Foundations

2

Strip

+

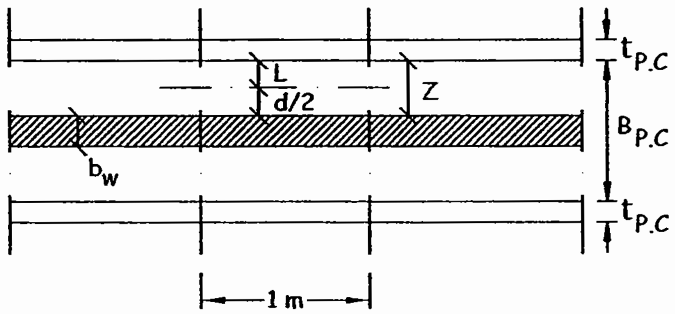
Square

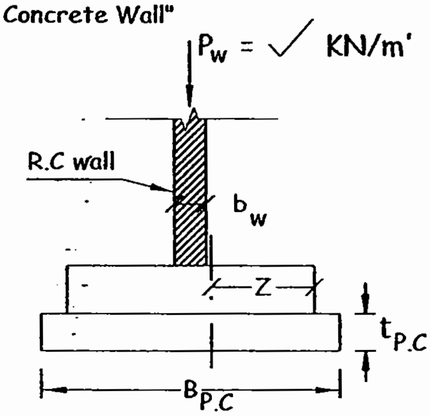
+

Rectangular Footings

Under Normal Loads Only

1 Design of Strip Footings: "Reinforced Concrete Wall"





- فى هذه النوعية من القواعد يكون الطول (L) كبير جدا بالنسبة للعرض (B) لذلك نأخذ من الطول شريحة ١ م للدراسة وبقية الطول يكون بالمثل .

> يعنى هنتعامل مع قاعدة أبعادها B * 1m

- Given :-
  - Load of wall = P_w = ✓ KN/m'
  - $q_{all.}$ = ✓ KN/m^2
  - b_w = ✓✓ (Wall width)
  - $t_{P.C}$ = ✓✓

❋ Steps of Design :

① Calculate the footing area as follows : (1m X B)

$$A = \frac{P_w}{q_{all.}} = ✓\ m^2 = B * 1m \Rightarrow \boxed{\text{get } B}$$

= $B_{P.C}$ * 1m

in case of

if $t_{P.C} \geqslant 20$ cm

Note That :

$B_{P.C} = B_{R.C} + 2t_{P.C}$

or

$B_{R.C} = B_{P.C} - 2t_{P.C}$

= $B_{R.C}$ * 1m

in case of

if $t_{P.C} < 20$ cm

② **Design of Critical sections for moments : (to Calculate $t_{R.C}$)**

- القطاع الحرج للعزوم يكون عند وش الحائط من أى ناحية . (انظر الشكل الصفحة السابقة)

- Calculate $Z = \frac{1}{2}[B_{R.C} - b_w]$
- Calculate q_u = ultimate stress on R.C footing

$$= \frac{P_w * 1.5}{B_{R.C} * 1m} = ✓✓ \quad KN/m^2 \quad \text{"Reaction"}$$

($B_{R.C} * 1m$ ← $A_{R.C}$ دائما)

$$\therefore M_u = q_u * \frac{(Z)^2}{2} * 1m = ✓✓ \quad KN.m/m' \quad \text{"As a Cantilever"}$$

$$\therefore d_{(mm)} = C_1 \sqrt{\frac{M_{(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * 1000}} = ✓✓ \quad mm$$

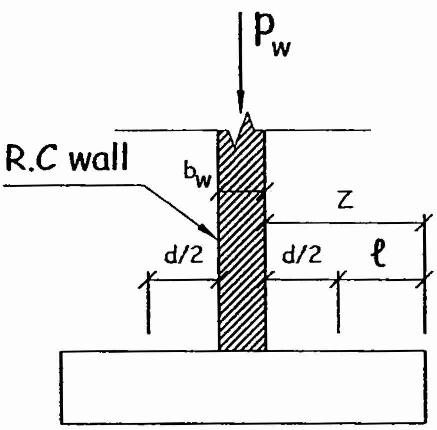
(1000 ← عرض الشريحة)

C_1 taken = 5 ⟶ 3.5 ✓✓

نأخذ C_1 كبيرة فى القواعد للحصول على سمك كبير يضمن ان تكون القاعدة rigid

- Check d ≮ 23cm

③ **Check Shear :**



- القطاع الحرج للقص يكون على بعد d/2 من وش الحائط من اى ناحية .

(طالما الحائط من الخرسانة المسلحة)

- Calculate $L = Z_{(m)} - d/2_{(m)}$
- Calculate Shear force $Q_S = q_u * \ell * 1m$

$= \checkmark\checkmark$ KN

- Calculate Shear stress $q_{su} = \frac{Q_s * 10^3}{d_{(mm)} * 1000} = \checkmark\checkmark$ N/mm^2

Check $q_{su} \ngtr q_{scu} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}}$ N/mm^2

- 0.16 وليس 0.24 كما فى الكمرات حيث ان فى القواعد لا يتم عمل كانات بسبب صعوبة تنفيذها.

If UNSAFE ($q_{su} > q_{scu}$)

⟹ Increase d & recheck ⟹ نعيد الحسابات من اول ال Check Shear

④ **Calculate :** $t_{safe} = d_{safe} + 7\ cm_{cover}$

⑤ **R.F.T :**

- Calculate $A_{s_{min.}}$ (mm/m') $= 1.5 * d_{mm}$ or $5\phi12/m'$ — ايهما اكبر

- Calculate $A_{s_{req.}} = \frac{M_u * 10^6}{F_y * 0.826 * d_{(mm)}} = \checkmark\checkmark$ mm^2/m' (0.826 as $C_1 = 5$)

choose ??ϕ??/m'

⟹ Check $A_{s_{req.}} > A_{s_{min.}}$

if not ⟶ use $A_{s_{min.}}$

-لاحظ ان التسليح الرئيسى المحسوب فى حالة القواعد الشريطية يكون تسليح عرضى بينما التسليح الطولى يكون ثانوى.

$A_{s_{long}} = A_{s_{min.}}$

⑥ **Details :**

As in the Examples

Example:-

It is required to design a strip footing to support a reinforced concrete (R.C) retaining wall of thickness 30cm. The wall load is 450 KN/m', and the allowable net bearing capacity in the footing site is 100 KN/m². (F_{cu} = 25 N/mm², F_y = 360 N/mm²). Details are required to scale 1:50.

Solution:-

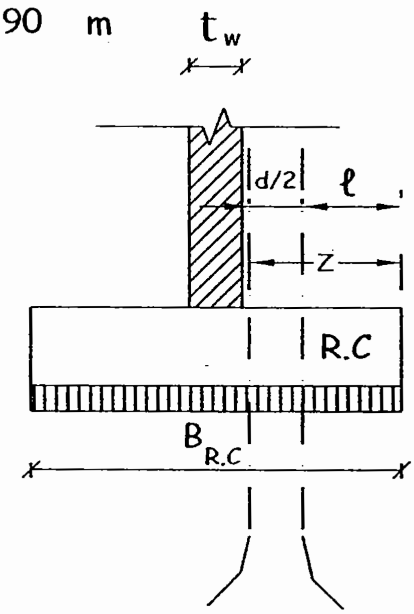
① Calculate the footing area :-

assume $t_{P.C} = 30 \text{ cm} > 20 \text{ cm}$

$$\therefore A_{P.C} = \frac{450}{100} = 4.50 \text{ m}^2 = B_{P.C} * 1\text{m}$$

$$\therefore B_{P.C} = 4.50 \text{ m}$$

$$B_{R.C} = 4.50 - 2 * 0.3 = 3.90 \text{ m}$$



② Ultimate loads :-

$$q_u = \frac{1.5 * 450}{(3.90 * 1)} = 173 \text{ KN/m}^2$$

$A_{R.C}$ not $A_{P.C}$ (Always)

③ Critical section for moment (M) :-

$$Z = \frac{1}{2}[B_{R.C} - t_w]$$

$$= \frac{1}{2}[3.9 - 0.3] = 1.8 \text{ m}$$

$$M_u = q_u * \frac{(Z)^2}{2} * 1\text{m}$$

$$= 173 * \frac{1.8^2}{2} * 1\text{m} = 280.26 \text{ KN.m/m'}$$

$$d_{(mm)} = C_1\sqrt{\frac{M_{(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * 1000}} = 5\sqrt{\frac{280.26 * 10^6}{25 * 1000}} = 529.4 \text{ mm} \simeq 530 \text{ mm}$$

④ **Check Shear :-**

$$\ell = Z - \frac{d}{2} = 1.8 - \frac{0.53}{2} = 1.535 \text{ m}$$

$$Q_{su} = q_u * \ell * 1m = 173 * 1.535 * 1 = 265.56 \quad KN/m'$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * 1000} = \frac{265.56 * 10^3}{530 * 1000} = 0.50 \quad N/mm^2$$

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \quad N/mm^2$$

$$\because \; q_{su} < q_{scu} \Rightarrow \therefore \text{ SAFE}$$

⑤ R.F.T :-

$$A_s = \frac{M_u * 10^6}{F_y * 0.826 * d} = \frac{280.26 * 10^6}{360 * 0.826 * 530} = 1778.3 \quad mm^2/m'$$

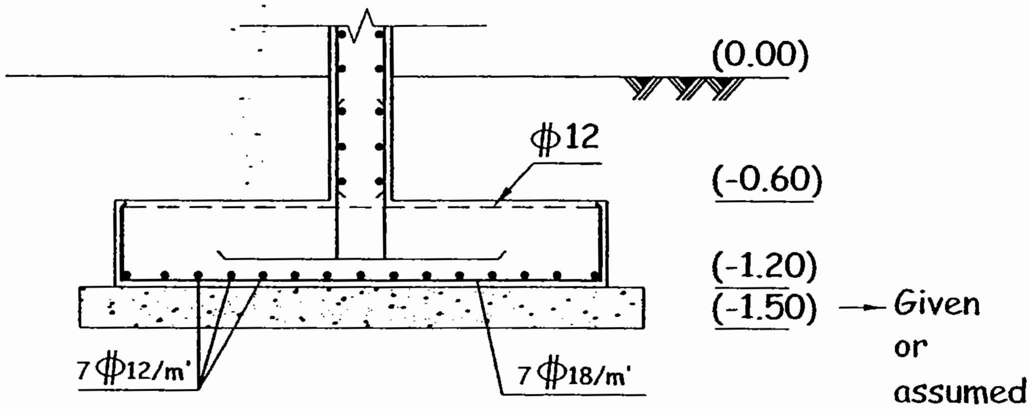
7 ϕ 18/m'

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 530 = 795 \quad mm^2/m' \\ 5 \phi 12/m' = 565 \quad mm^2/m' \end{cases}$$

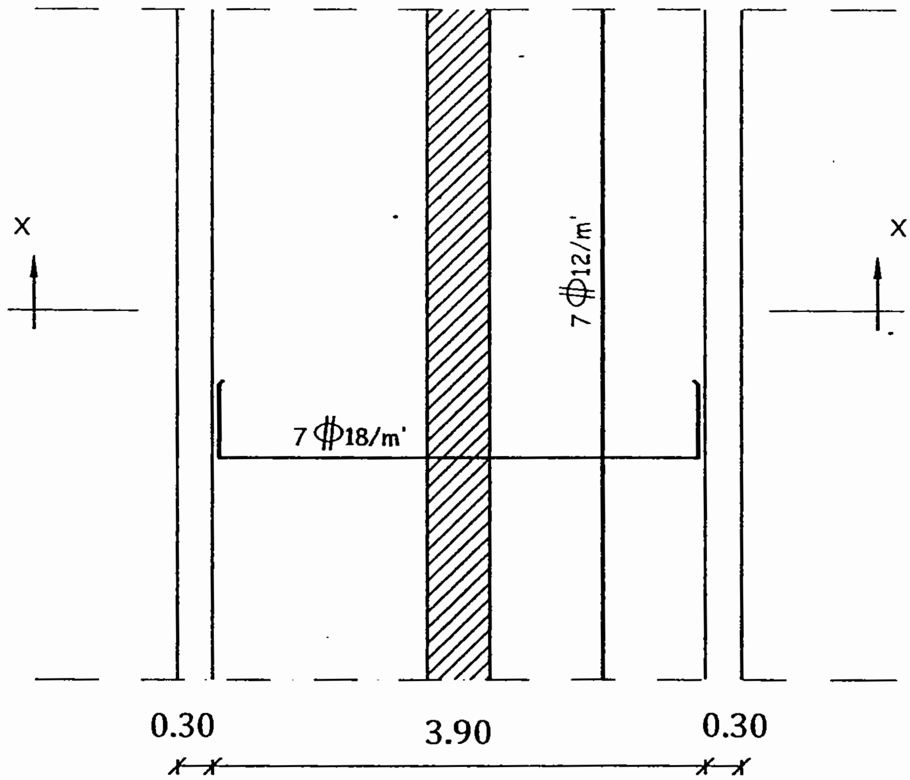
7 ϕ 12/m' (beside the first line)

$$\therefore t_{final} = d + 7\text{ cm}_{\text{cover}} = 53 + 7 = 60 \text{ cm}$$

⑥ Details : -



SEC. (X-X)

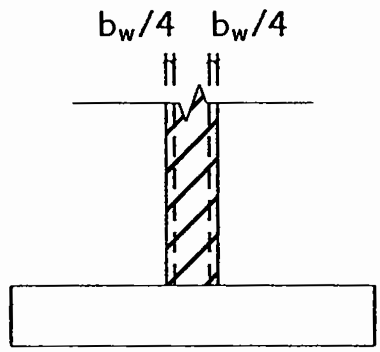


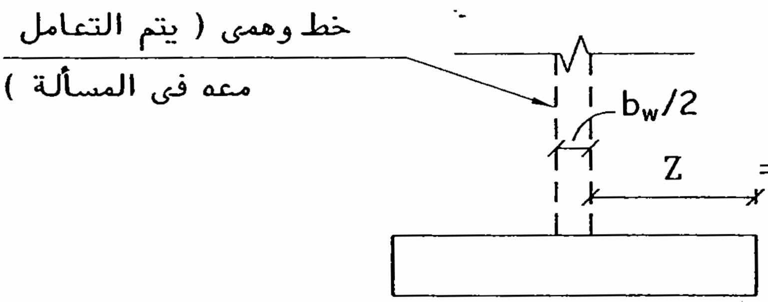
PLAN

✱ Notes :-

- In case of Masonry wall :- حائط طوب

Take the effective width of the wall as follows :





$$\Rightarrow Z = \frac{1}{2}\left[B_{R.C} - \frac{b_w}{2}\right]$$

$$b_{final} = b_w - \left[\frac{b_w}{4} + \frac{b_w}{4}\right] = \frac{b_w}{2}$$

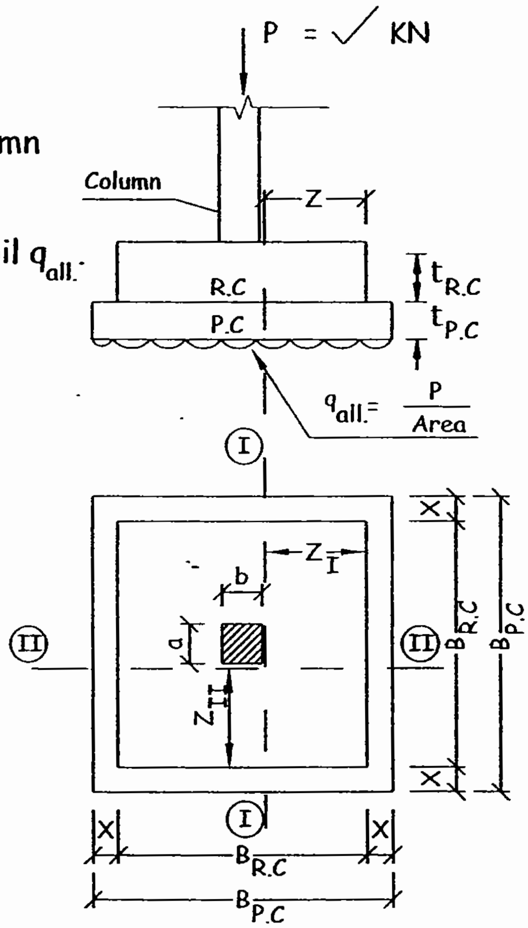
وهذا هو عرض الحائط b_{final} الذى سيتم التصميم عليه كما سبق فى حالة R.C wall .

2 Isolated Footings: القواعد المنفصلة

- هى القواعد التى يرتكز عليها عمود واحد فقط ويكون العمود اما مربع أو مستطيل او دائرى .
- يمكن للقاعدة المربعة ان تشيل عمود مستطيل او مربع وبالمثل القاعدة المستطيلة.

A Design of Isolated square footing :

- Steps of Design :-



* Given: - Working column load (P) and column dimensions (a * b) or (b * b)

- Allowable bearing capacity of soil $q_{all.}$

* Required:

- Full design of square footing to support this column and details.

* Solution "Design":

① Calculate the footing area: (B X B)

in case of $t_{P.C} \geqslant 20cm$

$$\therefore A_{P.C} = \frac{P}{q_{all.}} = B^2_{P.C}$$

get $B_{P.C}$ = ✓ m

وتقرب لأقرب 5cm بالزيادة

$$\therefore B_{R.C} = B_{P.C} - 2t_{P.C}$$

in case of $t_{P.C} < 20cm$

$$\therefore A_{R.C} = \frac{P}{q_{all.}} = B^2_{R.C}$$

get $B_{R.C}$ = ✓ m

وتقرب لأقرب 5cm بالزيادة

$$\therefore B_{P.C} = B_{R.C} + 2t_{P.C}$$

② **Calculate the ultimate stress acting under R.C :**

$$q_{ult.} = \frac{1.5 * P_w}{(B_{R.C})^2} = \checkmark \quad KN/m^2$$

$(B_{R.C})^2$ ← دائما $A_{R.C}$

③ **Design of critical sections for Moment:**

نأخذ القطاعات الحرجة للعزوم على وش العمود من الناحيتين اى ناحية .

($Z_I = Z_{II}$ حيث)

** For sec (I-I)

$$Z_I = \frac{1}{2}(B_{R.C} - b)$$

حيث b طول العمود

$$\therefore M_{u_I} = q_u * \frac{(Z_I)^2}{2} * (1\,m)$$

(1 m) ← عرض الشريحة

$$= \checkmark\checkmark \quad KN.m$$

ونصمم على العزم المحسوب .

$$\therefore d_{(mm)} = C_1 \sqrt{\frac{M_{u_{I\,(KN.m)}} * 10^6}{f_{cu\,(N/mm^2)} * 1000}} = \checkmark\checkmark \quad mm$$

C_1 taken $= 5 \longrightarrow 3.5$ ✓✓

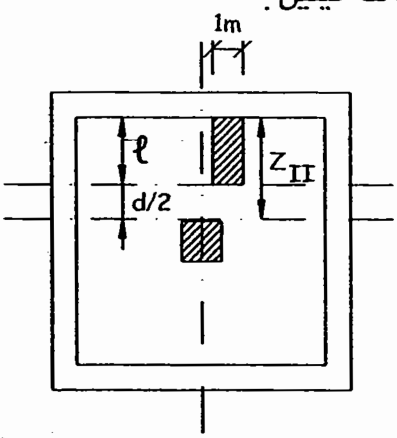
④ **Check Shear:**

القطاع الحرج فى القص على بعدd/2 من وش العمود من الناحيتين.

وحيث ان :-

$$Z_{II} = Z_I$$

∴ يتم عمل Check على اى Section



حيث $L = Z_{II}$ or $Z_I - d/2$

$\therefore Q_{su}$ = ultimate shear force on critical section

$= q_u * \ell * (1m)$ ← عرض الشريحة

$\therefore q_{su}$ = ultimate shear stress

$= \dfrac{Q_{su} * 10^3}{d_{(mm)} * (1000)} = ✓✓ \ N/mm^2$ ← (1000) عرض الشريحة

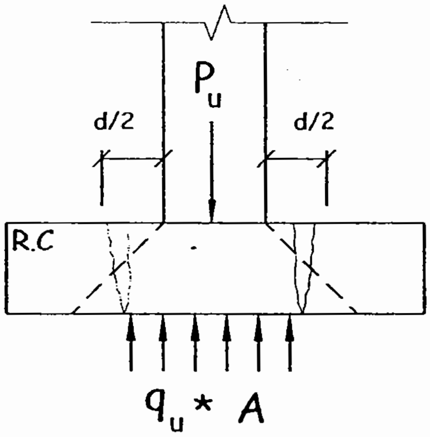
$$\text{Check } q_{su} \not> q_{scu} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \ N/mm^2$$

If UNSAFE $(q_{su} > q_{scu})$

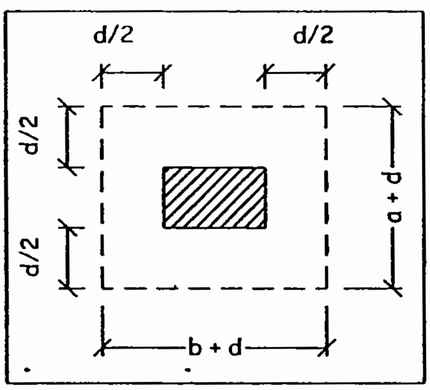
⟹ Increase d & recheck ⟹ نعيد الحسابات من اول ال Check Shear وليس من البداية

⑤ Check punching Shear:

الهدف هو التحقق من ان حمل العمود لن يأخذ جزء من القاعدة ويخترقها لأسفل.



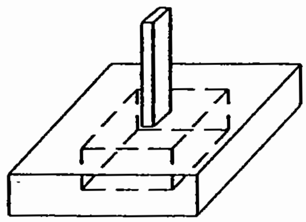
-القطاع الحرج فى القص الثاقب عبارة عن محيط يحيط بالعمود على مسافة d/2 من وش العمود من كل ناحية.



Where :- (d) is after being safe from shear.

$\therefore Q_p$ = Punching Force

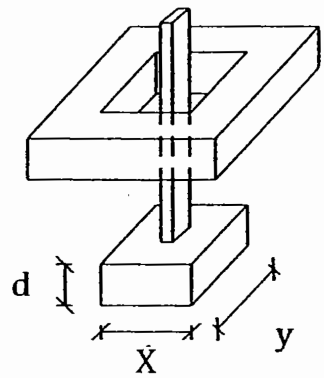
$= 1.5 * P_u - q_u * \underbrace{[(a+d)(b+d)]}_{\text{Punching Area}}$ (KN)



$\therefore q_p$ = Punching shear stress = $\dfrac{\text{punching force}}{\text{shearing area}}$
المساحة الجانبية

$= \dfrac{Q_p}{\text{depth} * \text{punching permeter}}$

$= \dfrac{Q_p * 10^3}{d_{(mm)} * [\underbrace{(a+d)}_{X\,(mm)} + \underbrace{(b+d)}_{Y\,(mm)}] * 2}$ (N/mm^2)



Check $q_p \ngtr q_{pcu}$ ← مقاومة الخرسانة فى القص الثاقب

where: $q_{pcu} = 0.316\left(0.5 + \dfrac{a}{b}\right)\sqrt{\dfrac{F_{cu}}{\gamma_c}}$ N/mm^2

a = width of column.

b = length of column.

and $\dfrac{a}{b} \ngtr 0.5$

if $\dfrac{a}{b} > 0.5 \Rightarrow$ taken = 0.5

If SAFE ⇒ d is safe in punching

If UNSAFE ⇒ Increase d & recheck ⇒ نعيد الحسابات من اول ال Check punching Shear وليس من البداية

⑥ <u>calculate final thickness of R.C:</u>

$t = d + 7$ cm

(d) safe for shear & punching

⑦ R.F.T:

- $$A_{s_I} = \frac{M_{u_I} * 10^6}{F_y * 0.826 * d_{(mm)}} = \checkmark\checkmark \quad mm^2/m'$$
  (0.826 as $C_1 = 5$)

- $$A_{s_{II}} = \frac{M_{u_{II}} * 10^6}{F_y * 0.826 * d_{(mm)}} = \checkmark\checkmark \quad mm^2/m'$$
  (0.826 as $C_1 = 5$)

and check A_{s_I} & $A_{s_{II}} \geqslant A_{s_{min.}}$

where: $A_{s_{min.}}$ (mm^2/m') $= 1.5 * d_{mm}$ or $5\phi 12/m'$ — ايهما اكبر

⑧ Details:

See the Example.

Example:-

It is required to design a square footing to support a square column with loads:
$P_D = 1250$ KN, $P_L = 450$ KN, $q_{all.} = 1.5$ Kg/cm^2, thickness of P.C = 40 cm,
St(36/52), $f_{cu} = 25$ N/mm^2.

Solution:-

$\because$ Column's dimensions are not given

$\therefore$ Design column using working method as follows
(Do NOT assume the dimensions)

$$\therefore \quad A_{col.} = \frac{P_{col.}}{f_{c_o}} = \frac{(1250 + 450) * 10^3}{7} = 242857 \ \text{mm}^2 = b * b$$

$$\therefore \quad b = 492 \approx 500 \ \text{mm}$$

① Calculate the footing area :-

$\because \quad t_{P.C} = 40 \text{ cm} > 20 \text{ cm} \quad , \quad q_{all.} = 1.5 \ \text{Kg/cm}^2$

$= 15 \ \text{t/m}^2$

$= 150 \ \text{KN/m}^2$

لاحظ الوحدات

$$\therefore \quad A_{P.C} = \frac{(1250 + 450)}{150} = 11.33 \ \text{m}^2 = B^2_{P.C}$$

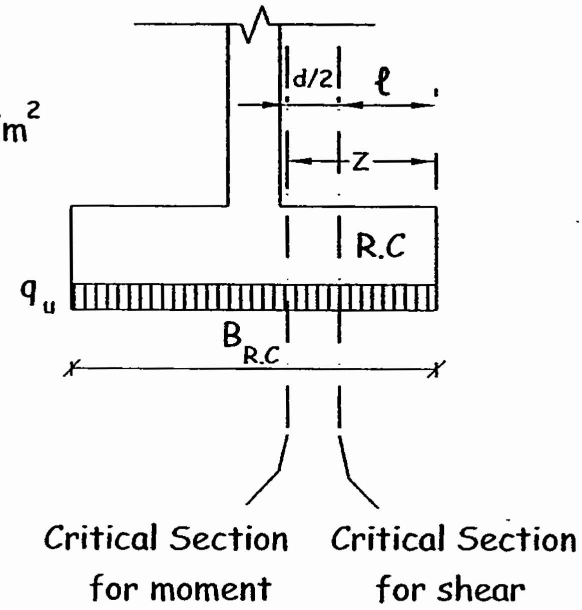
$$B_{P.C} = 3.36 \approx 3.40 \ \text{m}$$

$$B_{R.C} = 3.40 - 2 * 0.40 = 2.60 \ \text{m}$$

② **Ultimate loads :-**

$$q_u = \frac{1.5 * (1250 + 450)}{(2.6 * 2.6)} = 377 \ KN/m^2$$

$A_{R.C}$ not $A_{P.C}$ (Always)



③ **Critical section for moment (M) :-**

$$Z = \frac{1}{2}[2.6 - 0.5] = 1.05 \ m$$

$$M_u = q_u * \frac{(Z)^2}{2} * 1 \ m$$

$$= 377 * \frac{1.05^2}{2} * 1 \ m$$

$$= 207.8 \ KN.m$$

$$d_{(mm)} = C_1 \sqrt{\frac{M_{(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * B_{(mm)}}} = 5 \sqrt{\frac{207.8 * 10^6}{25 * 1000}} = 455.85 \ mm \simeq 480 \ mm$$

④ **Check Shear :-**

$$\ell = Z - \frac{d}{2} = 1.05 - \frac{0.48}{2} = 0.81 \ m$$

$$Q_{su} = q_u * \ell * 1m = 377 * 0.81 * 1m = 305.37 \ KN/m'$$

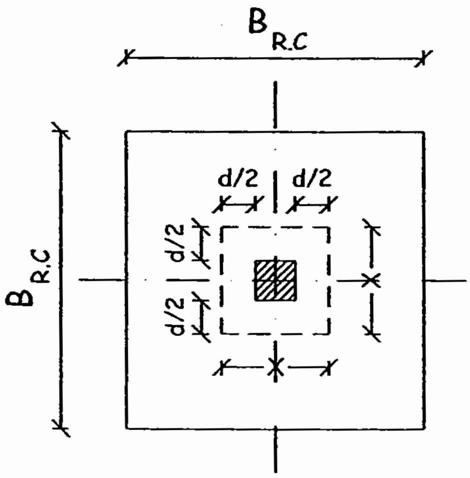
$$q_{su} = \frac{Q_{su} * 10^3}{d * 1000} = \frac{305.37 * 10^3}{480 * 1000} = 0.636 \ N/mm^2$$

$$q_{scu} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \ N/mm^2$$

$$\because q_{su} < q_{scu} \Rightarrow \therefore \text{SAFE}$$

⑤ Check Punching Shear :-

على بعد $\frac{d}{2}$ من وش العمود من كل ناحية



$X = 0.5 + 0.48 = 0.98 m$

$$Q_{p_u} = 1.5 * (1250 + 450) - q_u (X * X)$$

$$= 1.5 * (1250 + 450) - 377 * (0.98)^2$$

$$= 2137.9 \text{ KN}$$

$$q_{p_u} = \frac{2137.9 * 10^3}{480 * [980 + 980] * 2}$$

$$= 1.136 \text{ N/mm}^2$$

$$q_{p_{cu}} = 0.316 \left(0.5 + \frac{0.5}{0.5}\right) \sqrt{\frac{25}{1.5}}$$

$\frac{0.5}{0.5} = 1 \Longrightarrow$ take it $= 0.5$

$$= 1.29 \text{ N/mm}^2$$

$\because q_{p_u} < q_{p_{cu}} \Longrightarrow \therefore$ SAFE

⑥ Final Thickness :-

$$d_{final} = 480 \text{ mm}$$

$$t_{final} = 480 + 70 \text{ (cover)} = 550 \text{ mm}$$

⑦ R.F.T :-

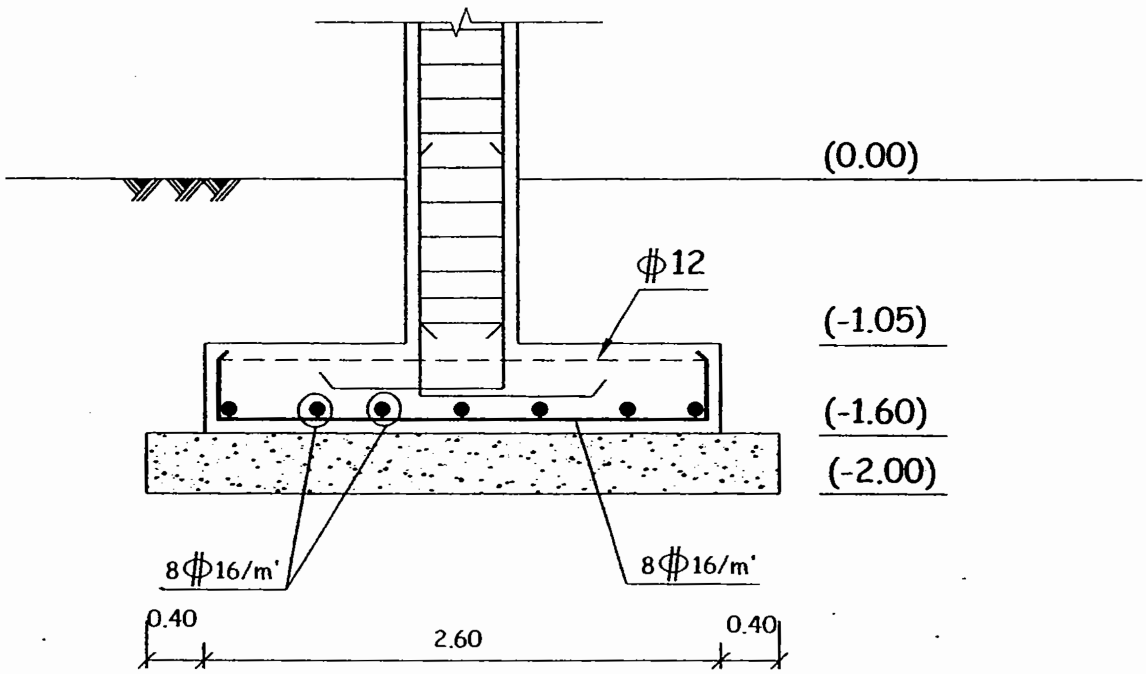
$$A_s = \frac{M_u * 10^6}{F_y * 0.826 * d} = \frac{207.8 * 10^6}{360 * 0.826 * 480} = 1455.86 \text{ mm}^2/\text{m}'$$

8 ɸ 16/m'

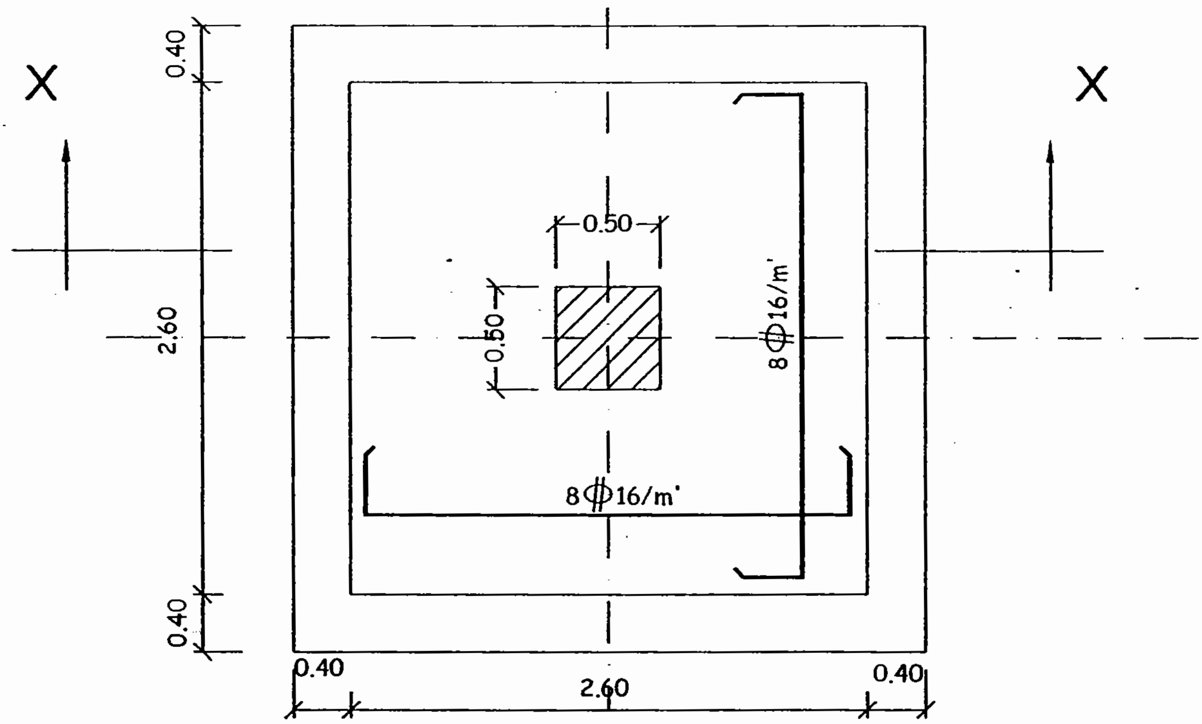
for both directions

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 480 = 720 \text{ mm}^2/\text{m}' \\ 5 ɸ 12/\text{m}' = 565 \text{ mm}^2/\text{m}' \end{cases} \therefore \text{O.K}$$

⑧ Details:



SEC. (X-X)



PLAN

Example:-

It is required to design an isolated footing to support a circular column carrying a vertical load of 1500 KN. Full details to scale 1:50 are required.

Given:-

- $t_{P.C} = 40$ cm
- $q_{all.} = 1.2$ kg/cm^2
- $f_{cu} = 30$ N/mm^2

Solution:-

∵ Column's dimensions are not given

∴ Design column using working method as follows
(Do NOT assume the dimensions)

$$\therefore A_{col.} = \frac{P_{col.}}{f_{c_o}} = \frac{1500 * 10^3}{6} = 25 * 10^4 \text{ mm}^2$$

$$A_{col.} = \frac{\pi * d^2}{4} = 25 * 10^4$$

$$\therefore d = 564 \approx 600 \text{ mm}$$

① Calculate the footing area :-

$$\because t_{P.C} = 40 \text{ cm} > 20 \text{ cm}$$

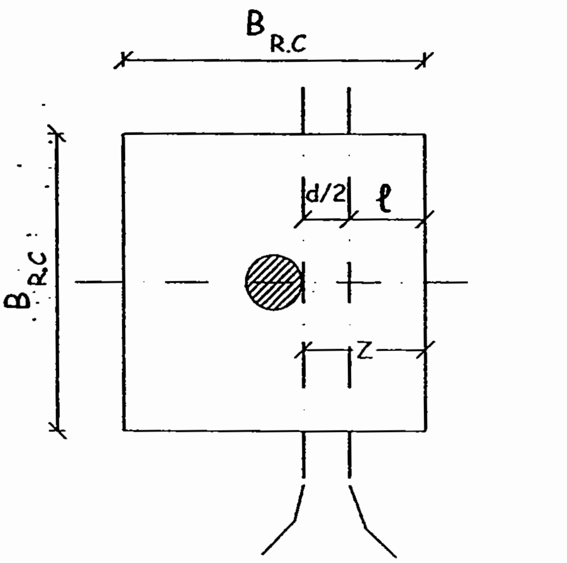
$$\therefore A_{P.C} = \frac{1500}{120} = 12.5 \text{ m}^2 = B^2_{P.C} \quad \text{(square footing)}$$

$$B_{P.C} = 3.53 \approx 3.55 \text{ m}$$

$$B_{R.C} = 3.55 - 2 * 0.40 = 2.75 \text{ m}$$

② Ultimate loads :-

$$q_u = \frac{1.5 * 1500}{2.75 * 2.75} = 297.5 \quad KN/m^2$$



③ Critical section for moment (M) :-

$$Z = \frac{1}{2}[\,2.75 - 0.6\,] = 1.075 \quad m$$

$$M_u = q_u * \frac{(Z)^2}{2} * 1\,m$$

$$= 297.5 * \frac{1.075^2}{2} * 1\,m$$

$$= 171.9 \quad KN.m$$

$$d_{(mm)} = C_1\sqrt{\frac{M_{(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * B_{(mm)}}} = 5\sqrt{\frac{171.9 * 10^6}{30 * 1000}} = 378.5 \quad mm$$

$$\simeq 380 \quad mm$$

④ Check Shear :-

$$\ell = Z - \frac{d}{2} = 1.075 - \frac{0.38}{2} = 0.885 \quad m$$

$$Q_{su} = q_u * \ell * 1m = 297.5 * 0.885 * 1m = 263.28 \quad KN/m'$$

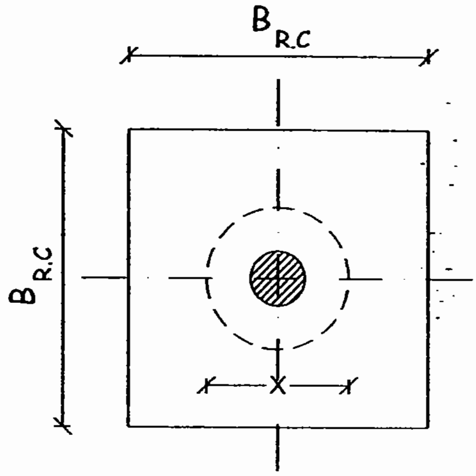
$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{263.28 * 10^3}{380 * 1000} = 0.69 \quad N/mm^2$$

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{30}{1.5}} = 0.715 \quad N/mm^2$$

$$\because\ q_{su} < q_{scu} \Rightarrow \therefore\ \text{SAFE}$$

⑤ Check Punching Shear :-

على بعد $\frac{d}{2}$ من وش العمود من كل ناحية



$X = 0.6 + 0.38 = 0.98$ m

$$Q_{p_u} = 1.5 * (1500) - q_u \left[\frac{\pi}{4} * X^2 \right]$$
$$= 1.5 * 1500 - 297.5 * \left[\frac{\pi}{4} * 0.98^2 \right]$$
$$= 2025.6 \text{ KN}$$
$$q_{p_u} = \frac{Q_{p_u} * 10^3}{(\pi X) * d}$$
$$q_{p_u} = \frac{2025.6 * 10^3}{(\pi * 980) * 380}$$
$$= 1.73 \text{ N/mm}^2$$
$$q_{p_{cu}} = 0.316 \left(0.5 + \frac{0.5}{0.5} \right) \sqrt{\frac{30}{1.5}} = 1.413 \text{ N/mm}^2$$

$\frac{0.5}{0.5} = 1 \Rightarrow$ take it $= 0.5$

$\because q_{p_u} > q_{p_{cu}} \Rightarrow \therefore$ UNSAFE

$\therefore$ Increase d

Take d = 430 mm

$$Q_{p_u} = 1.5 * (1500) - q_u \left[\frac{\pi}{4} * X^2 \right]$$
$$= 1.5 * 1500 - 297.5 * \left[\frac{\pi}{4} * 1.03^2 \right]$$
$$= 2002 \text{ KN}$$
$$q_{p_u} = \frac{Q_{p_u} * 10^3}{(\pi X) * d}$$
$$q_{p_u} = \frac{2002 * 10^3}{(\pi * 1030) * 430}$$
$$= 1.439 \text{ N/mm}^2$$

$\because \; q_{p_u} > q_{p_{cu}} \Rightarrow \therefore$ UNSAFE

$\therefore$ Increase d

Take d = 480 mm

$$Q_{p_u} = 1.5 * (1500) - q_u \left[\frac{\pi}{4} * X^2 \right]$$

$$= 1.5 * 1500 - 297.5 * \left[\frac{\pi}{4} * 1.18^2 \right]$$

$$= 1924.66 \text{ KN}$$

$$q_{p_u} = \frac{Q_{p_u} * 10^3}{(\pi X) * d}$$

$$q_{p_u} = \frac{1924.66 * 10^3}{(\pi * 1180) * 480}$$

$$= 1.08 \text{ N/mm}^2$$

$\because \; q_{p_u} < q_{p_{cu}} \Rightarrow \therefore$ SAFE

⑥ Final Thickness :-

$$d_{final} = 480 \text{ mm}$$

$$t_{final} = 480 + 70 \text{ (cover)} = 550 \text{ mm}$$

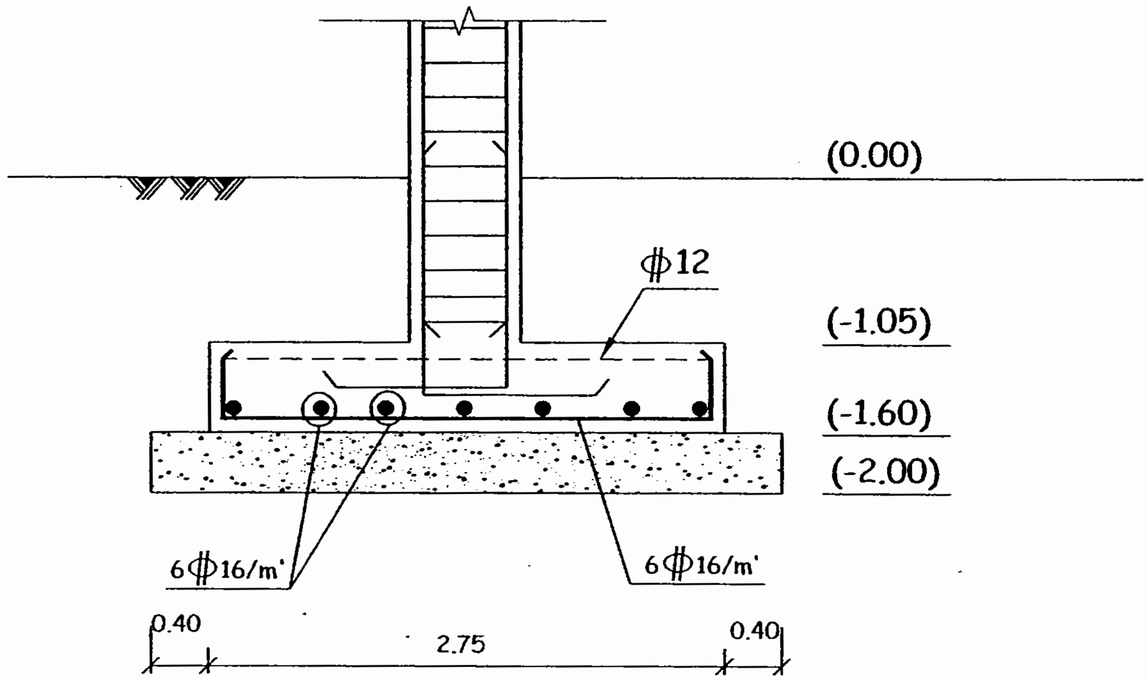
⑦ R.F.T :-

$$A_s = \frac{M_u * 10^6}{F_y * 0.826 * d} = \frac{171.9 * 10^6}{360 * 0.826 * 480} = 1204.34 \text{ mm}^2/\text{m}'$$

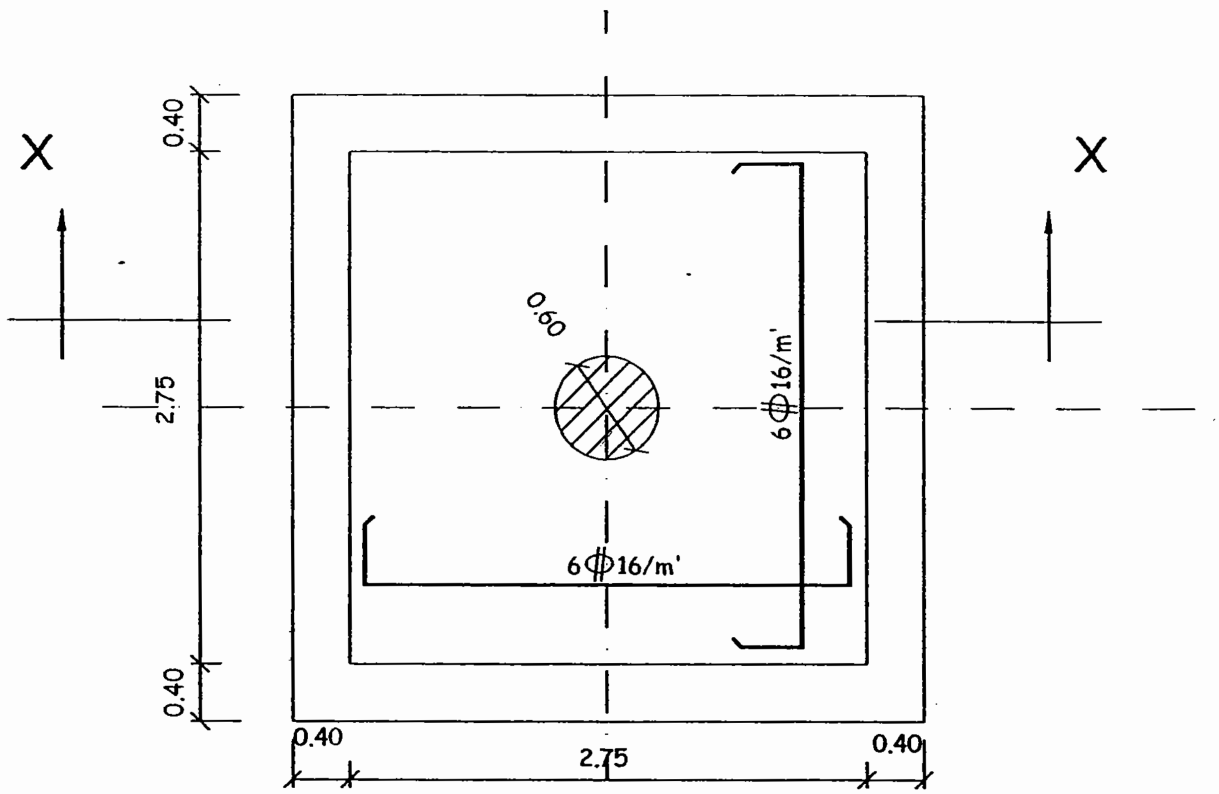
6 ϕ 16/m' for both directions

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 480 = 720 \text{ mm}^2/\text{m}' \\ 5 \phi 12/\text{m}' = 565 \text{ mm}^2/\text{m}' \end{cases} \therefore \text{O.K}$$

⑧ Details:



SEC. (X-X)

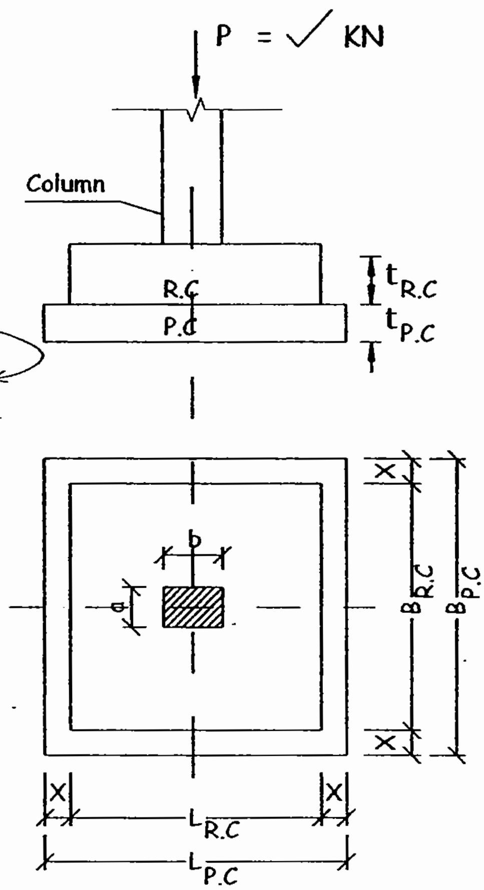


PLAN

B Design of Isolated rectangular footing :

- **Steps of Design :-**

① Calculate the footing area: (L X B)



* if $t_{P.C} \geqslant$ 20cm

$$A_{P.C} = \frac{P}{q_{all.}} = L_{P.C} * B_{P.C}$$

معادلة واحدة فى مجهولين

اذا نحتاج معادلة اخرى وهى :-

$$L_{P.C} - B_{P.C} = b - a$$

الفرق فى أبعاد القاعدة هو نفسه الفرق فى أبعاد العمود .

ومن خلال المعادلتين نستطيع حساب $L_{P.C}$ & $B_{P.C}$

ونقربهم الى اقرب 5cm بالزيادة ولكن مع المحافظة

على الشرط $L_{P.C} - B_{P.C} = b - a$

$$\therefore \; L_{R.C} = L_{P.C} - 2t_{P.C}$$

$$B_{R.C} = B_{P.C} - 2t_{P.C}$$

* if $t_{P.C} <$ 20cm

$$A_{R.C} = \frac{P}{q_{all.}} = L_{R.C} * B_{R.C}$$

$$L_{R.C} - B_{R.C} = b - a$$ and get $L_{R.C}$ & $B_{R.C}$

$$\therefore \; L_{P.C} = L_{R.C} + 2t_{P.C}$$

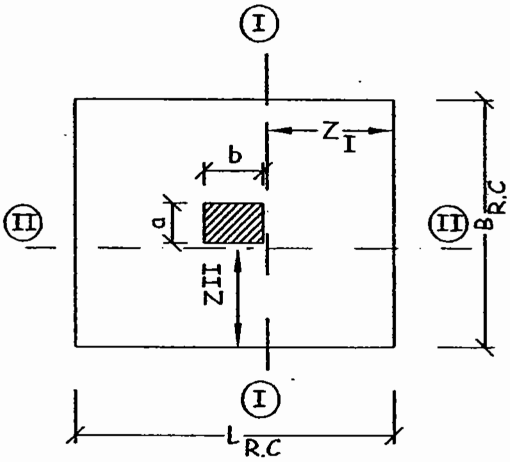
$$B_{P.C} = B_{R.C} + 2t_{P.C}$$

② Calculate ultimate stress acting on R.C:

$$q_u = \frac{1.5 * P_w}{L_{R.C} * B_{R.C}} \quad (KN/m^2)$$

③ Design of Critical sections for Moments:

نأخذ القطاعات الحرجة للعزوم على وش العمود من الناحيتين .



** For sec (I-I)

$$Z_I = \frac{1}{2}(L_{R.C} - b)$$

حيث b طول العمود

$$\therefore M_{u_I} = q_u * \frac{(Z_I)^2}{2} * 1\,m$$

= ✓✓ KN.m

$$\therefore d_I = C_1 \sqrt{\frac{M_{u_I\,(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * B}}$$

C_1 taken = 5 ⟶ 3.5

✓✓

** For sec (II-II)

$$Z_{II} = \frac{1}{2}(B_{R.C} - a)$$

حيث a عرض العمود

$$\therefore M_{u_{II}} = q_u * \frac{(Z_{II})^2}{2} * 1\,m$$

= ✓✓ KN.m

$$\therefore d_{II} = C_1 \sqrt{\frac{M_{u_{II}\,(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * B}}$$

C_1 taken = 5 ⟶ 3.5

✓✓

from d_I , d_{II} we should take the bigger

لاحظ الأتى :-

- اذا حافظنا على الشرط $L_{P.C} - B_{P.C} = b - a$ فانه سيكون $Z_I = Z_{II}$

ومن ثم سيكون $d_I = d_{II}$

اى انه يمكن ان ندرس اتجاه واحد فقط ويكون الاخر بالمثل .

④ Check Shear:

- على بعد d/2 من وش العمود من ناحية Z الأكبر.

(أو من اى ناحية فى حالة تحقق الشرط $L_{P.C} - B_{P.C} = b - a$)

$$\therefore Q_{su} = q_u * \ell * 1m$$

(1m : عرض الشريحة)

where: $\ell = Z - d/2$

(Z : الأكبر من Z_I او Z_{II})

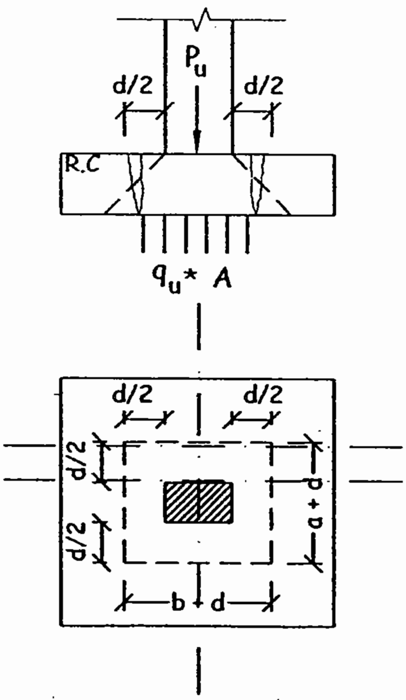
$$\therefore q_{su} = \frac{Q_{su} * 10^3}{d_{(mm)} * 1000} = \checkmark\checkmark \ N/mm^2$$

$$\text{Check } q_{su} \ngtr 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \ N/mm^2$$

If UNSAFE ($q_{su} > q_{scu}$)

$\Rightarrow$ Increase d & recheck $\Rightarrow$ نعيد الحسابات من اول ال Check Shear وليس من البداية

⑤ Check punching Shear:



-القطاع الحرج فى القص الثاقب عبارة عن محيط يحيط بالعمود على مسافة d/2 من وش العمود من كل ناحية.

Where :- (d) is after being safe from shear.

$\therefore Q_p$ = Punching Force

$= 1.5 * P_u - q_u * \underbrace{[(a+d)(b+d)]}_{\text{Punching Area}}$ (KN)

$$q_p = \frac{Q_p * 10^3}{d_{(mm)} * [(a+d)_{(mm)} + (b+d)_{(mm)}] * 2} \quad (N/mm^2)$$

Check $q_p \ngtr q_{pcu}$

where: $q_{pcu} = 0.316\ (0.5 + \frac{a}{b})\sqrt{\frac{F_{cu}}{\gamma_c}}$ N/mm^2

and $\frac{a}{b} \ngtr 0.5$

If UNSAFE $\Longrightarrow$ Increase d & recheck $\Longrightarrow$ نعيد الحسابات من اول ال Check punching Shear وليس من البداية

Calculate final thickness of R.C:

$t = d + 7$ cm

(d: safe for shear & punching)

⑦ R.F.T:

- $A_{s_I} = \frac{M_{u_I} * 10^6}{F_y * 0.826 * d_{(mm)}} = \checkmark\checkmark$ mm^2/m' (0.826 as $C_1 = 5$)
- $A_{s_{II}} = \frac{M_{u_{II}} * 10^6}{F_y * 0.826 * d_{(mm)}} = \checkmark\checkmark$ mm^2/m' (0.826 as $C_1 = 5$)

and check A_{s_I} & $A_{s_{II}} \geqslant A_{s_{min.}}$

where: $A_{s_{min.}}$ (mm/m') $= 1.5 * d_{mm}$ or $5\phi12$/m' — ايهما اكبر

⑧ Details:

See the Example.

Example:-

Design a rectangular R.C footing to support a column $[30 * 80]_{cm}$ carrying a load of 2000 KN. Allowable bearing capacity of soil is 1.30 kg/cm^2, thickness of P.C footing can be assumed 15 cm. [$F_{cu} = 25\ N/mm^2$, St[36/52]].

Solution:-

① Calculate the footing area :-

$\because\ t_{P.C} = 15\ cm < 20\ cm$

$$\therefore\ A_{R.C} = \frac{2000}{130} = 15.38\ m^2 = B_{R.C} * L_{R.C} \text{ ------→ ①}$$

$$L_{R.C} - B_{R.C} = b - a$$

$$L_{R.C} - B_{R.C} = 0.8 - 0.3 = 0.5\ m \text{ ------------→ ②}$$

Solving ① & ② :-

$$15.38 = B_{R.C} * (0.5 + B_{R.C}) \Longrightarrow B_{R.C} = 3.68 \approx 3.70\ m$$

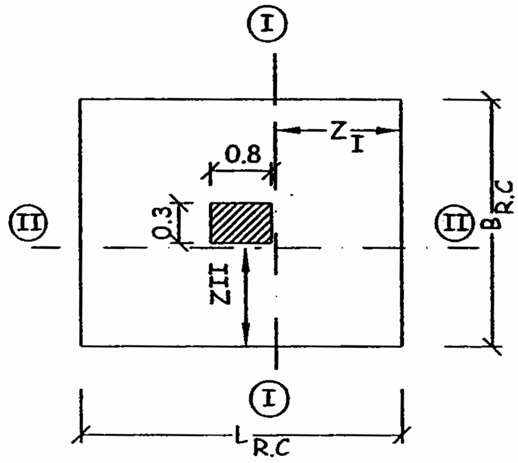
$$L_{R.C} = 0.5 + B_{R.C} = 0.5 + 3.70 = 4.20\ m$$

$$L_{P.C} = 4.20 + 2 * 0.15 = 4.50\ m$$

$$B_{P.C} = 3.70 + 2 * 0.15 = 4.00\ m$$

② Ultimate loads :-

$$q_u = \frac{1.5 * 2000}{4.20 * 3.70} = 193 \quad KN/m^2$$



③ Critical section for moment (M) :-

** For sec (I-I)

$$Z_I = \frac{1}{2}(4.20 - 0.8) = 1.70 \text{ m}$$

$$\therefore M_{u_I} = 193 * \frac{1.70^2}{2} * 1 \text{ m}$$

$$= 278.9 \quad KN.m$$

$$d_I = 5\sqrt{\frac{278.9 * 10^6}{25 * 1000}}$$

$$= 528.1 \text{ mm} \simeq 530 \text{ mm}$$

** For sec (II-II)

$$Z_{II} = \frac{1}{2}(3.70 - 0.3) = 1.70 \text{ m}$$

$$\therefore M_{u_{II}} = 193 * \frac{1.70^2}{2} * 1 \text{ m}$$

$$= 278.9 \quad KN.m$$

$$d_{II} = 5\sqrt{\frac{278.9 * 10^6}{25 * 1000}}$$

$$= 528.1 \text{ mm} \simeq 530 \text{ mm}$$

$$\therefore \boxed{d_I = d_{II} = 530 \text{ mm}}$$

④ Check Shear :-

$$\ell = (Z_I \text{ or } Z_{II}) - \frac{d}{2} = 1.70 - \frac{0.53}{2} = 1.435 \text{ m}$$

$$Q_{su} = q_u * \ell * 1m = 193 * 1.435 * 1m = 277 \quad KN/m'$$

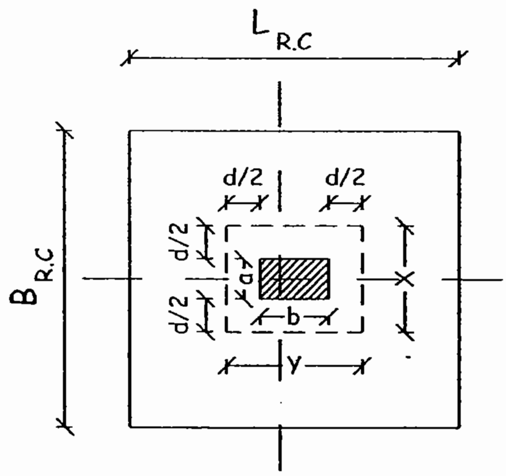
$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{277 * 10^3}{530 * 1000} = 0.522 \quad N/mm^2$$

$$q_{scu} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \quad N/mm^2$$

$$\because q_{su} < q_{scu} \Rightarrow \therefore \text{SAFE}$$

⑤ Check Punching Shear :-

على بعد $\frac{d}{2}$ من وش العمود من كل ناحية



$$Q_{p_u} = 1.5 * 2000 - q_u (X * Y)$$

$$= 1.5 * 2000 - 193 (0.83 * 1.33)$$

$$= 2786.9 \quad KN$$

$$q_{p_u} = \frac{2786.9 * 10^3}{530 * [1330 + 830] * 2}$$

$$= 1.217 \quad N/mm^2$$

$$q_{p_{cu}} = 0.316 \left(0.5 + \frac{0.3}{0.8}\right) \sqrt{\frac{25}{1.5}}$$

$$= 1.13 \quad N/mm^2$$

$$X = 0.3 + 0.53 = 0.83 \text{ m}$$

$$Y = 0.8 + 0.53 = 1.33 \text{ m}$$

$$\because q_{p_u} > q_{p_{cu}} \Rightarrow \therefore \text{UNSAFE}$$

$\therefore$ Increase d

Take d = 580 mm

$$Q_{p_u} = 1.5 * 2000 - q_u (X * Y)$$

$$= 1.5 * 2000 - 193 (0.88 * 1.38)$$

$$= 2765.6 \text{ KN}$$

$$q_{p_u} = \frac{2765.6 * 10^3}{580 * [1380 + 880] * 2}$$

$$= 1.055 \text{ N/mm}^2$$

$$\because q_{p_u} < q_{p_{cu}} \Rightarrow \therefore \text{SAFE}$$

⑥ Final Thickness :-

$$d_{final} = 580 \text{ mm}$$

$$t_{final} = 580 + 70 \text{ (cover)} = 650 \text{ mm}$$

⑦ R.F.T :-

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 580 = 870 \text{ mm}^2/\text{m}' \\ 5 \phi 12/\text{m}' = 565 \text{ mm}^2/\text{m}' \end{cases}$$

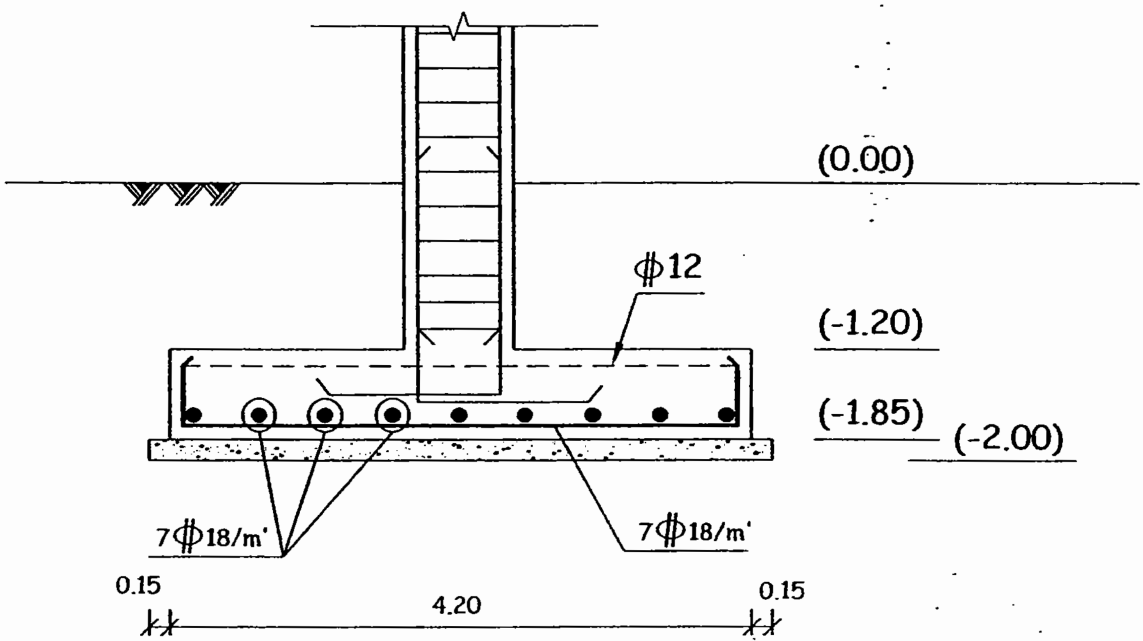
$$A_{s_I} = \frac{M_{u_I} * 10^6}{F_y * 0.826 * d} = \frac{278.9 * 10^6}{360 * 0.826 * 580} = 1617.1 \text{ mm}^2/\text{m}'$$

7 ϕ 18/m'

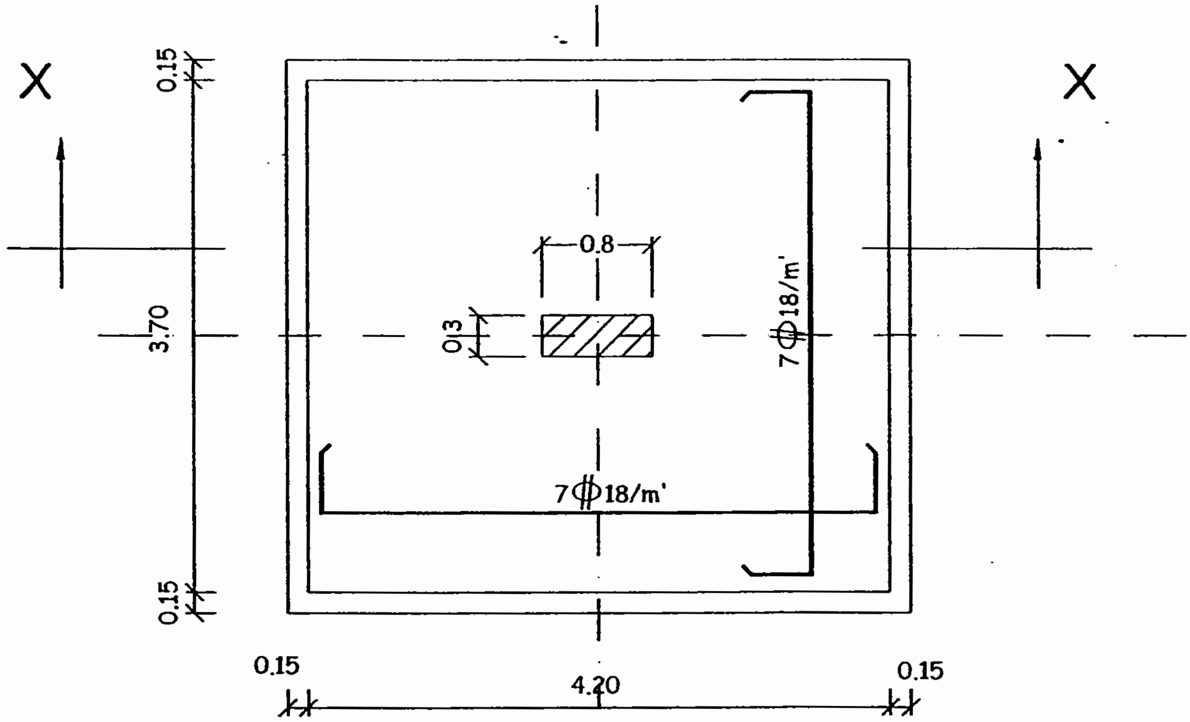
$$A_{s_{II}} = \frac{M_{u_{II}} * 10^6}{F_y * 0.826 * d} = \frac{278.9 * 10^6}{360 * 0.826 * 580} = 1617.1 \text{ mm}^2/\text{m}'$$

7 ϕ 18/m'

⑧ Details:



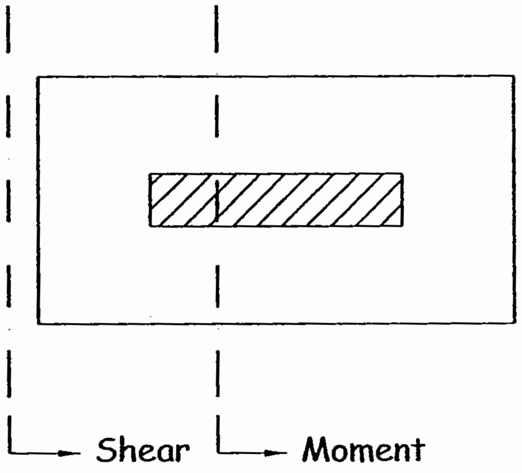
SEC. (X-X)



PLAN

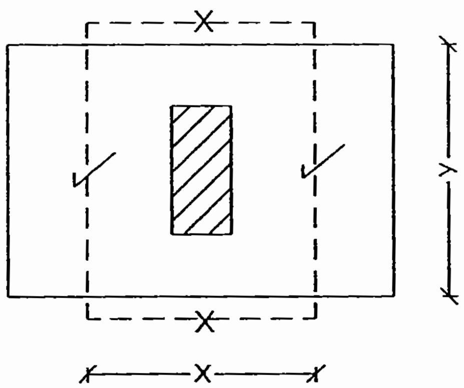
ملاحظات هامة :-

- في حالة خروج مستوى القص عن القاعدة فانه لا يكون عليه اجهاد قص



$$Q_{su} = Zero$$

- في حالة عمل Check Punching وكانت جوانب محيط الاختراق كالاتى :-



$$Q_p = P_u - q_u (X * Y)$$

$$q_p = \frac{Q_p}{d * ((Y + Y))}$$

لاحظ

الجانب Y هو الذى يقاوم ال Puncing على القاعدة