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1) Structural Engineering:

(A). Design of Reinforced cement concrete structure

Building structural Design

- → Design of Beam
- → Design of slab Limit state Method
- → Design of column
- → Design of footing.

* Difference Between working stress method and Limit state method

	WSM	LSM
(I).	Traditional desi., conservative method (elastic theory considered)	→ modern philosophy rational (plastic theory).
(II).	deterministic approach	→ probabilistic approach
(III).	concrete is assumed linear elastic method. Stress-strain diagram linear	(III). concrete non-linear inelastic material. stress-strain diagram is non-linear (parabolic)

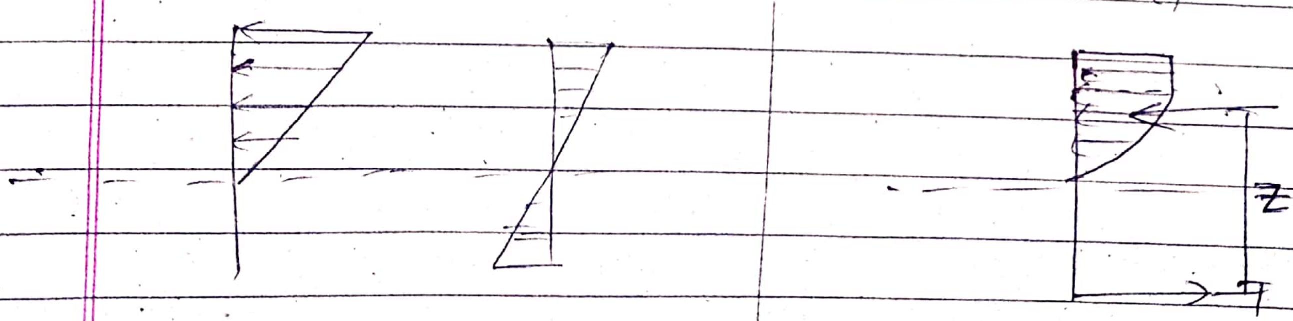

Fig: stress diagram in concrete

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(iv) FoS considered for concrete & steel "

Concrete => In bending compression => 3

σ_{cbc} = permissible compressive bending strength of concrete.

$$\sigma_{cbc} = \frac{f_{ck}}{3}$$

M20 के लिए $\sigma_{cbc} = \frac{20}{3} = 7 MPa$

underutilization of strength of concrete / uneconomical design.

& Direct compression का FoS = 4

σ_{cc} => permissible stress of concrete in direct compression.

Steel FoS => 1.78

permissible tensile stress

$$\sigma_{st} = \frac{f_y}{1.78}$$

(V) Load calculation:
working load / service load => actual आपका load

(iv). Partial safety factor for concrete.

Design compressive strength of concrete $= \frac{0.67 f_{ck}}{1.5}$

$= 0.446\ f_{ck}$

→ relatively smaller cross-section required as compared to (WSM).

→ economical design.

Steel

Partial safety factor = 1.15

Design tensile strength of steel $= f_y / 1.15$

$= 0.87 f_y$

(V) Load calculation
Partial safety factor from load को multiply करते हैं ~~Design~~ or ultimate = λ Partial / working

λ = ~~1.5~~ Load factor depends on nature of load.

Eg: DL & LL के लिए λ = 1.

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FOS for load is not considered, taken as it is.
So for design working load or service load is considered.
W => (DL+LL+.)

Drawbacks
- uneconomical
- FOS only for strength
- deterministic.

$W_u = 1.5\,(DL+LL)$

Load combination

IS ACI IS code.

(i) 1.5 (DL+LL)
(ii) 1.2 (DL+LL ± EQ_{any})

Why is load combination done?
envelope create गर्न to identify critical loading condition.
Design load ठूलो combination बाट आएको load हो ।

Limit state

Limit state of collapse
- strength, stiffness, structural integrity, load path, etc.
(strength parameters for safety)
- safety at ultimate load or factored load

Limit state of serviceability
- deflection control, vibration, crack, etc.
- proper functioning.

both fulfill भएमा मात्र Accept :

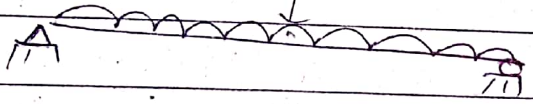
* **Design of Beams : (LSD)**

Procedure :

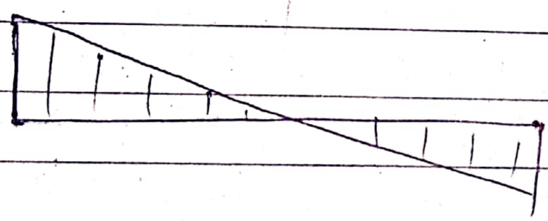
Step 1. Idealization of given structural system (type of beam : cantilever, simply supported, etc) .
(Define गर्ने)

2. Load calculation
DL आफैं निकाल्नुपर्छ निकाल्ने / γ conc * Cross section Area.
LL Given
As per IS : 875 Part I and Part II
(W_u) आउछ।

③. Structural Analysis : Stress calculation
Vmax निकाल्ने

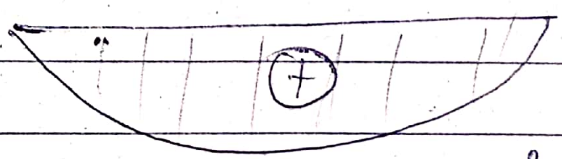


$W_u = 1.5(LL + DL)$



$\frac{wl}{2}$

Vmax
M_u



$M_u = \frac{w_u l^2}{8}$

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Step (4) Design

a) ~~cat~~ calculation of ~~rer~~ longitudinal reinforcement required.

singly आए / i.e $M_u \le M_{u,lim}$. Assume d

ultimate moment of resistance (MOR) $= 0.87 f_y A_{st} * d \left(1 - \frac{f_y A_{st}}{f_{ck} * b * d}\right)$

$$\frac{w_u l^2}{8} = 0.87 f_y A_{st} * d \left[1 - \frac{f_y A_{st}}{f_{ck} * b * d}\right]$$

A_{st} By solving A_{st} आयगा /

Note:

$M_u \Rightarrow$ calculate गरेको man.

$M_{u,lim} \Rightarrow$ limiting ultimate MOR of singly reinforced section. (code).

This comes 1st

Fe 250 $\Rightarrow$ $M_{u,lim} = 0.148 f_{ck} bd^2$

$M_{u,lim} = 0.138 f_{ck} bd^2$

$M_{u,lim} = 0.133 f_{ck} bd^2$

$M_u \le M_{u,lim} \Rightarrow$ singly मा safe cap

else $M_u > M_{u,lim} \Rightarrow$ go for doubly reinforc

↓

compression zone मा पनि steel राख्नु पर्छ /

A_{st} आयो ।

(5) Step 5 : Detailing and compliance with code
आएको steel codal provision अनुसार compliance मा छ कि छैन । check OK → step 6
else goto step 4.

Step 6 :

$$\text{no. of bars } (n) = \frac{A_{st}}{\pi\phi^2/4}$$

Assume ϕ to round off to greater whole.

$$A_{st\,min} = \left(\frac{0.85}{f_y}\right) \times bd \leq (A_{st})_{provided}$$

$\boxed{OK}$

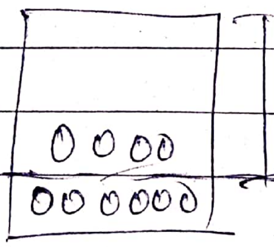
$$(A_{st})_{pro} = n \times \frac{\pi\phi^2}{4}$$

$$(A_{st})_{max} = 0.04bD \geq (A_{st})_{prov}.$$

$\boxed{OK}$

IS code अनुसार एउटा 1 layer मा max 6 वटा Bar मात्र राख्न मिल्छ ।

10 वटा भए 6 तल 4 माथि ।



centroid of

holding bar => 8mm (min^m).

min^m horizontal spacing between bars =

$$= \max \text{ of } \begin{cases} \text{max}^m \text{ diameter of bar if } \phi \text{ are equal.} \\ \cancel{\text{max}^m \text{ size of aggregate + 5mm}} \end{cases}$$

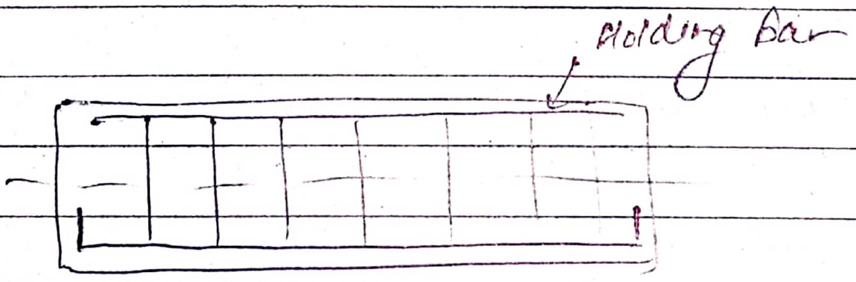
min^m vertical spacing between bars

$$= \text{max}^m \text{ of } \begin{cases} \text{(i) max}^m\ \phi \text{ of bar if } \phi \text{ are equal} \\ \text{(ii) 15 mm} \\ \text{(iii) } 2/3 \text{ of max. size of aggregate} \end{cases}$$

Step (6) Check deflection :

$$\frac{\cancel{l_{eff}}}{d} \le \alpha \beta \gamma \delta \quad \text{OK}$$

safe in serviceability.



* Doubly Reinforced Beam:

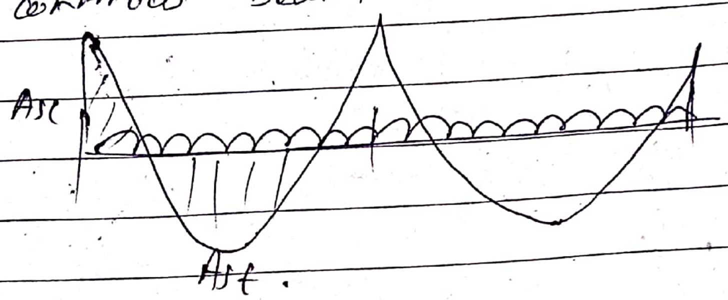
\# why doubly reinforced beam required?

→ for providing adequate headroom clearance. (Depth कम रखना होता है)

→ $M_u > M_{u,lim}$ for singly reinforced beam section

→ when earthquake load considered for structural design of building. (reversal load)

→ for continuous beam



→ ductility enhance
→ cross section reduced
→ high load resisting capacity.

Procedure:

STEP 1: structural idealization (define material, preliminary sizing.

STEP 2: load calculation (W_u)

STEP 3: Analysis

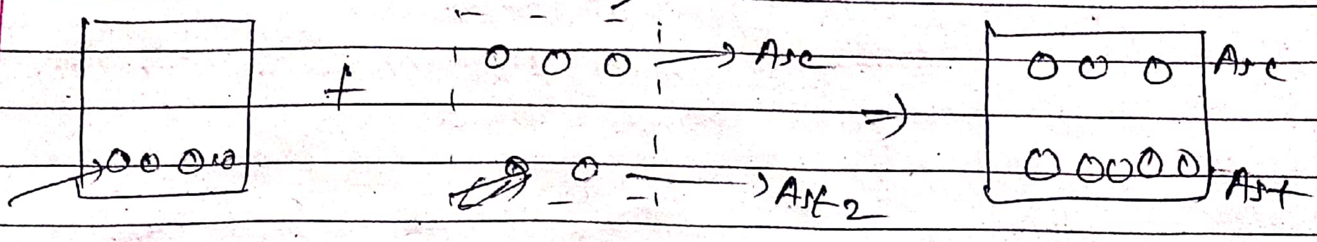
$M_u > M_{u,lim}$. doubly होता है।

V_u

Step 4:

Calculation of tension reinforcement.

Steel Beam theory



Mu,lim को लागि singly मानेर Design गर्ने

Mu − Mu,lim को लागि Design.

$A_{st} = A_{st1} + A_{st2}$

$M_{u,lim} = 0.87 f_y A_{st1} * d \left(1 - \frac{f_y * A_{st1}}{f_{ck}\, b * d}\right)$

$38 f_{ck} b d^2$ (Fe 415)

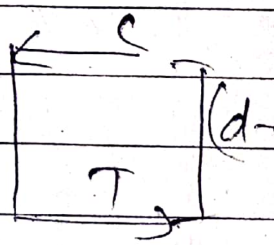
आउछ

$A_{st1} = \ldots\ldots$

Steel beam बाट

Mu

~~$M_u - M_{u,lim} = 0.87 f_y A_{st2}$ (~~



$M_u - M_{u,lim} = T * (d - d')$

$d'/d = 0.1$ (generally)

$(M_u - M_{u,lim}) = 0.87 f_y (A_{st2}) (d - d')$

A_{st2} आउछ।

$T = 0.87 f_y A_{st}$ लेकिन जितनी fully yielded
हो सकती A_{st2}
compression steel fully yield हो यह ।

* calculation of compression reinforcement

$T_2 = C_2$ | $M_u - M_{u,lim} = \sigma_{sc} A_{sc} \times (d - d')$

@ SP-16 Table F

Fe 415 $\sigma_{sc} = 350$ MPa

Step 5: Detailing of reinforcement & compliance check with codal provision.

no. of tension bars $(n_1) = \left(\frac{A_{st}}{\pi \phi^2 / 4} \right)$

$(A_{st})_{prov} =$

Check $(A_{st})_{min} = \frac{0.85 \, bd}{f_y} \leq (A_{st})_{prov}$

$(A_{st})_{max} = 0.04 \, bD > (A_{st})_{prov}$ [ok].

compression steel check

$(A_{sc})_{min} > 0$

$(A_{sc})_{max} = 0.04 \, bD$

no of compression bar $(n_2) = \frac{A_{sc}}{\pi \phi^2 / 4}$

spacing check (same as before)

STEP 6 Deflection check-

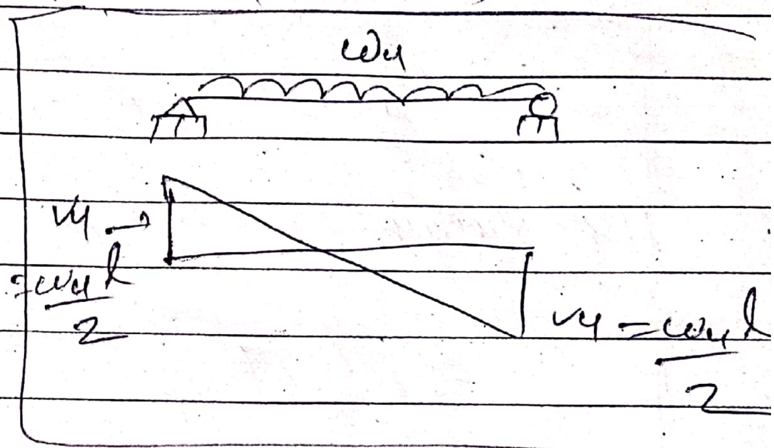
$$l/d \le \alpha\beta\gamma\lambda.$$

* Design of stirrups (shear Reinforcement).

Procedure :

STEP 1: calculate nominal shear stress (τ_v)

$$\tau_v = \frac{V_u}{bd}$$ V_u = factored shear force (ultimate)



STEP 2: Identify the value of τ_c from table (19) IS 456 : 2000

Assume approx. value.

- design shear strength of concrete without shear reinforcement

STEP 3: $\tau_{c\,max}$ from table (20) IS 456 : 20

$\tau_{c\,max}$ ⇒ max^{m} shear strength of concrete with shear reinforcement.

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STEP 4: when $\tau_v < \tau_c$: provide min^m shear reinforcement $(A_{sv})_{min}$

$$(A_{sv})_{min} = \frac{0.4 b S_v}{0.87 f_y}$$

where, $b \Rightarrow$ width of beam
$S_v \Rightarrow$ spacing of stirrups
$f_y \leq 415$ MPa for stirrups.

$\tau_{v} > \tau_c \Rightarrow$ design shear reinforcement stirrups.

$$V_{us} = \left[V_u - (\tau_c b d) \right]$$

shear strength of stirrups..

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

$A_{sv} \Rightarrow$ total area of stirrups.

choose 2-legged 8mm ϕ 414

$$A_{sv} = 2 \times \pi \phi^2 / 4$$

S_v = spacing of stirrups.

check:

$$(S_v)_{max} = \begin{cases} \text{(i) } 0.75d \\ \text{(ii) } 300\ mm \end{cases} \text{ Take smaller value}$$

$$S_v \le S_{v\,max}$$

* Slab

~~Design~~ ~~Types~~

→ Design of one way slab is similar to design of Beam.

→ Take 1m width strip for analysis and design purpose of slab

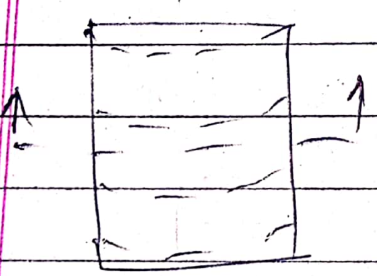
→ shear reinforcement is never provided (generally), यदि चाहिए होता instead of providing stirrups depth of slab is increased.

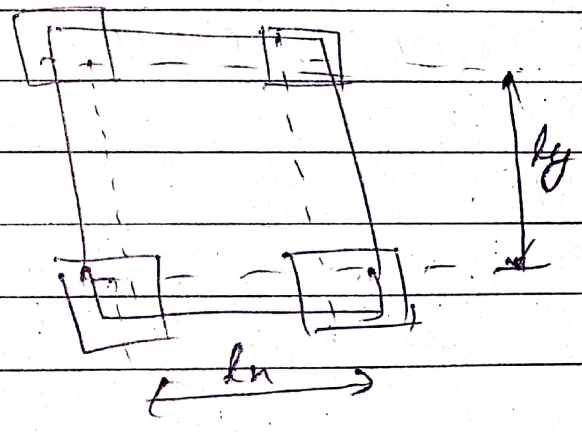
~~(i)~~ ~~(a)~~

a) One way slab:

Load distribution mechanism.

⇒ along shorter direction only

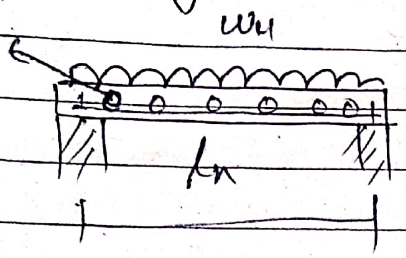




$l_y > l_x$

Beam Design [illegible]

Distribution bar (nominal reinforcement)



$$M_u = \frac{w_u l_x^2}{8}$$

main bar placed along shorter x-direction. Provide minm area of steel reinforcement along y to resist temperature and shrinkage.

Shear force calculation: $(V_u) \Rightarrow \tau_v$

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

$\tau_c' = K * \tau_c$
$\quad \rightarrow$ code manm $K = 1$

mostly $\tau_v < \tau_c'$

यदि कहीं नहीं $\tau_v > \tau_c'$ [illegible] increase d, $\tau_v \downarrow$

Design Procedure:

STEP 1 :- Select preliminary depth from deflection control criteria.

$$\frac{l_x}{d} < \underbrace{\alpha \beta \gamma \lambda}_{1} \delta$$

For cantilever, $\alpha = 7$

simply supported, $\alpha = 20$

continous, $\alpha = 26$

$d = \dots$

STEP 2: Load calculation

DL = Floor finishing = 1.5 kN/m²

self weight = $(\gamma_{RCC} \times D)$

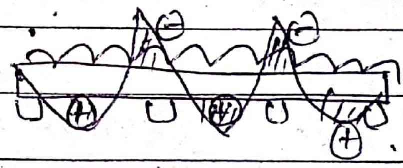
LL = 2 kN/m² for residential building.

= 3 kN/m² for office building.

$w_u = 1.5\,(DL + LL)$

STEP 3: Analysis.

Factored moment calculation

simply supported	continous slab
$M_u = \dfrac{w_u l^2}{8}$	 Table 12 IS 456 : 2000 BM coefficient. $M_u = \alpha\, w\, l_n^2$

STEP 4: M_u Design of main steel bars:

$(A_{st})_{x}$

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

$(A_{st})_n = \text{.....}$ Assume ϕ (8, 10, 12)

$$\text{Spacing} = \frac{1000 \left(\frac{\pi}{4}\phi^2\right)}{(A_{st})_n}$$

check with codal provision

(I) $(A_{st})_{min} \Rightarrow$ 0.15% bD for mild steel
0.12% bD for HYSD

(II) $\phi_{max} \leq \frac{D}{8}$

(III). Spacing of Bars = $S_{max} = \left\{ \begin{array}{c} 3d \\ 300mm \end{array} \right\}$ min^m of

STEP 5 : Provide "Distribution Bars"
→ along y-axis

$(A_{st})_{min}$ = provide same = 0.15% mild steel
= 0.12% HYSD

$$S_{max} = \left\{ \begin{array}{c} 5d \\ 450mm \end{array} \right\} \text{min}^m$$

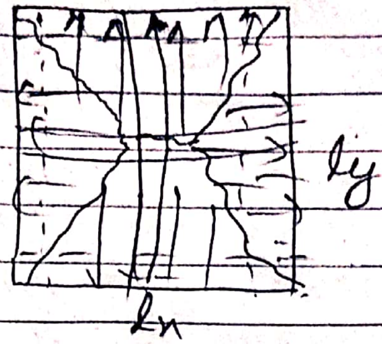
STEP 6: Check serviceability criteria

$\frac{l_n}{d} \leq \alpha \beta \gamma \delta$

* Design of two way slab :

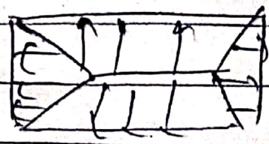
$l_y/l_x \leq 2$

Load distribution along two-direction i.e. (two (both) way spanning



Yield line Theory :
(Tributary loading cond^n)

BM along both direction (M_{ux}) and (M_{uy})
& A_{stx} (A_{sty})



Depending upon support condition
(i) Restrained slab (corner are held down, (monolithic construction joint))
(ii) simply supported ⇒ corners are free to lift up (not held down)

Imp **Simply Supported Two way slab**

Design Procedure :

Given : l_x, l_y, load.

STEP 1: Assume preliminary depth of slab

$\left(\frac{l_x}{d}\right)$

	mild steel (l_n/d)	HYSD (l_n/d)
~~mild steel~~		
(i) simply supported	35	28
(ii). continuous slab	40	32

~~(i) HYSD~~ STEP2 : Load calculation (w_u)

STEP 3 : calculate BM in both direction

$M_{ux} = \alpha_x w_u l_x^2$

$M_y = \alpha_y w_u l_x^2$

where, α_x, α_y are BM coefficient.

Refer IS 456 : 2000 Table 27

OR, from Rankine - Grashoff formulae.

$$\alpha_x = \frac{1}{8}\left(\frac{r^4}{1+r^4}\right) \quad \boxed{r = l_y/l_x}$$

$$\alpha_y = \frac{1}{8}\left(\frac{r^2}{1+r^4}\right) \quad r = l_y/l_x$$

only for simply supported.

STEP 4: Area of steel reinforcement in shorter and longer direction. ($A_{st})_x$ and $(A_{st})_y$.

$$M_{ux} = 0.87 f_y (A_{st})_x * d \left[1 - \frac{f_y (A_{st x})}{f_{ck} b * d}\right]$$

$b = 1m$

$(A_{st})_x = \ldots$

Assume ϕ_x (Spacing)$_x$ = $\dfrac{1000 \frac{\pi \phi_x^2}{4}}{(A_{st})_x}$

check (Spacing)$_{max}$ $\left\{ \begin{array}{l} 300\ mm \\ 3\phi_x \end{array} \right\}$ min^m of.

$(A_{st})_{min} = 0.15\%$ for mild steel
$= 0.12\%$ for HYSD.

$\phi_{max} \leq D/8$ check.

$(A_{st})_y = \ldots$ ϕ_y (Spacing)$_y$ = ...

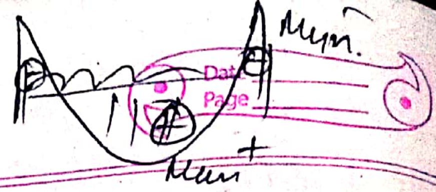
STEP 6: check for servicability criteria.
l_x/d < value from code
(आगे लिखेंगे.)

II Design of two way Restrained slab:

STEP 1: $\left(\frac{l_x}{d}\right)$ $d = \ldots$

STEP 2: Load calculation

STEP 3: B_{Mx} B_{My} M_{ux}, M_{uy} using IS code IS 456 : 2000. Table 26



$$M_{ux}^{+,-} = \alpha_x^{+,-} W_u l_x^2$$

$$M_{uy}^{+,-} = \alpha_y^{+,-} W_u l_x^2$$

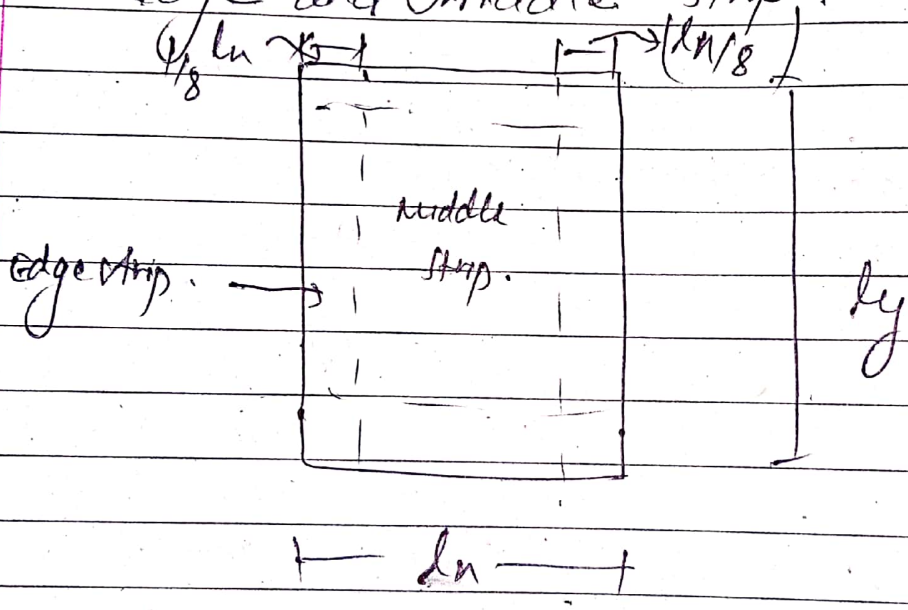
$\alpha_x^{+,-}$ $\alpha_y^{+,-}$ refer from IS 456:200 table (26)

Boundary condition 9 तरह होगा |

STEP 4: Calculate $(A_{stx})^{+,-}$ A_{sty} and check A_{st}.

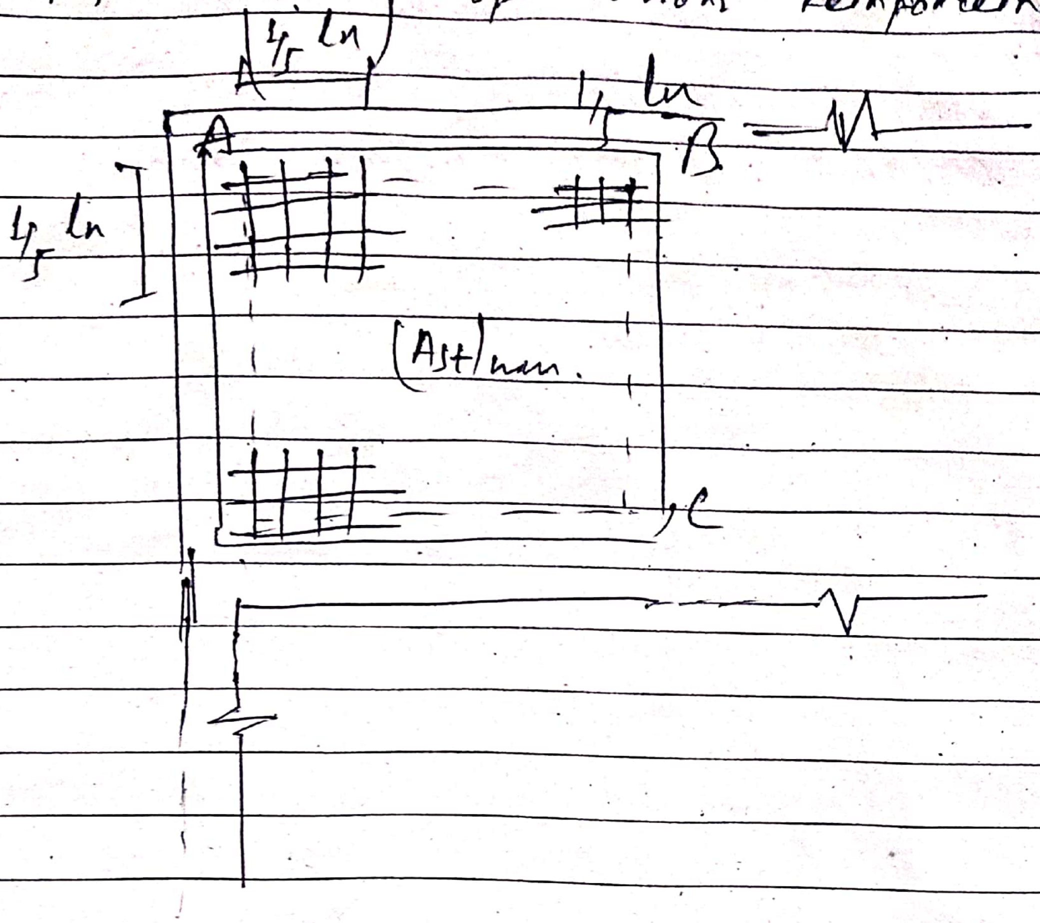
STEP 5: Calculate $(A_{sty})^{+,-}$ and check

STEP 6: Placing of reinforcement Bar in edge and middle strip.



Edge strip का minm area of steel Bar रखते
middle का design area का रखते |

STEP 7: Provision of Torsion Reinforcement.



Both adjacent edge continuous हो तो Torsion rein. नहीं देंगे।

At corner A

Full torsion reinforcement

$= 0.75\ (A_{st})_n^+$

at each layer. → actually max^m of +, at mid generally n वाले ही होते हैं।

At corner B

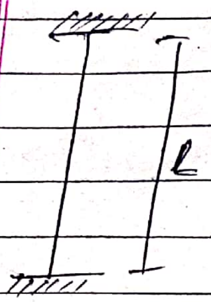
half torsion $= \frac{1}{2} \times 0.75\ (A_{st})_n^+$

At C not needed.

* Design Procedure of short Axially loaded column:

STEP 1: Slenderness Ratio:

l_{eff} = recommended value of effective length
IS 456 : 2000 Table No 28.



$b \Rightarrow$ least lateral dimension.

$l_{eff} = 0.65 l$

$b \Rightarrow$ minimum lateral dimension of column

STEP 2: Calculate minimum eccentricity (e_{min}).
Practically all column shall be designed for e_{min}

e_{min} = accidental eccentricity $= \dfrac{l}{500} + \dfrac{b}{30}$

≥ 20 mm

If $e_{min} \leq 0.05 b \Rightarrow$ ~~purely~~ axially loaded column

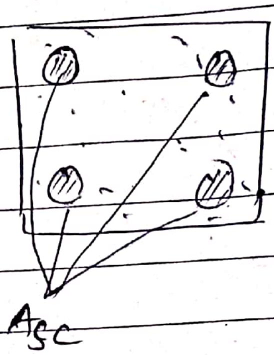
If $e_{min} > 0.05 b \Rightarrow$ eccentricity should be considered.

STEP 3: calculate area of long. reinforcement A_{sc}

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

P_u = factored axial load = 1.5 service load (P)

A_c = Area of concrete



$A_g = BD$

$A_c = A_g - A_{sc}$

A_{sc} = ...

STEP 4:

check with codal provision (IS 456 : 2000)

(i). Min. of longitudinal bar = $(A_{sc})_{min}$ = 0.8 % of BD

(ii). max. area of long = 6 % of BD (theoritically).

= 4 % of BD (practical for proper compaction

(iii). min^m no. of bars = 4

for circular column = 6

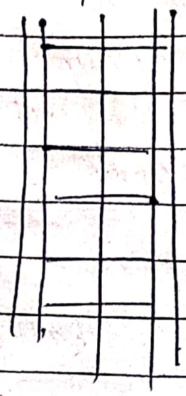
(iv). min^m dia of long. bar = 12 mm

STEP 5: Design of transverse reinforcement / lateral ties

(i) Minm Dia. of lateral tie

$\geq \left(\frac{1}{4}\right)^{th}$ of max. ϕ of long. bar

$\geq$ 8mm   maxm of

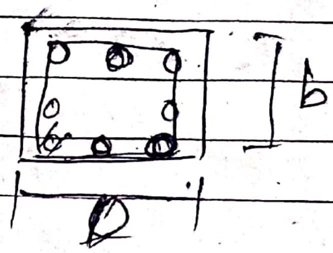


(ii). Spacing of lateral ties (pitch)

$\leq$ least lateral dimension of column X-section

$\leq$ 16 * minm dia of long. bar

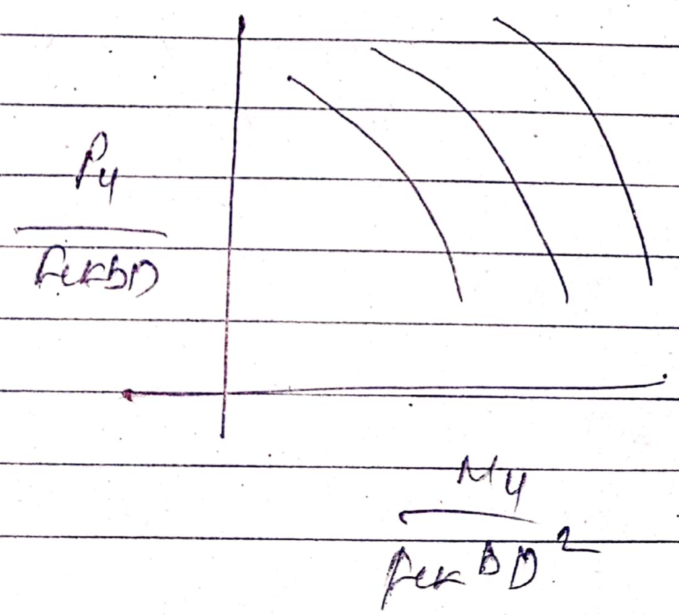
$\leq$ 300 mm



यदि eccentricity $> 0.05\,b$

axially loaded + bending moment M_u.

$\frac{P_u}{f_{ck} BD}$ $\frac{M_u}{f_{ck} BD^2}$



$$D_f = \frac{q_u}{\gamma_{soil}}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

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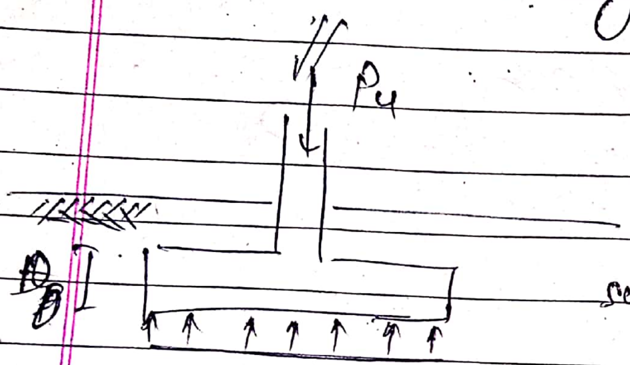
* Footing Design:

→ safely transmit the load of superstructure to subsoil without excessive settlement and

Types of footing:

① Shallow foundation: ($D_f \le B$)

(a) Isolated footing (b) combined (c) Raft

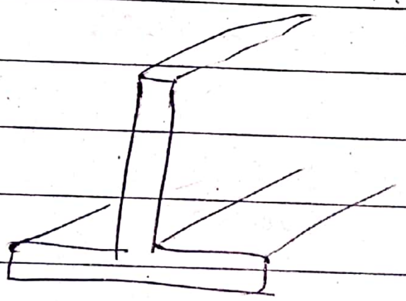


P_u

D_f

sub-soil bearing

uniform thickness



masonry load bearing
per m width
similar to RCC.

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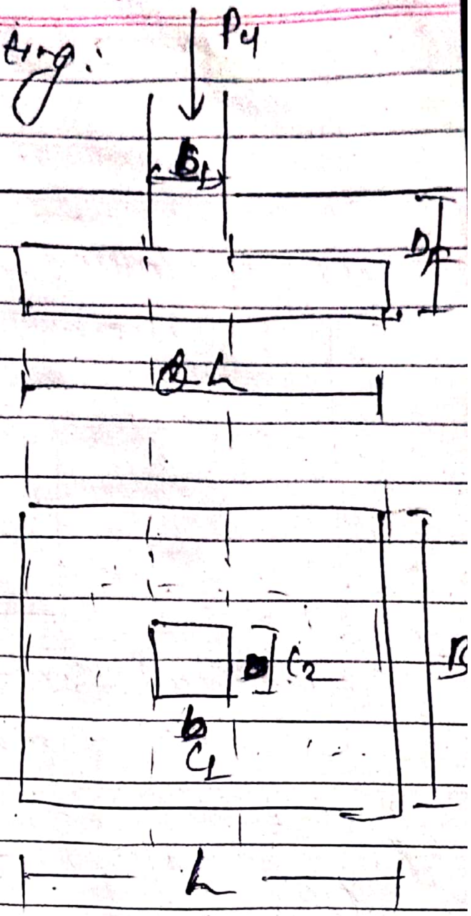
* Design Procedure for Isolated footing:



Given: P_u, Q_u, c_1, c_2

STEP 1: Determine the ~~type~~ shape and size of footing.

$$A_{footing} = \frac{1.1\ P_{service}}{Q_u}$$

10% more weight taken for overburden ~~and~~ pressure and ~~service~~ self-weight of footing.

$$LB = \frac{1.1\ P_{ser}}{Q_u}$$

$$\frac{L}{B} = 1.5 \text{ to } 2 \quad (\text{assume generally})$$

$L = \ldots \qquad B = \ldots$

STEP 2: Calculate upward soil pressure
(super structure, & P_u का जो soil पर footing का net pressure)

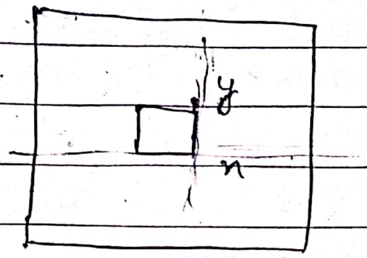
⇒ uniform pressure ~~assume~~ : if CG of P_u coincides with centroid of footing area.

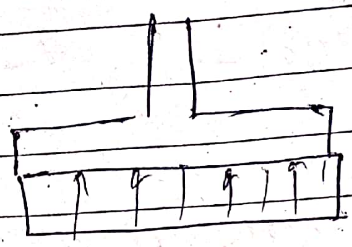
$$q_u = \frac{P_u}{A_{prov}} = \frac{1.5 P_{ser}}{LB}$$

STEP 3: Calculation of thickness of footing.

(1) Moment criteria

cantilever मानके





critical section for BM is at face of the column

$$M_{u_{xx}} = q_u \times L \left(\frac{L - C_L}{2}\right) \times \frac{L - C_L}{4}$$

$$= q_u \frac{B (L - C_L)^2}{8}$$

$$M_{u_{yy}} = q_u \frac{L (B - C_2)^2}{8}$$

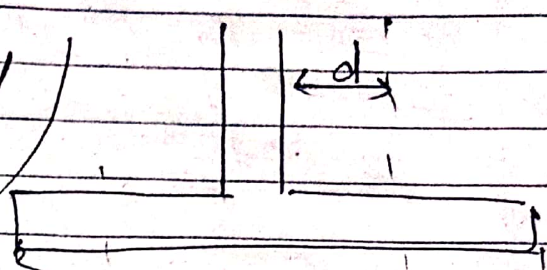
$M_{u_x} = 0.138 f_{ck} B d^2$

$M_{u_{y\,max}} = \ldots$

$d = \ldots$

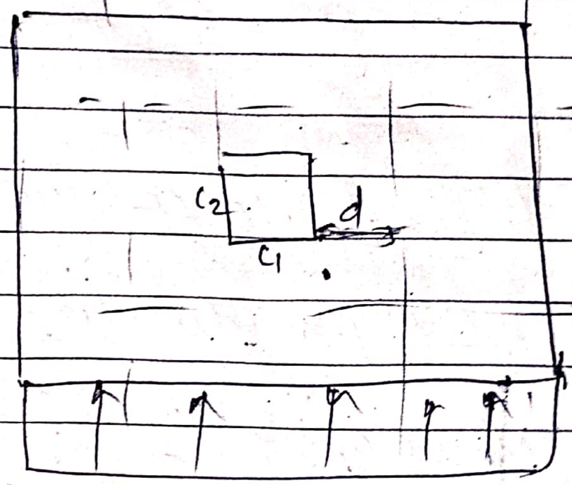
(II). Shear criteria one way shear.
max^m shear at a distance d from face of the column.

$$V_{max} = V_u = q_u * B * \left(\frac{L - C_1}{2} - d\right)$$



$\tau_v = k\tau_c$ $\quad \tau = 0.36\ N/mm^2$
$k = 1$ for $d > 300mm$.

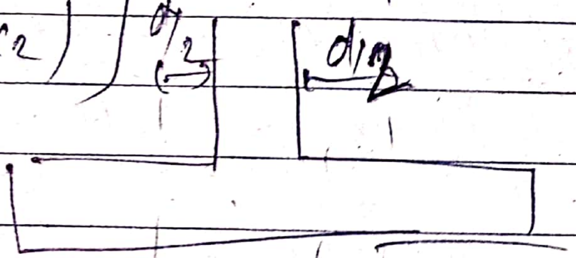
$$\frac{V_u}{Bd} = k\tau_c$$



$d = \ldots$

(III) Two-way shear.

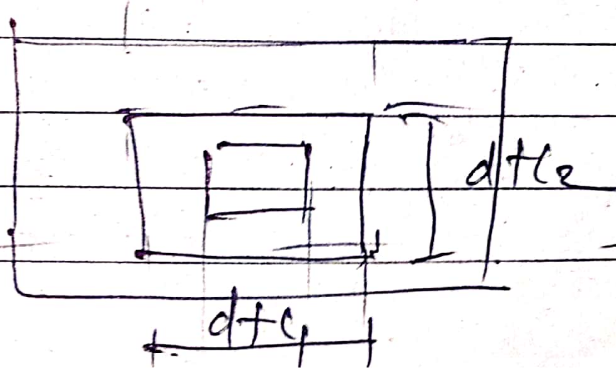
$$V_u = q_u * \left[BL - (d+c_1)(d+c_2)\right]$$



$b_o \Rightarrow$ punching area or perimeter

$= 2(d+c_1) + 2(d+c_2)$

$$\tau_v = \frac{V_u}{b_o d}$$



$M_n =$ M_y

$$\boxed{\tau_c = 0.25\sqrt{f_{ck}}}$$ $K = 1$ $d > 300\,m$

$$\tau_v = K\tau_c$$

or, $$\frac{V_u}{b_o d} = 0.25\sqrt{f_{ck}}$$

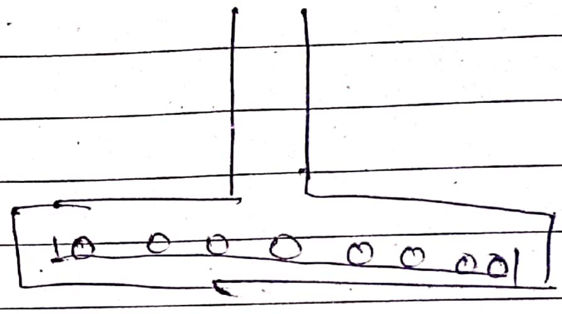
$$d = \_\_\_\_$$

(A) Adopt maximum from the three criteria
i.e. d_{max}

STEP 4: Design of reinforcement

Along x-direction

~~$M_{ux} = 0.87$~~



$$M_{ux} = 0.87 f_y (A_{st})_x d \left[1 - \frac{f_y (A_{st})_x}{f_{ck} B d}\right]$$

Assume ϕ and check.

$A_{st\,min} = 0.15\%$ of BD

similar for slab design

[illegible] check

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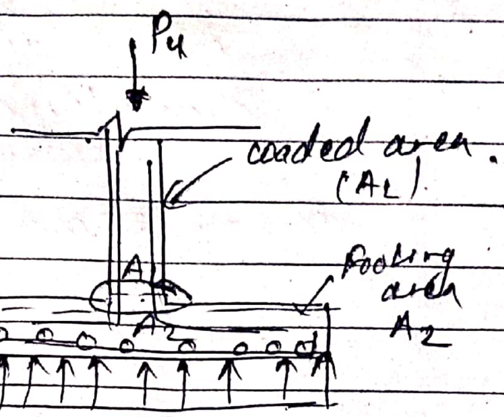
along y - direction

$$M_{uy} = 0.87 f_y (A_{st})_y * d \left[1 - \frac{f_y (A_{st})_y}{f_{ck}\, b * d} \right]$$

$(A_{st})_y = \ldots$

Assume $\phi_y = \ldots$

STEP 5 : Check for Bearing



Allowable bearing strength of concrete $(\sigma_{ba}) = 0.45 f_{ck} \sqrt{\frac{A_2}{A_1}}$

$$A_2 / A_1 \leq 2$$

$f_{ck} \Rightarrow$ take of column

$\sigma_{\text{this}} = \frac{P_u}{A_1}$

If $\sigma < \sigma_b$ no need of dowel bars

or column bars are curtailed at junction and column load safely transmitted to the footing.

If $\sigma > \sigma_b$ column load not safely

transfer ~~...~~ two option
a). ~~dowel~~ extra dowel bar or
b) column bar are ~~embedded~~ extended into the footing.

a) Dowel bar.
→ min^m. 4 nos of bar
→ min^m. area of dowel bars = 0.5% of A_g
→ diameter of dowel bars ≯ (ϕ_{column} + 3mm)

Eg: ϕ_{column} = 25 mm s.t. ϕ_{dowel} ≯ 28 mm max.

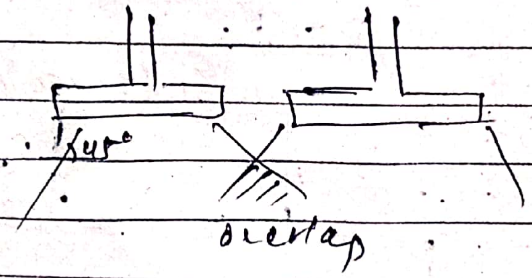
* Design of combined footing :

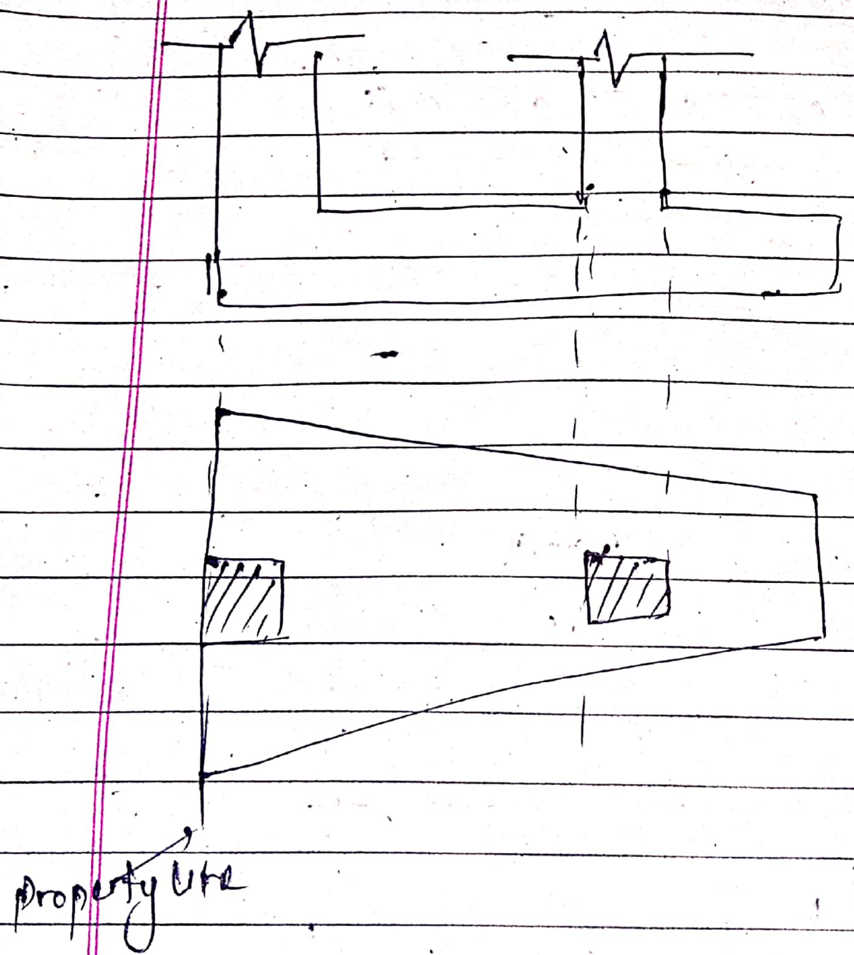
when to go for combined footing ?

a) Area occupied by isolated footing overlap.

b) Isolated footings close to each other such that the stress distribution below overlaps.

c). at property line





* Design of combined footing

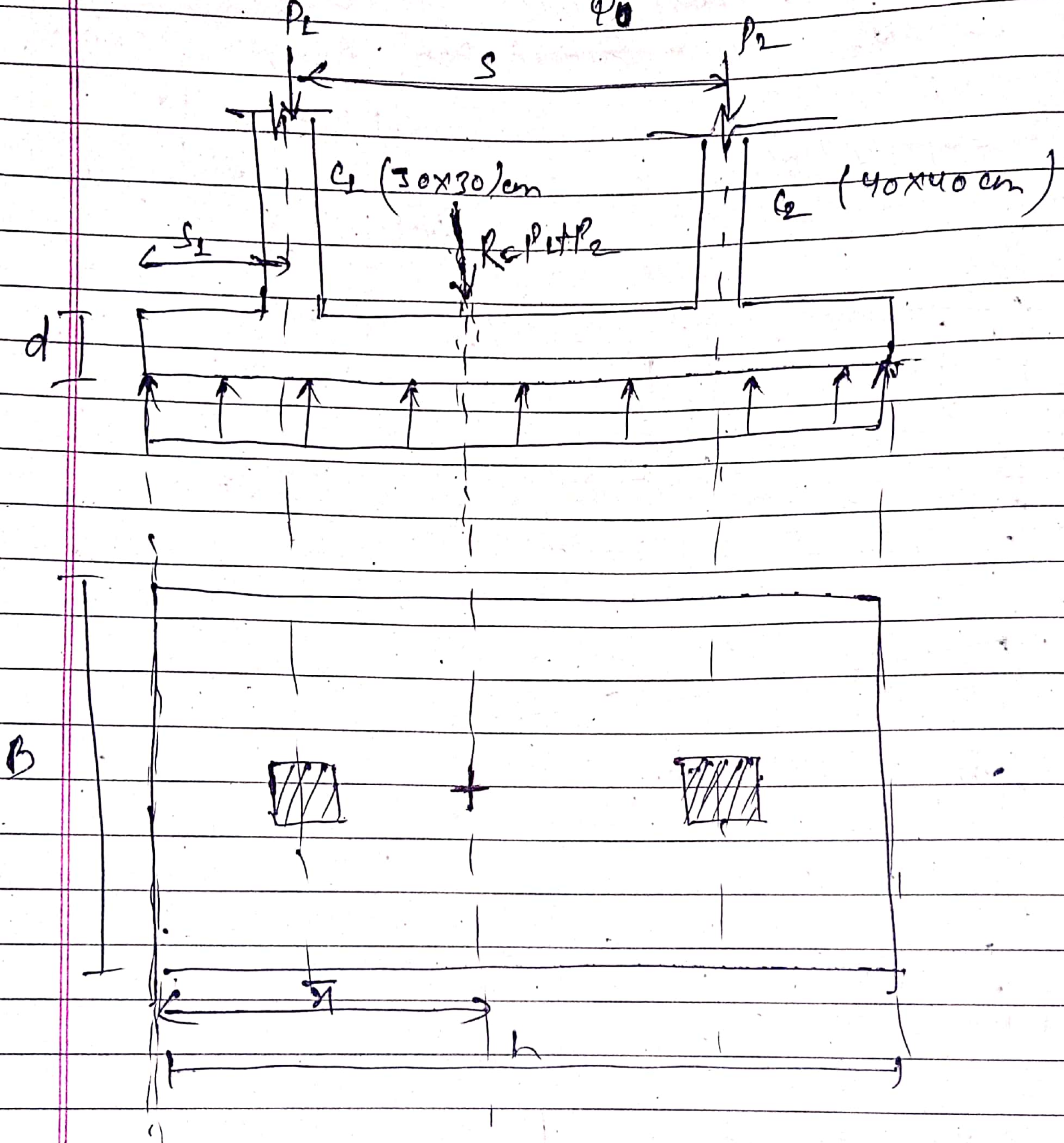
Procedure :

STEP 1 : Determine shape and size of combined footing

→ Shape : either rectangular or trapezoidal

Size :

$$A = \frac{1.1(P_1+P_2)}{q_0}$$



~~calculate upward soil pressure~~ (q_u) :

uniform soil pressure distribution পাওতে resultant load at CG should coincide with footing centroid.

$$D_p = \frac{q_0}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

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position of resultant load

$$(P_1+P_2)\bar{x} = P_1 * s_1 + P_2(s_1+s)$$

$$\bar{x} = \ldots$$

$\bar{x} = h/2$ for ... position ... .

$L = 2\bar{x}$ $\quad$ $B = A''/L$

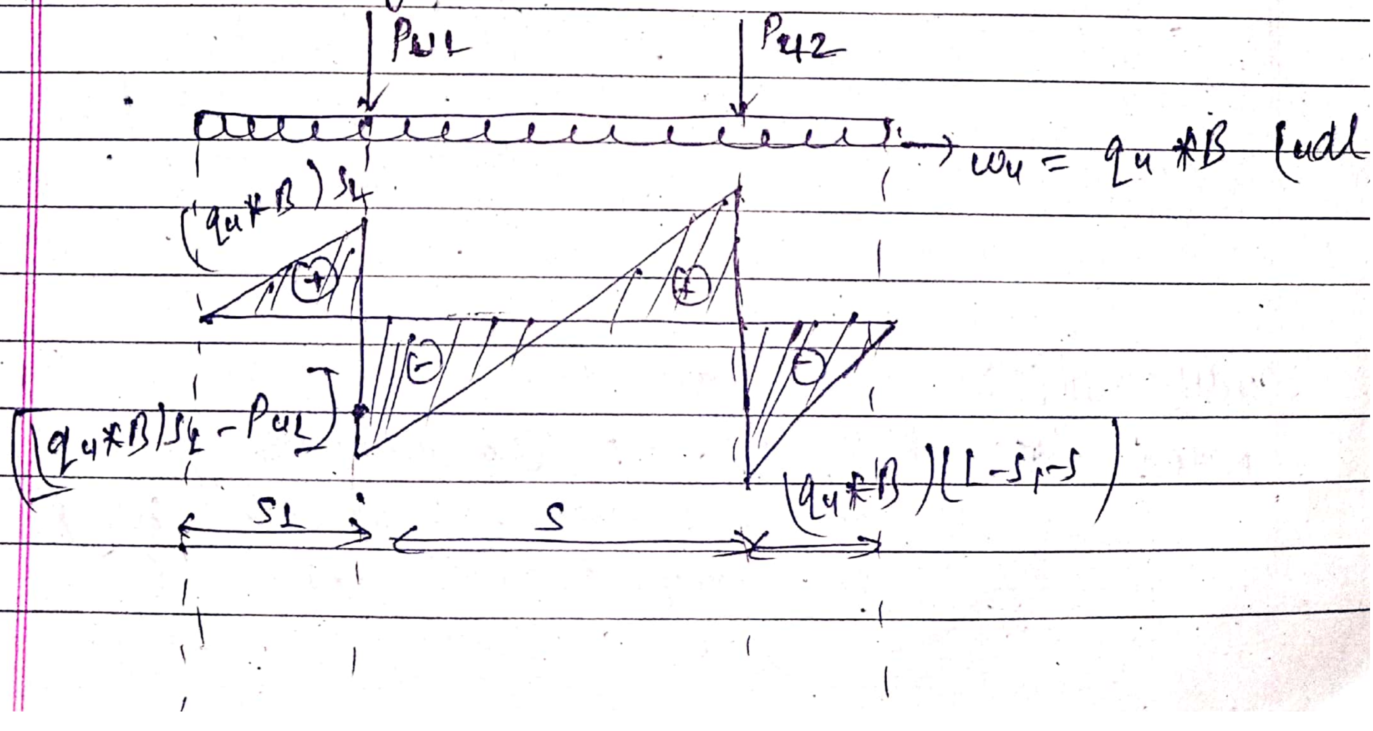
Area provided $(A') = L \times B$

STEP 2: calculation of upward soil pressure (q_u)

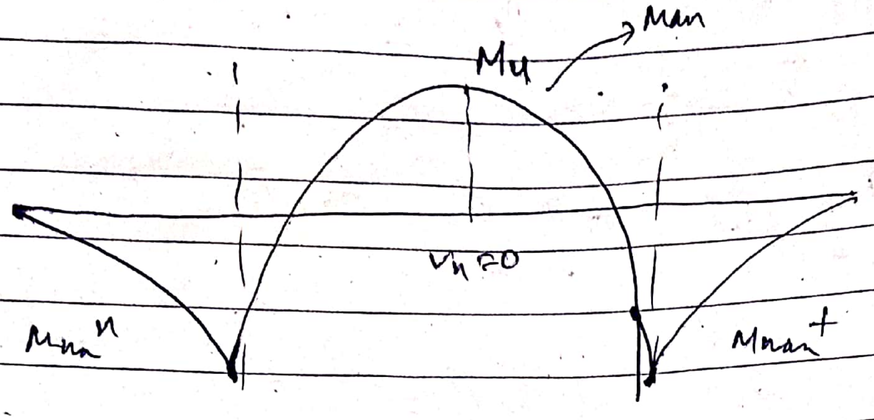
$$q_u = \frac{1.5(P_1+P_2)}{A'}$$

STEP 3: calculation of footing thickness (d)

structural longitudinal beam



max Shear force (V_u)



BMD

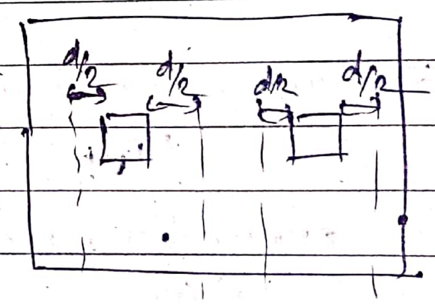
यहाँ one way shear governs so only calc. from this.

Condition (i) : Moment criteria

$$M_{max} = 0.138 f_{ck} B d^2$$

Condition (ii) : Two way shear

calculate separately for both column C_1 and C_2



Condition (iii) : One way shear

Note: ~~dep~~ thickness of ~~ro~~ combined footing is most always governed by one-way shear criteria.

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C_1 $\qquad$ C_2

d $\qquad$ d

take maxm d.

Take maxm from (I), (II), (III).

STEP 4: Calculation of steel reinforcement.

a) Bottom Reinforcement (positive moment.)..

under column C_1

$$\left(M_{max}^{+}\right)_{C_1} = 0.87 f_y (A_{st})^{+}_{C_1} d \left[1 - \frac{f_y (A_{st})_{C_1}}{f_{ck} B d}\right]$$

$$(A_{st})_{C_1} =$$

C_2 column

$$\left(M_{max}^{+}\right)_{C_2} = 0.87 f_y (A_{st})^{+}_{C_2} d \left[1 - \frac{f_y (A_{st})_{C_2}}{f_{ck} B d}\right]$$

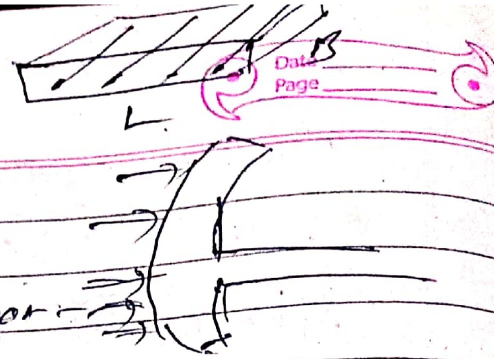
$$(A_{st})_{C_2} = \ldots$$

b) Top steel reinforcement

$$\left(M_{max}^{-}\right) = 0.87 f_y A_{st}^{-} d \left[1 - \frac{f_y A_{st}}{f_{ck} B d}\right]$$

$$(A_{st})_{C_1} = \ldots$$

CamScanner

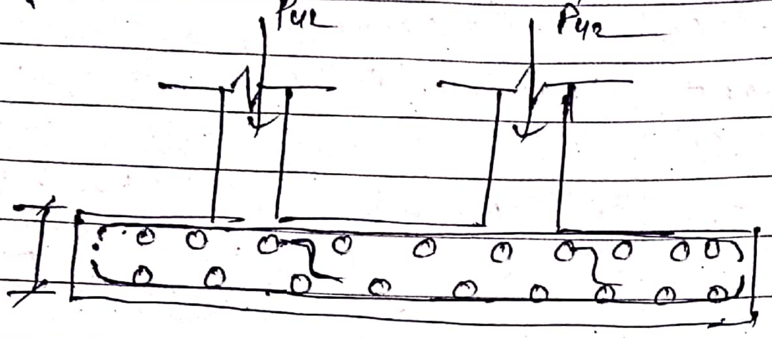


STEP 5 : Transverse Reinforcement

क्योंकि isolated मानते है

तो provide min^m % reinfor-
cement as transverse steel
Bars at top and Bottom.

a). Bottom & top trans. reinforcement = 0.12% of L×d



Note: stirrups provide करना
increase d by 50%