أشغال عامة - ٢٠١٣

Foundations

4

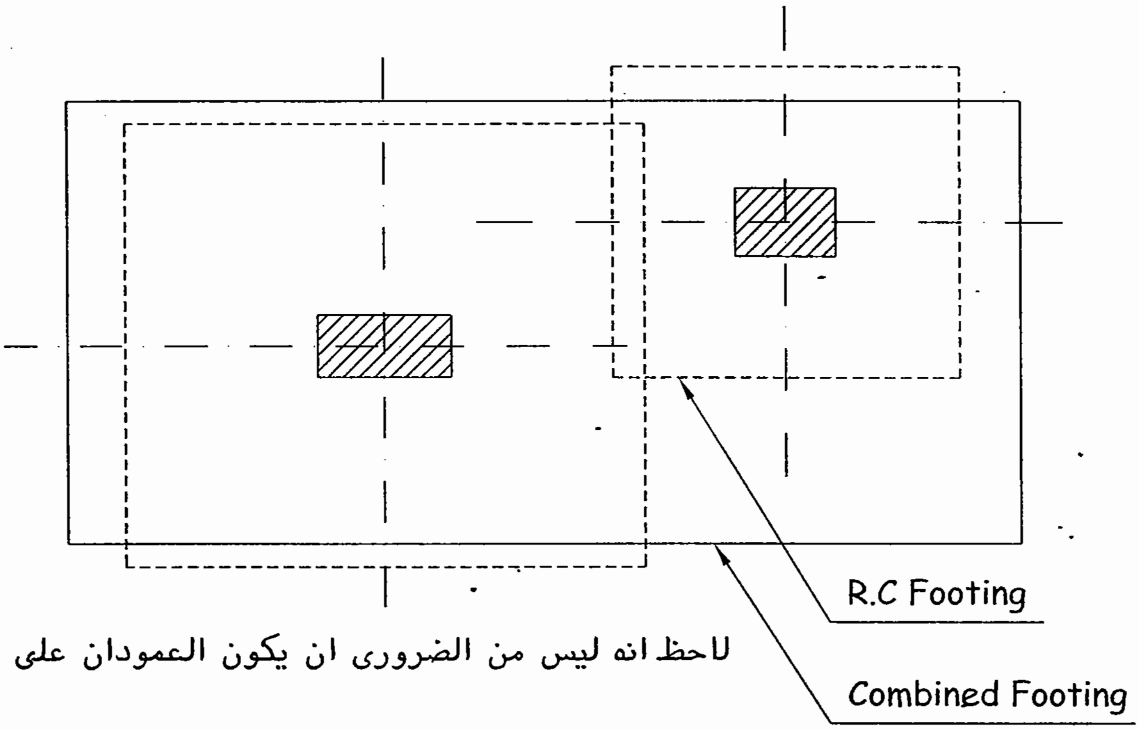
Combined Footing

4 Design of Combined Footings:- تصميم القواعد المشتركة

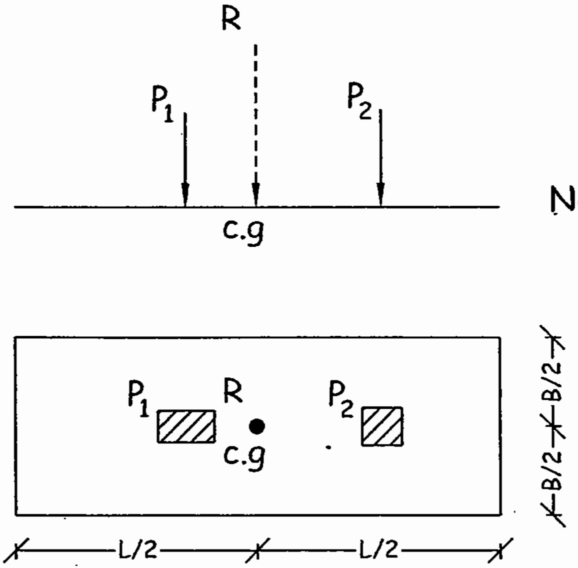
- القواعد المشتركة هى عبارة عن قاعدة واحدة مستطيلة الشكل غالبا يوجد عليها اكثر من عمود واحد.
- ونلجأ لاستخدام القواعد المشتركة عند:-

تحديد ابعاد الـ R.C لقاعدتين منفصلتين لعمودين متجاورين ووجد ان القاعدتين المسلحتين سوف يتداخلان معا وهو ما لا يمكن تنفيذه.

- لذلك نلجأ لاستبدال القاعدتين المنفصلتين بقاعدة واحدة كبيرة مشتركة بين العمودين.



لاحظ انه ليس من الضرورى ان يكون العمودان على محور واحد



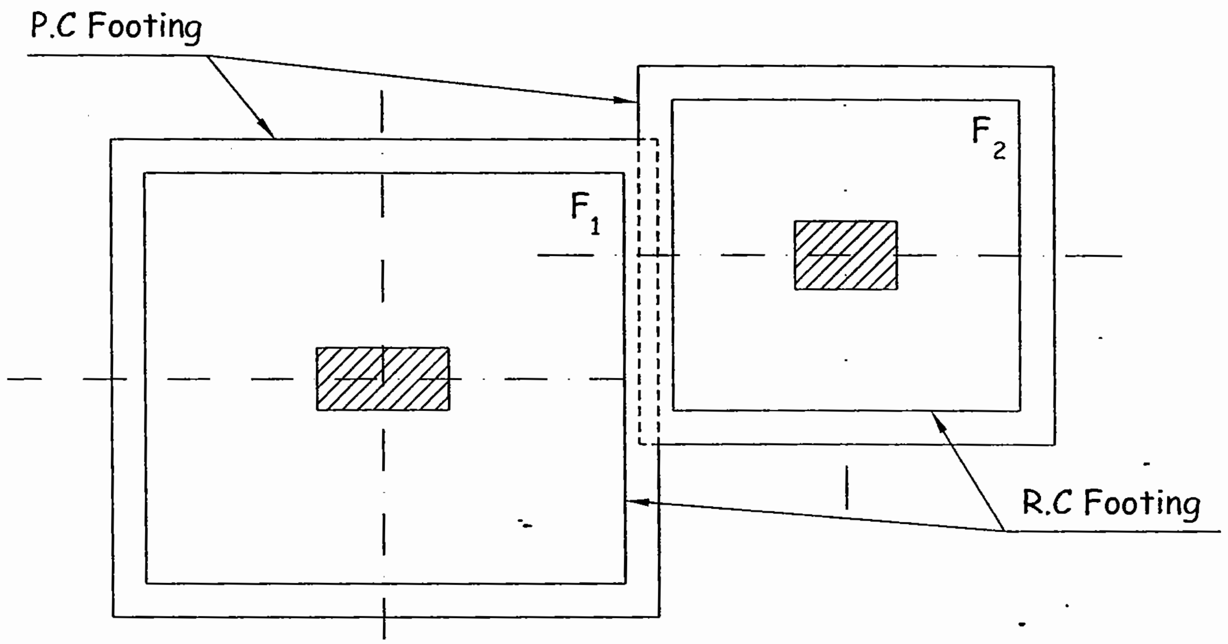
- الفكرة العامة فى تصميم القواعد المشتركة:-

ان يكون مركز الأحمال هو مركز القاعدة

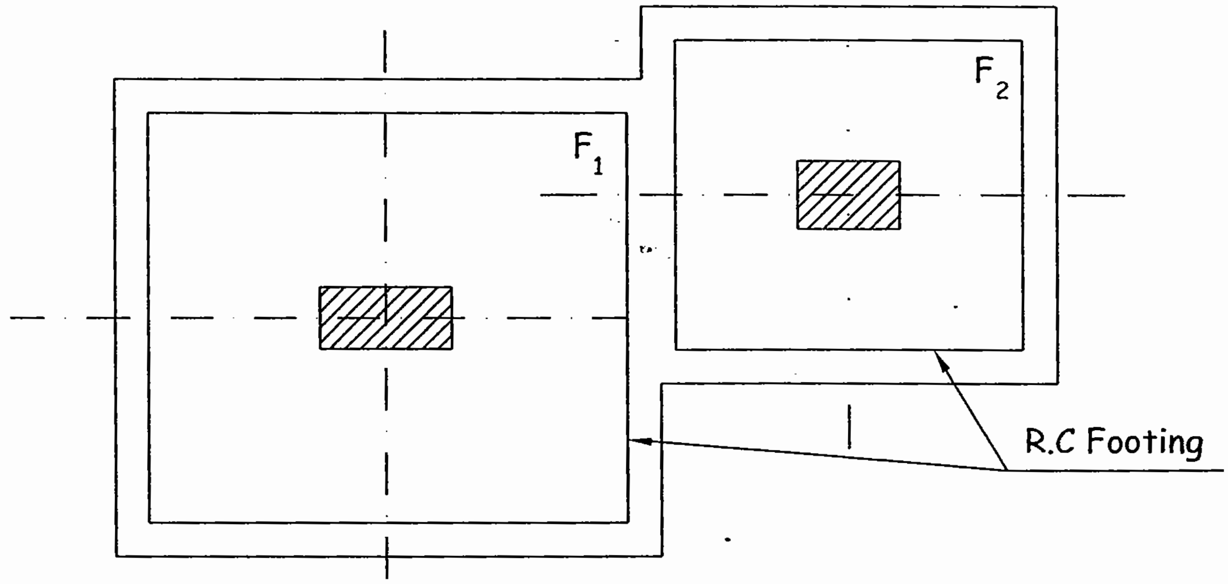
وبالتالى تكون القاعدة عليها Normal Force ONLY

- ملاحظة هامة :-

- عند تصميم قواعد منفصلة لعمودين مجاورين ووجد ان القواعد المسلحة لم تتداخل بل حدث تتداخل للقواعد العادية (Plain footings) يمكن اكمال التصميم على انهم قواعد منفصلة (عادى جدا كلا منهم على حدة) ولا نلجأ لحل القاعدة المشتركة(Combined footing).



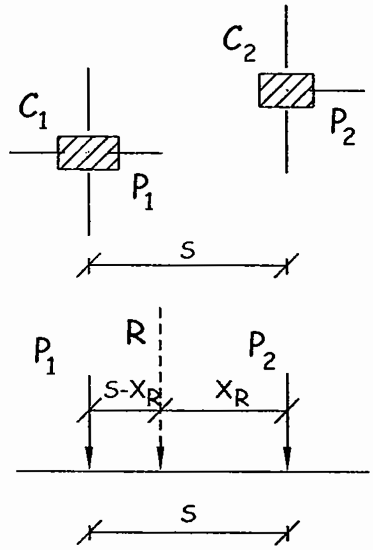
Plain footings overlapping



Combined Plain footings

❋❋ Steps of Design of Rectangular combined footing:-

*** Givens:-**



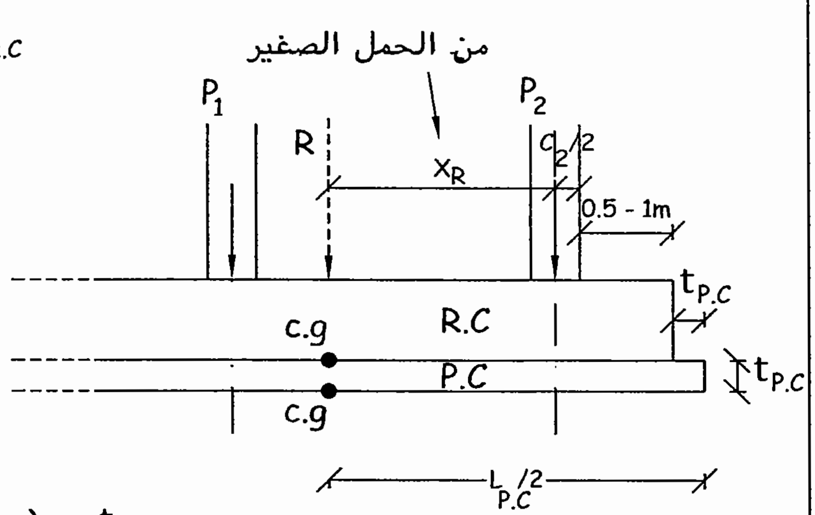
1. Columns' Loads. احمال العمدان
2. Columns' Dimensions. ابعاد العمدان
3. Allowable bearing capacity ($q_{all.}$)
4. $t_{P.C}$ or assumed
5. Spacing S.

1- Calculate: $R = P_1 + P_2$ and $X_R = \frac{P_1 * S}{R}$

Where $P_1 > P_2$

يتم تعيين محصلة الأحمال ومكان تأثيرها

2- Calculate: $L_{P.C}$, $L_{R.C}$



$$\frac{L_{P.C}}{2} = X_R + \frac{C_2}{2} + (0.5 - 1m) + t_{P.C}$$

$$\therefore \quad L_{P.C} = 2 * \frac{L_{P.C}}{2}$$

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

3- Calculate: $B_{P.C}$, $B_{R.C}$

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

$\therefore \; A_{R.C} = \dfrac{R}{q_{all.}} = \checkmark \; m^2 = B_{R.C} * L_{R.C}$

get $B_{R.C}$

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

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

$\therefore \; A_{P.C} = \dfrac{R}{q_{all.}} = \checkmark \; m^2 = B_{P.C} * L_{P.C}$

get $B_{P.C}$

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

4- Calculate ultimate actions:

$P_{1u} = 1.5 * P_1 \quad , \quad P_{2u} = 1.5 * P_2 \quad , \quad R_u = 1.5 * R$

* $W_u = \dfrac{R_u}{L_{R.C}}$ = KN/m' = ultimate uniform load under R.C

* $q_u = \dfrac{R_u}{L_{R.C} * B_{R.C}}$ = KN/m^2 = ultimate uniform stress under R.C

5- Design in long direction:

مع وجود الأبعاد كلها يمكن رسم B.M.D, S.F.D
وذلك من خلال حساب قيم B.M, S.F
على وش الاعمدة.

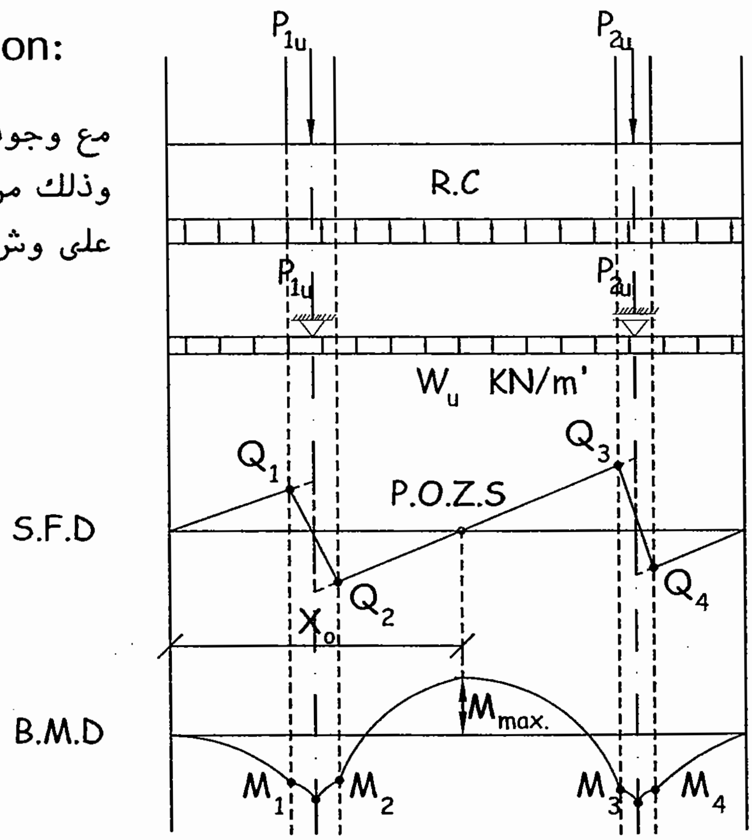
* get the point of zero shear:-

$P_{1u} = W_u * X_o$ get X_o

* Calculate $M_{max.}$ at $X_o = \checkmark$

لاحظ ان هذا العزم على العرض
كله $B_{R.C}$ وليس لشريحة 1m

$\therefore d = 5 \sqrt{\dfrac{M_{max.} * 10^6}{f_{cu} * B_{R.C\,(mm)}}}$



* Check Shear:- "in long direction"

على بعد d/2 من وش العمود اللى عنده $Q_{max.}$

- get $Q_{max.}$ = the bigger from Q_1 , Q_2 , Q_3 , Q_4

$$\therefore \; Q_{su} = Q_{max.} - W_u * \frac{d}{2} = \checkmark\checkmark \text{ KN} \Longrightarrow \text{Shear Force on } B_{R.C}$$

$$\therefore \; q_{su} = \frac{Q_{su} * 10^3}{B_{R.C\,(mm)} * d_{(mm)}} = \checkmark\checkmark \text{ N/mm}^2$$

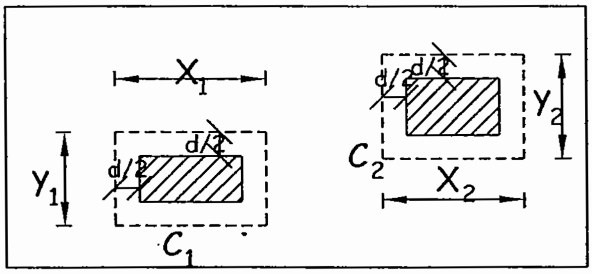
$$\text{Check } q_{su} \not> 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \text{ N/mm}^2$$

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

$\Longrightarrow$ Increase d & recheck $\Longrightarrow$ نعيد الحسابات من اول

* Check punching:-

نتحقق لكل عمود على حدا على بعد d/2 من وش العمود من كل ناحية.



For C_1

$$Q_{p_1} = P_{1u} - q_u * (X_1 * y_1)$$

$$q_{p_1} = \frac{Q_{p_1}}{d * 2(X_1 + y_1)}$$

$$\not> q_{p_{cu}} = 0.316 \left(0.5 + \frac{a_1}{b_1}\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\frac{a_1}{b_1} \not> 0.5$

If UNSAFE $\Longrightarrow$ Increase d

For C_2

$$Q_{p_2} = P_{2u} - q_u * (X_2 * y_2)$$

$$q_{p_2} = \frac{Q_{p_2}}{d * 2(X_2 + y_2)}$$

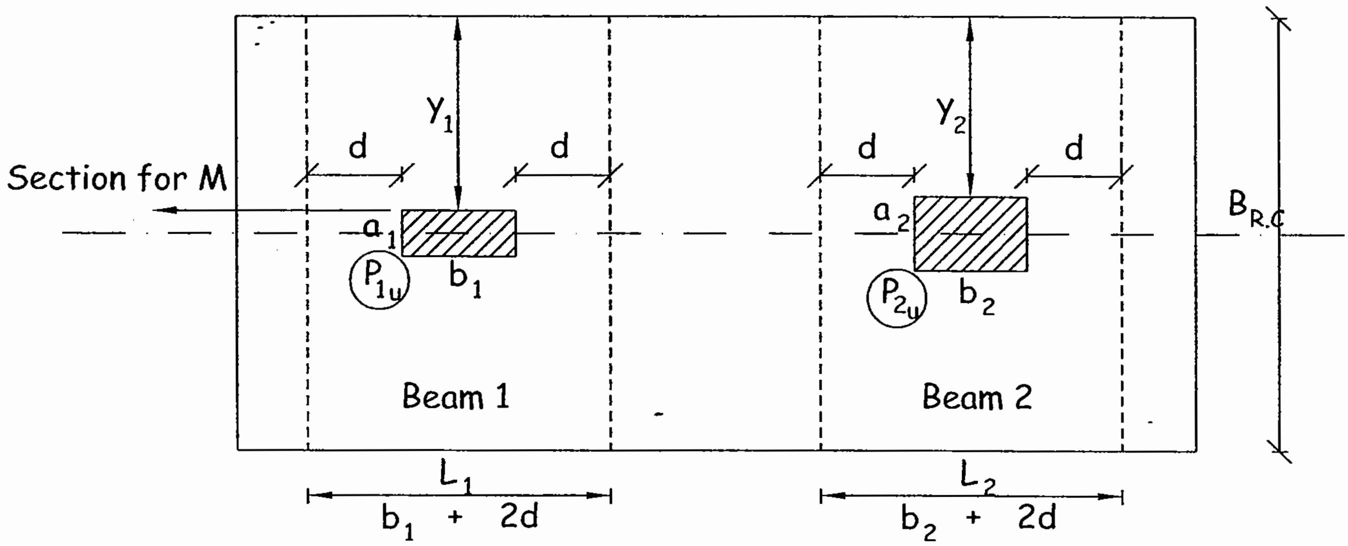
$$\not> q_{p_{cu}} = 0.316 \left(0.5 + \frac{a_2}{b_2}\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\frac{a_2}{b_2} \not> 0.5$

If UNSAFE $\Longrightarrow$ Increase d

6- Design in transverse direction {short direction}:-

"Hidden Beams"



نتخيل اسفل كل عمود "Hidden Beams" ابعادها L * B

Where :
- $B = B_{R.C}$ of footing
- $L = b_{col.} + 2d$ عرض العمود فى الاتجاه الطويل + ٢ ال depth

For Beam 1	For Beam 2
$B_{R.C} * L_1$	$B_{R.C} * L_2$
$\therefore q_{u_1} = \dfrac{P_{1_u}}{B_{R.C} * L_1}$	$\therefore q_{u_2} = \dfrac{P_{2_u}}{B_{R.C} * L_2}$
$\therefore Y_1 = \dfrac{B_{R.C} - a_1}{2}$	$\therefore Y_2 = \dfrac{B_{R.C} - a_2}{2}$
$\therefore M_1 = q_u * \dfrac{Y_1^2}{2} * 1m$	$\therefore M_2 = q_u * \dfrac{Y_2^2}{2} * 1m$
= ✓✓ KN.m/m'	= ✓✓ KN.m/m'

∴ Choose the bigger Moment from M_1 & M_2 and

where :- $\therefore d = C_1 \sqrt{\frac{M_{max.} * 10^6}{f_{cu} * (1000)}}$ ← عرض الشريحة

get $C_1 \nless 2.8$

if $C_1 < 2.8 \Rightarrow$ unsafe $\Rightarrow$ increase d & recheck the transverse direction

Check Shear:–

$L = Z - \frac{d}{2}$, $Q_{su} = q_u * \ell * 1m$, $q_{su} = \frac{Q_{su} * 10^3}{d_{(mm)} * 1000}$

and check as before

7– R.F.T:–

[1] In Long direction:-

- $A_{s_{top}} = \frac{M_{max.\,top} * 10^6}{F_y * J * d_{(mm)} * B_{R.C\,(m)}} = \checkmark\checkmark$ mm^2/m' علوى

  بالمتر

- $A_{s_{bottom}} = \frac{M_{max.\,bottom} * 10^6}{F_y * J * d_{(mm)} * B_{R.C\,(m)}} = \checkmark\checkmark$ mm^2/m' سفلى

  بالمتر

[1] In short direction:-

- $A_{s_1} = \frac{M_1 * 10^6}{F_y * J * d_{(mm)}} = \checkmark\checkmark$ mm^2/m' سفلى (M_1: From beam 1)

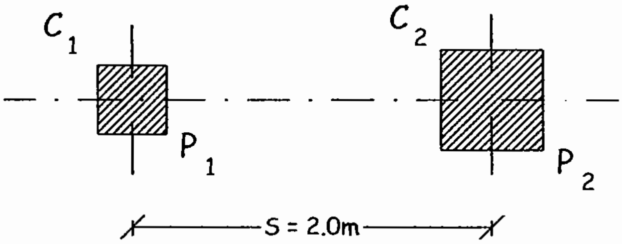
- $A_{s_2} = \frac{M_2 * 10^6}{F_y * J * d_{(mm)}} = \checkmark\checkmark$ mm^2/m' سفلى (M_2: From beam 2)

8– Details :–

See the Example

Example No. (1):-

Design a rectangular combined footing to support the shown two columns.



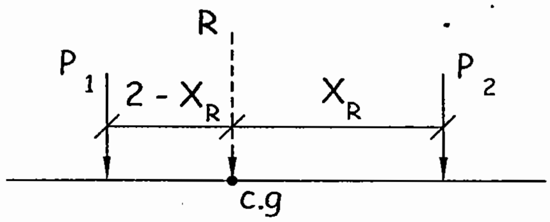
Given:-

- $t_{P.C}$ = 40 cm
- $q_{all.}$ = 200 KN/m^2
- f_{cu} = 30 N/mm^2 , f_y = 360 N/mm^2
- C_1 and C_2 are two square columns
- P_1 = 1800 KN
- P_2 = 1600 KN

Solution:-

$$R = P_1 + P_2 = 1800 + 1600 = 3400 \text{ KN}$$

$$X_R = \frac{1800 * 2}{3400} = 1.05 \text{ m}$$

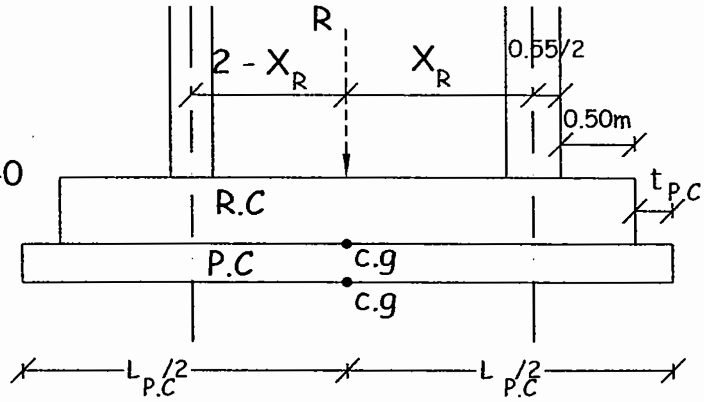


For columns dimensions:-

$$A_{c_1} = \frac{1800 * 10^3}{6} = 3 * 10^5 \text{ mm}^2 \quad [60 * 60 \text{ cm}]$$

$$A_{c_2} = \frac{1600 * 10^3}{6} = 266666.7 \text{ mm}^2 \quad [55 * 55 \text{ cm}]$$

① Calculate the footing area :-



$$\frac{L_{P.C}}{2} = X_R + \frac{C_2}{2} + 0.50 + t_{P.C}$$

$$= 1.05 + \frac{0.55}{2} + 0.50 + 0.40$$

$$= 2.225 \text{ m}$$

$$L_{P.C} = 2 * 2.225 = 4.45 \text{ m}$$

$$L_{R.C} = 4.45 - 2 * 0.40 = 3.65 \text{ m}$$

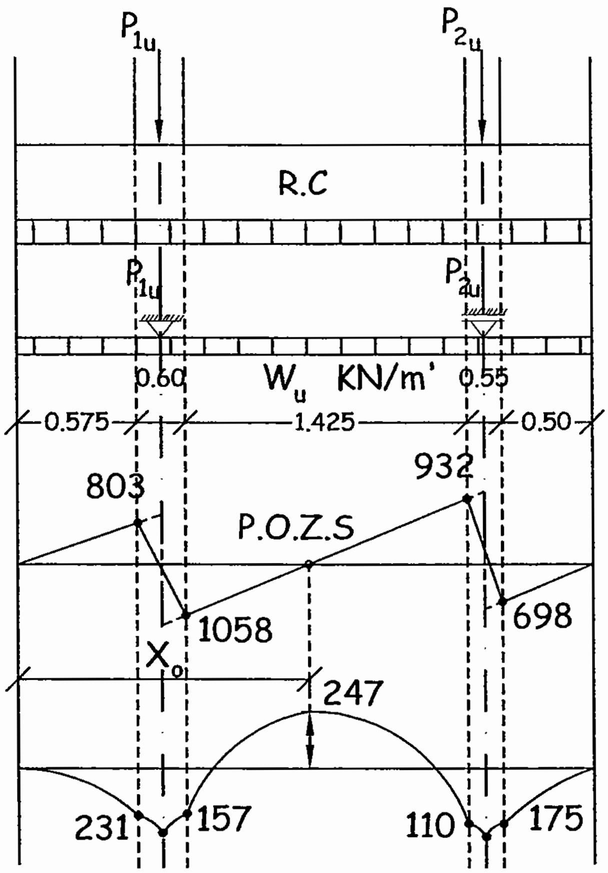
$\because$ $t_{P.C} = 40 \text{ cm} > 20 \text{ cm}$

$$\therefore A_{P.C} = \frac{N}{q_{all.}} = \frac{3400}{200} = 17 \text{ m}^2$$

$$\therefore B_{P.C} = \frac{A_{P.C}}{L_{P.C}} = \frac{17}{4.45} = 3.82 \text{ m} \approx 3.85 \text{ m}$$

$$B_{R.C} = 3.85 - 2 * 0.40 = 3.05 \text{ m}$$

② Design in long direction:-



$$P_{1u} = 1.5 * 1800 = 2700 \text{ KN}$$

$$P_{2u} = 1.5 * 1600 = 2400 \text{ KN}$$

$$R_u = 1.5 * 3400 = 5100 \text{ KN}$$

$$W_u = \frac{5100}{3.65} = 1397 \text{ KN/m'}$$

$$q_u = \frac{5100}{3.65 * 3.05} = 452 \text{ KN/m}^2$$

* get the point of zero shear:-

$$2700 = 1397 * X_o \Longrightarrow X_o = 1.93 \text{ m}$$

$$M_{max.} = 1397 * \frac{1.93^2}{2} - 2700 * [1.93 - 0.575 - \frac{0.60}{2}]$$

$$= -247 \text{ KN.m}$$

$$\therefore d = 5\sqrt{\frac{M_{max.} * 10^6}{f_{cu} * B_{R.C\,(mm)}}} = 5\sqrt{\frac{247 * 10^6}{30 * 3050}} = 259 \text{ mm}$$

take d = 330 mm

③ Check Shear :-

$Q_{max.} = 1058$ KN

$$Q_{su} = Q_{max.} - W * \frac{d}{2} = 1058 - 1397 * \frac{0.33}{2} = 827.5 \text{ KN}$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{827.5 * 10^3}{330 * 3050} = 0.822 \text{ N/mm}^2$$

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{30}{1.5}} = 0.719 \text{ N/mm}^2$$

$\because q_{su} > q_{scu} \Rightarrow \therefore$ UNSAFE

$\therefore$ Increase d

Take d = 380 mm

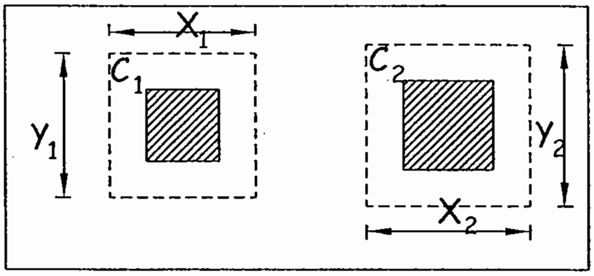
$$Q_{su} = Q_{max.} - W * \frac{d}{2} = 1058 - 1397 * \frac{0.38}{2} = 792.57 \text{ KN}$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{792.57 * 10^3}{380 * 3050} = 0.684 \text{ N/mm}^2$$

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{30}{1.5}} = 0.719 \text{ N/mm}^2$$

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

④ Check Punching Shear :-



For C_1

$$Q_{p_1} = 2700 - 452 * (0.98)^2 = 2266 \text{ KN}$$

$$q_{p_1} = \frac{2266 * 10^3}{380 * [980 + 980] * 2}$$

$$= 1.52 \text{ N/mm}^2$$

$$q_{p_{cu_1}} = 0.316 \left(0.5 + \frac{0.6}{0.6}\right)\sqrt{\frac{30}{1.5}}$$

$$= 1.413 \text{ N/mm}^2$$

$$\because q_{p_1} > q_{p_{cu_1}} \Rightarrow \therefore \text{UNSAFE}$$

increase d $\Rightarrow$ d = 430 mm

$$Q_{p_1} = 2700 - 452 * (1.03)^2 = 2220.5 \text{ KN}$$

$$q_{p_1} = \frac{2220.5 * 10^3}{430 * [1030 + 1030] * 2}$$

$$= 1.25 \text{ N/mm}^2$$

$$\because q_{p_1} < q_{p_{cu_1}} \Rightarrow \therefore \text{SAFE}$$

For C_2

$$Q_{p_2} = 2400 - 452 * (0.98)^2 = 1966 \text{ KN}$$

$$q_{p_2} = \frac{1966 * 10^3}{430 * [980 + 980] * 2}$$

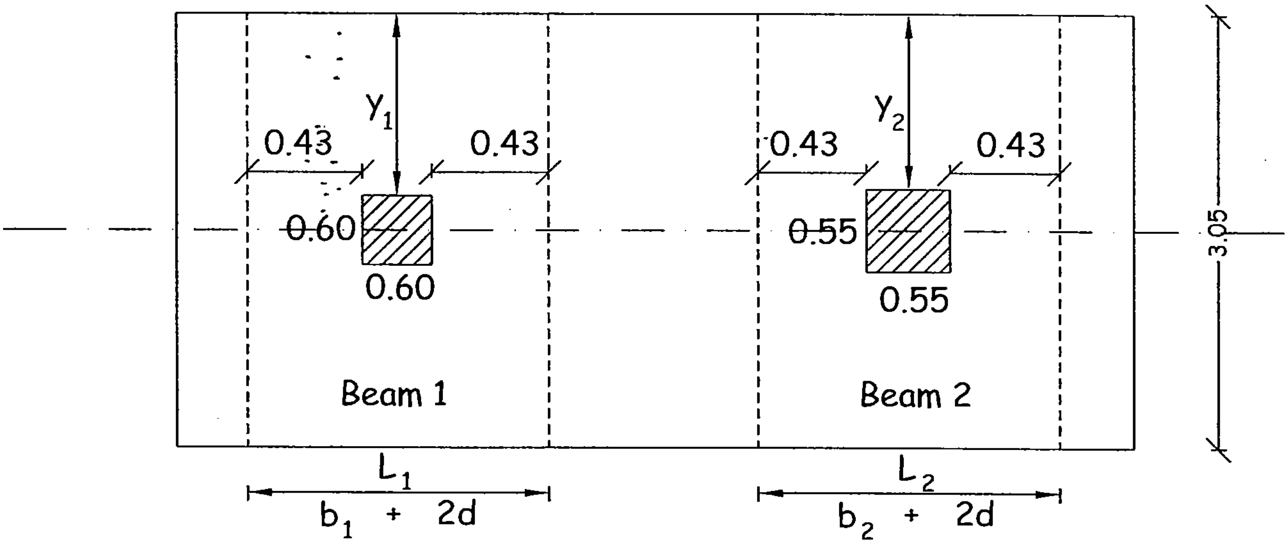
$$= 1.17 \text{ N/mm}^2$$

$$q_{p_{cu_2}} = 0.316 \left(0.5 + \frac{0.55}{0.55}\right)\sqrt{\frac{30}{1.5}}$$

$$= 1.413 \text{ N/mm}^2$$

$$\because q_{p_2} < q_{p_{cu_2}} \Rightarrow \therefore \text{SAFE}$$

⑤ Design in short direction:-



For Beam 1

$L_1 = 0.60 + 2 * 0.43 = 1.46$ m

$\therefore q_{u_1} = \dfrac{2700}{3.05 * 1.46} = 606.3$ KN/m^2

$\therefore Y_1 = \dfrac{3.05 - 0.60}{2} = 1.225$ m

$\therefore M_1 = 606.3 * \dfrac{1.225^2}{2} * 1m$

$= 455$ KN.m/m'

For Beam 2

$L_2 = 0.55 + 2 * 0.43 = 1.41$ m

$\therefore q_{u_2} = \dfrac{2400}{3.05 * 1.41} = 558$ KN/m^2

$\therefore Y_2 = \dfrac{3.05 - 0.55}{2} = 1.25$ m

$\therefore M_2 = 558 * \dfrac{1.25^2}{2} * 1m$

$= 436$ KN.m/m'

$M_{bigger} = M_1 = 455$ KN.m/m'

$\therefore d = 430 = C_1 \sqrt{\dfrac{455 * 10^6}{30 * 1000}} \Rightarrow C_1 = 3.49 > 2.8 \quad \therefore$ SAFE

⑥ Final Thickness :-

$d_{final} = 430$ mm

$t_{final} = 430 + 70$ (cover) $= 500$ mm

⑦ R.F.T :-

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 430 = 645 \ mm^2/m' \\ 5 \phi 12/m' = 565 \ mm^2/m' \end{cases}$$

6 ϕ 12/m'

In Long direction:-

$$A_{s_{Top}} = \frac{M_{u_{top}} * 10^6 / B}{F_y * 0.826 * d} = \frac{247 * 10^6 / 3.05}{360 * 0.826 * 430} = 633 \ mm^2/m' < A_{s_{min.}}$$

$$A_{s_{Bottom}} = \frac{M_{u_{bot.}} * 10^6 / B}{F_y * 0.826 * d} = \frac{231 * 10^6 / 3.05}{360 * 0.826 * 430} = 592 \ mm^2/m' < A_{s_{min.}}$$

use $A_{s_{min.}}$ **6 ϕ 12/m'**

In Short direction:-

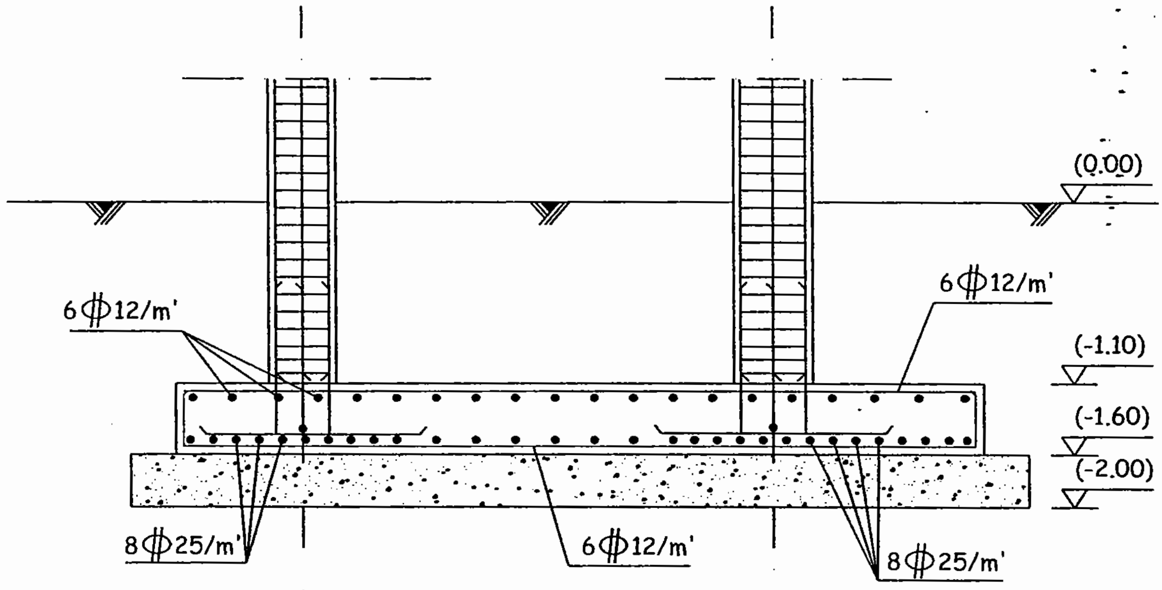
$$A_{s_1} = \frac{M_{u_1} * 10^6}{F_y * 0.78 * d} = \frac{455 * 10^6}{360 * 0.78 * 430} = 3768 \ mm^2/m'$$

8 ϕ 25/m'

$$A_{s_2} = \frac{M_{u_2} * 10^6}{F_y * 0.79 * d} = \frac{436 * 10^6}{360 * 0.79 * 430} = 3520 \ mm^2/m'$$

8 ϕ 25/m'

⑧ Details:



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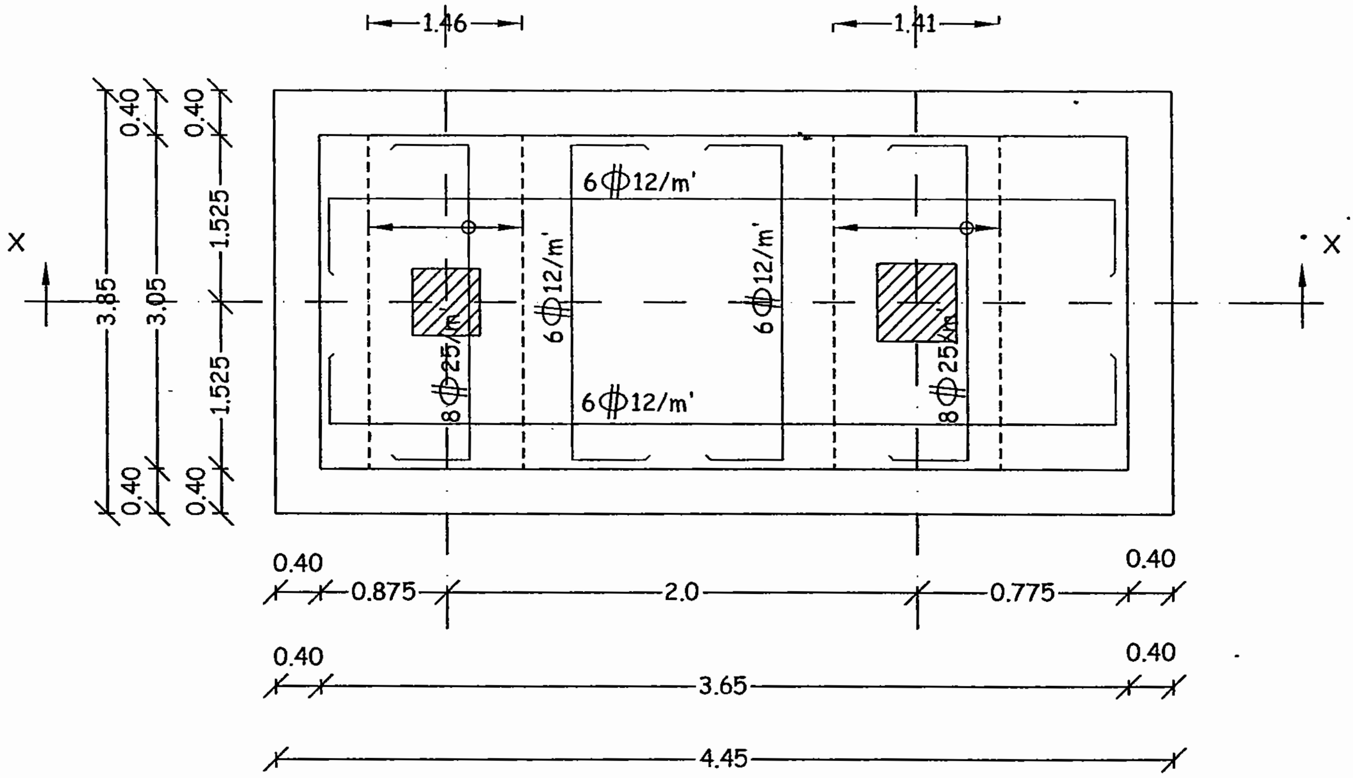

PLAN