ mm dia bars @ S2 mm c/c
X
X