- رابعة مدني أشغال

أشغال عامة - ٢٠١٣

- ٤١

فونديشن رابعة

أشغال

م/ أحمد مدحت

٥

Foundations

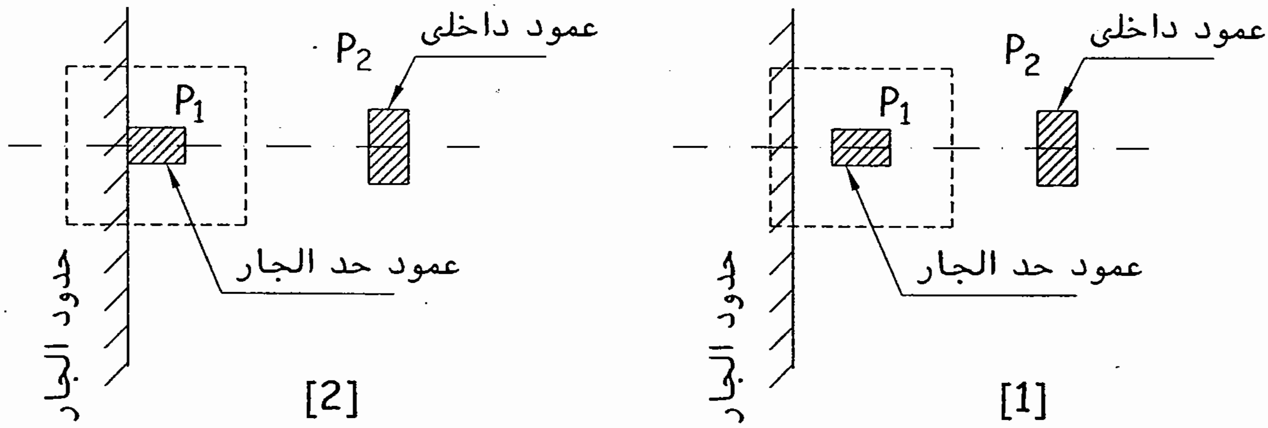
5

Strap Beam Footing

❊ Design of footings for columns near an existing property lines:

تصميم القواعد بجوار حد الجار

- تصميم القواعد لاعمدة تقع بالقرب من حدود منشأ مجاور قائم [حد جار].



- عندما يوجد عمود قريب من حد جار (حالة ١) فاننا نحاول ايجاد أبعاد لقاعدة منفصلة عادية جدا تحت هذا العمود فاذا حدث وكانت ابعاد هذه القاعدة سوف تدخل وتتعدى حد الجار فان ذلك لا يمكن تنفيذه.
- وبالتالى نلجأ لعمل قاعدة كبيرة تربط عمود حد الجار بعمود آخر داخلى داخل المبنى المطلوب انشاءه.
- عندما يوجد عمود حد جار ملاصق تماما لحدود الجار (حالة ٢) فاننا مباشرة نلجأ لعمل قاعدة كبيرة تربط عمود حد الجار بعمود داخلى.

- ويتوقف اختيار نوع القاعدة التى سوف تربط عمود حد الجار بالعمود الداخلى على :-

1) Spacing between the two columns C_1, C_2.

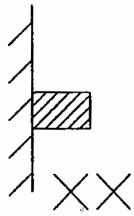
2) The values of columns loads P_1 , P_2 .

3) Allowable bearing capacity of soil.

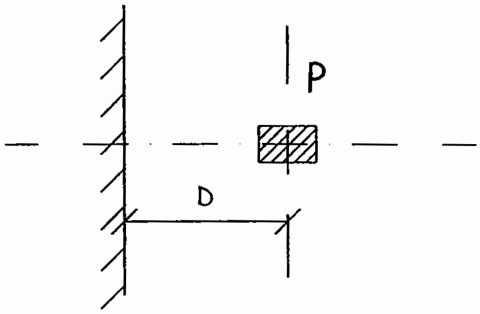
- متى يمكن استخدام قاعدة منفصلة لعمود عند حد الجار ؟

اذا توافرت الشروط الاتية :-

1) آلا يكون العمود ملاصق لحد الجار .

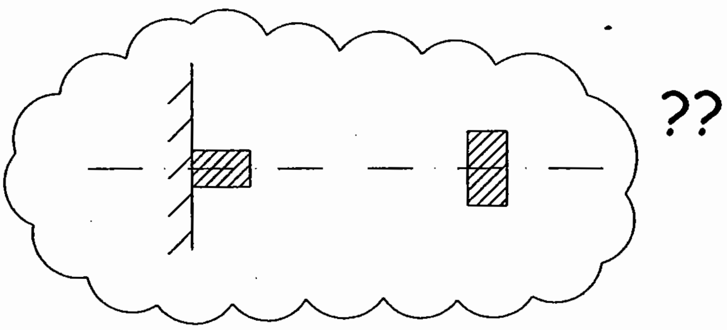


2) ان يكون العمود يبعد عن حد الجار مسافة D من محور العمود بحيث يكون



$$\frac{1}{2}\sqrt{\frac{P_{col.}}{q_{all.}}} \ngtr D$$

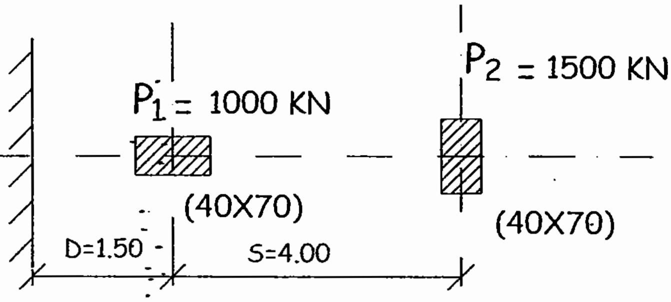
- اذا لم تتحقق هذه الشروط سيكون مستحيل استخدام isolated footing للعمود بجوار حد الجار .
- وبالتالى يتم التفكير فى نوع آخر من انواع الاساسات التى تعتمد فكرتها على ربط هذا العمود بعمود آخر داخلى .



Example No. (2):-

$q_{all.} = 150 \quad KN/m^2$

$$\frac{1}{2}\sqrt{\frac{P_1}{q_{all.}}} = \frac{1}{2}\sqrt{\frac{1000}{150}}$$



$= 1.29 < D$

$\therefore$ **use Isolated footings**

$t_{P.C} = 40$ cm , $q_{all.} = 150 \quad KN/m^2$

$\therefore$ **For P_1 :-**

isolated rectangular footing

$$A_{P.C} = \frac{1000}{150} = 6.66^2 = L_{P.C} X \; B_{P.C} \longrightarrow ①$$

$$L_{P.C} - B_{P.C} = 0.30 \longrightarrow ②$$

From 1 & 2 $\quad L_{P.C} = 2.75$ m , $B_{P.C} = 2.45$ m

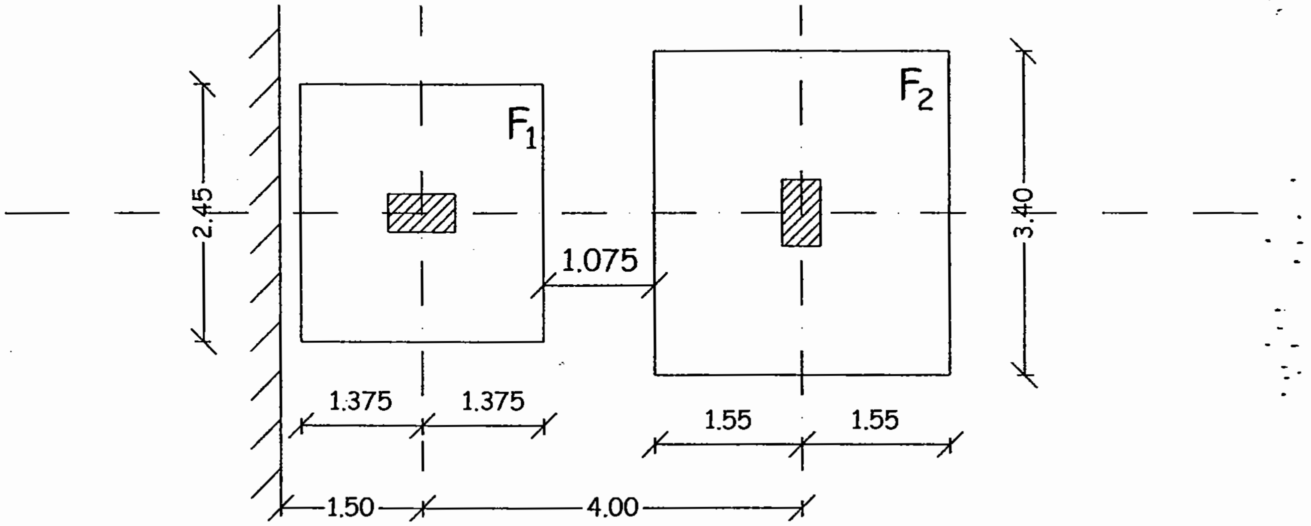
$\therefore$ **For P_2 :-**

isolated rectangular footing

$$A_{P.C} = \frac{1500}{150} = 10 \; m^2 = L_{P.C} X \; B_{P.C} \longrightarrow ①$$

$$L_{P.C} - B_{P.C} = 0.30 \longrightarrow ②$$

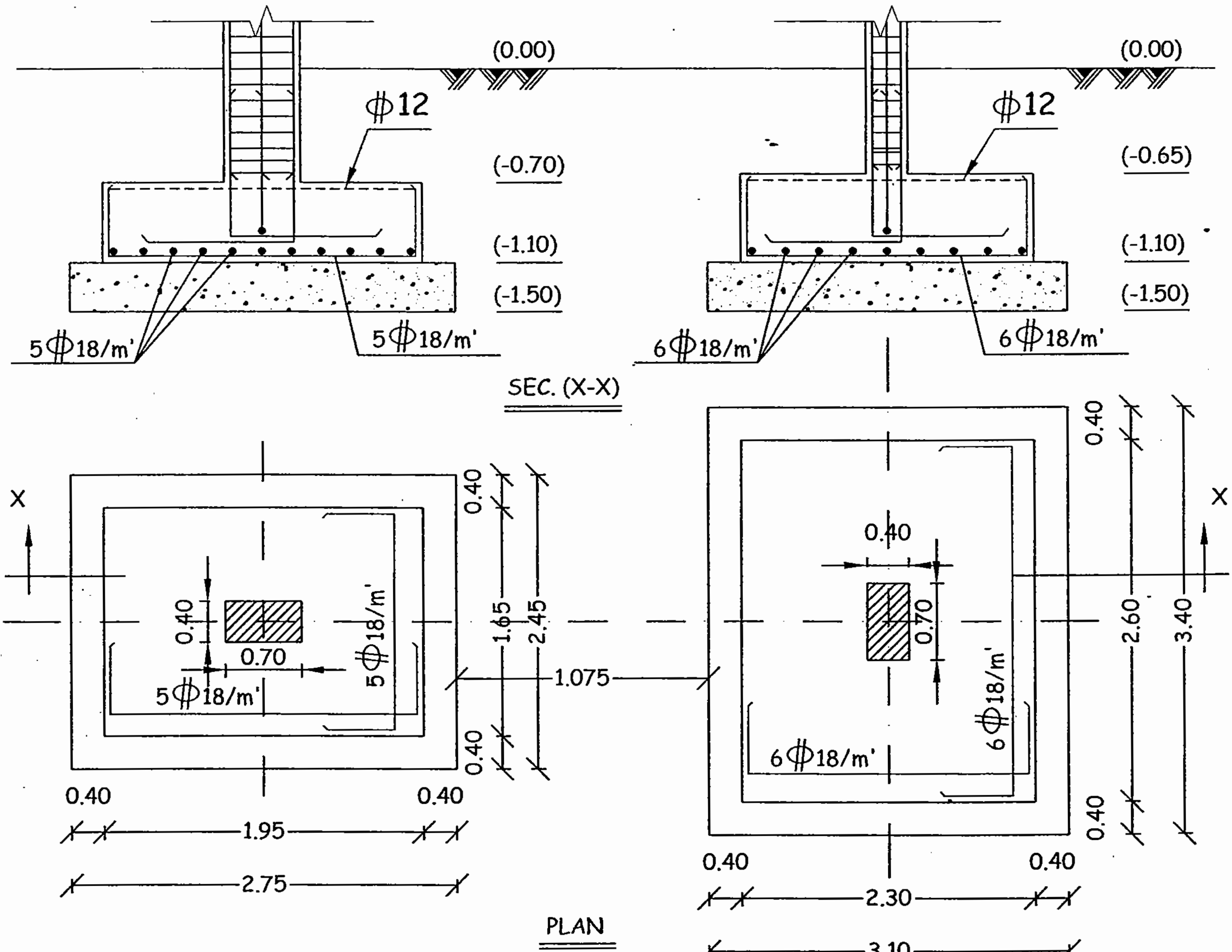
From 1 & 2 $\quad L_{P.C} = 3.40$ m , $B_{P.C} = 3.10$ m



لم يحدث تداخل بين القاعدتين

∴ Isolated footings system is O.K.

ويتم عمل Design كامل كما سبق فى القواعد المستطيلة المنفصلة , ولكن يتم رسم تفاصيل القواعد بجانب بعضهم كالأتى :-



** Usable types of foundation systems in case of columns beside property line:-

- ما هى انواع الاساسات المناسبة فى حالة وجود عمود بجوار حد جار :-

[A] Strap Beam:-

- دائما فى البداية اذا فشل حل isolated footing

نحاول عمل strap beam ونحسب ابعاد قواعد الكمرة F_1 , F_2

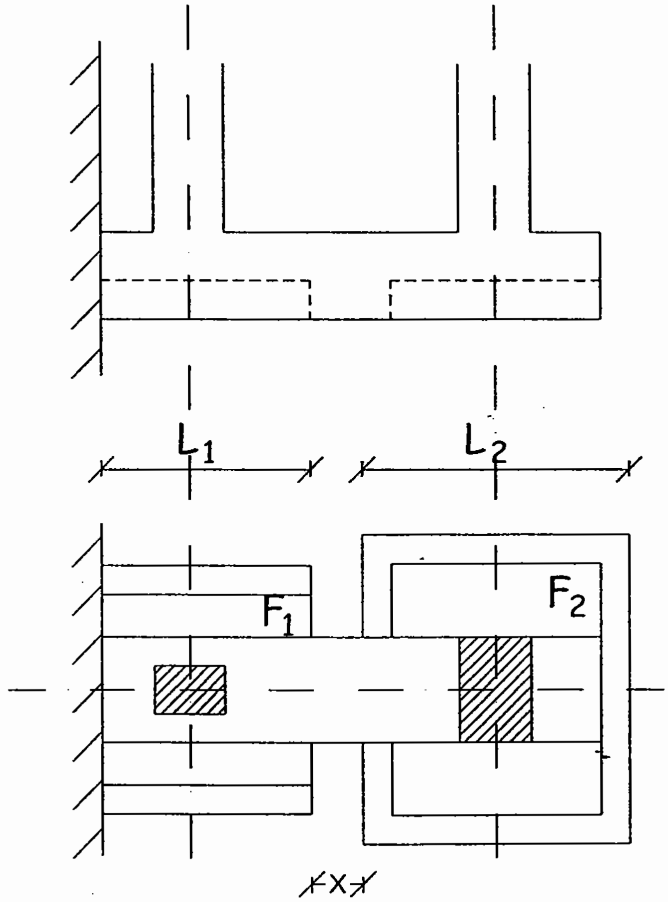
ونقوم بعمل Check

- If $X \geqslant \frac{L_1}{2}$ or $\frac{L_2}{2}$ ايهما اصغر

  ∴ use strap beam

- If $X < \frac{L_1}{2}$ or $\frac{L_2}{2}$ ايهما اصغر

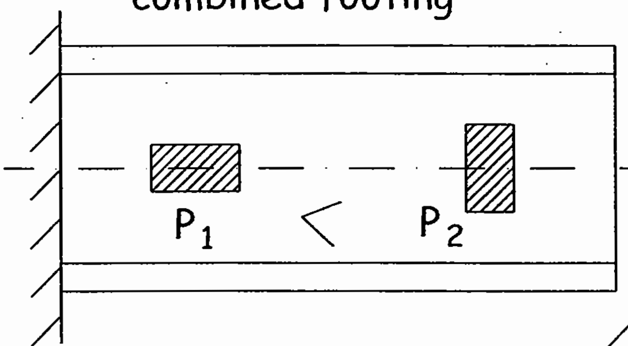
  ∴ use combined footing



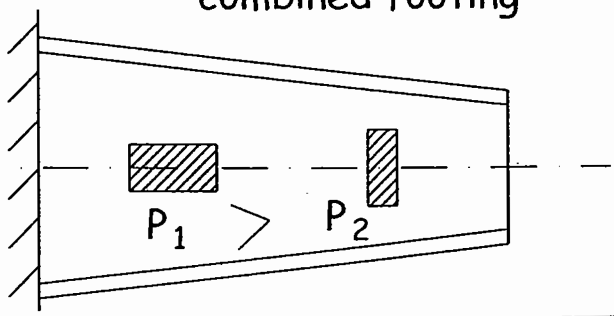
[B] Combined Footing :-

- اذا فشل حل الـ strap beam نقوم بعمل قاعدة مشتركة للعمود بجوار حد الجار وعمود آخر داخلى .
- وفى هذه الحالة يوجد نوعان من القواعد المشتركة :-

If $P_1 < P_2$ use rectangular combined footing



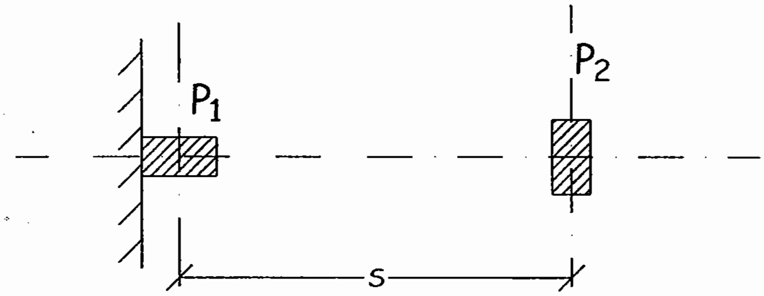
If $P_1 > P_2$ use trapezoidal combined footing



A Design of Strap Beam Foundation system for column near an existing edge of construction:-

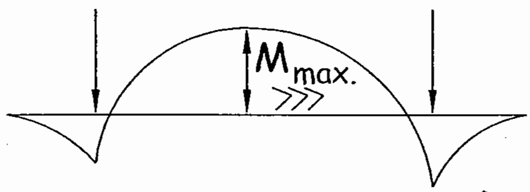
- تذكر ان :-

عندما يفشل حل استخدام قاعدة منفصلة للعمود بجوار حد الجار لابد ان نبدأ بتجربة حل الـ strap beam

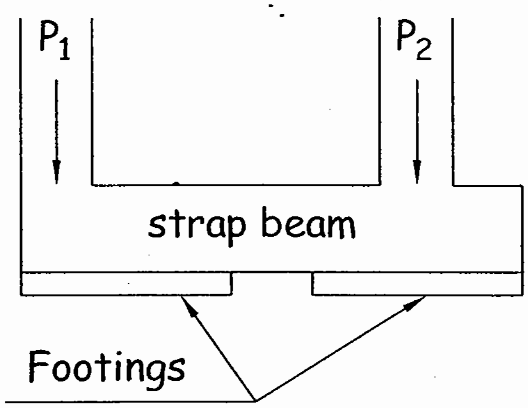


- الفكرة :-

عندما تكون المسافة (S) بين العمود ناحية الجار والعمود الداخلى كبيرة والاحمال كبيرة والمفترض عمل قاعدةتربط العمودين معا فان طول هذه القاعدة سيكون كبيرا جدا وبالتالى يكون عليها عزوم كبيرة .



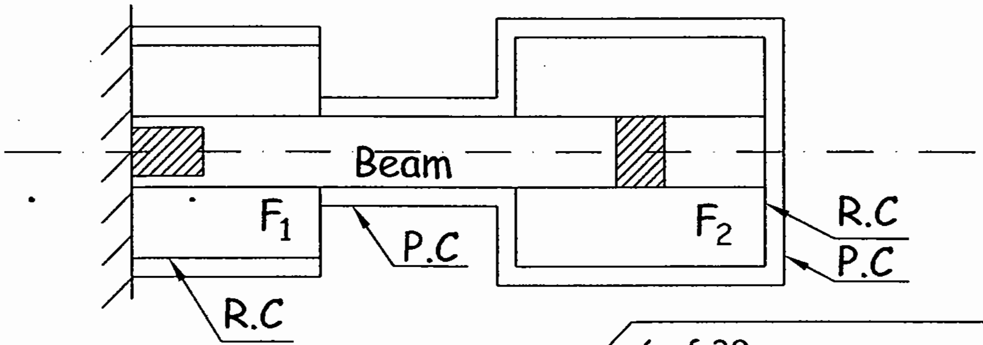
- لذلك نلجأ الى فكرة الـ strap beam :-
وهى ان احمال الأعمدة تنزل اولا على كمرة كبيرة (اى ذات عمق كبير) .



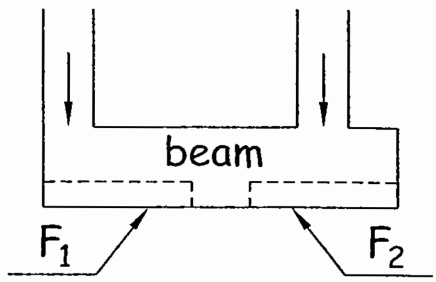
ثم يتم عمل قاعدتين ليكونا بمثابة supports للكمرة تنقل الـ reaction الى التربة .

اذا ترتيب نقل حمل المنشأ يكون كالأتى :-

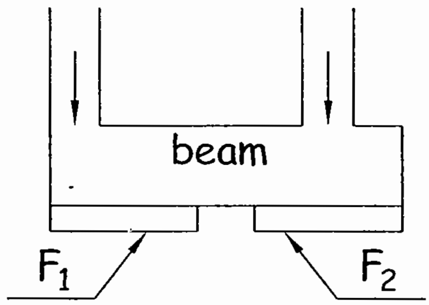
columns ⟶ strap beam ⟶ 2 footings ⟶ soil



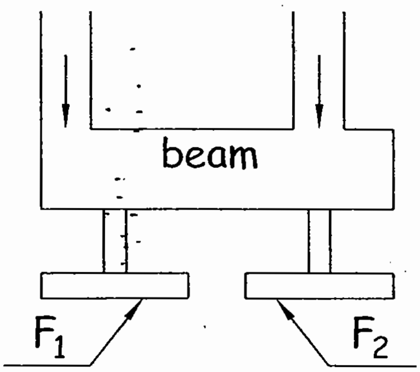
- اشكال الـ strap beam والقاعدتين :-



- منسوب قاع القاعدتين عند منسوب قاع الكمرة .
- وهو الشكل الأكثر استخداما لأنه يوفر فى عمق الحفر .



- القاعدتين اسفل الكمرة .
- هذا الشكل غير مفضل لانه يحتاج عمق حفر كبير ويتطلب معه ان يكون سمك القاعدتين واحد .

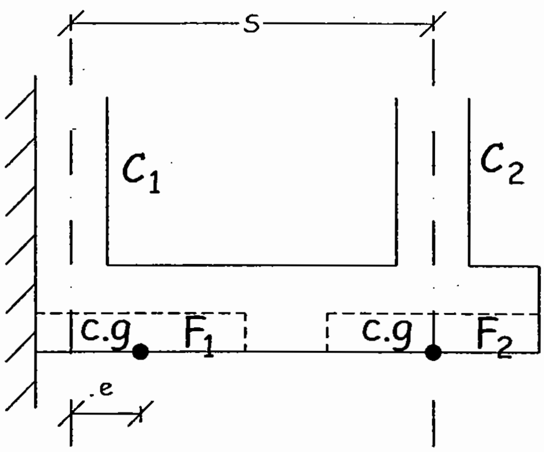


- حيث يتم تحميل الكمرة على القاعدتين عن طريق رقبة (مثل جزء من العمود).
- نلجأ لهذا الشكل اذا كان عمق الحفر كبير .

❋ ملحوظة هامة جدا :-

١) مركز القاعدة F_2 "اسفل العمود الداخلى" يكون اسفل محور العمود مباشرة او بمعنى آخر القاعدة F_2 دائما متمركزة مع العمود C_2

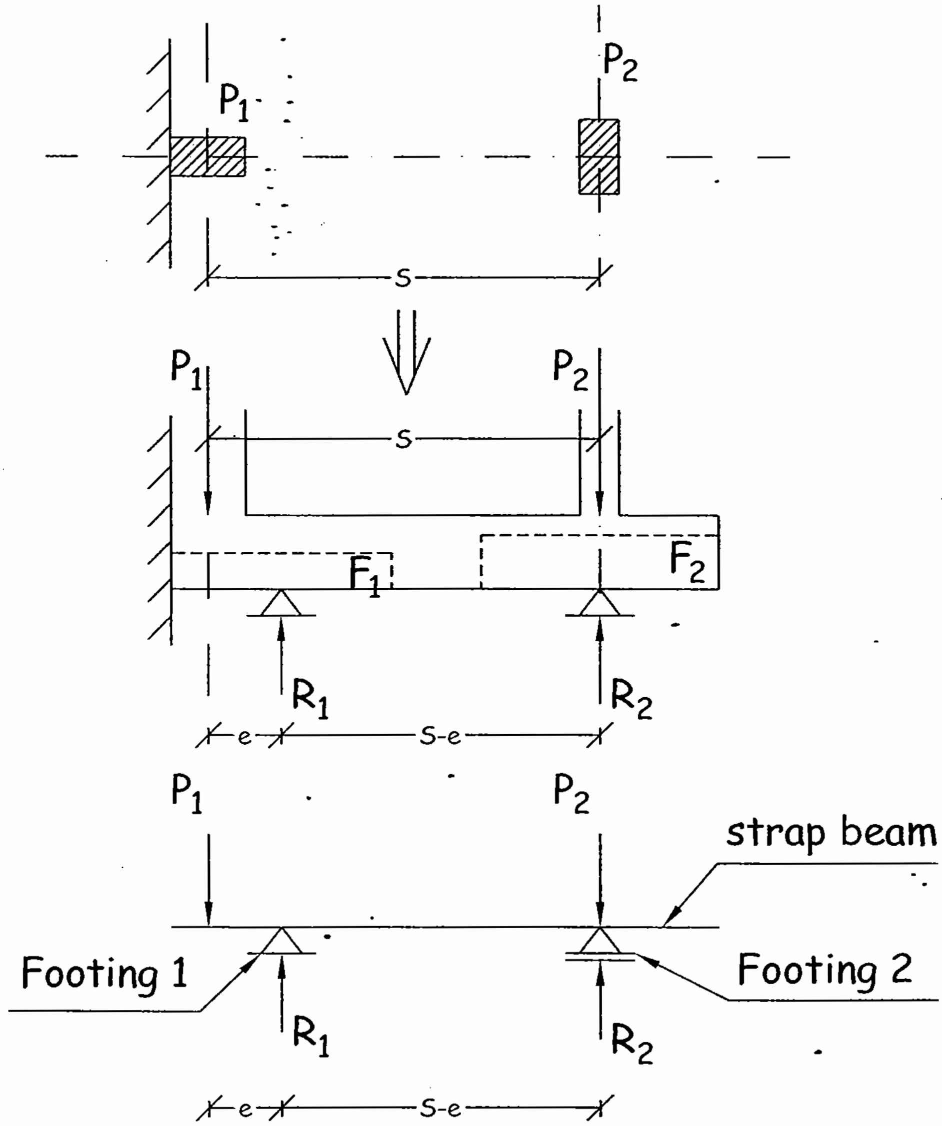
٢) مركز القاعدة F_1 "اسفل عمود الجار" يكون على بعد مسافة (e) من محور العمود C_1 .



where $e = 0.1 \longrightarrow 0.2\ S$

وذلك حتى لا تدخل القاعدة F_1 فى منطقة الجار .

- Steps of Design :-



(1) Calculations of footings dimensions:-

- assume $e = 0.1 \longrightarrow 0.20\ S$
- calculate the reactions R_1 , R_2

$$R_1 = \frac{P_1 * S}{S - e} = \checkmark \text{ KN} \Longrightarrow \text{" From } \sum M @ P_2 = 0 \text{ "}$$

$$R_2 = P_1 + P_2 - R_1 = \checkmark \text{ KN} \Longrightarrow \text{" From } \sum F_y = 0 \text{ "}$$

where :

R_1 = load from beam on footing (1)

R_2 = load from beam on footing (2)

For F1 :-

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

$$A_{P.C} = \frac{R_1}{q_{all.}} = L_{P.C} * B_{P.C}$$

where $L_{P.C} = 2 [e + \frac{C_1}{2}]$

and get $B_{P.C}$

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

$$L_{R.C} = L_{P.C}$$

لا يتم عمل تخفيض للأبعاد بمقدار $2t_{P.C}$ حتى لا يكون $c.g_{P.C} \neq c.g_{R.C}$.

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

$$A_{R.C} = \frac{R_1}{q_{all.}} = L_{R.C} * B_{R.C}$$

where $L_{R.C} = 2 [e + \frac{C_1}{2}]$

and get $B_{R.C}$

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

$$L_{R.C} = L_{P.C}$$

لا يتم عمل بروز لل P.C بسبب وجود حد الجار .

For F2 :-

"Could be rectangular or square"

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

$$A_{P.C} = \frac{R_2}{q_{all.}} = L_{P.C} * B_{P.C}$$

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

and get $L_{P.C}$ & $B_{P.C}$

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

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

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

$$A_{R.C} = \frac{R_2}{q_{all.}} = L_{R.C} * B_{R.C}$$

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

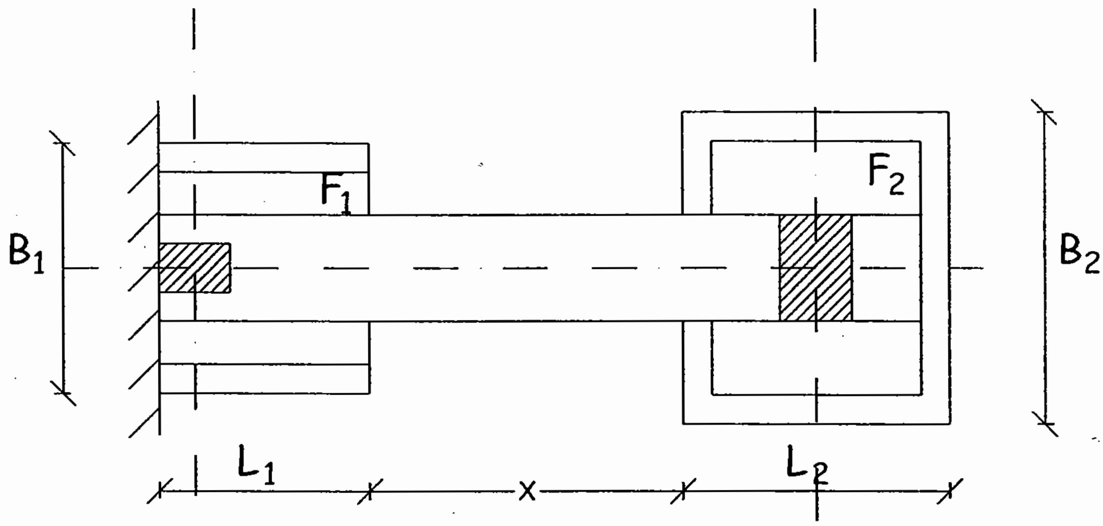
and get $L_{R.C}$ & $B_{R.C}$

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

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

Check the validity of using strap beam:-

- نرسم sketch للقاعدتين F_1 , F_2 ونحدد عليه ابعاد كل قاعدة .



- شروط استخدام الـ strap beam :-

١) لا يحدث تداخل بين F_1 , F_2

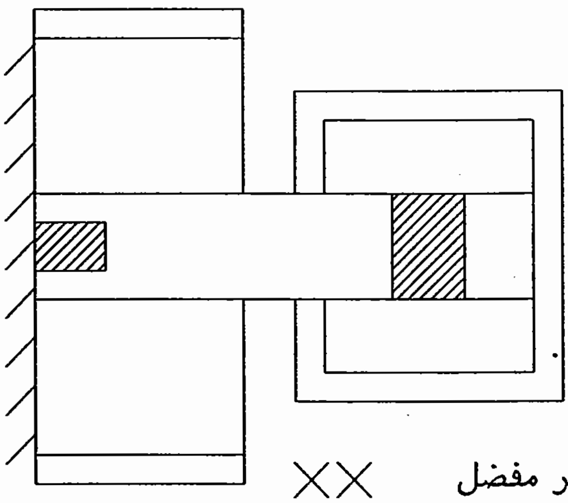
٢) اذا لم يحدث تداخل بين القاعدتين F_1 , F_2 يجب الا يقل الخلوص بين القاعدتين عن نصف طول F_2 او F_1 ايهما اصغر

$$X \geqslant \frac{L_1}{2} \text{ or } \frac{L_2}{2}$$ ايهما اصغر

٣) يجب الا تكون F_1 ذات استطالة كبيرة فى اتجاه حد الجار

$$\frac{B_1}{L_1} \leqslant 1.0 \longrightarrow 1.50$$

اذا لم يتحقق اى من الشروط السابقة نروح لحل الـ combined .

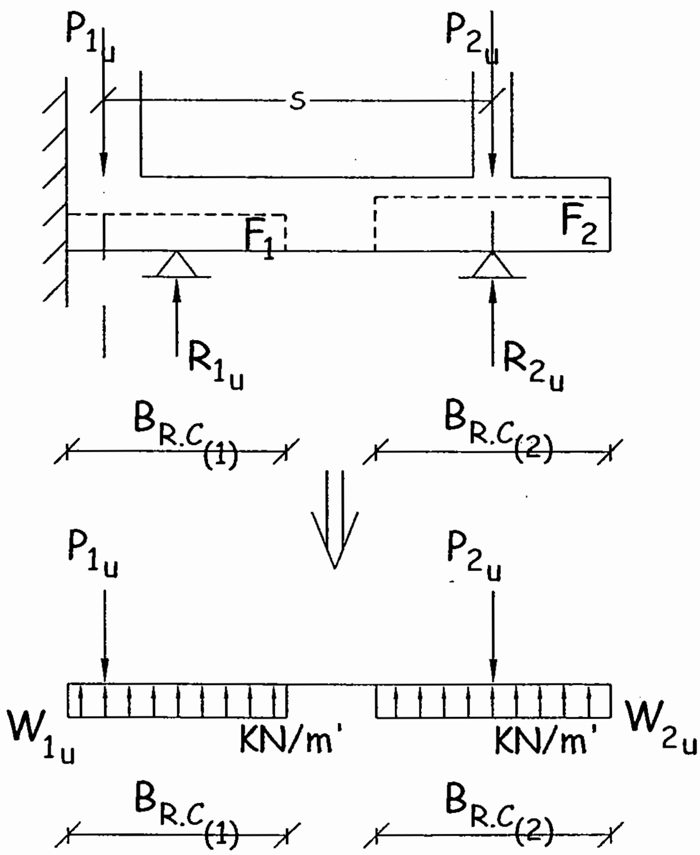


شكل غير مفضل XX

- اذا تحققت شروط ال strap beam نكمل التصميم كالآتى :-

(2) Calculate the ultimate loads and reactions on strap beam:-

P_{1_u} , P_{2_u} , R_{1_u} , R_{2_u}



* $W_{1_u} = \dfrac{R_{1_u}}{B_{R.C_{(1)}}} =$ KN/m'

* $W_{2_u} = \dfrac{R_{2_u}}{B_{R.C_{(2)}}} =$ KN/m'

(3) Design of strap beam:-

Draw S.F.D & B.M.D

- Point of zero shear:-

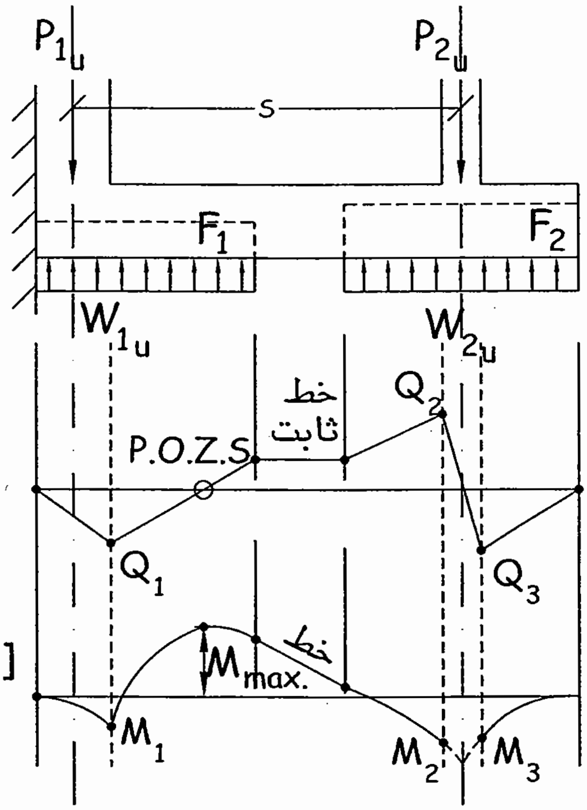
$P_{1_u} - W_{1_u} * X_o = \text{zero}$

get $X_o =$ ✓

$\therefore M_{max.} = \sum M @ X_o$

$= W_{1_u} * \dfrac{X_o^2}{2} - P_{1_u} [X_o - \dfrac{C_1}{2}]$

$=$ -ve KN.m علوى



- $$d_{beam\,(mm)} = C_1 \sqrt{\frac{M_{(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * b_{(mm)}}}$$ where $C_1 = 4.50$ [as a beam]

وتؤخذ كالمعتاد٣ و حاجة او٨ وحاجة

- $b \nless 40$ cm
- $b \nless C_1$ or C_2

لا يقل عرض الكمرة عن عرض العمود العمودى عليها

XX غير مفضل ✓✓

recommended b = d/2

- Check shear for strap beam:- [as a beam]

على بعد d/2 من وش العمود

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

من ال S.F.D

$$\therefore \quad Q_{su} = Q_{max.} - \frac{d}{2} * W_{1u} \text{ (or } W_{2u})$$

على حسب $Q_{max.}$ عند اى حمل من الاثنين

$$q_{su} = \frac{Q_{su}}{b * d} = \checkmark\checkmark \text{ N/mm}^2$$

[as a beam]

If $q_{su} < q_{scu\,min.} = 0.24 \sqrt{\frac{F_{cu}}{\gamma_c}}$

$\Longrightarrow$ use min. shear R.F.T 5 ϕ 10/m' 4 branches

لان عرض الكمرة 40 cm او اكثر

$\Rightarrow$ If $q_{su} > q_{scu\,max.} = 0.70 \sqrt{\frac{F_{cu}}{\gamma_c}}$

UNSAFE $\Rightarrow$ increase d_{beam} & recheck

$\Rightarrow$ If $q_{scu\,min.} < q_{su} < q_{scu\,max.}$ يتم تصميم الاكانات المطلوبة

design req. shear R.F.T :-

$$q_{su} - \frac{q_{scu}}{2} = \frac{n * A_{\varnothing} * F_y / \gamma_s}{b * S}$$ ⟶ assume n = 4 or 6

Ø 10 or 12

and get S

$$t_{beam} = d_{safe} + 7_{cm\ cover}$$

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* **Beam R.F.T:-**

- $A_{s\,top} = \dfrac{M_{max.\,top} * 10^6}{F_y * J * d(mm)} = \checkmark\checkmark \ mm^2/m'$

- $A_{s\,bott.} = \dfrac{M_{bottom} * 10^6}{F_y * J * d(mm)} = \checkmark\checkmark \ mm^2/m'$

M_{bottom} = biggest of M_1, M_2, M_3

العزوم على وش العمود من B.M.D

check $A_{s\,min.}$ =
- $1.3\ A_{s\,req.}$
- $\frac{1.1}{F_y}\ b\ d$

الاقل (of the two above)

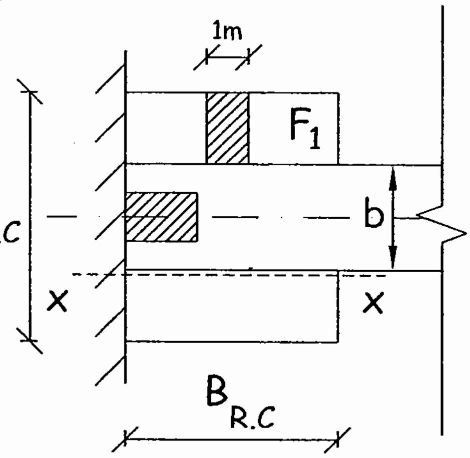
- $\frac{.15}{100}\ b\ d$

الاكبر (of الاقل and $\frac{.15}{100}\ b\ d$)

(4) Design of footings:- "as strip footing"

* For [F_1]:-

$$q_{u_1} = \frac{R_{1u}}{\underbrace{B_{R.C} * L_{R.C}}_{\text{of footing (1)}}} = \checkmark\checkmark \ KN/m^2$$



- critical section of moment:-

(x-x) على وش الكمرة

where $Z_1 = \frac{1}{2}(L_{R.C} - b)$

حيث b عرض الكمرة

$$\therefore M_{u_1 \, x-x} = q_{u_1} * \frac{Z_1^2}{2} * 1m = \checkmark\checkmark KN.m/m'$$

$$\therefore d_{(mm)} = 5\sqrt{\frac{M_{u1(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * 1000}} = \checkmark\checkmark \ mm$$

- check shear:-

على بعد $\frac{d}{2}$ من وش الكمرة

$$\therefore Q_{su1} = q_{u_1} * \ell_1 * 1m \qquad \text{where:-} \ \ell_1 = Z_1 - \frac{d}{2}$$

(d = depth of footing 1)

$$q_{su_1} = \frac{Q_{su_1}}{1000 * d_{f_1}} = \checkmark\checkmark \ N/mm^2 < q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}}$$

If UNSAFE

⟹ Increase d & recheck

$$t_{f_1} = d_{f_1 \, safe} + 7_{cm \, cover}$$

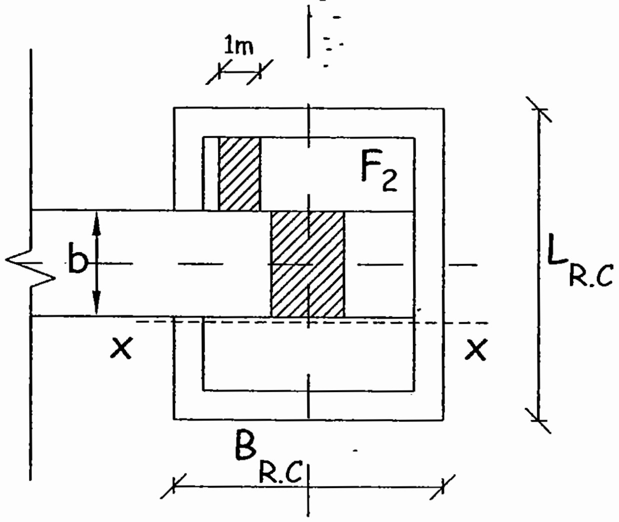
- R.F.T:

  - $A_{s_1} = \dfrac{M_{u_1} * 10^6}{F_y * J * d_{f_1}} = \checkmark\checkmark \; mm^2/m' \not< A_{s_{min./m'}}$ — تسليح سفلى عرضى

* For [F_2]:-

بالمثل مع F_1

$$q_{u_2} = \frac{R_{2u}}{\underbrace{B_{R.C} * L_{R.C}}_{\text{of footing (2)}}} = \checkmark\checkmark \; KN/m^2$$



$$Z_2 = \frac{1}{2}\left(L_{R.C\,②} - b\right)$$

$$M_{u_2} = q_{u_2} * \frac{Z_2^2}{2} * 1m = \checkmark\checkmark \; KN.m/m'$$

$$d_{f_2} = 5\sqrt{\frac{M_{u2(KN.m)} * 10^6}{f_{cu\,(N/mm^2)} * 1000}} = \checkmark\checkmark \; mm$$

- check shear:-

$$\ell_2 = Z_2 - \frac{d}{2}$$

(d = depth of footing 2)

$$\therefore Q_{su2} = q_{u_2} * \ell_2 * 1m$$

$$q_{su_2} = \frac{Q_{su_2}}{1000 * d_{f_2}} = \checkmark\checkmark \; N/mm^2 < q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}}$$

If UNSAFE

⟹ Increase d & recheck

$$t_{f_2} = d_{f_2\,safe} + 7_{cm\ cover}$$

- R.F.T:
  - $A_{s_2} = \dfrac{M_{u_2} * 10^6}{F_y * J * d_{f_2}} = \checkmark\checkmark \; mm^2/m' \not< A_{s_{min./m'}}$

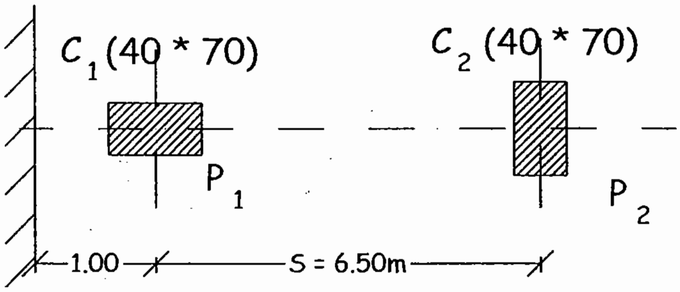
    تسليح سفلى عرضى

(5) Details :-

See the Example.

Example No. (3):-

Design a suitable foundation system for the shown two columns.



Given:-

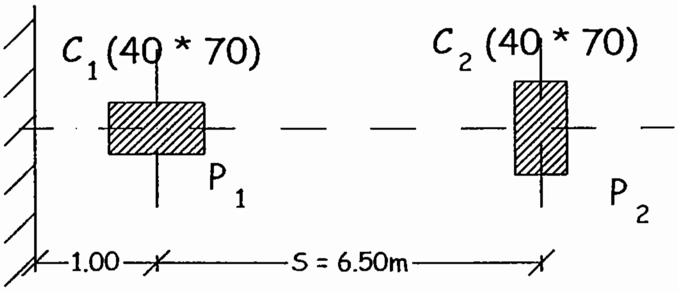
- $t_{P.C}$ = 40 cm
- $q_{all.}$ = 150 KN/m^2
- f_{cu} = 30 N/mm^2 , f_y = 360 N/mm^2
- P_1 = 1200 KN
- P_2 = 1500 KN

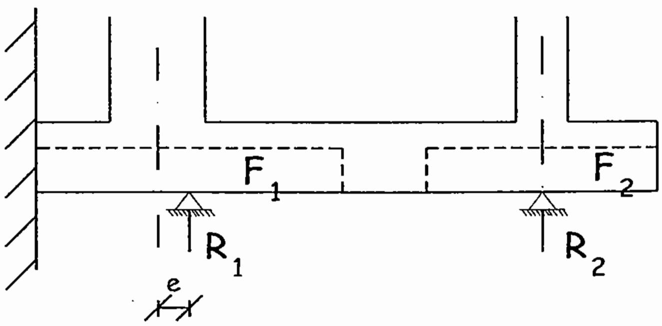
Solution:-

$$\frac{1}{2}\sqrt{\frac{P_1}{q_{all.}}} = \frac{1}{2}\sqrt{\frac{1200}{150}}$$

$$= 1.41 \text{ m} > D$$

$\therefore$ We can't use isolated footing, try strap beam.





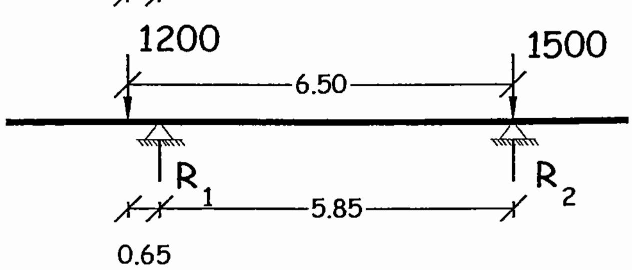
assume e = (0.1 ⟶ 0.2) * 6.50

e = 0.65 m

$$\therefore R_1 = \frac{1200 * 6.5}{5.85} = 1333.3 \text{ KN}$$

$$\therefore R_2 = [1200 + 1500] - 1333.3$$

$$= 1366.7 \text{ KN}$$



① Calculate the footing area :-

For [F_1]

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

$$\therefore\ A_{P.C} = \frac{R_1}{q_{all.}} = \frac{1333.3}{150} = 8.88\ m^2$$

$L_{P.C} = 2\,[\,e + D\,] = 2 * [0.65 + 1.0] = 3.30\ m$

$$\therefore\ B_{P.C} = \frac{A_{P.C}}{L_{P.C}} \quad \frac{8.88}{3.30} = 2.69\ m \approx 2.70\ m$$

$L_{R.C} = L_{P.C} = 3.30\ m$

$B_{R.C} = 2.70 - 2 * 0.40 = 1.90\ m$

For [F_2]

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

$$\therefore\ A_{P.C} = \frac{R_2}{q_{all.}} = \frac{1366.7}{150} = 9.11\ m^2 = B_{P.C} * L_{P.C} \quad \text{------→ ①}$$

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

$L_{P.C} - B_{P.C} = 0.7 - 0.4 = 0.3\ m \quad \text{------------→ ②}$

Solving ① & ② :-

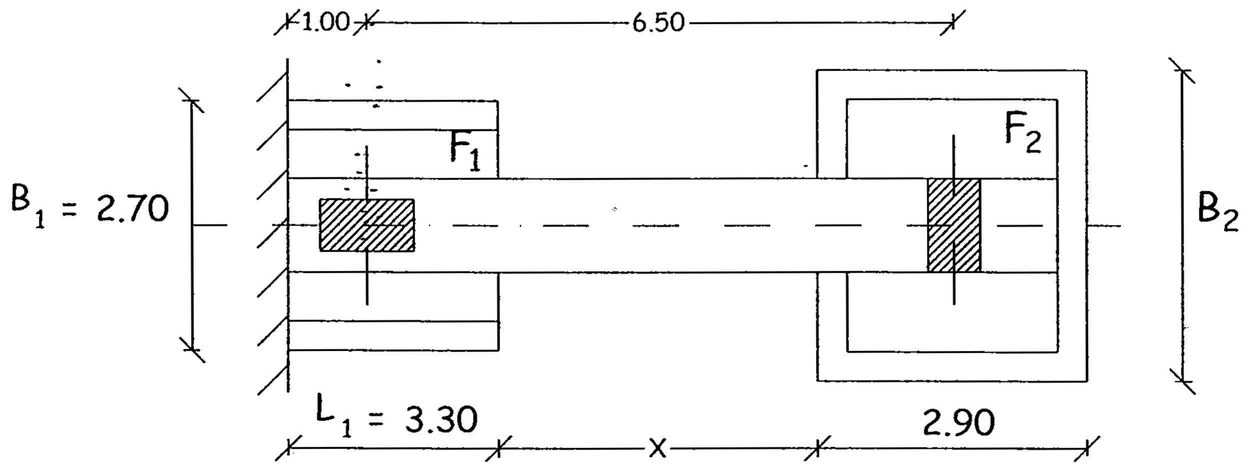
$9.11 = B_{P.C} * (0.3 + B_{P.C}) \implies B_{P.C} = 2.87 \approx 2.90\ m$

$L_{P.C} = 0.3 + B_{P.C} = 0.3 + 2.90 = 3.20\ m$

$L_{R.C} = 3.20 - 2 * 0.40 = 2.40\ m$

$B_{R.C} = 2.90 - 2 * 0.40 = 2.10\ m$

Check the validity of using strap beam:-



$$X = 1 + 6.5 - 3.3 - \frac{2.90}{2} = 2.75 \text{ m} > \frac{2.90}{2}$$

$$\frac{B_1}{L_1} = \frac{2.70}{3.30} < 1.00$$

OK

② Ultimate Loads and recations on Strap beam:-

P_{1_u} = 1.5 * 1200 = 1800 KN

P_{2_u} = 1.5 * 1500 = 2250 KN

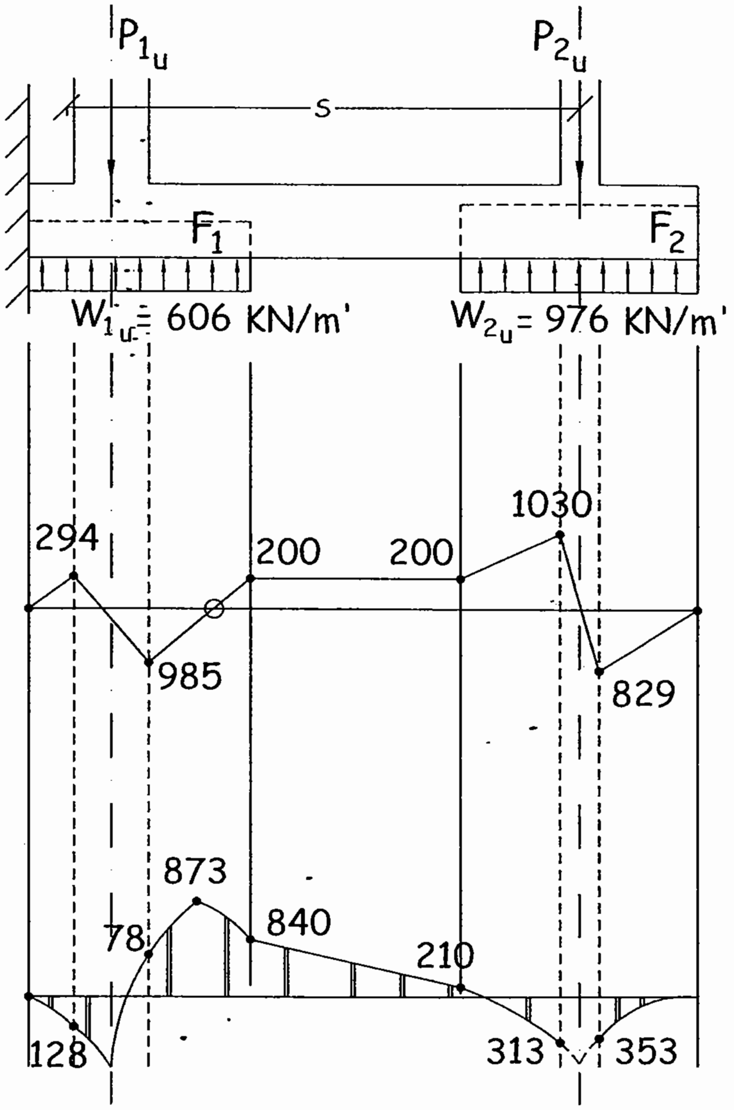
R_{1_u} = 1.5 * 1333.3 = 2000 KN

R_{2_u} = 1.5 * 1366.7 = 2050 KN

$$W_{1_u} = \frac{2000}{3.30} = 606 \text{ KN/m'}$$

$$W_{2_u} = \frac{2050}{2.10} = 976 \text{ KN/m'}$$

* get the point of zero shear:-



$$1800 = 606 * X_o \Longrightarrow X_o = 2.97 \text{ m}$$

$$M_{max.} = 606 * \frac{2.97^2}{2}$$

$$- 1800 * [2.97 - 1.00]$$

$$= - 873 \text{ KN.m}$$

$$\therefore d_b = 4.5\sqrt{\frac{M_{max.} * 10^6}{f_{cu} * b_{beam}}} = 4.5\sqrt{\frac{873 * 10^6}{30 * 700}} = 917.5 \text{ mm}$$

take d = 930 mm

③ Check Shear :-

$$Q_{max.} = 1030 \text{ KN}$$

$$Q_{su} = Q_{max.} - W * \frac{d}{2} = 1030 - 976 * \frac{0.93}{2} = 576.16 \text{ KN}$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{576.16 * 10^3}{700 * 930} = 0.885 \quad N/mm^2$$

$$q_{scu} = 0.24 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.24 \sqrt{\frac{30}{1.5}} = 1.07 \quad N/mm^2$$

$$\because \; q_{su} < q_{scu} \Rightarrow \therefore \text{ Use Min. Stirrups}$$

5 ϕ 10/m' 4 branches

④ R.F.T of beam:-

$$A_{s_{min.}} = \begin{cases} \frac{1.1}{360} * 700 * 930 = 1989.2 \ mm^2 \\ 1.3 * 1270 = 1651 \ mm^2 \longrightarrow \boxed{5 \phi 22} \\ 1.3 * 3220 = 4186 \ mm^2 \\ \frac{0.15}{100} * 700 * 930 = 977 \ mm^2 \end{cases}$$

$$A_{s_{Top}} = \frac{M_{u_{top}} * 10^6}{F_y * J * d} = \frac{873 * 10^6}{360 * 0.810 * 930} = 3220 \ mm^2$$

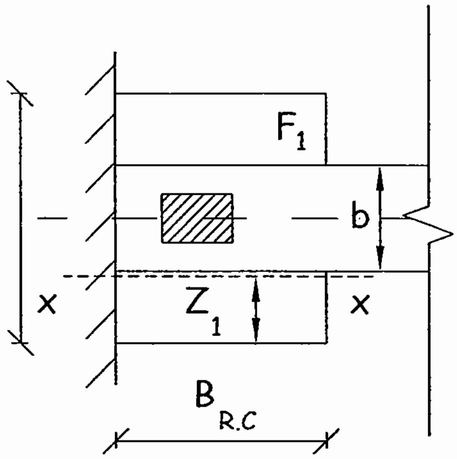
9 ϕ 22

$$A_{s_{Bottom}} = \frac{M_{u_{bot.}} * 10^6}{F_y * J * d} = \frac{353 * 10^6}{360 * 0.810 * 930} = 1270 \ mm^2 < A_{s_{min.}}$$

Use $A_{s_{Bottom}} = A_{s_{min.}} =$ **5 ϕ 22**

(5) Design of footings:-

For [F_1]



$$q_{u_1} = \frac{2000}{1.90 * 3.90} = 319 \quad KN/m^2$$

$$Z_1 = \frac{1}{2}(1.90 - 0.70) = 0.60 \; m$$

$$\therefore M_{u_1} = 319 * \frac{0.60^2}{2} * 1m$$

$$= 57.4 \quad KN.m/m'$$

$$d_{f_1} = 5\sqrt{\frac{57.4 * 10^6}{30 * 1000}} = 218 \quad mm < d_{min.} = 330 \quad mm$$

take d_{f_1} = 330 mm

Check Shear :-

$$\ell_1 = Z_1 - \frac{d}{2} = 0.60 - \frac{0.33}{2} = 0.435 \; m$$

$$Q_{su_1} = q_{u_1} * \ell_1 * 1m = 319 * 0.435 * 1m = 138.76 \quad KN/m'$$

$$q_{su_1} = \frac{Q_{su1} * 10^3}{d_1 * B_1} = \frac{138.76 * 10^3}{330 * 1000} = 0.42 \quad N/mm^2$$

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{30}{1.5}} = 0.716 \quad N/mm^2$$

$$\because q_{su_1} < q_{scu} \Rightarrow \therefore \text{SAFE}$$

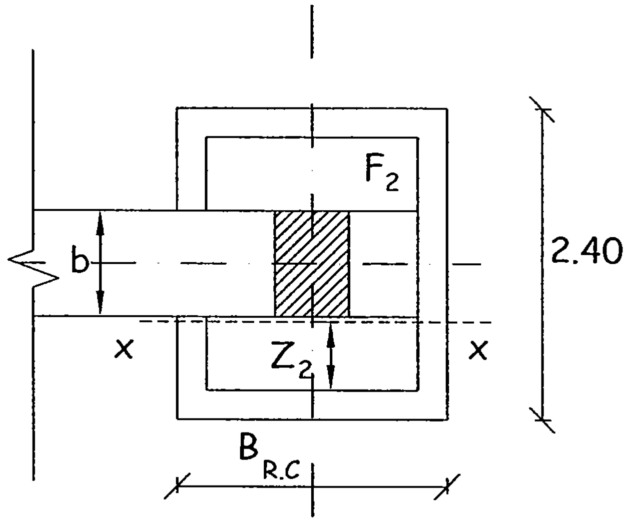
R.F.T:-

$$A_{s_1} = \frac{M_{u_1} * 10^6}{F_y * 0.826 * d} = \frac{57.4 * 10^6}{360 * 0.826 * 330} = 585 \quad mm^2/m'$$

6 ϕ 12/m'

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 330 = 495 \quad mm^2/m' \\ 5 \phi 12/m' = 565 \quad mm^2/m' \end{cases}$$

For [F_2]



$$q_{u_2} = \frac{2050}{2.10 * 2.40} = 407 \ KN/m^2$$

$$Z_2 = \frac{1}{2}(2.40 - 0.70) = 0.85 \ m$$

$$\therefore M_{u_2} = 407 * \frac{0.85^2}{2} * 1m$$

$$= 147 \ KN.m/m'$$

$$d_{f_2} = 5\sqrt{\frac{147 * 10^6}{30 * 1000}} = 351 \ mm$$

take $d_{f_2} = 380$ mm

Check Shear :-

$$\ell_2 = Z_2 - \frac{d}{2} = 0.85 - \frac{0.38}{2} = 0.66 \ m$$

$$Q_{su_2} = q_{u_2} * \ell_2 * 1m = 407 * 0.66 * 1m = 268.62 \ KN/m'$$

$$q_{su_2} = \frac{Q_{su_2} * 20^3}{d_2 * B_2} = \frac{268.62 * 10^3}{380 * 1000} = 0.706 \ N/mm^2$$

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{30}{1.5}} = 0.716 \ N/mm^2$$

$$\because q_{su_2} < q_{scu} \Rightarrow \therefore \text{SAFE}$$

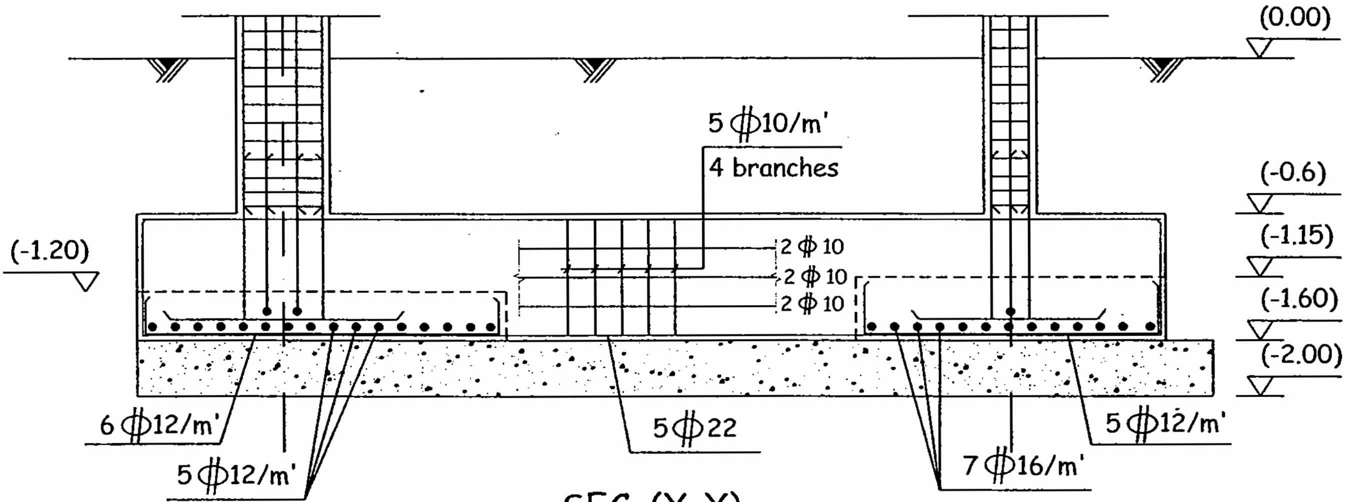
R.F.T:-

$$A_{s_2} = \frac{M_{u_2} * 10^6}{F_y * 0.826 * d} = \frac{147 * 10^6}{360 * 0.826 * 380} = 1300 \ mm^2/m'$$

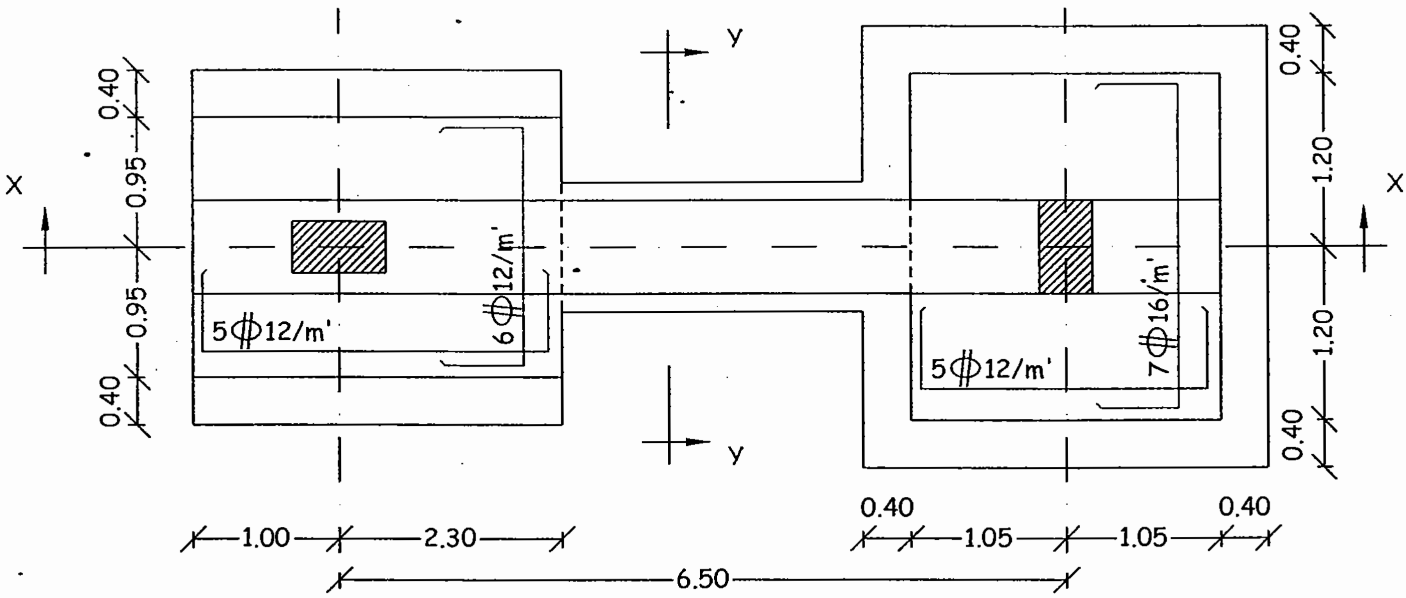
7 ϕ 16/m'

$$A_{s_{min.}} = \begin{cases} 1.5 * d_{mm} = 1.5 * 380 = 570 \ mm^2/m' \\ 5 \phi 12/m' = 565 \ mm^2/m' \end{cases}$$

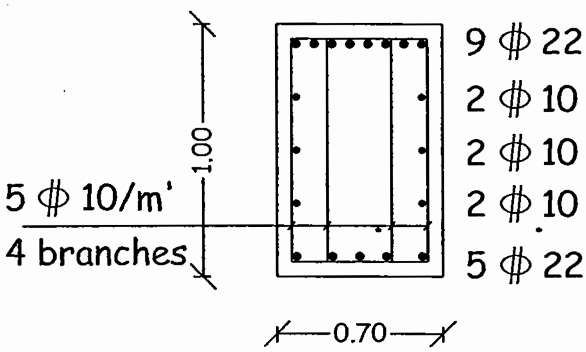
⑧ Details:



SEC. (X-X)



PLAN



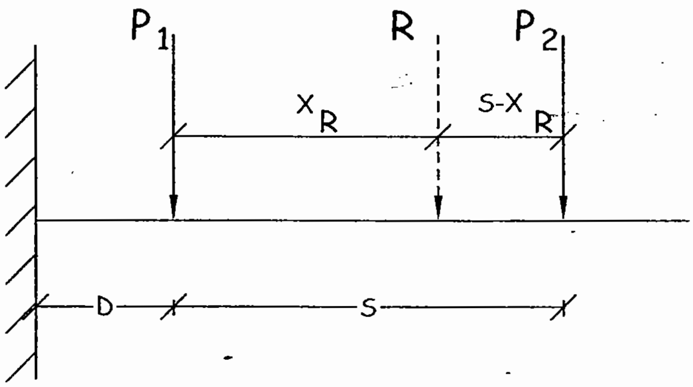
SEC. (Y-Y)

- فى حالة فشل حل ال strap beam   If $P_1 < P_2$

B Design of rectangular combined footing for existing "property lines" :-

- يتم حساب ابعاد الاساس بنفس الاسلوب العادى الذى سبق وان شرحناه فى ال combined footing مع ملاحظة الاتى :-

$P_1 < P_2$



$R = P_1 + P_2$

$$X_R = \frac{P_1 * S}{R}$$

$$\frac{L_{P.C}}{2} = X_R + D$$

$$\therefore L_{P.C} = 2(X_R + D)$$

and $L_{R.C} = L_{P.C} \Rightarrow$ وذلك لانه غير مسموح ببروز ال P.C عن ال R.C من ناحية الجار وبالتالى غير مسموح بالبروز من الناحية الاخرى حتى يظل $c.g_{R.C}$ at $c.g_{P.C}$ at $c.g_R$

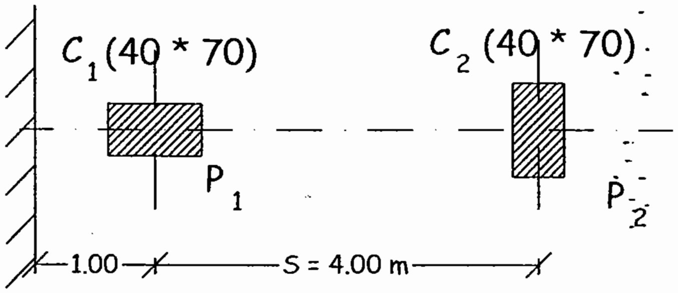
and get $B_{R.C}$, $B_{P.C}$

مسموح بالبروز فى الاتجاه العرضى عادى جدا

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

Example No. (4):-

Design a suitable foundation system for the shown two columns.



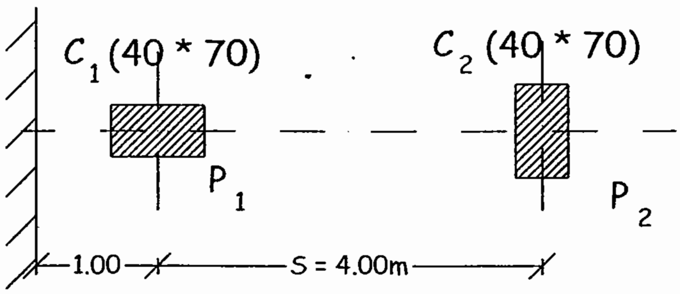
Given:-

- $t_{P.C}$ = 40 cm
- $q_{all.}$ = 150 KN/m²
- f_{cu} = 30 N/mm² , f_y = 360 N/mm²
- P_1 = 1200 KN
- P_2 = 1500 KN

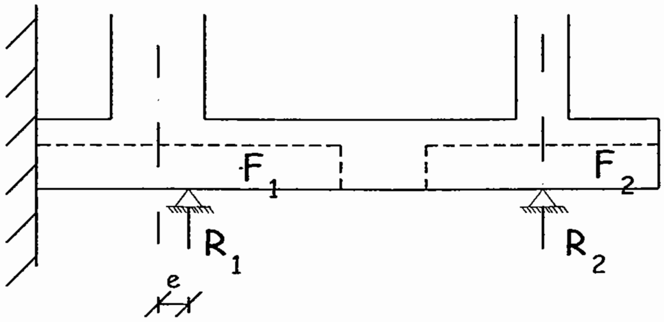
Solution:-

$$\frac{1}{2}\sqrt{\frac{P_1}{q_{all.}}} = \frac{1}{2}\sqrt{\frac{1200}{150}}$$

$$= 1.41 \text{ m} > D$$



∴ We can't use isolated footing, try strap beam.



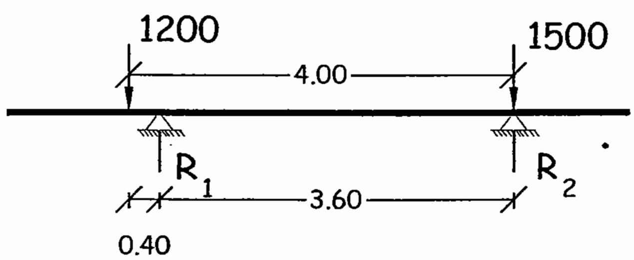
assume $e = (0.1 \longrightarrow 0.2) * 4.00$

$e = 0.40$ m

$$\therefore R_1 = \frac{1200 * 4.0}{3.60} = 1333.3 \text{ KN}$$

$$\therefore R_2 = [1200 + 1500] - 1333.3$$

$$= 1366.7 \text{ KN}$$



① Calculate the footing area :-

For [F_1]

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

$$\therefore\ A_{P.C} = \frac{R_1}{q_{all.}} = \frac{1333.3}{150} = 8.88\ m^2$$

$$L_{P.C} = 2\,[\,e + D\,] = 2 * [0.40 + 1.0] = 2.80\ m$$

$$\therefore\ B_{P.C} = \frac{A_{P.C}}{L_{P.C}} \quad \frac{8.88}{2.80} = 3.17\ m \approx 3.20\ m$$

For [F_2]

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

$$\therefore\ A_{P.C} = \frac{R_2}{q_{all.}} = \frac{1366.7}{150} = 9.11\ m^2 = B_{P.C} * L_{P.C} \quad \text{------→ ①}$$

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

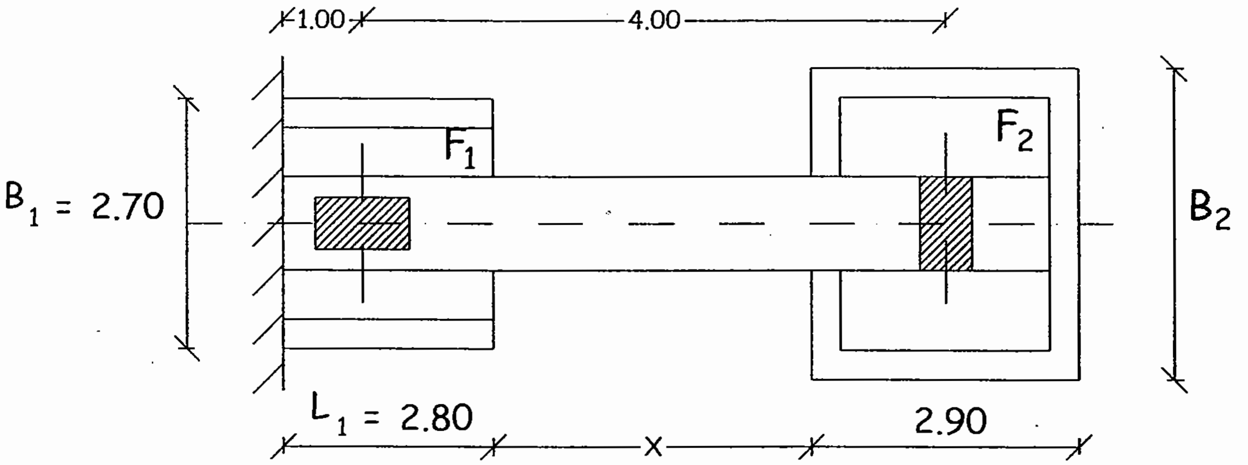
$$L_{P.C} - B_{P.C} = 0.7 - 0.4 = 0.3\ m \quad \text{------→ ②}$$

Solving ① & ② :-

$$9.11 = B_{P.C} * (0.3 + B_{P.C}) \Longrightarrow B_{P.C} = 2.87 \approx 2.90\ m$$

$$L_{P.C} = 0.3 + B_{P.C} = 0.3 + 2.90 = 3.20\ m$$

Check the validity of using strap beam:-



$$X = 4 + 1.0 - 2.80 - \frac{2.90}{2} = 0.75 \text{ m} < \frac{2.80}{2}$$

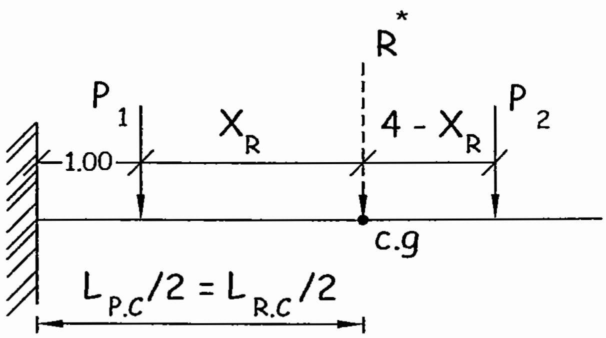
$$\frac{B_1}{L_1} = \frac{2.80}{3.20} < 1.00$$

We can't use Strap Beam

$\therefore$ Use combined footing $\Rightarrow \because P_1 < P_2 \Rightarrow \therefore$ Use rectangular combined

$$R^* = P_1 + P_2 = 1200 + 1500 = 2700 \text{ KN}$$

$$X_R = \frac{1500 * 4}{2700} = 2.22 \text{ m}$$



① Calculate the footing area :-

$$\frac{L_{P.C}}{2} = X_R + D = 2.22 + 1.00 = 3.22 \text{ m}$$

$$L_{P.C} = 2 * 3.22 = 6.44 \text{ m} \approx 6.45 \text{ m}$$

$$L_{P.C} = L_{R.C} = 6.45 \text{ m}$$

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

$$\therefore A_{P.C} = \frac{R^*}{q_{all.}} = \frac{2700}{150} = 18 \text{ m}^2 = B_{P.C} * 6.45$$

$$\therefore B_{P.C} = \frac{A_{P.C}}{L_{P.C}} = \frac{18}{6.45} = 2.79 \text{ m} \approx 2.80 \text{ m}$$

$$B_{R.C} = 2.80 - 2 * 0.40 = 2.00 \text{ m}$$

② Design in long direction:-

$$P_{1_u} = 1.5 * 1200 = 1800 \text{ KN}$$

$$P_{2_u} = 1.5 * 1500 = 2250 \text{ KN}$$

$$R^*_u = 1.5 * 2700 = 4050 \text{ KN}$$

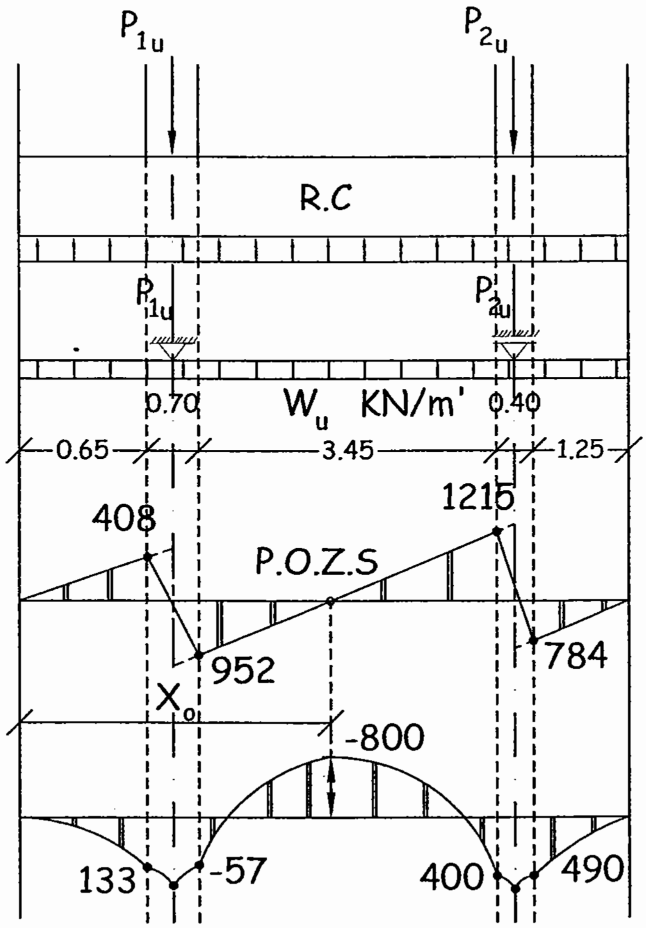
$$W_u = \frac{4050}{6.45} = 628 \text{ KN/m'}$$

$$q_u = \frac{4050}{6.45 * 2.00} = 314 \text{ KN/m}^2$$

* get the point of zero shear:-

$$1800 = 628 * X_o \Longrightarrow X_o = 2.87 \text{ m}$$

$$M_{max.} = 628 * \frac{2.87^2}{2} - 1800 * [2.87 - 0.65 - \frac{0.70}{2}] = -800 \text{ KN.m}$$



$$\therefore d = 5\sqrt{\frac{M_{max.} * 10^6}{f_{cu} * B_{R.C}(mm)}} = 5\sqrt{\frac{800 * 10^6}{30 * 2000}} = 577 \text{ mm}$$

take d = 580 mm

③ Check Shear :-

$Q_{max.} = 1215$ KN

$$Q_{su} = Q_{max.} - W * \frac{d}{2} = 1215 - 628 * \frac{0.58}{2} = 1032.88 \text{ KN}$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{1032.88 * 10^3}{580 * 2000} = 0.89 \text{ N/mm}^2$$

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

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

increase d $\Rightarrow$ take d = 680 mm

$$Q_{su} = Q_{max.} - W * \frac{d}{2} = 1215 - 628 * \frac{0.68}{2} = 1001.48 \text{ KN}$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{1001.48 * 10^3}{680 * 2000} = 0.736 \text{ N/mm}^2$$

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

increase d $\Rightarrow$ take d = 730 mm

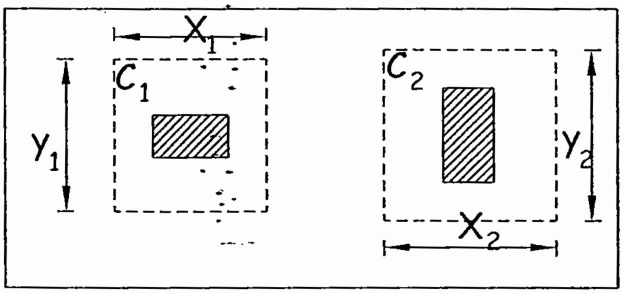
$$Q_{su} = Q_{max.} - W * \frac{d}{2} = 1215 - 628 * \frac{0.73}{2} = 985.76 \text{ KN}$$

$$q_{su} = \frac{Q_{su} * 10^3}{d * B} = \frac{985.78 * 10^3}{730 * 2000} = 0.675 \text{ N/mm}^2$$

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

take d = 730 mm

(4) Check Punching Shear :-



For C_1

$$Q_{p_1} = 1800 - 314 * (1.43 * 1.13)$$

$$= 1292.6 \text{ KN}$$

$$q_{p_1} = \frac{1292.6 * 10^3}{730 * [1430 + 1130] * 2}$$

$$= 0.345 \text{ N/mm}^2$$

$$q_{p_{cu_1}} = 0.316 \left(0.5 + \frac{0.4}{0.7}\right)\sqrt{\frac{30}{1.5}}$$

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

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

For C_2

$$Q_{p_2} = 2250 - 314 * (1.43 * 1.13)$$

$$= 1742.6 \text{ KN}$$

$$q_{p_2} = \frac{1742.6 * 10^3}{730 * [1430 + 1130] * 2}$$

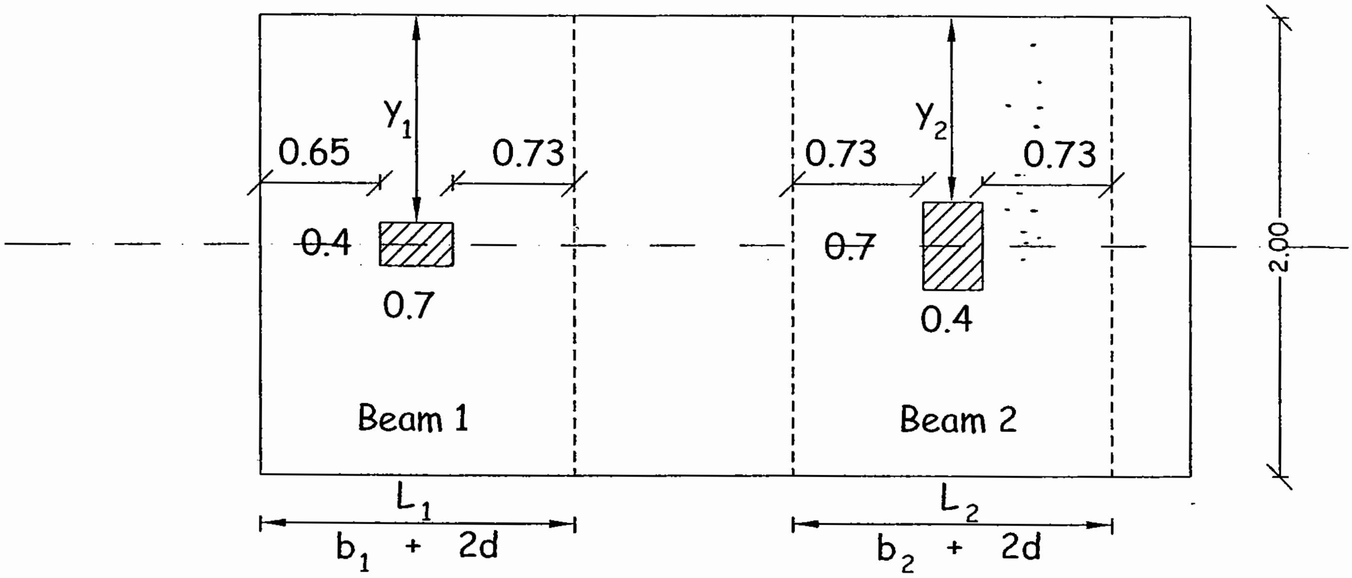
$$= 0.466 \text{ N/mm}^2$$

$$q_{p_{cu_2}} = 0.316 \left(0.5 + \frac{0.4}{0.7}\right)\sqrt{\frac{30}{1.5}}$$

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

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

(5) Design in short direction:-



For Beam 1

$L_1 = 0.7 + 0.73 + 0.65 = 2.08 \text{ m}$

$\therefore q_{u_1} = \dfrac{1800}{2.00 * 2.08} = 432.7 \text{ KN/m}^2$

$\therefore Y_1 = \dfrac{2.00 - 0.40}{2} = 0.80 \text{ m}$

$\therefore M_1 = 432.7 * \dfrac{0.80^2}{2} * 1\text{m}$

$= 138.46 \text{ KN.m/m'}$

For Beam 2

$L_2 = 0.40 + 2 * 0.73 = 1.86 \text{ m}$

$\therefore q_{u_2} = \dfrac{2250}{2.00 * 1.86} = 604.84 \text{ KN/m}^2$

$\therefore Y_2 = \dfrac{2.00 - 0.70}{2} = 0.65 \text{ m}$

$\therefore M_2 = 604.84 * \dfrac{0.65^2}{2} * 1\text{m}$

$= 127.77 \text{ KN.m/m'}$

$$M_{bigger} = M_1 = 138.46 \text{ KN.m/m'}$$

$$\therefore d = 730 = C_1 \sqrt{\frac{138.46 * 10^6}{30 * 1000}} \Rightarrow C_1 = 10.75 > 2.8 \quad \therefore \text{SAFE}$$

(6) Final Thickness :-

$d_{final} = 730 \text{ mm}$

$t_{final} = 730 + 70 \text{ (cover)} = 800 \text{ mm}$

⑦ R.F.T :-

$$A_{s_{min.}} = \begin{Bmatrix} 1.5 * d_{mm} = 1.5 * 730 = 1095 \ mm^2/m' \\ 5 \phi 12/m' = 565 \ mm^2/m' \end{Bmatrix} \boxed{6 \phi 16/m'}$$

In Long direction:-

$$A_{s_{Top}} = \frac{M_{u_{top}} * 10^6 / B}{F_y * 0.826 * d} = \frac{800 * 10^6 / 2.00}{360 * 0.826 * 730} = 1842.7 \ mm^2/m'$$

$$\boxed{8 \phi 18/m'}$$

$$A_{s_{Bottom}} = \frac{M_{u_{bot.}} * 10^6 / B}{F_y * 0.826 * d} = \frac{490 * 10^6 / 2.00}{360 * 0.826 * 730} = 1128.65 \ mm^2/m'$$

$$\boxed{6 \phi 16/m'}$$

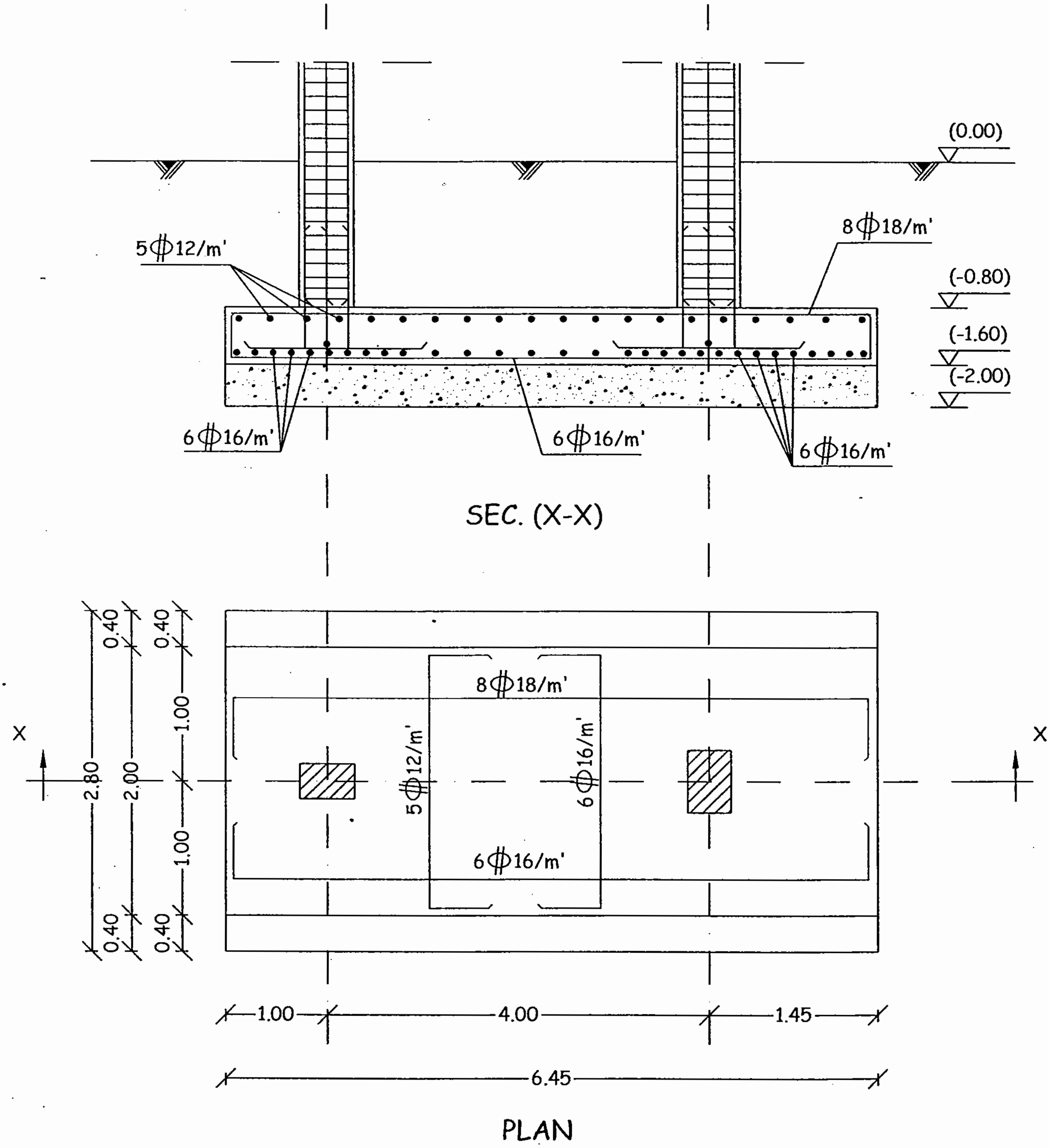
In Short direction:-

$$A_{s_1} = \frac{M_{u_1} * 10^6}{F_y * 0.826 * d} = \frac{138.46 * 10^6}{360 * 0.826 * 730} = 637 \ mm^2/m' < A_{s_{min.}}$$

$$A_{s_2} = \frac{M_{u_2} * 10^6}{F_y * 0.826 * d} = \frac{127.77 * 10^6}{360 * 0.826 * 730} = 588 \ mm^2/m' < A_{s_{min.}}$$

use $A_{s_{min.}}$ $\boxed{6 \phi 16/m'}$

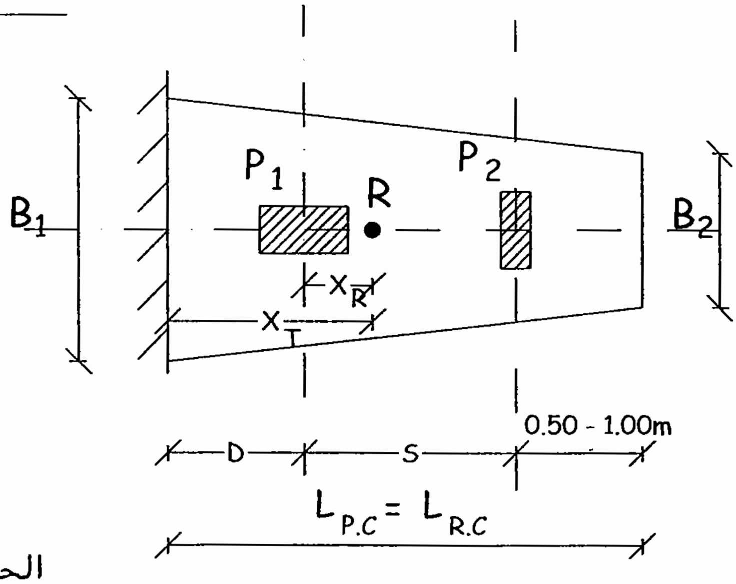
⑧ Details:



(0.00)
8Φ18/m'
5Φ12/m'
(-0.80)
(-1.60)
(-2.00)
6Φ16/m'
6Φ16/m'
6Φ16/m'
SEC. (X-X)
X
X
0.40
0.40
1.00
2.80
2.00
1.00
0.40
0.40
8Φ18/m'
5Φ12/m'
6Φ16/m'
6Φ16/m'
1.00
4.00
1.45
6.45
PLAN

If $P_1 > P_2$ strap beam فى حالة فشل حل ال -

C Design of Trapezoidal combined footing for existing "property lines" :-



- Steps of Design :-

(1) Dimensions of footing:-

- $R = P_1 + P_2$

الحمل الصغير

$$X_R = \frac{P_2 * S}{R}$$

$c.g_{loads} \equiv c.g_{trapezoidal\ area}$

لاحظ ان
$L_{P.C} = L_{R.C}$

- get $X_T = X_R + D$
- get $L_{P.C} = L_{R.C} = D + S + \frac{C_2}{2} + (0.5 - 1m)$

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

$$A_{P.C} = \frac{R}{q_{all.}} = L * [\frac{B_1 + B_2}{2}] \rightarrow ①$$

and

$$X_T = \frac{L}{3} * [\frac{B_1 + 2B_2}{B_1 + B_2}] \rightarrow ②$$

and get $B_{1\,P.C}$ & $B_{2\,P.C}$

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

$$A_{R.C} = \frac{R}{q_{all.}} = L * [\frac{B_1 + B_2}{2}] \rightarrow ①$$

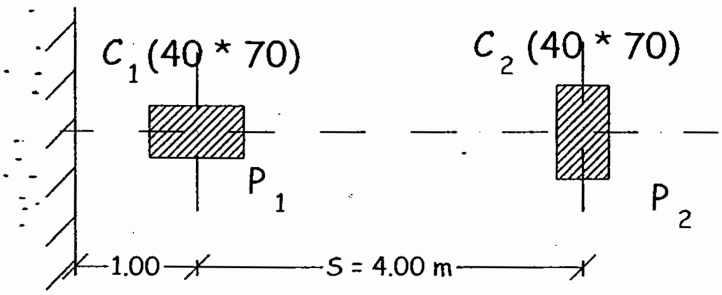
and

$$X_T = \frac{L}{3} * [\frac{B_1 + 2B_2}{B_1 + B_2}] \rightarrow ②$$

and get $B_{1\,R.C}$ & $B_{2\,R.C}$

Example No. (5):-

Design a suitable foundation system for the shown two columns.



Given:-

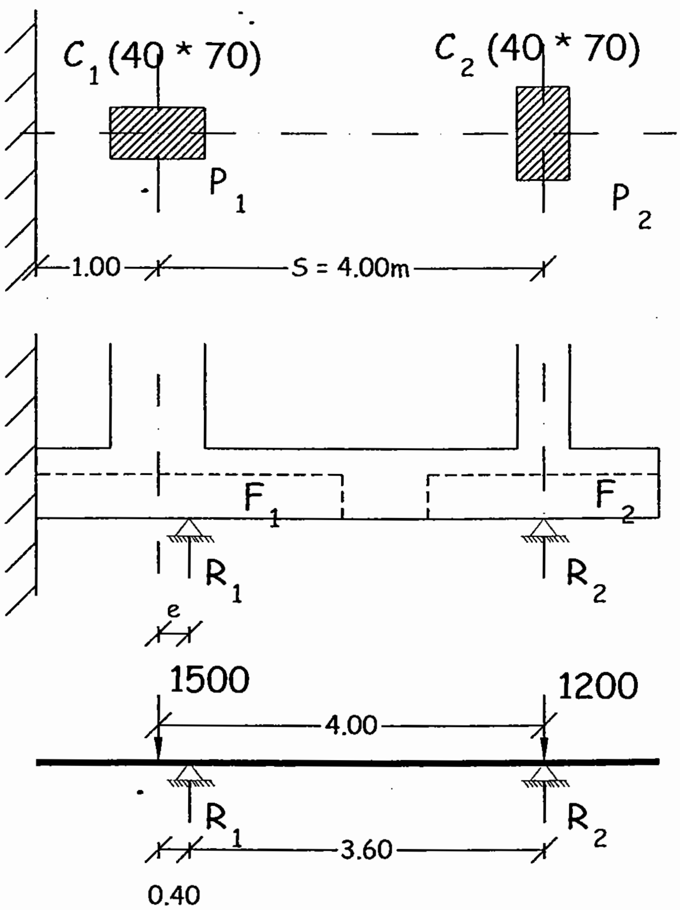
- $t_{P.C}$ = 40 cm
- $q_{all.}$ = 150 KN/m²
- f_{cu} = 30 N/mm², f_y = 360 N/mm²
- P_1 = 1500 KN
- P_2 = 1200 KN

Solution:-

$$\frac{1}{2}\sqrt{\frac{P_1}{q_{all.}}} = \frac{1}{2}\sqrt{\frac{1500}{150}}$$

$$= 1.58\,m > D$$

∴ We can't use isolated footing, try strap beam.



assume $e = (0.1 \longrightarrow 0.2) * 4.00$

$e = 0.40$ m

$$\therefore R_1 = \frac{1500 * 4.0}{3.60} = 1666.7 \text{ KN}$$

$$\therefore R_2 = [1200 + 1500] - 1666.7$$

$$= 1033.3 \text{ KN}$$

① Calculate the footing area :-

For [F_1]

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

$$\therefore\ A_{P.C} = \frac{R_1}{q_{all.}} = \frac{1666.7}{150} = 11.11\ m^2$$

$$L_{P.C} = 2\,[\,e + D\,] = 2 * [0.40 + 1.0] = 2.80\ m$$

$$\therefore\ B_{P.C} = \frac{A_{P.C}}{L_{P.C}} \quad \frac{11.11}{2.80} = 3.96\ m \approx 4.00\ m$$

For [F_2]

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

$$\therefore\ A_{P.C} = \frac{R_2}{q_{all.}} = \frac{1033.3}{150} = 6.89\ m^2 = B_{P.C} * L_{P.C} \quad \longrightarrow ①$$

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

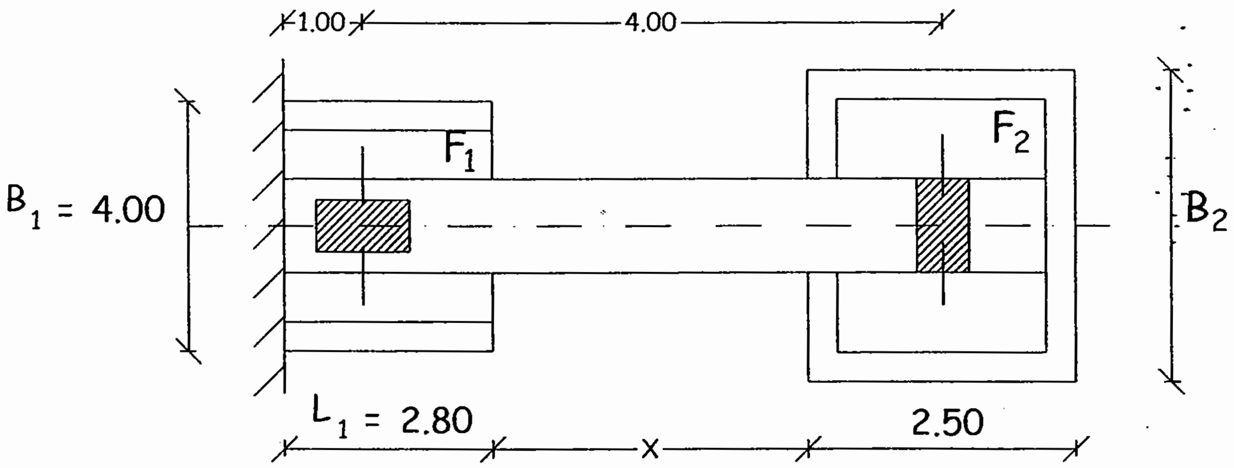
$$L_{P.C} - B_{P.C} = 0.7 - 0.4 = 0.3\ m \quad \longrightarrow ②$$

Solving ① & ② :-

$$6.89 = B_{P.C} * (0.3 + B_{P.C}) \implies B_{P.C} = 2.48 \approx 2.50\ m$$

$$L_{P.C} = 0.3 + B_{P.C} = 0.3 + 2.50 = 2.80\ m$$

Check the validity of using strap beam:-



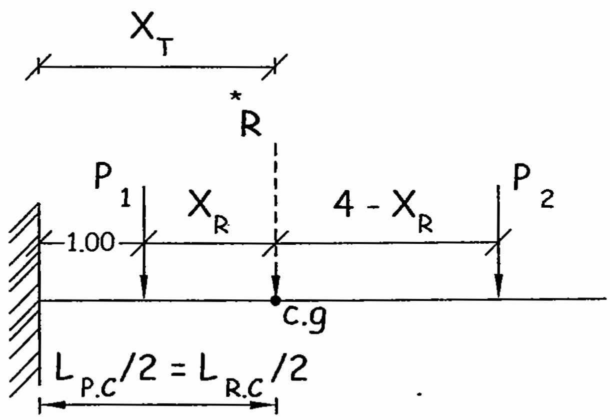
$$X = 4 + 1.0 - 2.80 - \frac{2.50}{2} = 0.875 \text{ m} < \frac{2.50}{2}$$

$$\frac{B_1}{L_1} = \frac{2.80}{4.00} < 1.00$$

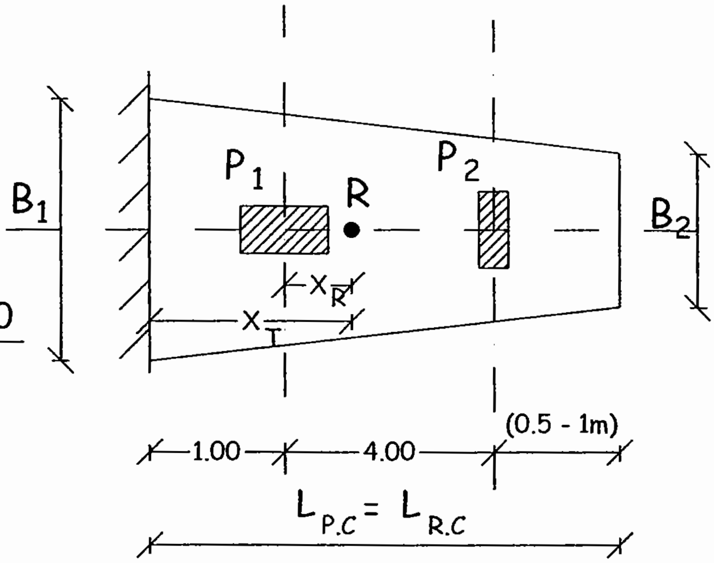
We can't use Strap Beam

$\therefore$ Use combined footing $\Rightarrow \because P_1 > P_2 \Rightarrow \therefore$ Use trapezoidal combined

$$R = P_1 + P_2 = 1500 + 1200 = 2700 \text{ KN}$$



① Calculate the footing area :-



$$X_R = \frac{1200 * 4}{2700} = 1.78 \text{ m}$$

$$X_T = 1.78 + 1.00 = 2.78 \text{ m}$$

$$L_{P.C} = L_{R.C} = 1.00 + 4.00 + \frac{0.40}{2} + 0.5 \text{ m} = 5.70 \text{ m}$$

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

$$\therefore A_{P.C} = \frac{R}{q_{all.}} = \frac{2700}{150} = 18 \text{ m}^2$$

$$18 = 5.70 * \frac{B_1 + B_2}{2} \Rightarrow B_1 + B_2 = 6.316 \text{ m} \quad \text{---→ ①}$$

$$\because X_T = \frac{L}{3}\left[\frac{B_1 + 2B_2}{B_1 + B_2}\right] \Rightarrow 2.78 = \frac{5.70}{3}\left[\frac{B_1 + 2B_2}{B_1 + B_2}\right] \quad \text{---→ ②}$$

Solving ① & ② :-

$$2.78 = \frac{5.70}{3}\left[\frac{6.316 + B_2}{6.316}\right] \Rightarrow \therefore B_1 = 3.40 \text{ m}, \quad B_2 = 2.95 \text{ m}$$

$B_1 > B_2$ Logic