Design of Shallow Foundations.

نسألكم الدعاء

نتقدم بالشكر للدكتور/ محمد ماهر توفيق .
حيث كانت مذكراته هى المرجع الرئيسى لمعلوماتنا فى هذا الملف .

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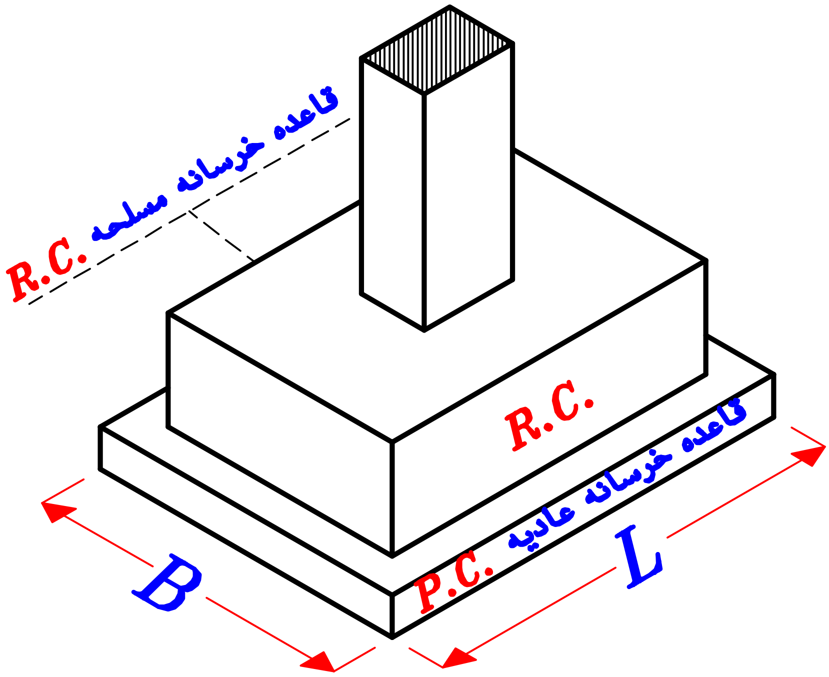
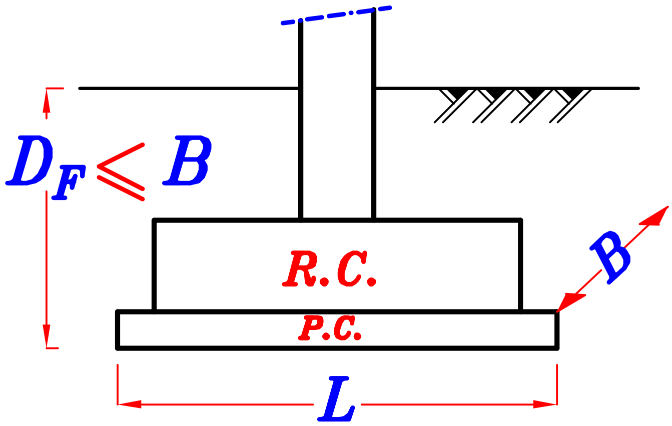
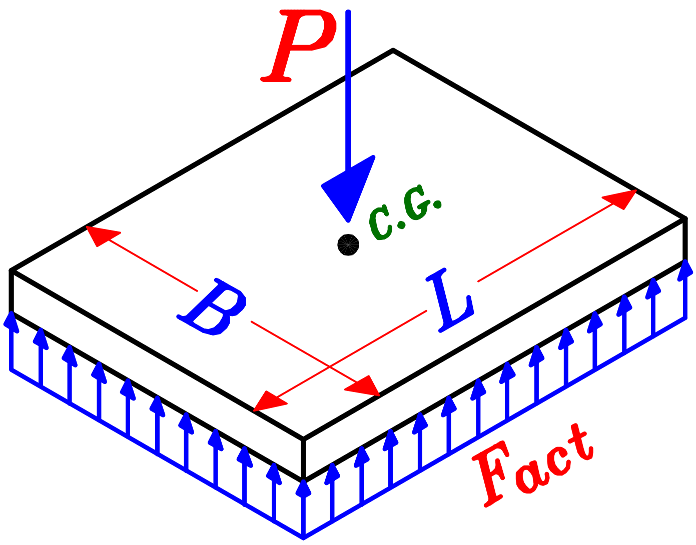
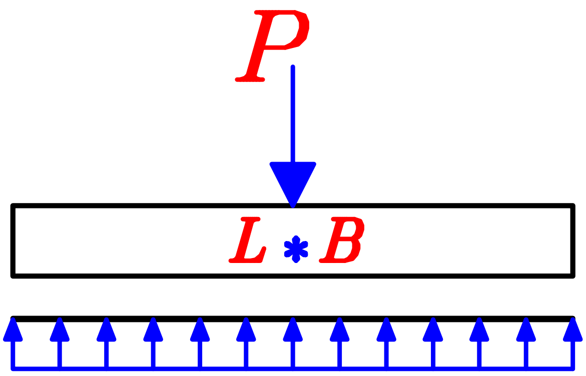
مقدمه تصميم القواعد السطحيه .









$$F_{act} = \frac{P}{L * B}$$

الهدف من استخدام القواعد السطحيه (***Shallow Foundations***)

هو تحويل حمل (***Load***) العمود المركز الى اجهاد منتظم (***uniform stress***) على التربه .

و ذلك لانه من الافضل لتربه التأسيس تحمل اجهادات منتظمه (***uniform stresses***)

عن تحمل أحمال مركزه (***Concentrated Loads***) من الاعمده .

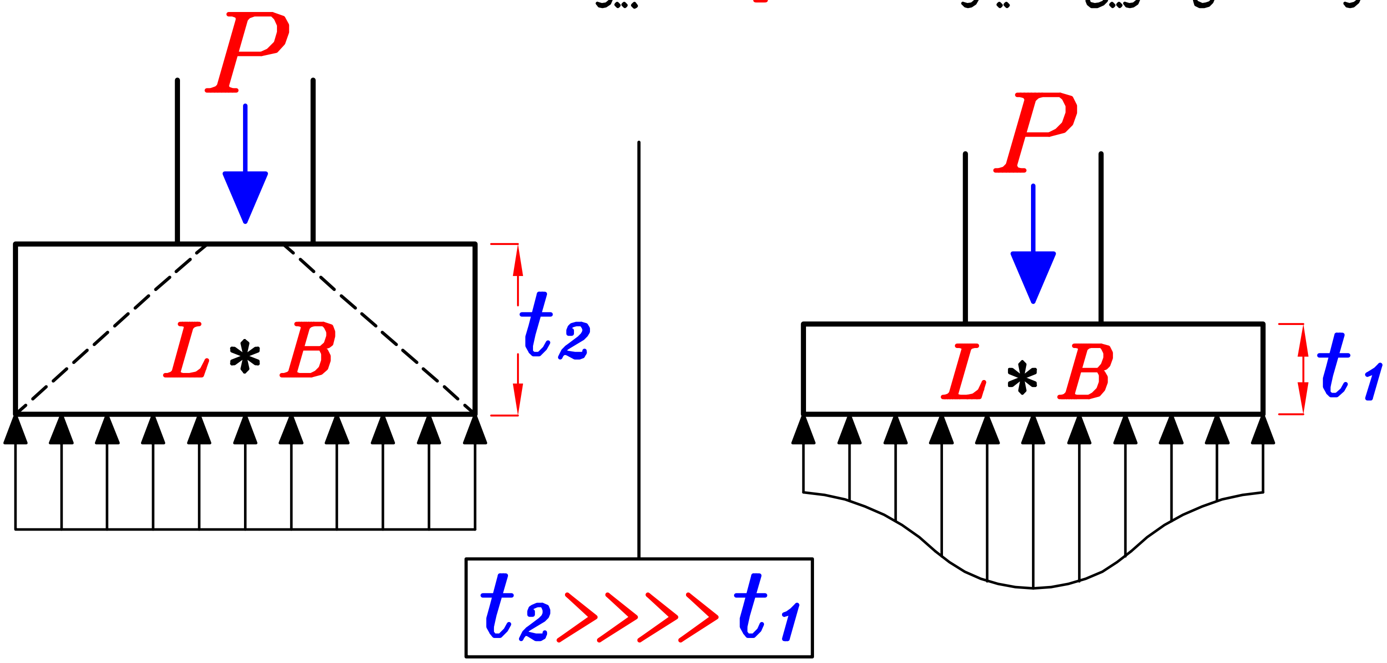
و ذلك لتفادى حدوث اختراق (***punching***) للعمود داخل التربه .

المبدأ الأساسى فى تصميم القواعد السطحيه .

يعتمد التصميم البسيط للقواعد السطحيه على عمل اجهاد منتظم (**uniform stresses**) على القواعد يمثل رد فعل تربه التأسيس .

و لتحقيق ذلك يجب أن تكون القاعده جاسئه (**Rigid Footing**)

و ذلك عن طريق اختيار سُمك (**depth**) كبير للقاعده .



Footing (2)

Rigid Footing

- Area $L * B$
- Column Load P

Uniform contact stress.

Footing (1)

Flexible Footing

- Area $L * B$
- Column Load P

Non-Uniform contact stress.

لعمل قاعده جاسئه (**Rigid Footing**) يجب اختيار (**depth**) كبير للقاعده .

توجد عده أنواع و أشكال للقواعد السطحيه يتم أختيارها تبعا ل :-

١- شكل العمود أو الحائط المحمول على القاعده .

٢- الحمل على العمود و المسافات بين الاعمده .

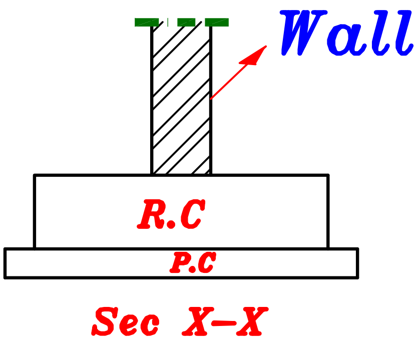
٣- وجود حد جار (*property Line*) بجوار الاعمده .

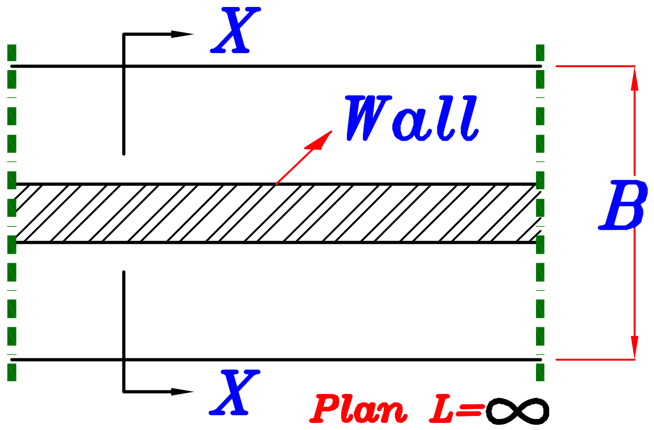
Types of Shallow Foundations.

أنواع القواعد السطحيه .

1- Strip Footing . القواعد الشريطيه

- هى قواعد طوليه لحمل الحوائط السانده و الاسوار .





2- Isolated Footing . القواعد المنفصله

- هى قواعد ذات مساحه محدده (*L * B*) تنفذ لتحمل عمود واحد فقط و لها اشكال مختلفه منها :-

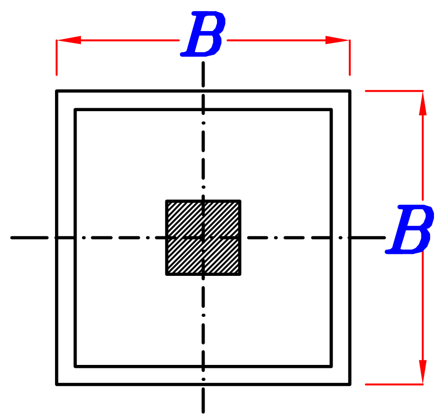
a - Squared Isolated Footing. قواعد مربعه

- تستخدم فى حالة :

– عمود مربع .

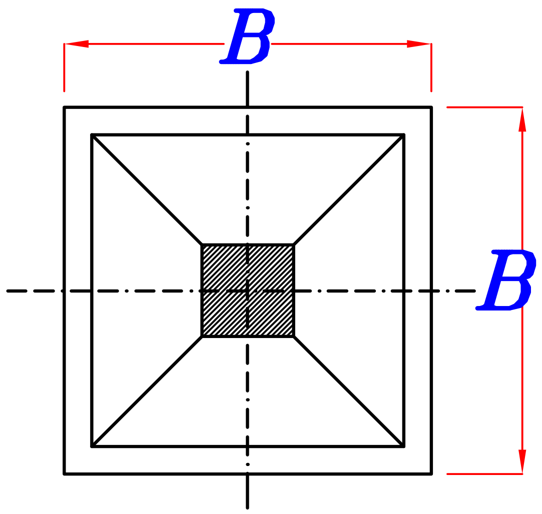
– عمود دائرى .

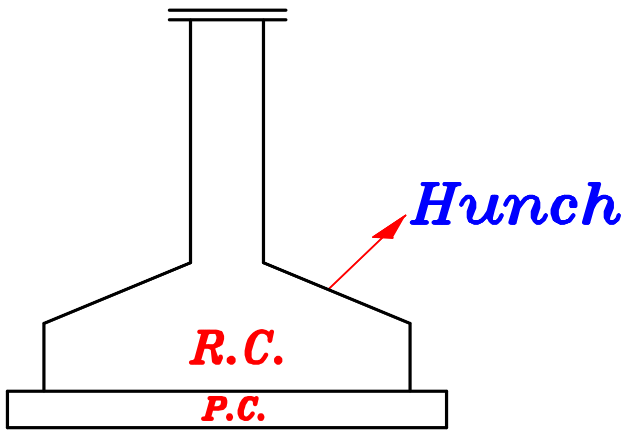
– يُمكن مع الاعمده المستطيله لكنه غير مفضل .



b - Haunched Square Isolated Footing.

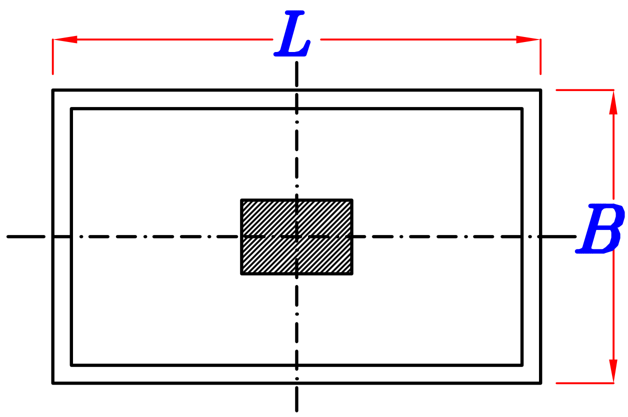
• هى قواعد منفصله ذات سُمك متغير (كبير عند العمود و يقل عند الاطراف).
و تستخدم مع الاعمده ذات الاحمال الكبيره جدا مثل اعمده الكبارى .





c - Rectangular Isolated Footing. قواعد مستطيله

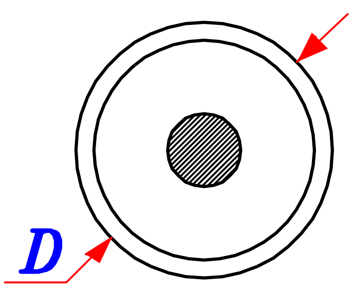
• تستخدم فى حالة :
- الاعمده المستطيله .
- يُمكن مع الاعمده المربعه لكنه غير مفضل .



d - Circular Isolated Footing. قواعد دائريه

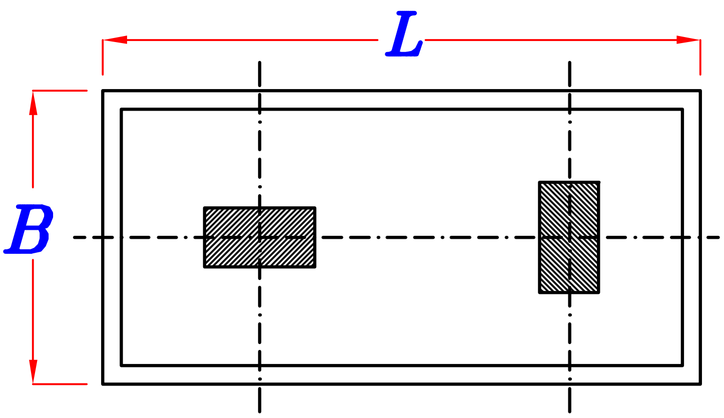
• تستخدم فقط مع الاعمده الدائرية

* و هى صعبه و مكلفه فى التنفيذ لذلك يستخدم بدلا منها القواعد المربعه .

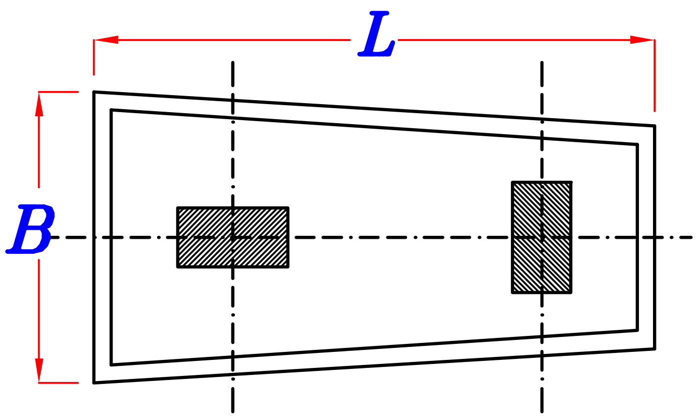


3- Combined Footing. القواعد المشتركه

• هى قواعد تحمل عمودين أو أكثر و لها شكلان :-



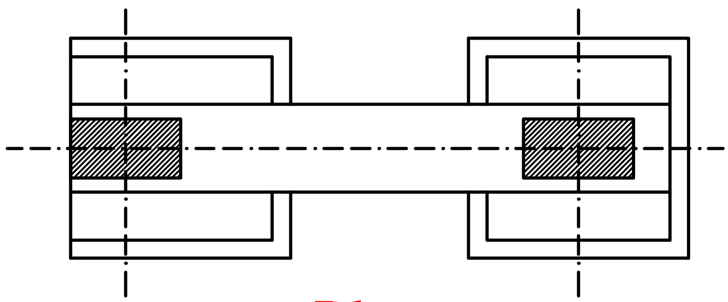
Rectangular



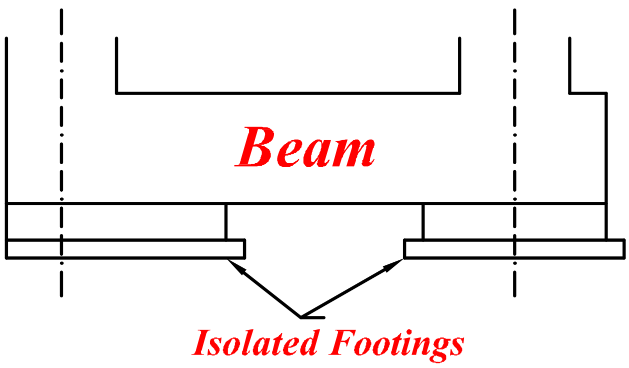
Trapezoidal

4- Strap Beam.

• هى كمره عميقه (مقلوبه) تتحمل عمودين و تربطهما سويا ثم ترتكز على قاعدتين منفصلتين .



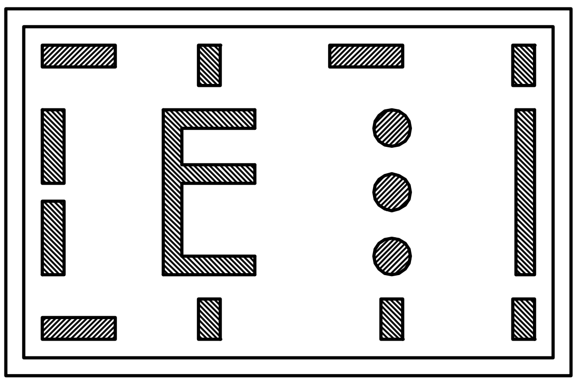
Plan



5- Raft. (اللبشه)

• هى قاعده واحده تتحمل جميع أعمده المنشأ بكافه أشكال الاعمده و كذلك

ال *Cores , Shear Walls*

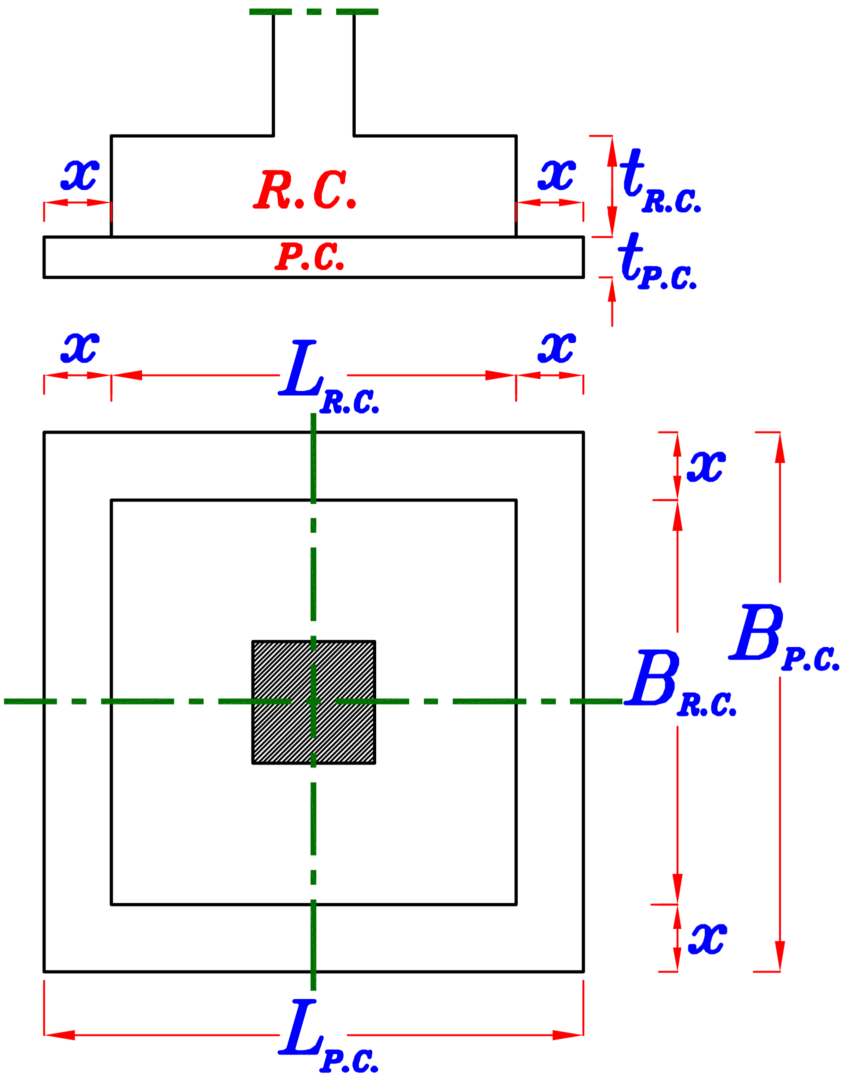


Components Of Shallow Foundations

دائما تتكون أى قاعده من جزئين :-

1- *Plain Concrete Footing* (*P.C.*)

2- *Reinforced Concrete Footing* (*R.C.*)



* وظيفه القاعده العاديه (*P.C.*) :-

١- تكون بمثابه فرشه أسفل القاعده المسلحه لضمان تسويه السطح الذى سوف يُرص عليه حديد التسليح و كذلك ليكون الحديد بعيدا عن حبيبات التربه لما قد تحمله التربه من أملاح قد تؤدى الى صدأ الحديد.

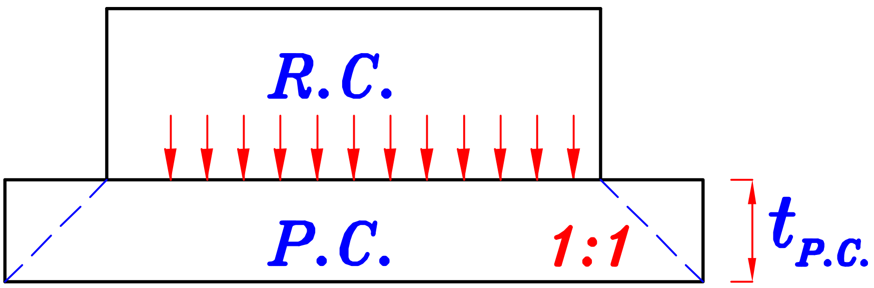
٢- وجود القاعده العاديه يحسن كثيرا من توزيع اجهاد القاعده من حمل الصمود على تربه التأسيس.

ملحوظه هامه :

تكون أبعاد القاعده العاديه $(L_{P.C.}, B_{P.C.})$ أكبر من أبعاد القاعده المسلحه $(L_{R.C.}, B_{R.C.})$ بمقدار (X) من كل جهه .

حيث المسافه (X) تمثل بروز القاعده العاديه عن المسلحه و تؤخذ بما يكفى لمنع حدوث إنهيار بالقص على هذا الجزء .

Diagonal tention failure due to stress Concentration at P.C footing lower corner



" Recommended " $$X = t_{P.C.}$$

و بالتالى تكون العلاقه بين القاعدتين المسلحه و العاديه دائما كالاتى :-

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

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

Allowable stress of concrete.

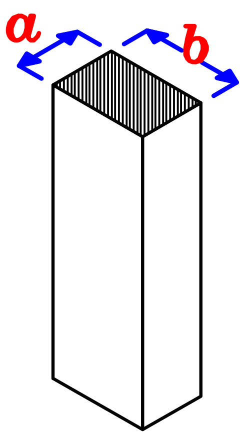
(1) $q_{s\,cu}$ = Allowable shear stress in Foundations.

$$q_{s\,cu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$\gamma_c = 1.5$$

(2) $q_{p\,cu}$ = Allowable punching shear stress in Foundations.

$$q_{p\,cu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



حيث

a = عرض العمود

b = عمق العمود

بشرط $\frac{a}{b} < 0.5$

IF $\frac{a}{b} > 0.50$ taken = 0.50

Requirments For design of shallow Foundations.

لتصميم أى قاعده لابد من توافر المعلومات الاتيه :

* Givens :-

1- Column load حمل العمود

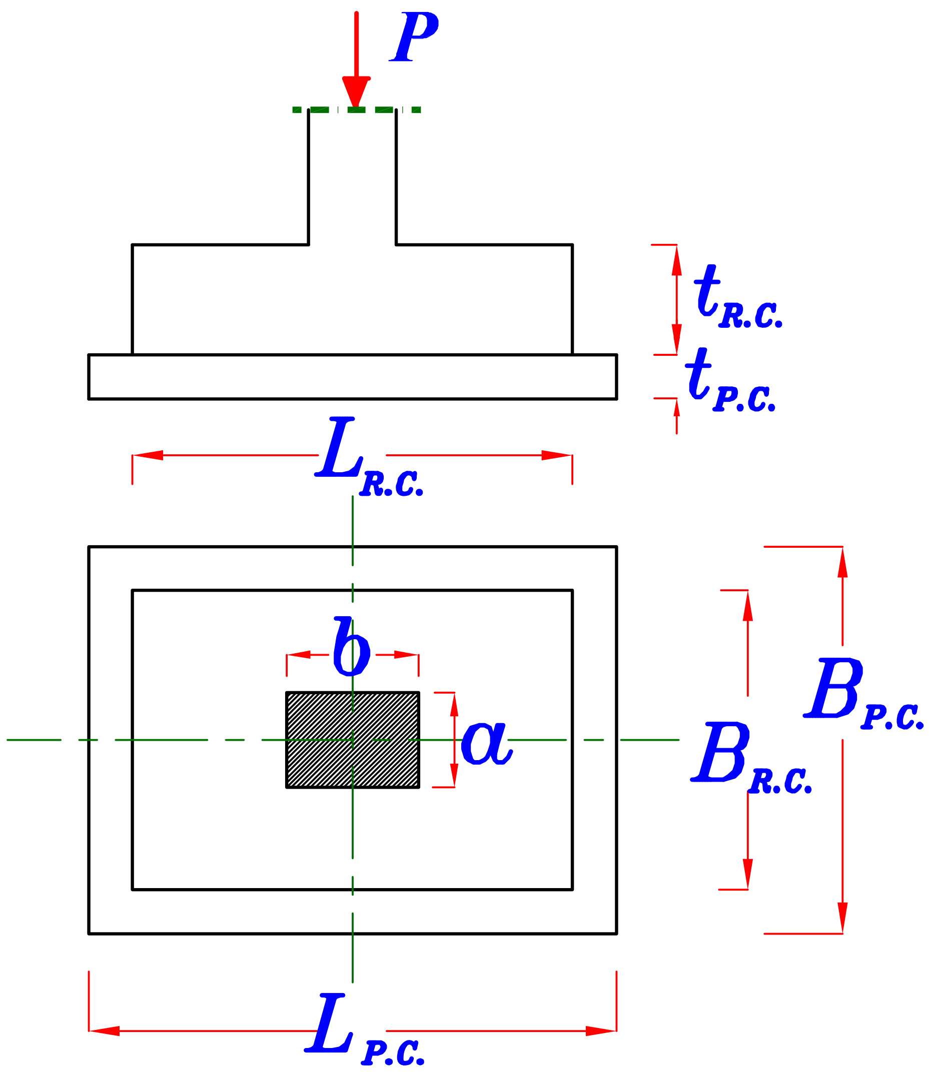
2- Column dimensions أبعاد العمود

3- Allowable bearing capacity q_{all}

4- $t_{P.C.}$ can be assumed.

5- F_{cu} , F_y

* Concrete dimensions of shallow Foundations.



المبادئ الاساسيه لحسابات أبعاد أى قاعده.

① $t_{P.C.}$ is assumed $10 \longrightarrow 40$ cm

$t_{P.C.} = 10 \longrightarrow 20$ cm فرشه نظافه و لا تؤخذ فى حسابات التصميم

$t_{P.C.} = 20 \longrightarrow 40$ cm تعتبر قاعده عاديه و تؤخذ فى حسابات التصميم

② To calculate the area of the Footing.

Actual Stress on Soil = Allawable Stress of soil

$$F_{act} = \frac{P_{Col.}\,(working)\ (kN)}{Area\ of\ Footing\ (m^2)} = q_{all}\ (\text{Bearing Capacity of the soil})\ (kN/m^2)$$

where:

* $P_{Col.}$ (working) هو الحمل على العمود المراد عمل قاعده له و يكون (working) و يكون محسوب مسبقا من تصميم العمود من (load distribution)

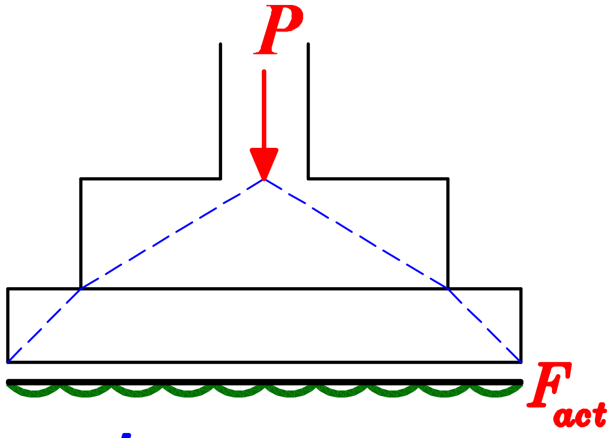
* Area of Footing (m^2) أقل مساحه مطلوبه للقاعده

IF $t_{P.C.} \geq 20$ cm و تكون مساحه القاعده العاديه

IF $t_{P.C.} < 20$ cm و تكون مساحه القاعده المسلحه

* q_{all} (Bearing Capacity of the soil) هو أكبر اجهاد تتحمله التربه (kN/m^2) و يتم تحديده من تقرير التربه .

$$Area\ of\ Footing\ (m^2) = \frac{P_{Col.}\,(working)\ (kN)}{q_{all}\ (kN/m^2)}$$

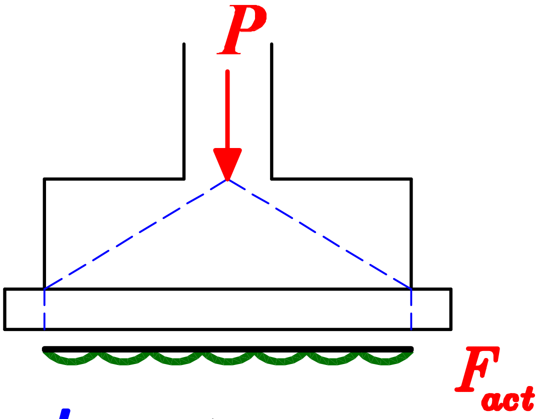


$t_{P.C.} \geq 20\ cm$

• عند استخدام قاعده عاديه ذات سمك $t_{P.C.}$ كبير فان حمل العمود يتوزع داخل القاعده المسلحه ثم يعاد توزيعه داخل القاعده العاديه نظرا لوجود المسافه الكافيه $t_{P.C.}$ لتوزيع الاجهاد للتربه.

$$\therefore\ F_{act} = \frac{P}{A_{P.C.}} = q_{all}$$

$$\therefore\ \boxed{A_{P.C.} = \frac{P}{q_{all}}}$$



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

• عند استخدام قاعده عاديه ذات سمك $t_{P.C.}$ صغير فان حمل العمود يتوزع داخل القاعده المسلحه ثم ينتقل مباشره[تقريبا] الى تربه التاسيس دون اعاده توزيع داخل القاعده العاديه نظرا لعدم وجود المسافه الكافيه $t_{P.C.}$ لاعاده توزيع الاجهاد.

$$\therefore\ F_{act} = \frac{P}{A_{R.C.}} = q_{all}$$

$$\therefore\ \boxed{A_{R.C.} = \frac{P}{q_{all}}}$$

* Minimum dimensions of R.C. Footing.

• يجب ألا تقل أبعاد و تسليح القواعد الخرسانيه المسلحه عن الاتى :-

• لا يقل عرض القاعده المسلحه عن 80 cm

$$\boxed{B_{R.C.\ minimum} = 80\ cm}$$

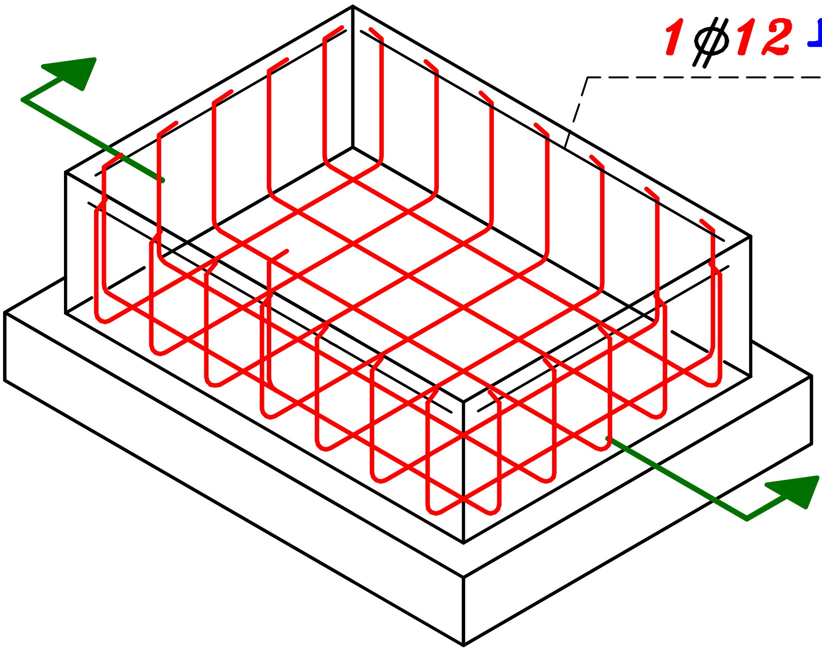
• لا يقل سُمك القاعده المسلحه عن 40 cm

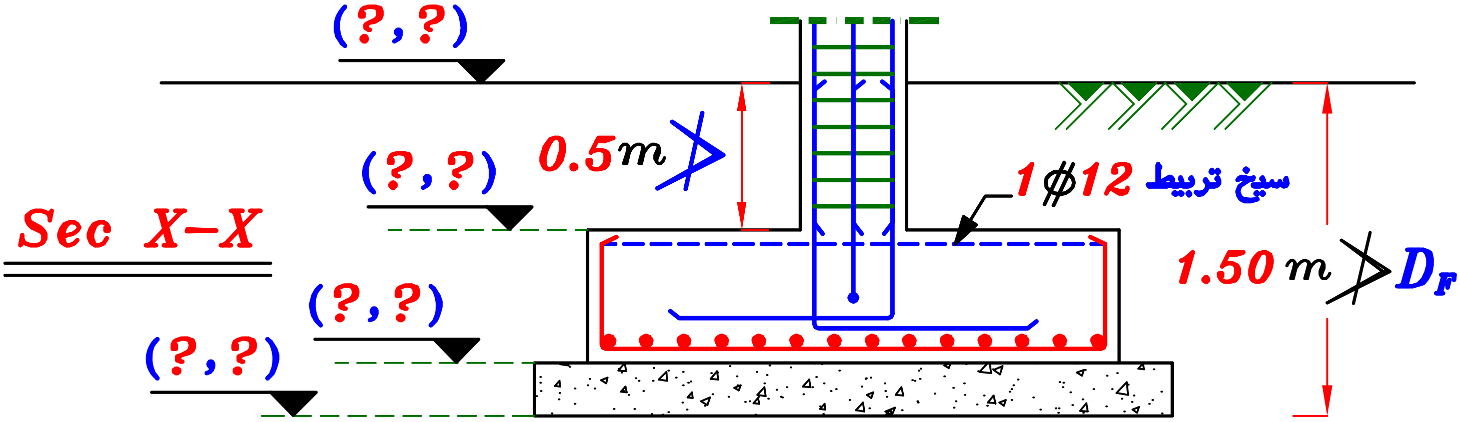
$$\boxed{t_{R.C.\ minimum} = 40\ cm}$$

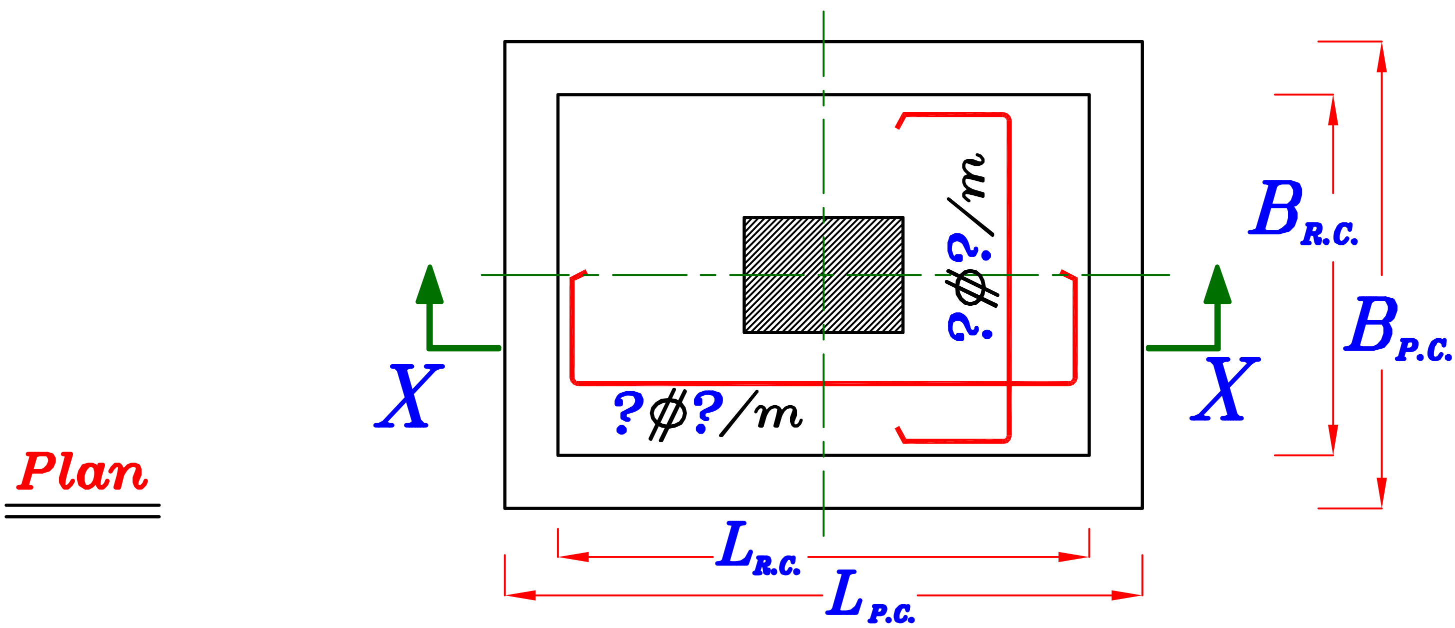
$$\boxed{d_{R.C.\ minimum} = 33\ cm}$$

Details of RFT. of shallow Foundation.

ملاحظات عامه على تفاصيل رسم القواعد [عامه لانواع القواعد]







• دائما حديد القواعد يكون سفلى فى الحالات الاتيه

- *Strip Footings*
- *Isolated Footings*

• يكون حديد القواعد سفلى+علوى فى الحالات الاتيه

- *Strip Footings*
- *Isolated Footings*
- *Combined Footings*
- *Strap beams*

(Strip Footings, Isolated Footings) → *in case of* $t_{R.C.} \geq 100\ cm$
حيث توضع شبكه علويه
$5 \phi 12/m'$

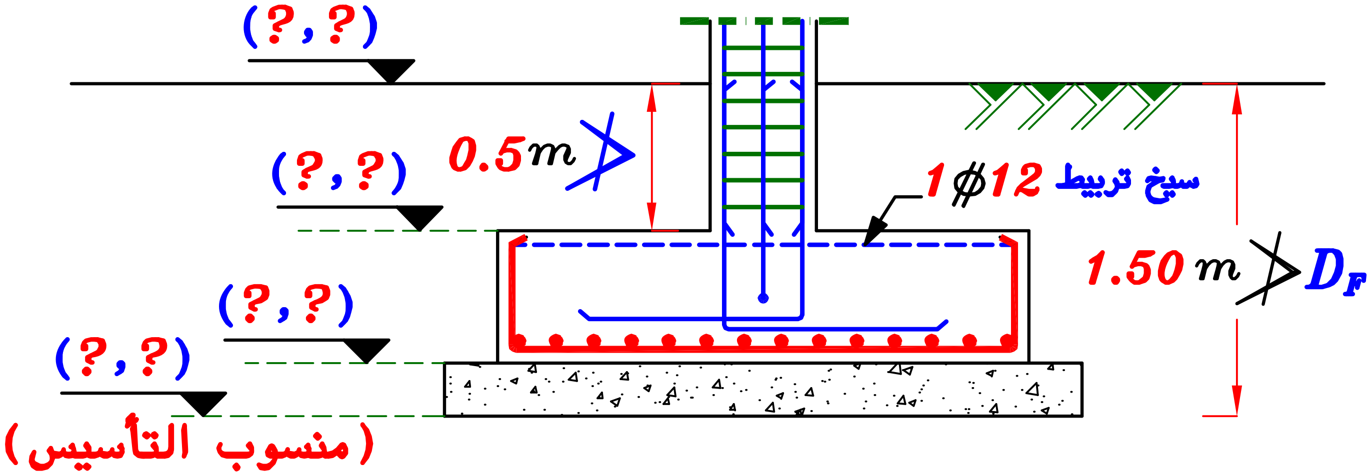
• يوضع سيخ تربيط $1 \phi 12$ عند أعلى الاسياخ فقط فى حاله القواعد المنفصله .

• أقل قطر سيخ يمكن استخدامه فى القواعد هو $\phi 12$
و أقل عدد للاسياخ فى المتر هو 5 و أكبر عدد هو 10

$A_{s_{min}}$

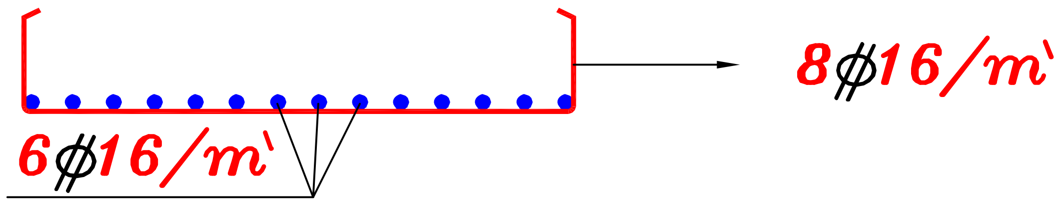
$$A_{s_{min}}\ (mm^2/m) = \begin{Bmatrix} 1.5\, d\ (mm) \\ 5 \phi 12 / m' \end{Bmatrix} \text{الأكبر}$$

يجب مراعاه الاتى فى ال x-section

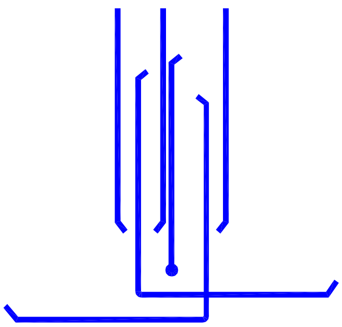


- يتم تهشير القاغده العاديه
- رسم حديد التسليح فى الاتجاهين و كتابه قيمه التسليح عليه

i.e



- يجب مراعاه وضوح ال Cover = 7cm = 70 mm

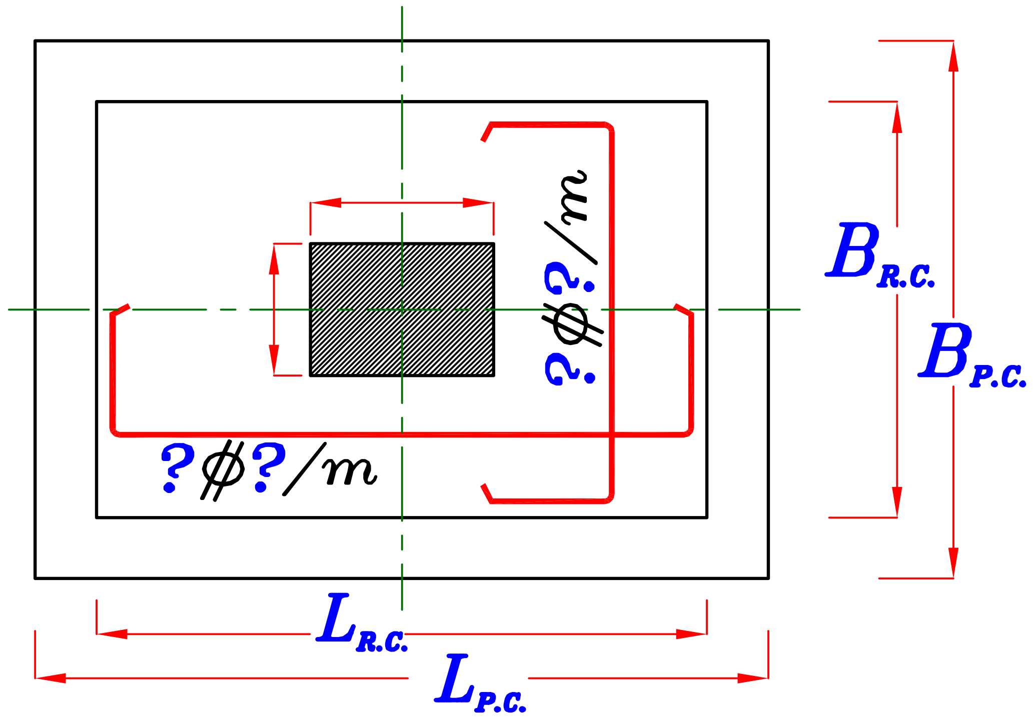


- يتم رسم حديد العمود و كيفيه اتصاله بالقاعده .
- يجب توضيح أماكن توقيف حديد العمود للاشاير

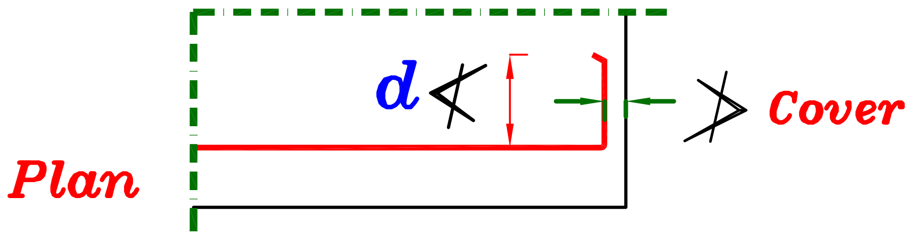
- يتم كتابه المناسيب للاتى :

١- التربه
٢- بدايه القاعده المسلحه
٣- بدايه القاعده العاديه
٤- نهايه القاعده العاديه (منسوب التأسيس)

يجب مراعاه الاتى فى ال Plan



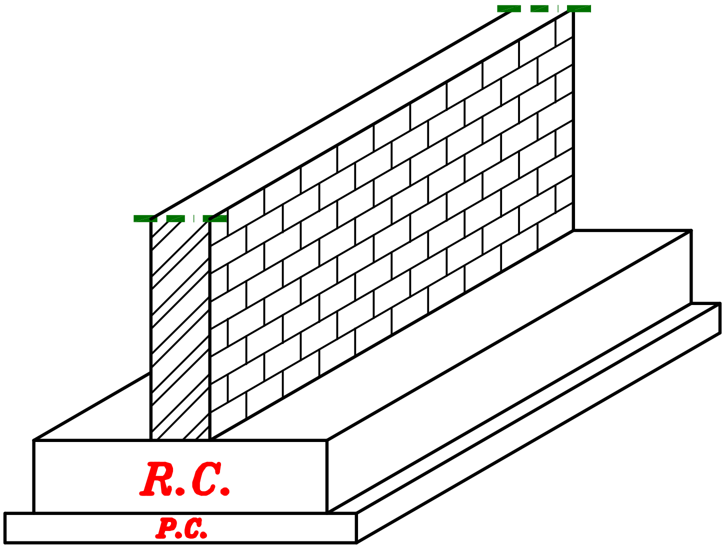
- رسم القاعده العاديه و المسلحه
- رسم محاور العمود مع توقيع العمود بأبعاده و تهشير العمود
- تفريد الحديد فى الاتجاهين مع مراعاه ال **Cover** و أن ركبه السيخ لا تزيد عن ال **depth**

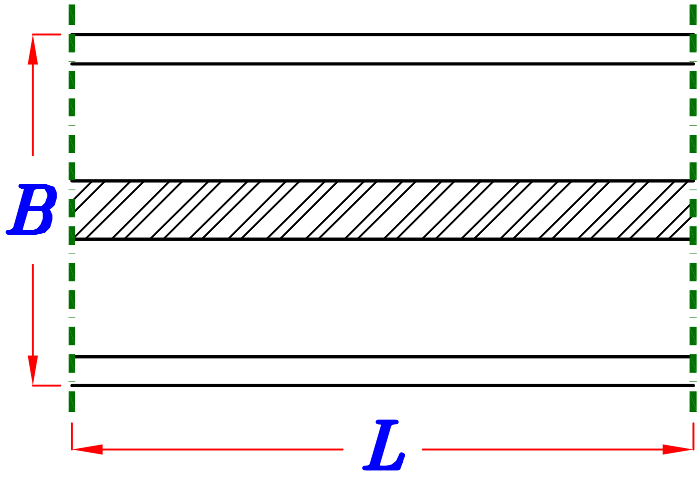


- كتابه قيم التسليح على الاسياخ ?ϕ?/m
- وضع أبعاد كامله لل **R.C Footing , P.C Footing , Column**

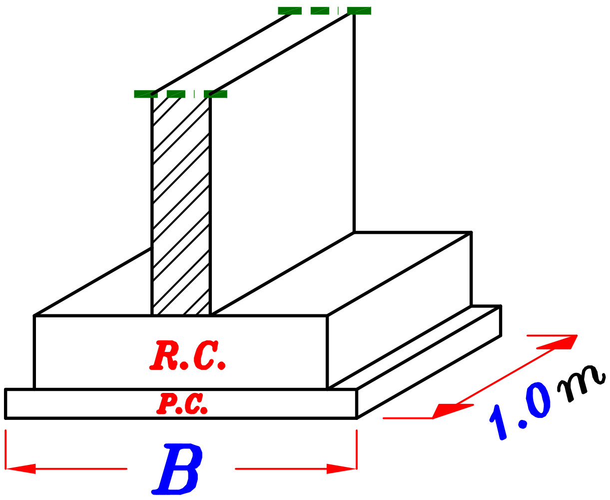
1 Design of strip Footings. تصميم القواعد الشريطيه .

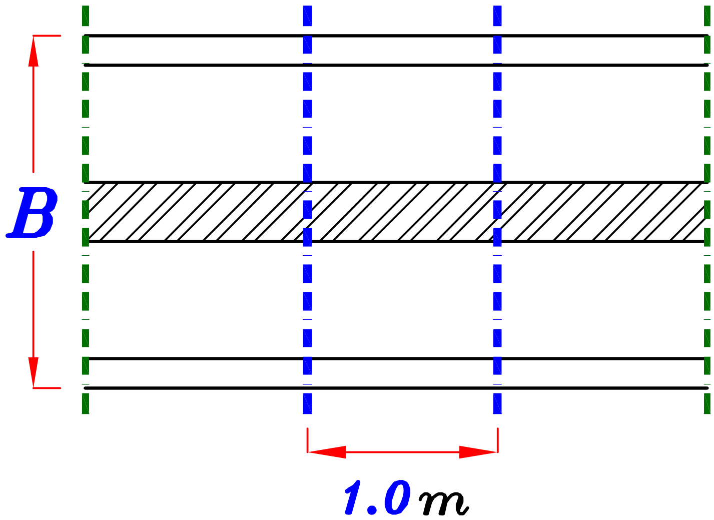
هى قواعد طوليه لحمل الحوائط الساندة و الاسوار .





- فى هذه النوعيه من القواعد يكون الطول L كبيرا جدا بالنسبه للعرض B
لذلك نأخذ شريحه فى الاتجاه الطولى عرضها – ١,٠ م و بقيه الطول بالمثل .

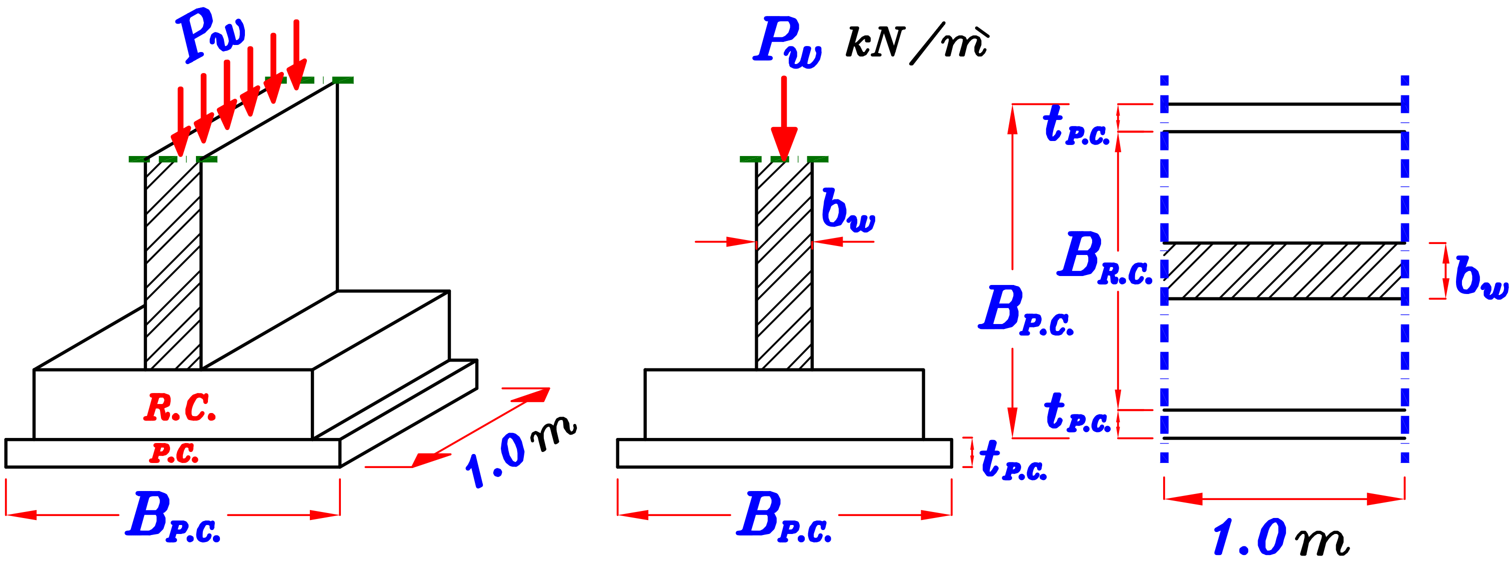




∴ نتعامل مع شريحه فى القاعده أبعادها $B * 1.0\ m$

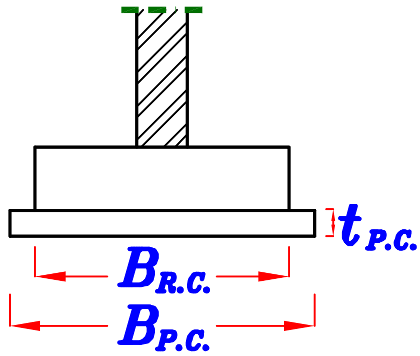
* Given :-

- * Load of wall = P_w = ✓✓ kN/m
- * q_{all} = ✓✓ kN/m²
- * b_w = ✓✓ wall thickness
- * $t_{P.C.}$ = ✓✓



Steps of design.

1– Calculate the Footing area (Width of R.C. Footing.)



IF $t_{P.C.} \geq 20$ cm

$$A_{P.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark \; m^2 = B_{P.C.} * 1.0\,m \qquad \text{get } B_{P.C.}$$

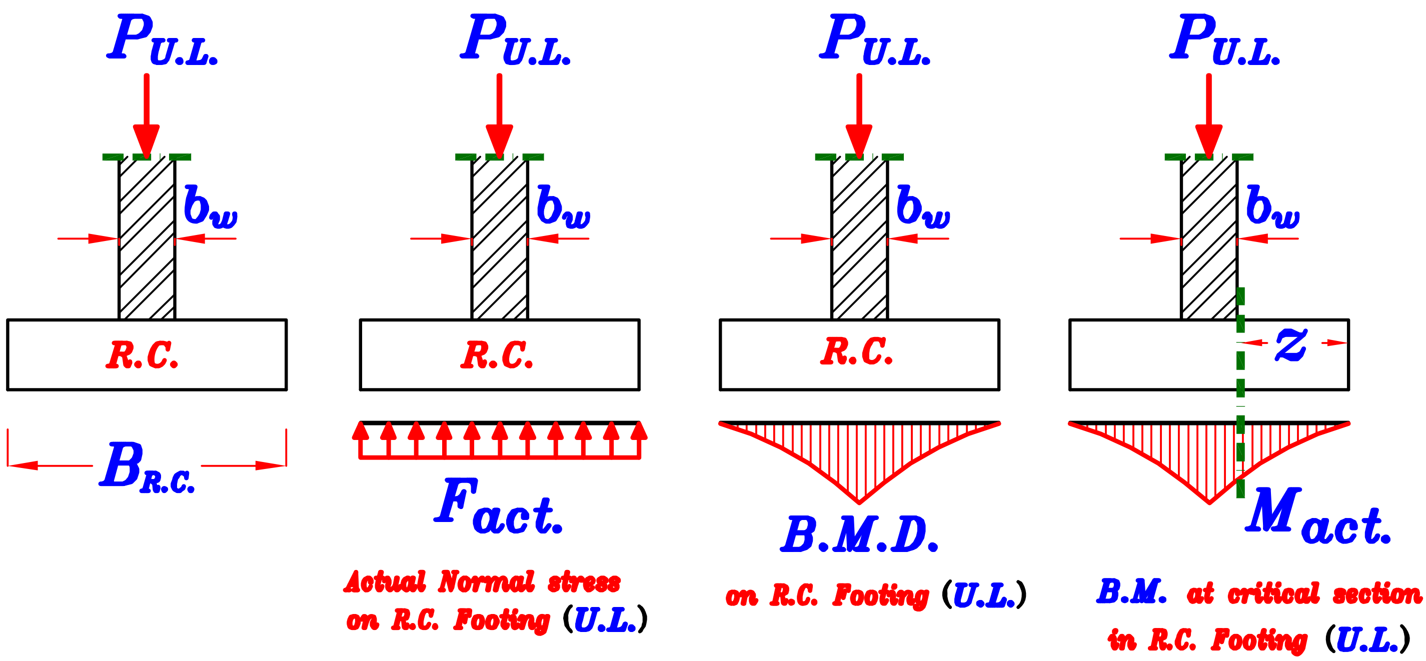
$$\boxed{B_{P.C.} = \frac{P_w}{q_{all}}} \qquad \boxed{B_{R.C.} = B_{P.C.} - 2\,t_{P.C.}}$$

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

$$A_{R.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark \; m^2 = B_{R.C.} * 1.0\,m \qquad \text{get } B_{R.C.}$$

$$\boxed{B_{R.C.} = \frac{P_w}{q_{all}}} \qquad \boxed{B_{P.C.} = B_{R.C.} + 2\,t_{P.C.}}$$

2– Design the critical sections For moment. (Depth of R.C. Footing.)

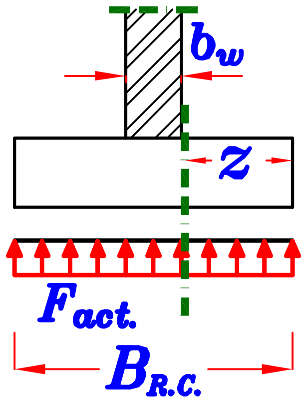


$B_{R.C.} = ✓✓ \ m$

$$P_{U.L.} = P_w * 1.5 \quad (kN)$$

– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * 1.0 \ m} \quad (kN/m`)$$



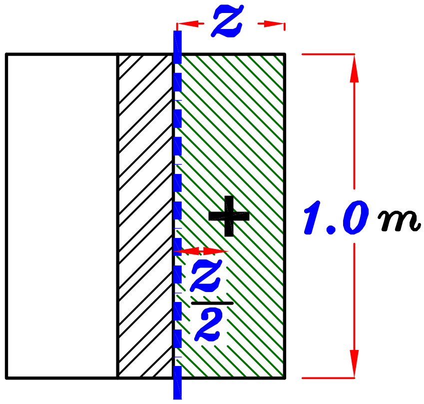
– Critical section of bending at R.C. Footing.

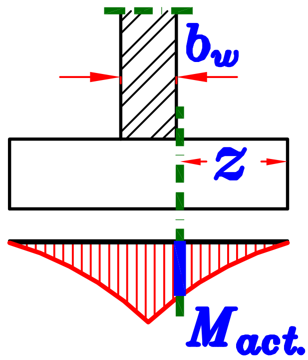
القطاع الحرج للعزوم يكون عند وش الحائط من أى جهه .

$$Z = \frac{B_{R.C.} - b_w}{2} \quad (m)$$

Force = Stress * Area

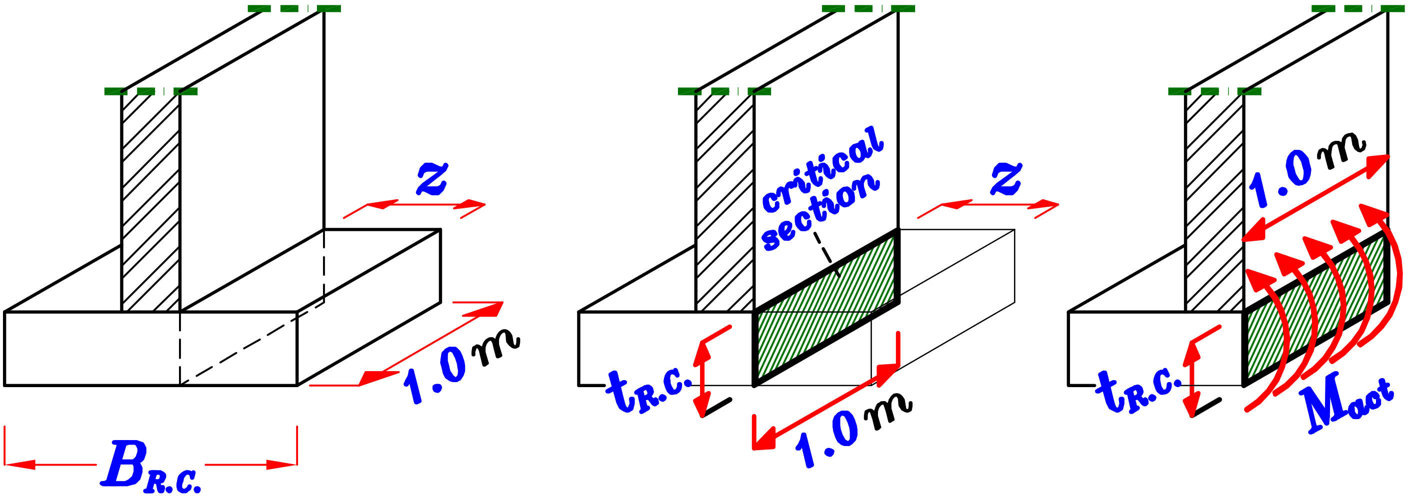
Force = $F_{act.} * Z * 1.0 \ m$





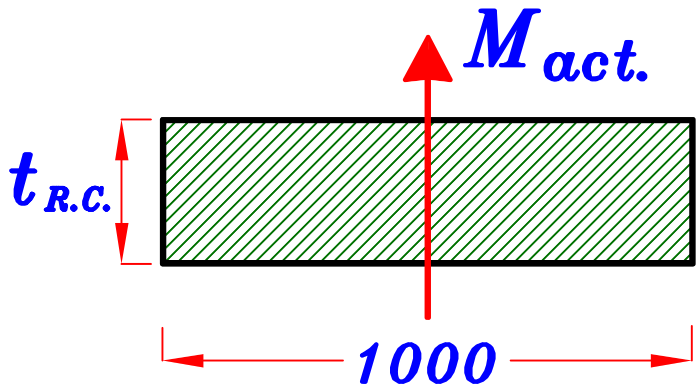
Moment = Force * Distance

$$M_{act.} = (F_{act.} * Z * 1.0) \ \frac{Z}{2} \quad (kN.m/m`)$$



Critical section

القطاع الذى سيتم تصميمه فى القاعده



$$d_{(mm)} = C_1 \sqrt{\frac{M_{act.}(kN.m) * 10^6}{F_{cu}(N/mm^2) * 1000 \, (mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده **Rigid**

Get $d = \checkmark\checkmark$ (mm)

Take cover = 70 mm

يفضل أن يكون الـ **cover** فى القواعد كبير
لحمايه الحديد من الصداء .

$$t_{R.C.} = d + cover \, (70 \, mm)$$

تقرب لاقرب ٥٠ مم بالزياده

$t_{R.C.\,minimum} = 400$ mm

$d_{R.C.\,minimum} = 330$ mm

3 – Check Shear.

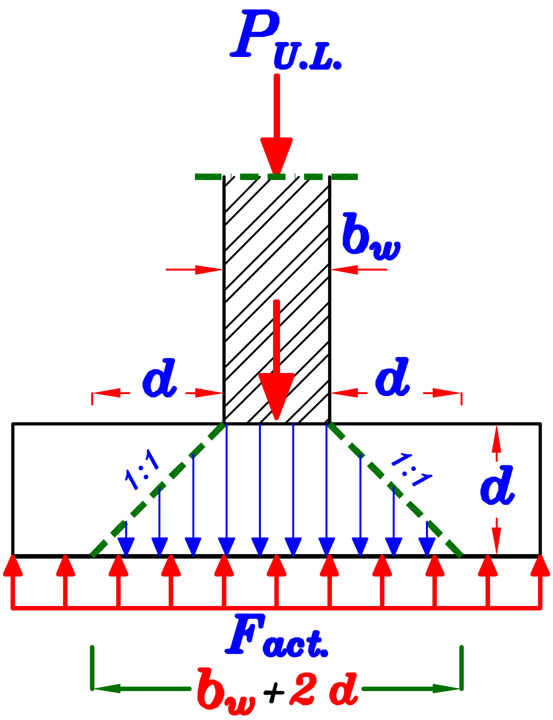
Critical section of shear at R.C. Footing.

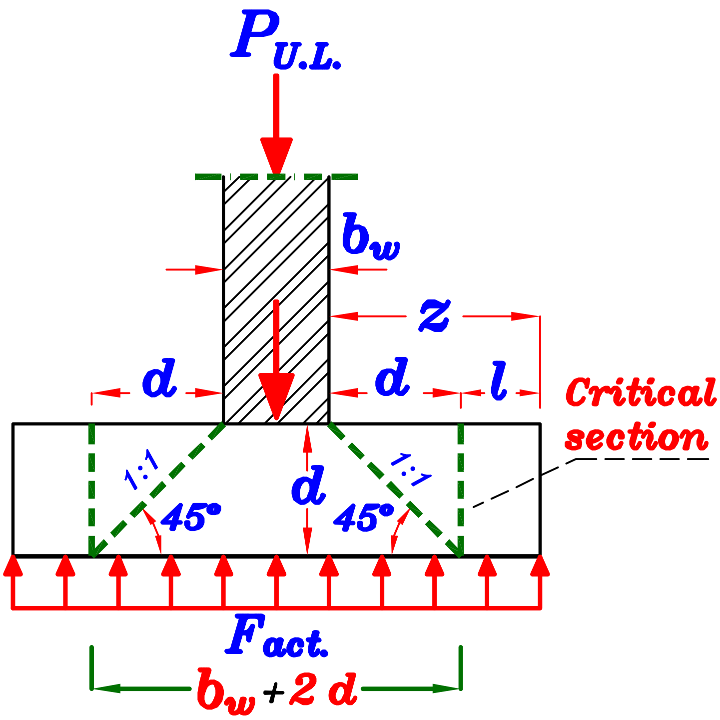
حمل الحائط يتوزع من أعلى الى أسفل داخل القاعده بميل $(1:1)$ أى بزاويه ميل 45^{o}
أى يكون تأثيره على القاعده على عرض (b_w+2d)

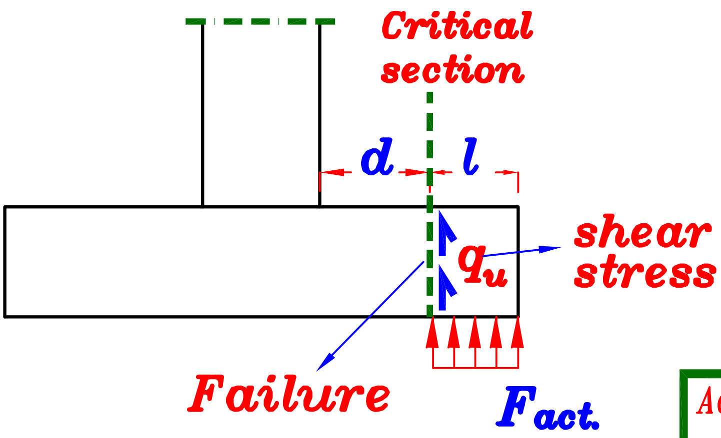
فتكون المنطقه فى منتصف القاعده (b_w+2d) عليها أقل اجهادات قص

حيث تكون قيمته تساوى رد فعل التربه على القاعده $F_{act.}$ مطروحا منه حمل الحائط $P_{U.L.}$

فيكون القطاع الحرج الذى عليه أكبر اجهادات قص على بعد d من وش الحائط من أى جهه
لانه أول قطاع عليه رد فعل الارض فقط و بالتالى يكون عليه أكبر **Shear stress** .





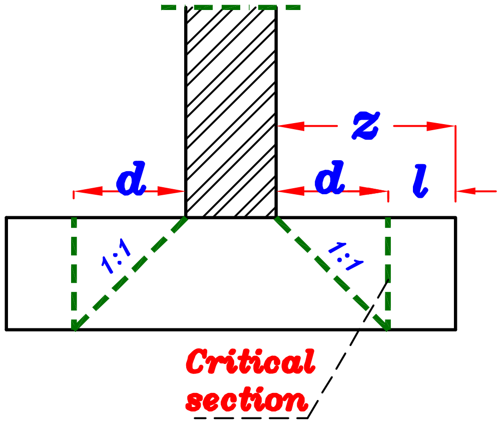


[Shear Failure]

لذلك يجب التحقق من أن اجهاد القص
على جانب السطح المتوقع للانفصال
لا يتعدى مقاومه الخرسانه فى القص

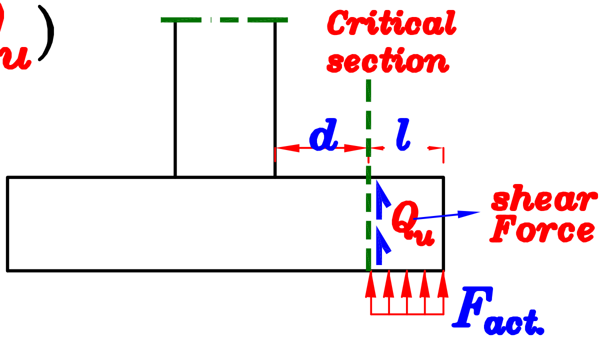
Actual Shear stress	≤	Allowable Shear stress
q_u	$\leq$	q_{su}

* *Calculate* $l = z - d$ (m)

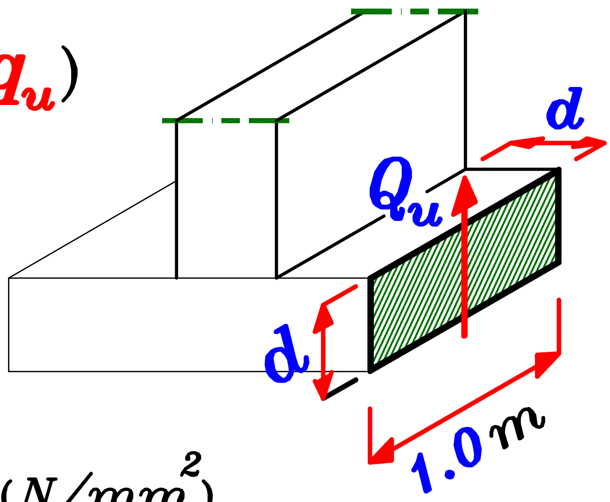


* *Calculate Actual shear Force.* (Q_u)

$$Q_u = F_{act.} * l * 1.0\ m \quad (kN)$$



* *Calculate Actual shear stress.* (q_u)



$$q_u = \frac{Q_u}{b * d} = \frac{Q_u (kN) * 10^3}{1000 * d\ (mm)} \quad (N/mm^2)$$

* *Calculate Allowable shear stress.* (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

لاحظ أنه فى القواعد نعتمد فقط على مقاومه الخرسانه فى القص لانه لا توجد كانات حيث يصعب تشكيلها بالابعاد الضخمه للقواعد .

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ $\longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_u > q_{su}$ $\longrightarrow$ Unsafe shear stresses
We have to increase dimensions.

IF Unsafe shear stresses increase $t_{R.C.}$ by 100 mm

then Calculate:

$$d = t_{R.C.} - 70 \text{ mm}$$

$$l = z - d \quad (m)$$

$$Q_u = F_{act.} * l * 1.0 \text{ m} \quad (kN)$$

$$q_u = \frac{Q_u (kN) * 10^3}{1000 * d (mm)} \quad (N/mm^2)$$

then Recheck:

Actual shear stress (q_u) & Allowable shear stress (q_{su})

4- Reinforcement of the Footing.

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get
$$A_s = \frac{M_{act.}}{J\, F_y\, d} \quad (mm^2)$$

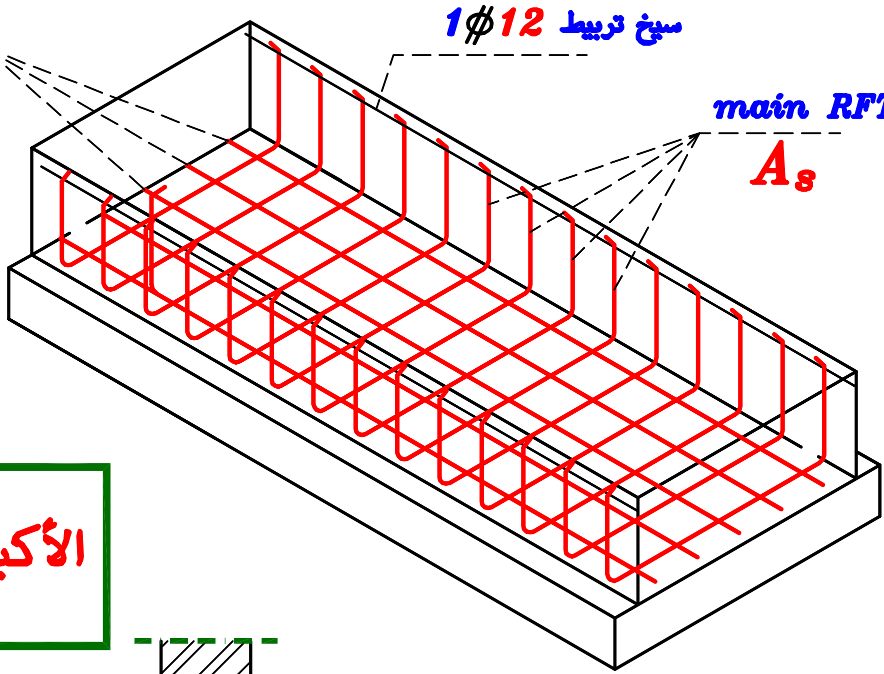
Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \left\{ \begin{array}{l} 1.5\, d\ (mm) \\ 5\phi 12/m' \end{array} \right\}$$ الأكبر

IF $A_s \geq A_{s\,min} \longrightarrow$ o.k.

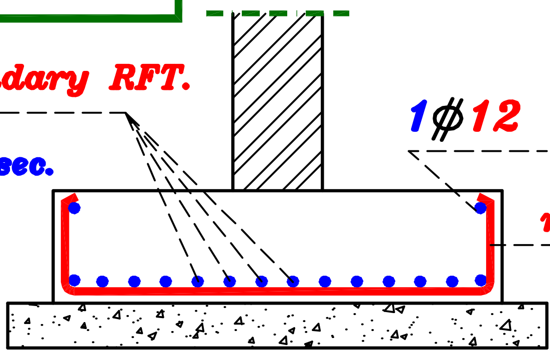
IF $A_s < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

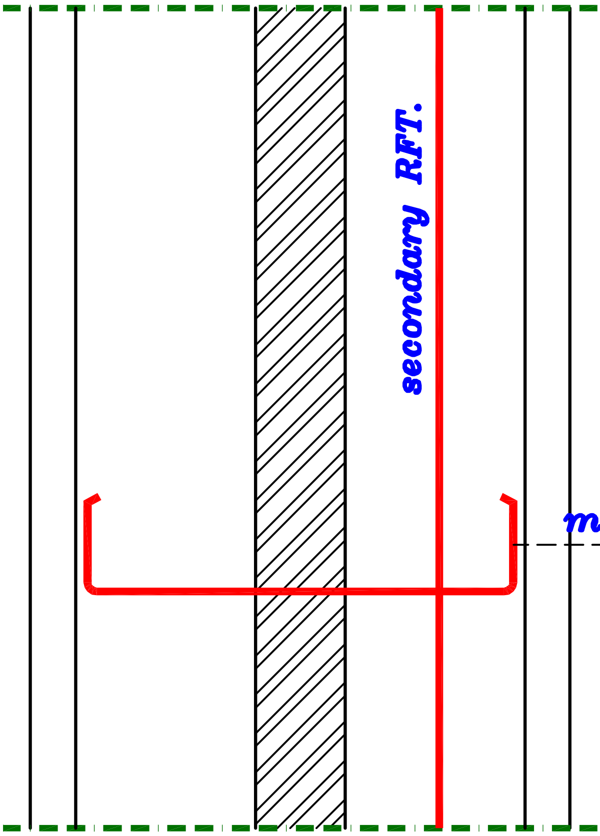
5- Details of Reinforcement.



التسليح الرئيسى فى القواعد الشريطيه المحسوب من التصميم يكون تسليح عرضى أما التسليح الطولى فيكون حديد ثانوى و تحسب قيمته من

$$A_{s\,sec.} = \left\{ \begin{array}{l} 20\%\ A_s \\ A_{s\,min} \end{array} \right\} \text{ الأكبر}$$





Example.

It is required to design a strip Footing to Support a R.C retaining wall of thikness 25 cm. The wall working load is 350 kN/m`, and the allowable net bearing capacity in the Footing site is 100 kN/m^2. (F_{cu} = 25 N/mm^2, F_y = 360 N/mm^2). and draw details of RFT. to scale 1:50

Solution.

Data given:

Wall of thickness = 250 mm

P_{wall} (working) = 350 kN/m`    $P_{wall}$ (U.L.) = 350 * 1.5 = 525 kN/m`

Bearing capacity of the soil = q_{all} = 100 kN/m^2

F_{cu} = 25 N/mm^2 F_y = 360 N/mm^2

1– Calculate the Footing area (Width of R.C. Footing.)

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

$$B_{P.C.} = \frac{P_w}{q_{all}} = \frac{350\ (kN)}{100\ (kN/m^2)} = 3.50\ m$$

$$B_{R.C.} = B_{P.C.} - 2\, t_{P.C.} = 3.50 - 2 * 0.3 = 2.90\ m$$

$B_{P.C.} = 3.50\ m$ $B_{R.C.} = 2.90\ m$

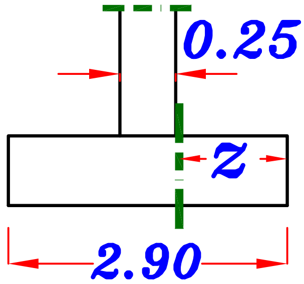
2– Design the critical sections for moment. (Depth of R.C. Footing.)

– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * 1.0\ m} = \frac{525}{2.90 * 1.0} = 181.03\ kN/m^{`}$$

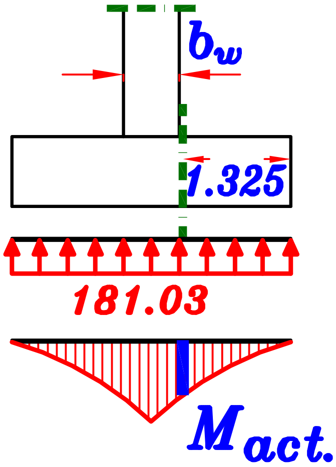
– Critical section of bending at R.C. Foorting.

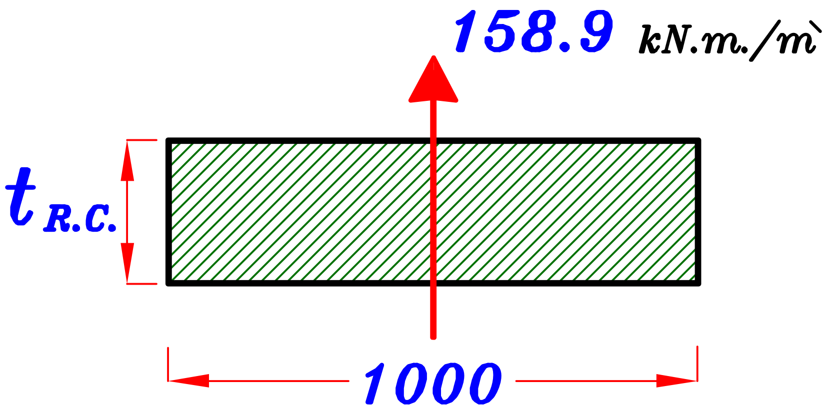
$$Z = \frac{B_{R.C.} - b_w}{2} = \frac{2.90 - 0.25}{2} = 1.325\ m$$

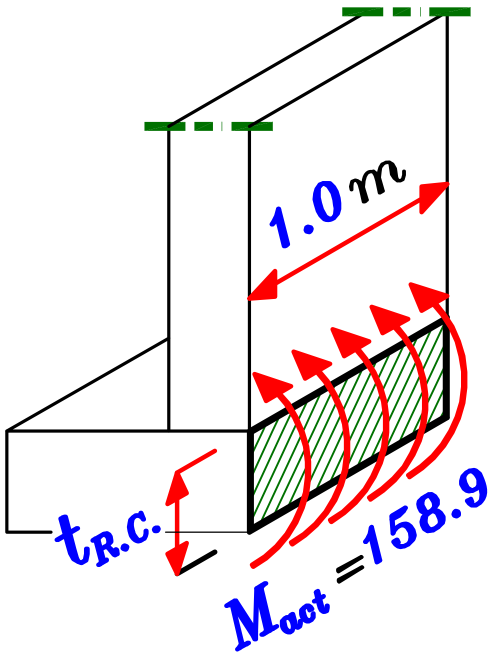


$$M_{act.} = \frac{F_{act.} * Z^2}{2} * 1.0\ m$$

$$M_{act.} = \frac{181.03 * 1.325^2}{2} = 158.9\ kN.m./m^{`}$$







$$\because \; d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

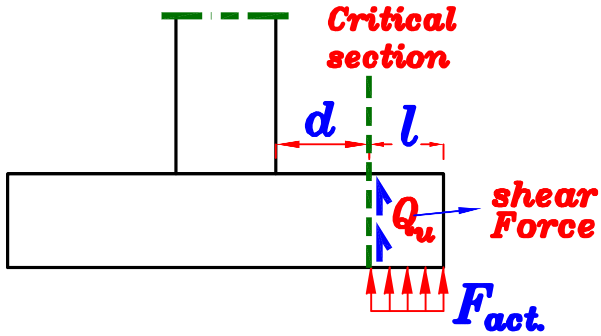
$$\therefore \; d = 5.0 \sqrt{\frac{158.9 * 10^6}{25 \; * 1000}} = 398.6 \; mm$$

$$t_{R.C.} = d + 70 \; mm = 398.6 + 70 = 468.6 \; mm$$

$t_{R.C.} = 500 \; mm$ $\qquad$ $d = 430 \; mm$

---

3 – Check Shear.



* **Critical section For Shear.**

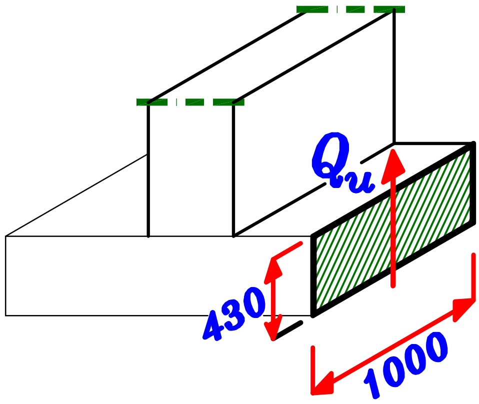
$$l = z - d$$

$$l = 1.325 - 0.43 = 0.895 \; m$$

* **Actual shear Force.** (Q_u)

$$Q_u = F_{act.} * l * 1.0 \; m = 181.03 * 0.895 * 1.0 = 162.02 \; kN$$

* **Actual shear stress.** (q_u)



$$q_u = \frac{Q_u}{b * d} = \frac{162.02 * 10^3}{1000 * 430} = 0.376 \; N/mm^2$$

* **Allowable shear stress.** (q_{su})

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

$q_u < q_{su}$ $\longrightarrow$ Safe shear stresses

No need to increase dimensions.

4- Reinforcement of the Footing.

From $C_1 = 5.0 \longrightarrow J = 0.826$

$$A_s = \frac{M_{act.}}{J\,F_y\,d} = \frac{158.9 * 10^6}{0.826 * 360 * 430} = 1242.7\ mm^2$$

Check $A_{s\,min}$

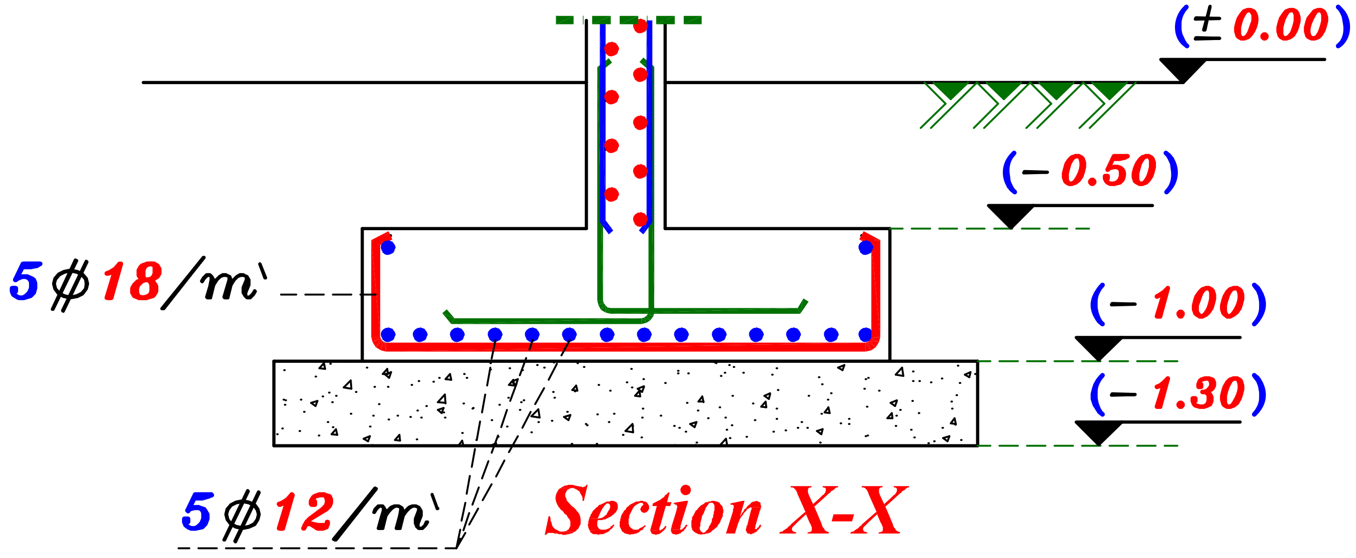
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 430 = 645 \\ 5\phi 12/m' = 565 \end{array} \right\} 645\,mm^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow o.k.$$

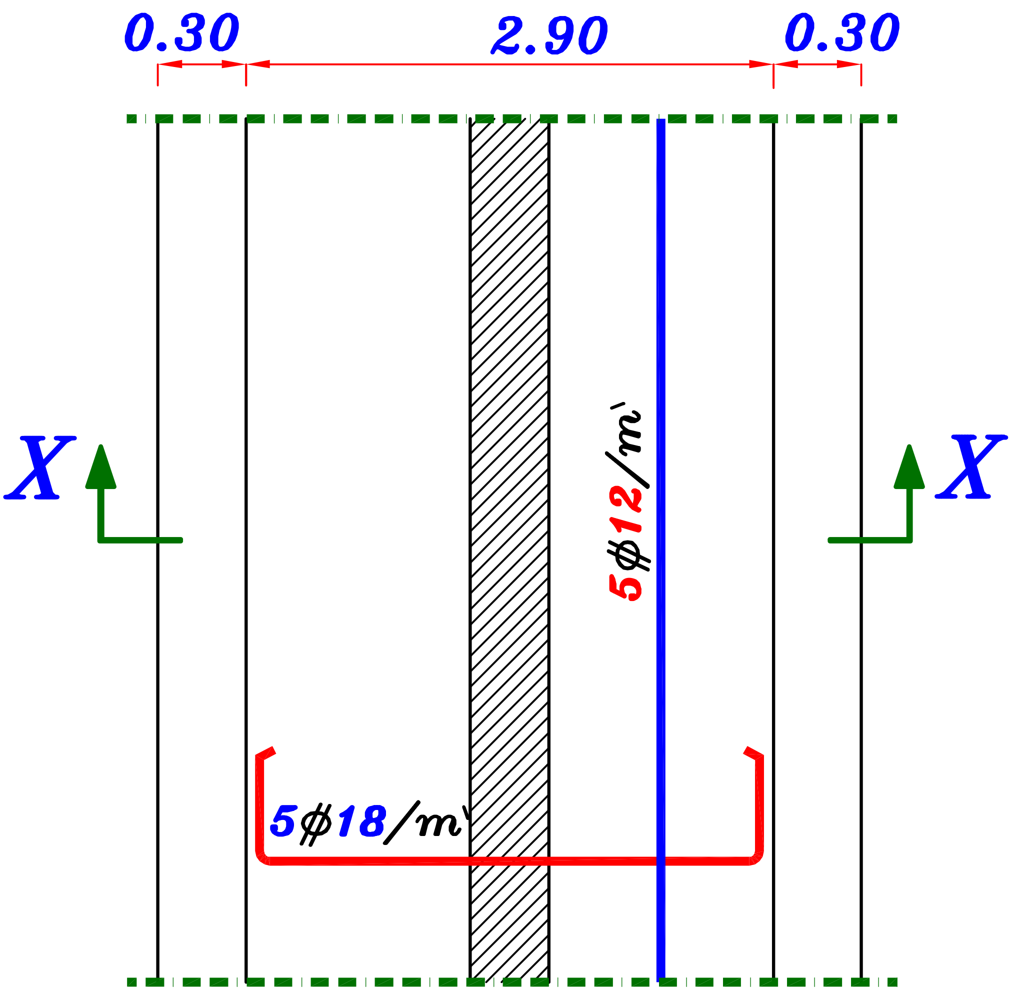
$A_s = 1242.7\ mm^2$ $\boxed{5\phi 18/m'}$

5- Details of Reinforcement.

scale 1:50



Section X-X



Plan

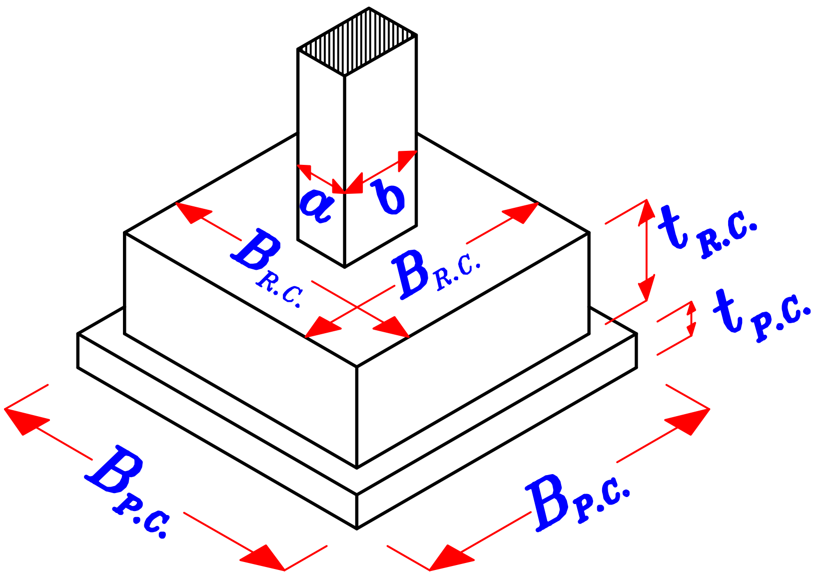
Isolated Footings القواعد المنفصله

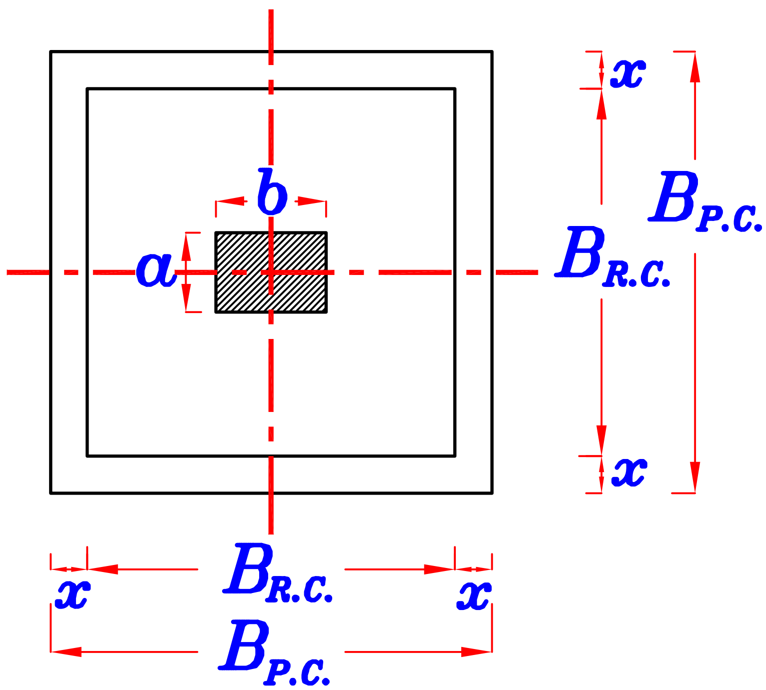
* هى القواعد التى يرتكز عليها عمود واحد فقط و تكون اما مربع أو مستطيل و يكون العمود مربع أو مستطيل أو دائرى .

* يمكن للقاعده المربعه أن تحمل عمود مستطيل أو مربع و بالمثل القاعده المستطيله .

2 Design of Isolated Square Footings .

تصميم القواعد المنفصله المربعه .





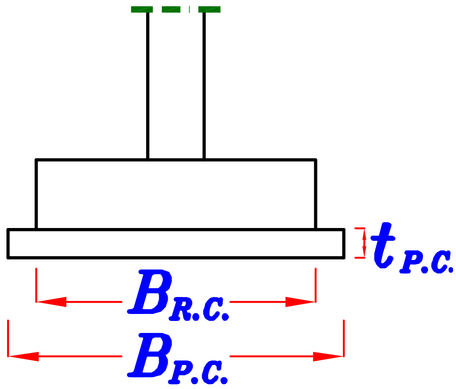
Steps of design.

* Given :-
  * Load of column $= P_w =$ ✓✓ kN
  * Bearing capacity of soil $= q_{all} =$ ✓✓ kN/m^2
  * Dimensions of the column. $(a * b)$ مستطيل أو مربع
  * $t_{P.C.} =$ ✓✓

1– Calculate the Footing area. (Width of R.C. Footing.)

IF $t_{P.C.} \geq 20$ cm

get $B_{P.C.}$ From



$$A_{P.C.} = \frac{P_w}{q_{all}} = ✓✓ \; m^2 = B_{P.C.} * B_{P.C.}$$

$$B_{P.C.} = \sqrt{\frac{P_w}{q_{all}}}$$

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

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

get $B_{R.C.}$ From

$$A_{R.C.} = \frac{P_w}{q_{all}} = ✓✓ \; m^2 = B_{R.C.} * B_{R.C.}$$

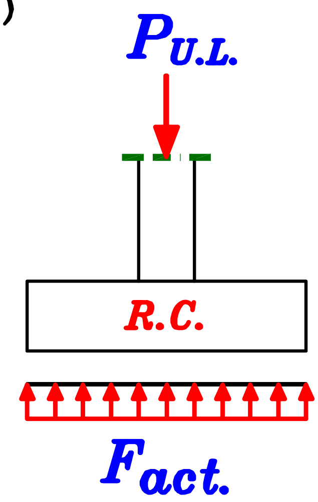
$$B_{R.C.} = \sqrt{\frac{P_w}{q_{all}}}$$

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

2– Design the critical sections For moment. (Depth of R.C. Footing.)

$B_{R.C.} = \checkmark\checkmark \; m$

$$P_{U.L.} = P_w * 1.5 \quad (kN)$$



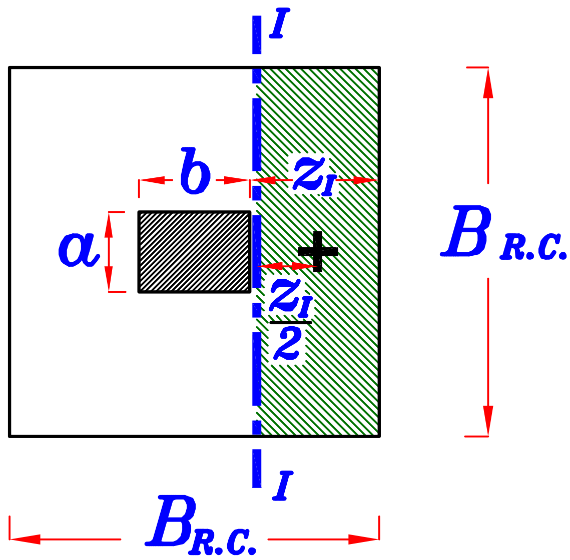
– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * B_{R.C.}} \quad (kN/m)$$

– Critical section of bending at R.C. Footing.

ناخذ القطاعات الحرجه للعزوم على وش العمود من الجهتين .

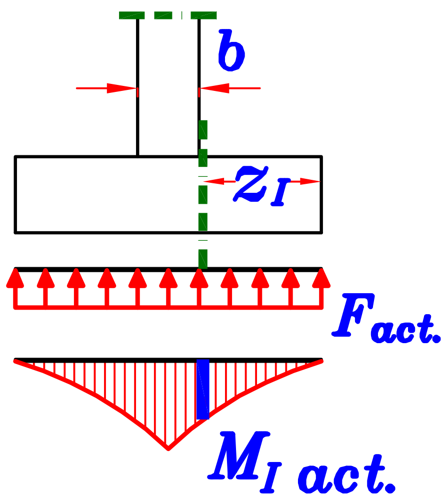
Direction I



$$z_I = \frac{B_{R.C.} - b}{2} \quad (m)$$

$$Force = Stress * Area$$

$$Force = F_{act.} * z_I * B_{R.C.}$$



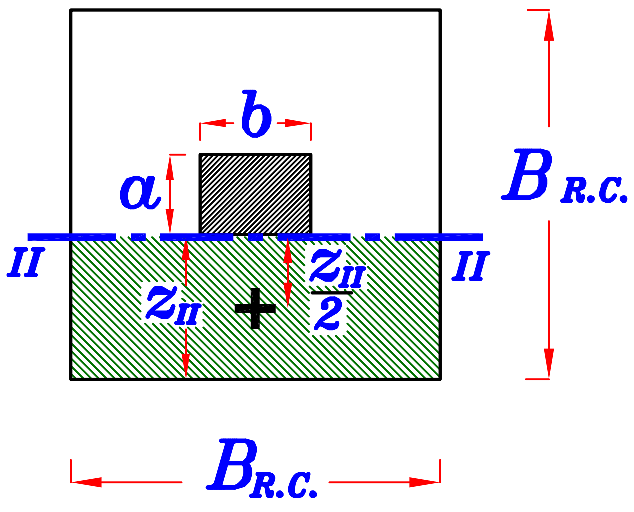
$$Moment = Force * Distance$$

$$M_{I\,act.} = (F_{act.} * z_I * B_{R.C.}) \; \frac{z_I}{2}$$

$$(kN.m/B)$$

Direction II

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



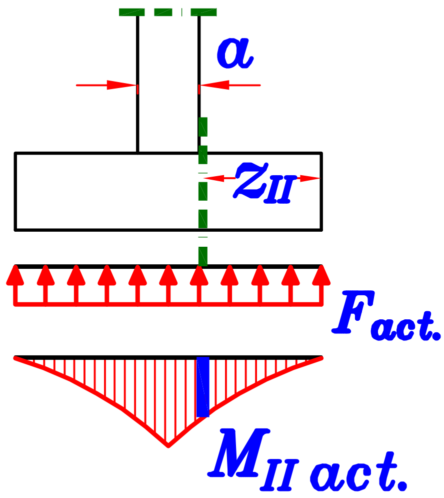
$$Force = Stress * Area$$

$$Force = F_{act.} * Z_{II} * B_{R.C.}$$

$$Moment = Force * Distance$$

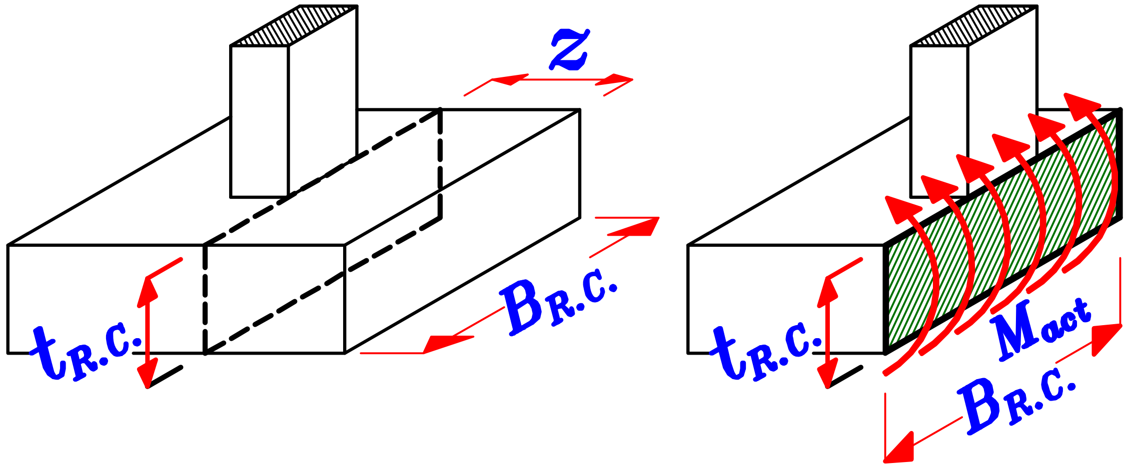
$$M_{II\,act.} = (F_{act.} * Z_{II} * B_{R.C.}) \; \frac{Z_{II}}{2}$$

$(kN.m/B)$



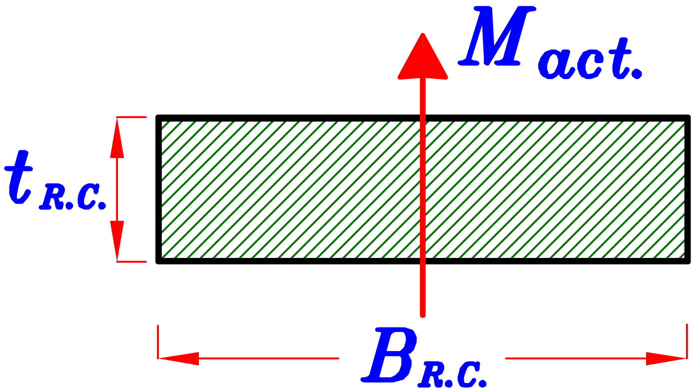
يتم التصميم على العزم الاكبر من $M_{I\,act.}$ & $M_{II\,act.}$

ملحوظه $M_{II\,act.} < M_{I\,act.}$ لان $Z_{II} < Z_{I}$



Critical section

القطاع الذى سيتم تصميمه فى القاعده



$$d_{(mm)} = C_1 \sqrt{\frac{M_{act.}(kN.m) * 10^6}{F_{cu}(N/mm^2) * B_{R.C.}(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده *Rigid*

Get $d = ✓✓ \ (mm)$

Take cover = 70 mm

يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصداء .

$$t_{R.C.} = d + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

$$t_{R.C.\ minimum} = 400\ mm$$

$$d_{R.C.\ minimum} = 330\ mm$$

3 – Check Shear.

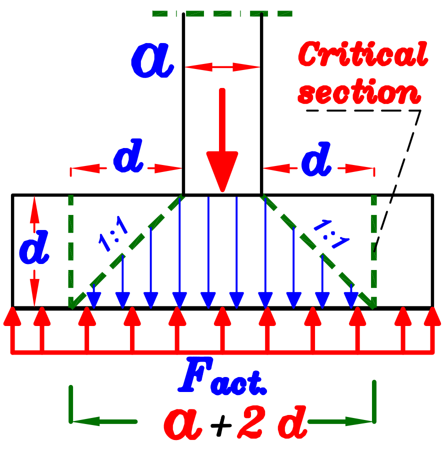
Critical section of shear at R.C. Footing.

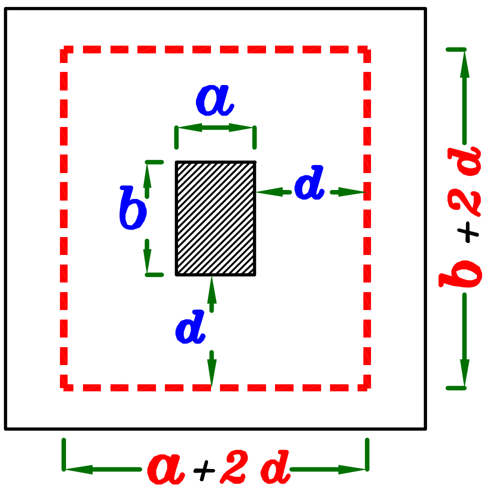
حمل العمود يتوزع من أعلى الى أسفل داخل القاعده بميل (1:1) أى بزاويه ميل 45^o
أى يكون تأثيره على القاعده على عرض $(b+2d)$ & $(a+2d)$

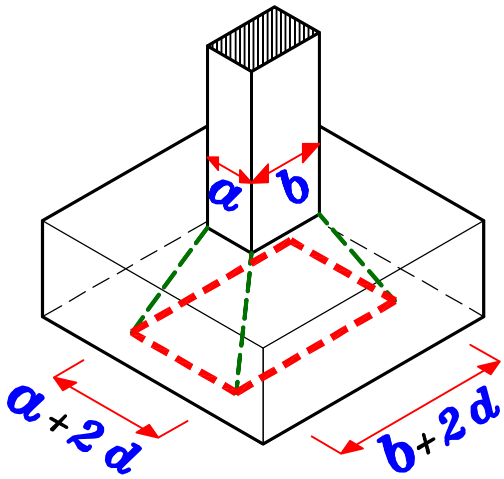
فتكون المساحه $(b+2d) * (a+2d)$ في منتصف القاعده عليها أقل اجهادات قص

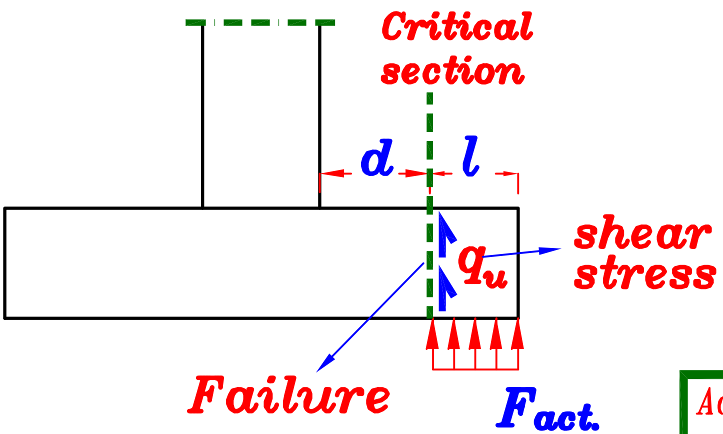
حيث تكون قيمته تساوى رد فعل التربه على القاعده $F_{act.}$ مطروحا منه حمل العمود $P_{U.L.}$

فيكون القطاع الحرج الذى عليه أكبر اجهادات قص على بعد d من وش العمود من أى جهه
لانه أول قطاع عليه رد فعل الارض فقط و بالتالى يكون عليه أكبر **Shear stress** .





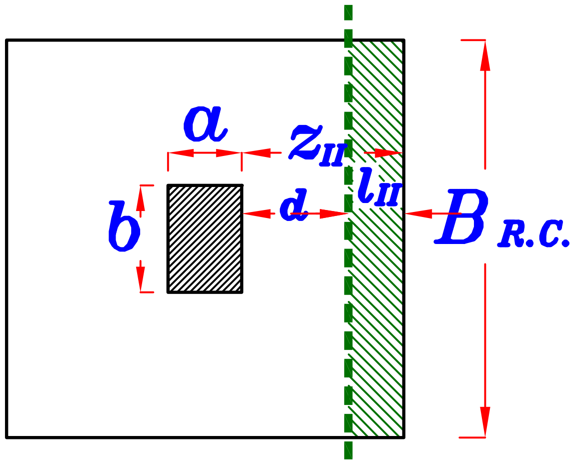


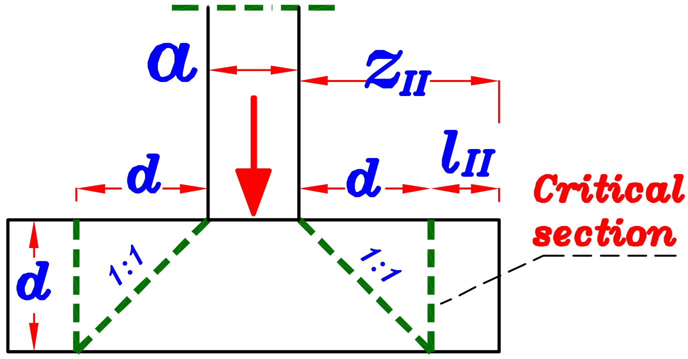


[Shear Failure]

لذلك يجب التحقق من أن اجهاد القص
على جانب السطح المتوقع للانفصال
لا يتعدى مقاومه الخرسانه فى القص

Actual Shear stress	$\leqslant$	Allowable Shear stress
q_u	$\leqslant$	q_{su}



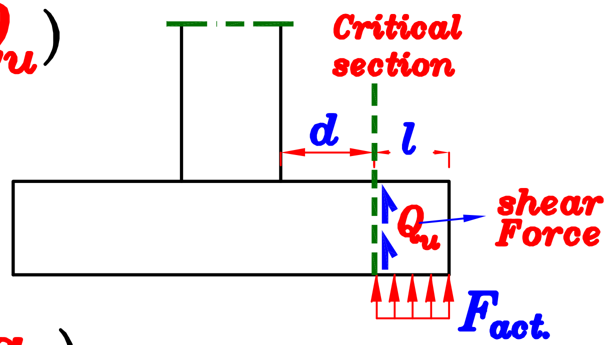


* Calculate $l_{II} = z_{II} - d$ (m)

ملحوظه $l_I < l_{II}$ لان $z_I < z_{II}$

* Calculate Actual shear Force. (Q_u)

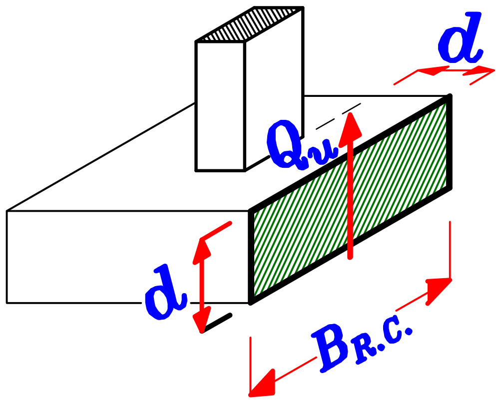
$$Q_u = F_{act.} * l_{II} * B_{R.C.} \quad (kN)$$



* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d}$$

$$q_u = \frac{Q_u (kN) * 10^3}{B_{R.C.} * d (mm)} \quad (N/mm^2)$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

لاحظ أنه فى القواعد نعتمد فقط
على مقاومه الخرسانه فى القص
لانه لا توجد كانات حيث يصعب
تشكيلها بالابعاد الضخمه للقواعد .

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ $\longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_u > q_{su}$ $\longrightarrow$ UnSafe shear stresses
We have to increase dimensions.

IF UnSafe shear stresses increase $t_{R.C.}$ by 100 mm

then Calculate:

$$d = t_{R.C.} - 70 \text{ mm}$$

$$l_{II} = z_{II} - d \quad (m)$$

$$Q_u = F_{act.} * l_{II} * B_{R.C.} \quad (kN)$$

$$q_u = \frac{Q_{u\,(kN)} * 10^3}{B_{R.C.} * d_{\,(mm)}} \quad (N/mm^2)$$

then ReCheck:

Actual shear stress (q_u) & Allowable shear stress (q_{su})

$4-$ Check Punching Shear. القص الثاقب .

يجب التأكد من أن العمود لن يخترق القاعده .

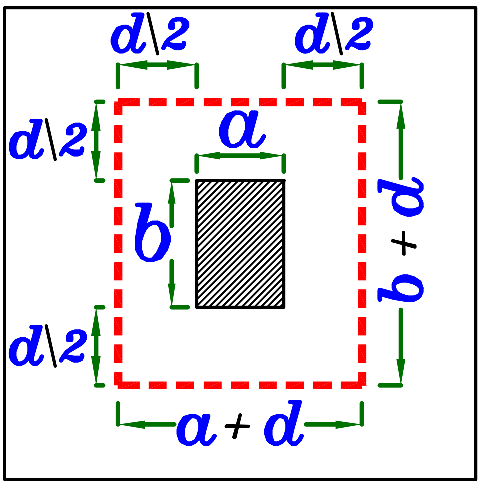
و للتأكد من ذلك نحسب q_{pu} و هو اجهاد القص الذى سينتج عن ثقب العمود للقاعده .

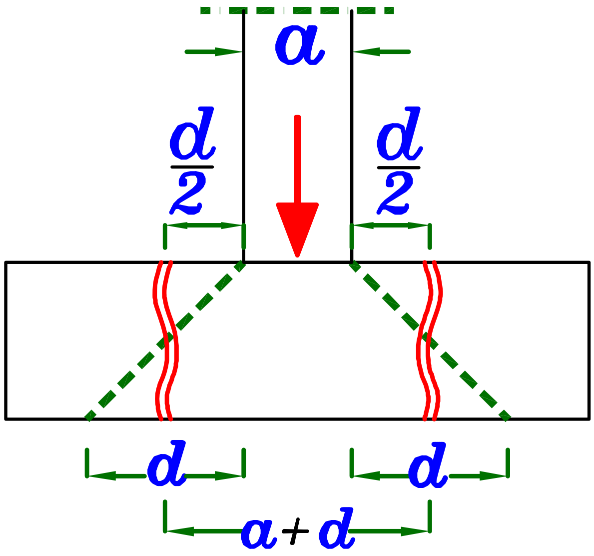
و نحسب q_{pcu} و هى مقاومه الخرسانه للقص الناتج عن ثقب القاعده .

The concrete area which resist punching shear.

تحديد مساحه الخرسانه المقاومه للقص الثاقب .

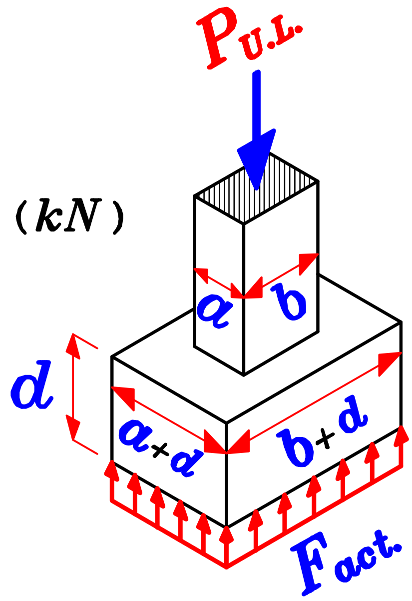
القطاع الحرج فى القص الثاقب عباره عن محيط يحيط بالعمود على مسافه $\frac{d}{2}$ من وش العمود من كل جهه .





* **Calculate Punching Force.** (Q_p)

$$Q_p = P_{U.L.} - (F_{act.})\left[(a+d)(b+d)\right] \quad (kN)$$



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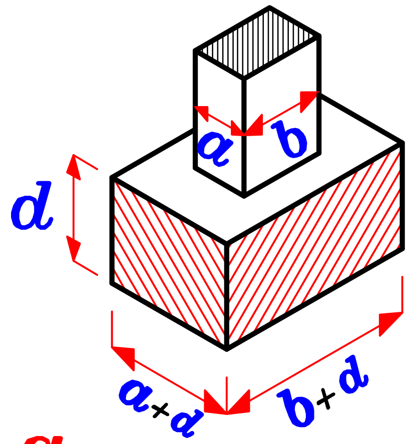
* Calculate Punching shear area. (A_p)



المحيط العمق

$$A_p = \left[2(a+d)+2(b+d)\right] * d \quad (mm^2)$$

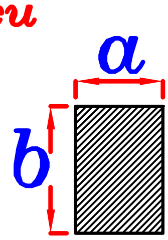
* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{\text{Punching Force}}{\text{Punching area}}$$

$$q_{pu} = \frac{Q_p\ (kN) * 10^3}{\left[2(a+d)+2(b+d)\right] * d \quad (mm^2)} \quad (N/mm^2)$$

* Calculate allowable Punching shear stress. q_{pcu}

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



IF $\left(0.5+\frac{a}{b}\right) \leq 1.0$ Take $\longrightarrow$ $q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$

---

* Compare between

Actual punching shear stress (q_{pu}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu} \leq q_{pcu} \longrightarrow$ Safe punching shear. No need to increase dimensions.

* IF $q_{pu} > q_{pcu} \longrightarrow$ UnSafe punching shear. We have to increase dimensions.

5- Reinforcement of the Footing.

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get
$$A_s = \frac{M_{act.}}{J\,F_y\,d} \quad (mm^2)$$

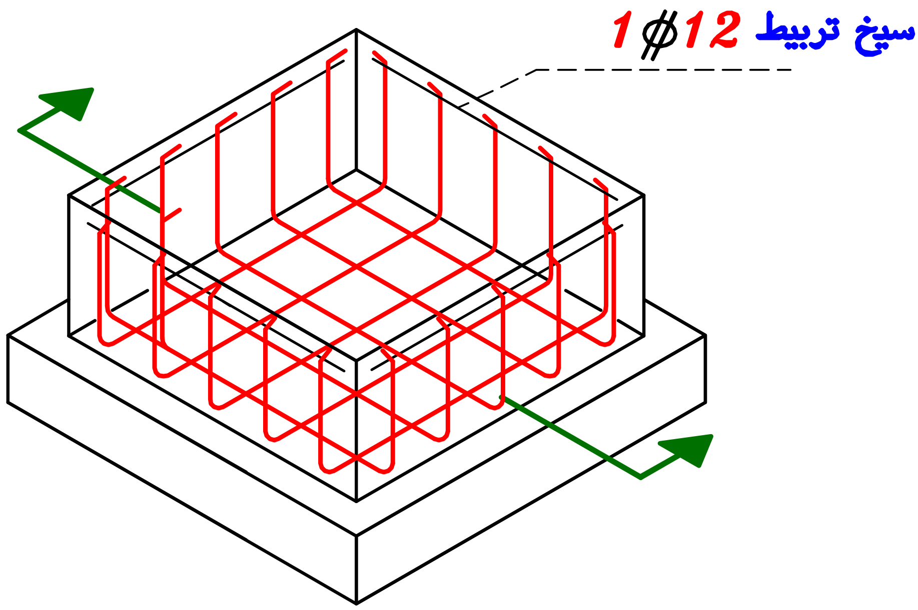
Check $A_{s\,min}$

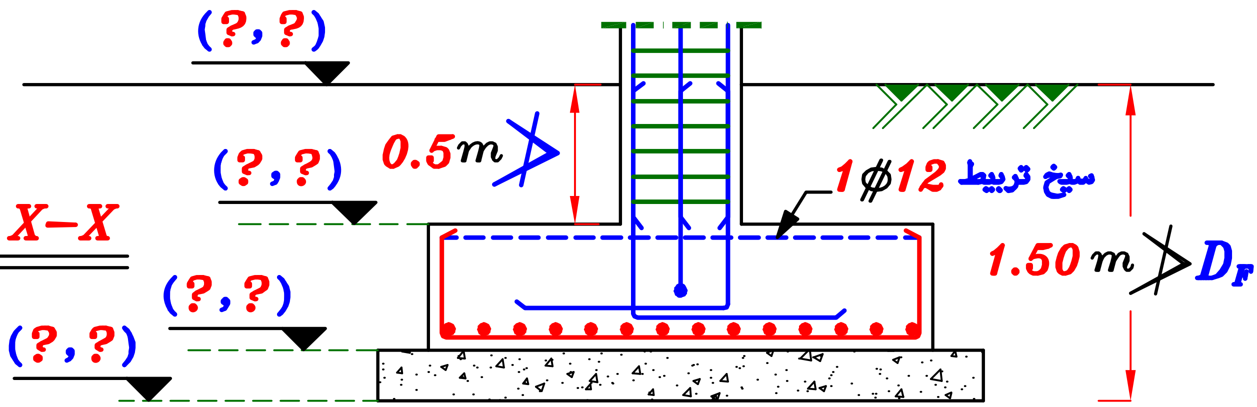
$$A_{s\,min}\ (mm^2/m) = \left\{\begin{array}{l} 1.5\,d\ (mm) \\ 5\phi 12/m' \end{array}\right\} \text{الأكبر}$$

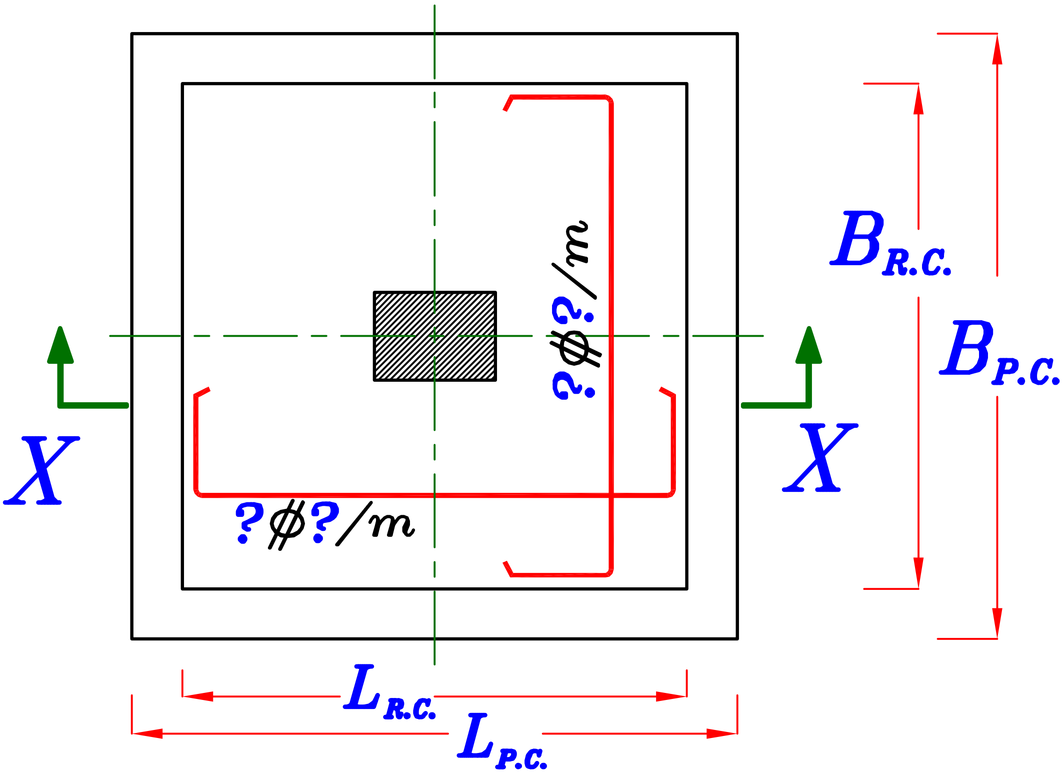
IF $A_s \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_s < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

6 – Details of Reinforcement.







Plan

Example.

It is required to design a square Footing to Support a R.C column of thickness $(45*60)$ cm.
The column working load is 1450 kN, and the allowable net bearing capacity in the Footing site is 150 kN/m^2. ($F_{cu} = 25\ N/mm^2$, $F_y = 360\ N/mm^2$).
and draw details of RFT. to scale 1:50

Solution.

Data given:

column dimensions $(450*600)$ mm

$P_{col.}(working) = 1450\ kN$ $\quad$ $P_{col.}(U.L.) = 1450*1.5 = 2175\ kN$

Bearing capacity of the soil $= q_{all} = 150\ kN/m^2$

$F_{cu} = 25\ N/mm^2$ $\quad$ $F_y = 360\ N/mm^2$

1- Calculate the Footing area (Width of R.C. Footing.)

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

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1450\ (kN)}{150\ (kN/m^2)} = 9.67\ m^2$$

$$A_{P.C.} = B_{P.C.} * B_{P.C.} = 9.67\ m^2$$

$B_{P.C.} = 3.10\ m$ $\quad$ $B_{R.C.} = 2.30\ m$

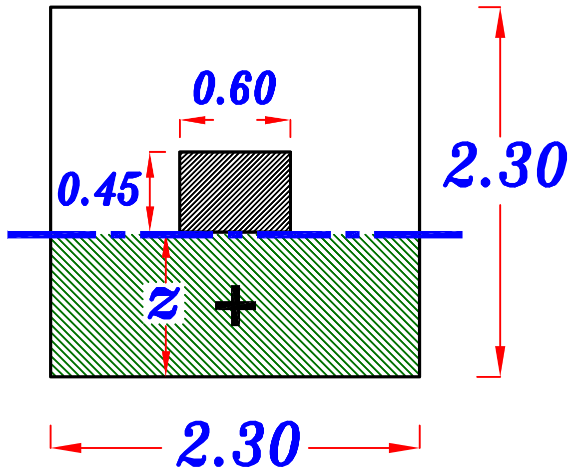
2– Design the critical sections For moment. (Depth of R.C. Footing.)

– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * B_{R.C.}} = \frac{2175}{2.30 * 2.30} = 411.1 \ kN/m^2$$

$$Z = \frac{B_{R.C.} - a}{2} = \frac{2.30 - 0.45}{2}$$

$$= 0.925 \ m$$

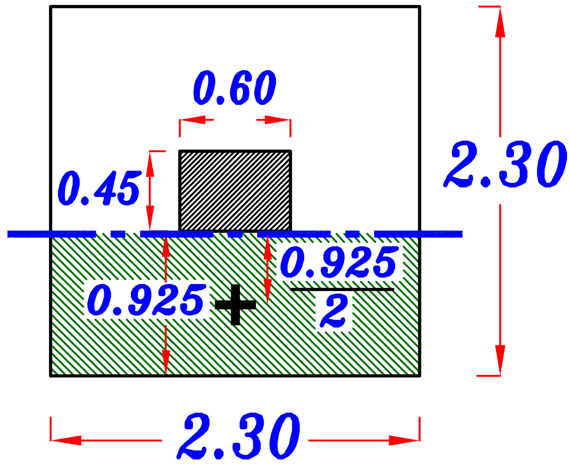


$$Force = Stress * Area$$

$$Force = F_{act.} * Z * B$$

$$= 411.1 * 0.925 * 2.30$$

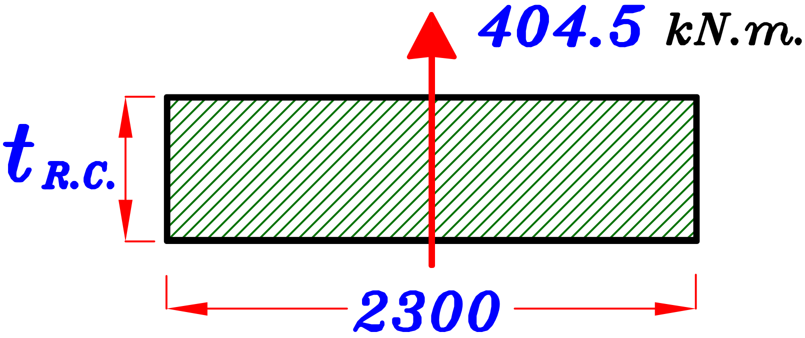
$$= 874.6 \ kN$$



$$moment = Force * Distance$$

$$M_{act.} = (F_{act.} * Z * B_{R.C.}) \frac{Z}{2}$$

$$= (411.1 * 0.925 * 2.30) \frac{0.925}{2} = 404.5 \ kN.m$$



$\because \; d = C_1 \sqrt{\dfrac{M_{act.}}{F_{cu} * b}}$

Choose $C_1 = 5.0$

$\therefore \; d = 5.0 \sqrt{\dfrac{404.5 * 10^6}{25 \; * 2300}} = 419.36 \; mm$

$t_{R.C.} = d + 70 \; mm = 419.36 + 70 = 489.3 \; mm$

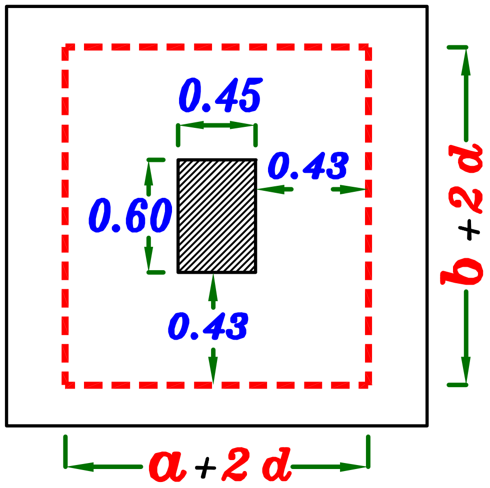
$t_{R.C.} = 500 \; mm$ $\quad$ $d = 430 \; mm$

---

3 – Check Shear.

$a + 2\,d = 0.45 + 2 * 0.43 = 1.31 \; m$

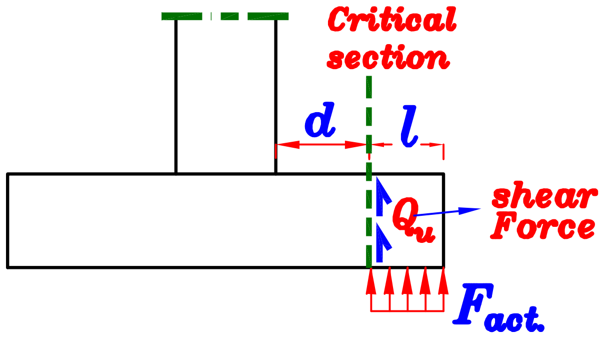
$b + 2\,d = 0.60 + 2 * 0.43 = 1.46 \; m$



*** Critical section For Shear.**

$l = z - d$

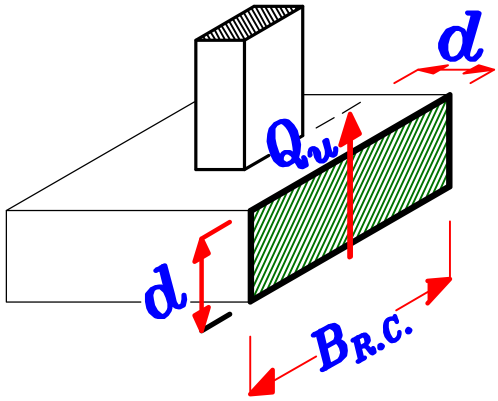
$l = 0.925 - 0.43 = 0.495 \; m$



*** Actual shear Force. (Q_u)**

$Q_u = F_{act.} * l * B_{R.C.} = 411.1 * 0.495 * 2.30 = 468.0 \; kN$

* Calculate Actual shear stress. (q_u)



$$q_u = \frac{Q_u}{b * d} = \frac{468.0 * 10^3}{2300 * 430} = 0.473 \; N/mm^2$$

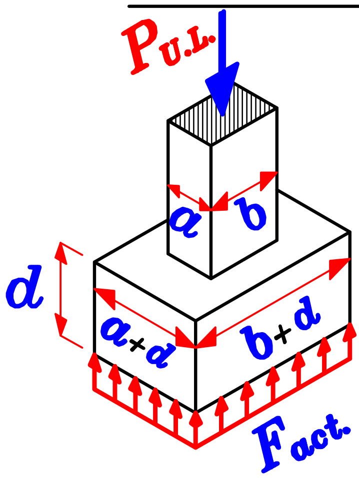
* Allowable shear stress. (q_{su})

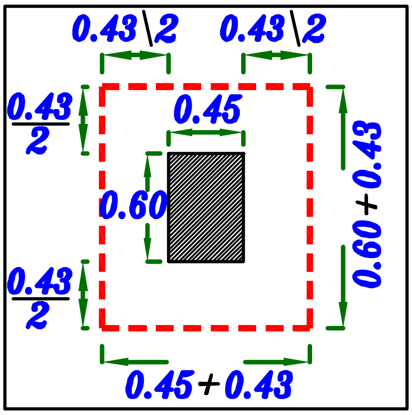
$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \; N/mm^2$$

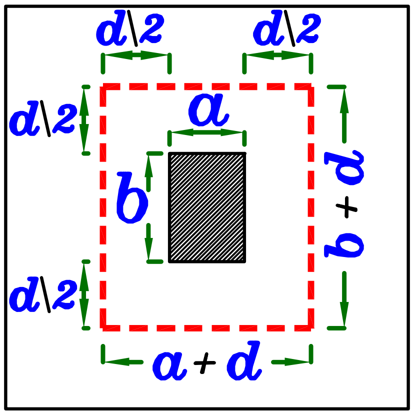
$q_u < q_{su}$ → Safe shear stresses

No need to increase dimensions.

4 – Check Punching Shear.







$$a + d = 0.45 + 0.43 = 0.88 \, m$$

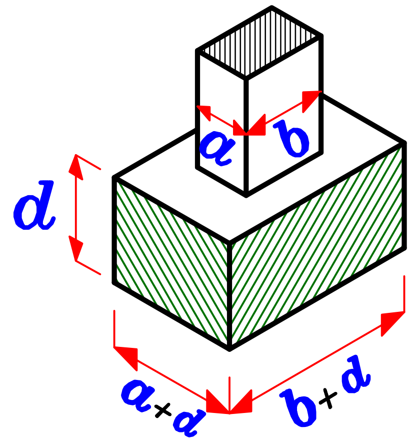
$$b + d = 0.60 + 0.43 = 1.03 \, m$$

* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{act.}) \left[(a+d)(b+d) \right]$$

$$Q_p = 2175 - 411.1 \left[0.88 * 1.03 \right] = 1802.4 \; kN$$

* Calculate Punching shear area. (A_p)



$$A_p = [2(a+d)+2(b+d)] * d$$

$$A_p = [2(450+430)+2(600+430)] * 430$$

$$A_p = 1642600 \ mm^2$$

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)] * d}$$

$$q_{pu} = \frac{1802.4 * 10^3}{1642600} = 1.097 \ N/mm^2$$

* Calculate allowable Punching shear stress. q_{pcu}

$$q_{pcu} = 0.316 \left(0.5 + \frac{a}{b}\right) \sqrt{\frac{F_{cu}}{\delta_c}} =$$

$$q_{pcu} = 0.316 \left(0.5 + \frac{0.45}{0.60}\right) \sqrt{\frac{25}{1.5}} = 1.61 \ N/mm^2$$

$q_{pu} \leqslant q_{pcu} \longrightarrow$	Safe punching shear. No need to increase dimensions.

5- Reinforcement of the Footing.

From $C_1 = 5.0 \longrightarrow J = 0.826$

$$A_s = \frac{M_{act.}}{J\, F_y\, d} = \frac{404.5 * 10^6}{0.826 * 360 * 430} = 3163.5\ mm^2$$

$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{3163.5}{2.30} = 1375.4\ mm^2/m'$$

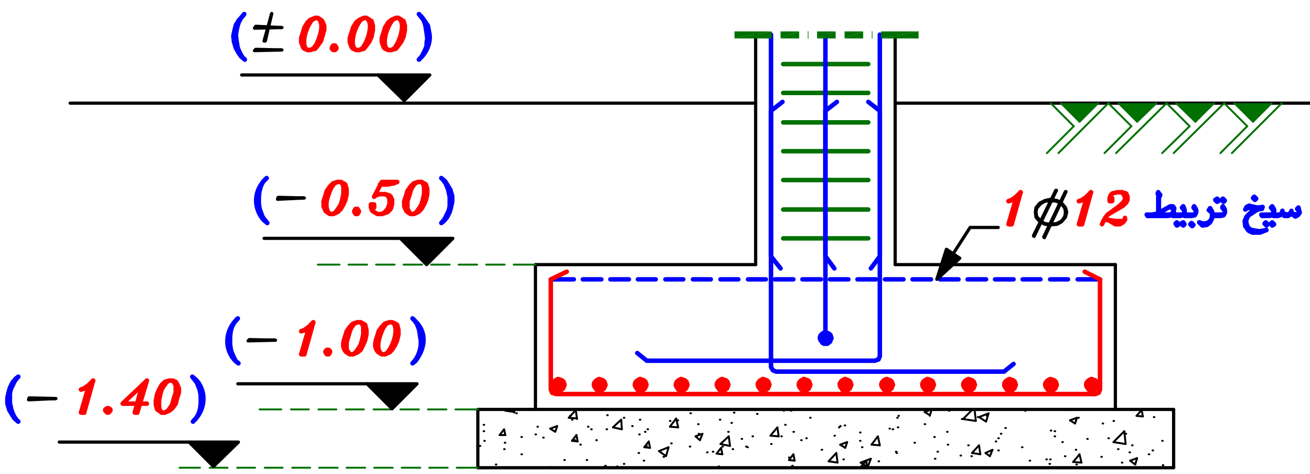
Check $A_{s_{min}}$

$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 430 = 645 \\ 5\, \phi\, 12/m' = 565 \end{array} \right\} 645\, mm^2$$

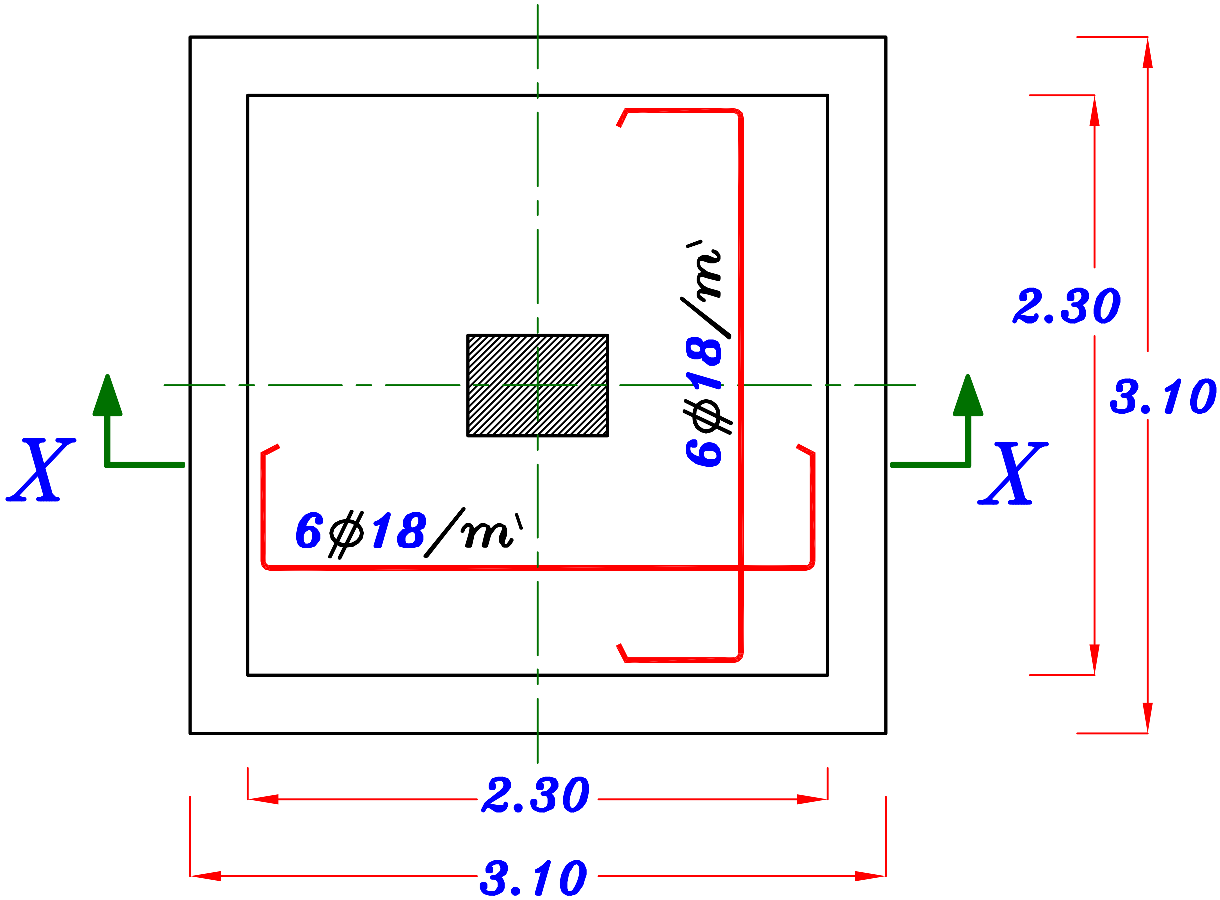
$$\therefore A_s > A_{s_{min}} \longrightarrow o.k.$$

$A_s = 1375.4\ mm^2$ **$6\, \phi\, 18/m'$**

6 – Details of Reinforcement.



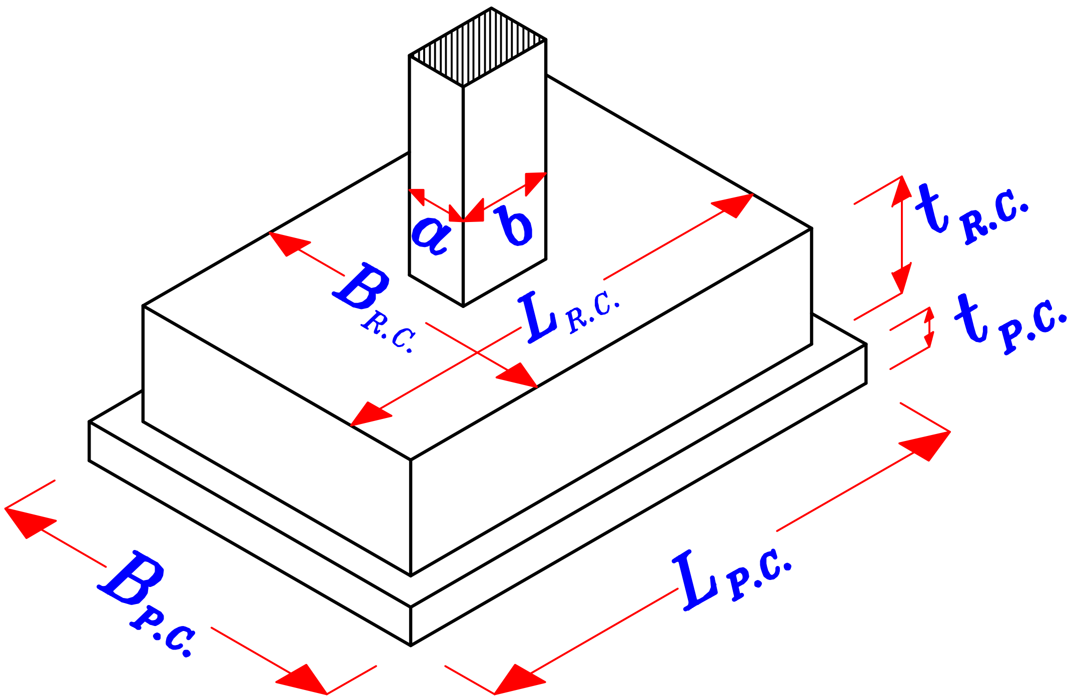
Sec X–X

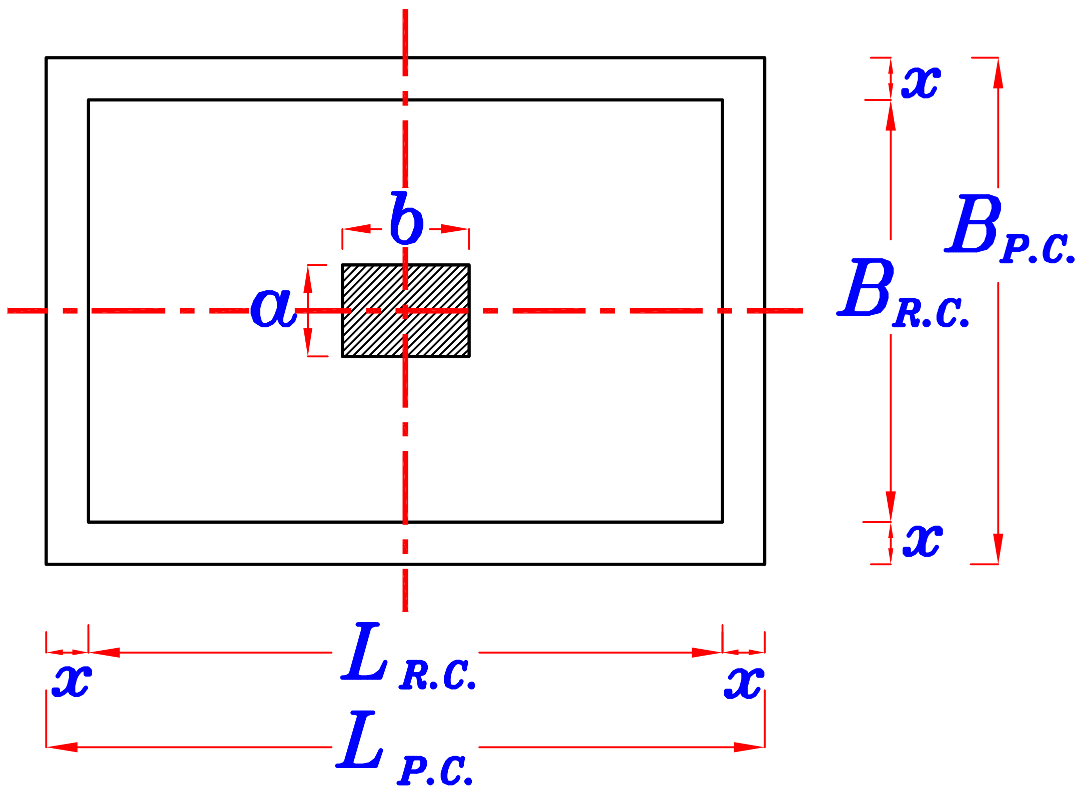


Plan

3 Design of Isolated Rectangular Footings .

تصميم القواعد المنفصله المستطيله .



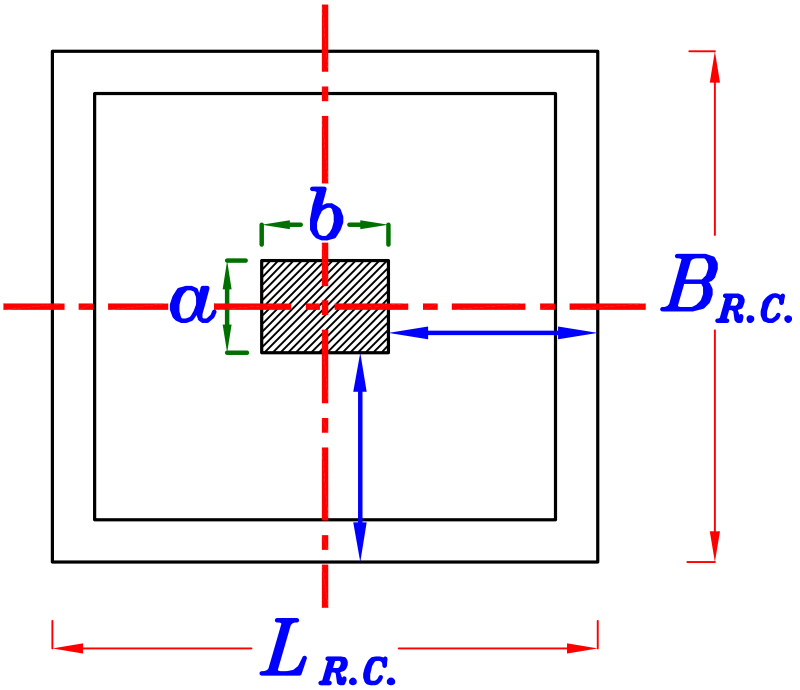


ملحوظه

يفضل فى القواعد المستطيله .

أن تكون المسافه من وش القاعده المسلحه لوش العمود متساويه من الجهتين .

و هذا ليس شرط.



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

1– Calculate the Footing area. (*Width & Length of R.C. Footing.*)

IF $t_{P.C.} \geq 20\ cm$

get $B_{P.C.}$, $L_{P.C.}$ From

$$A_{P.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark\ m^2 = B_{P.C.} * L_{P.C.} \quad \text{------} (1)$$

$$L_{P.C.} - B_{P.C.} = b - a \quad \text{------} (2)$$

بعد حساب $B_{P.C.}$ & $L_{P.C.}$ يقربا لاقرب ٥٠ مم بالزياده

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

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

IF $t_{P.C.} < 20\ cm$

get $B_{R.C.}$, $L_{R.C.}$ From

$$A_{R.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark\ m^2 = B_{R.C.} * L_{R.C.} \quad \text{------} (1)$$

$$L_{R.C.} - B_{R.C.} = b - a \quad \text{------} (2)$$

بعد حساب $B_{R.C.}$ & $L_{R.C.}$ يقربا لاقرب ٥٠ مم بالزياده

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

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

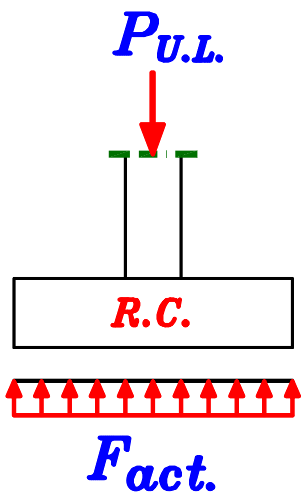
2– Design the critical sections For moment. (Depth of R.C. Footing.)

$B_{R.C.} = \checkmark\ m$, $L_{R.C.} = \checkmark\ m$

$$P_{U.L.} = P_w * 1.5 \quad (kN)$$

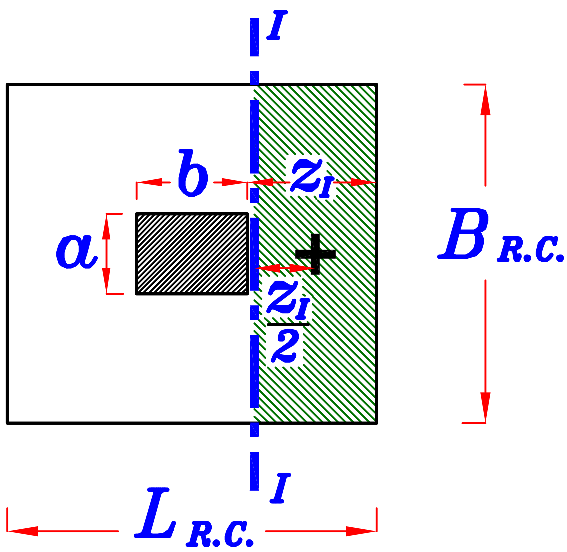
– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} \quad (kN/m^2)$$



– Critical section of bending at R.C. Foorting.

ناخذ القطاعات الحرجه للعزوم على وش العمود من الجهتين .



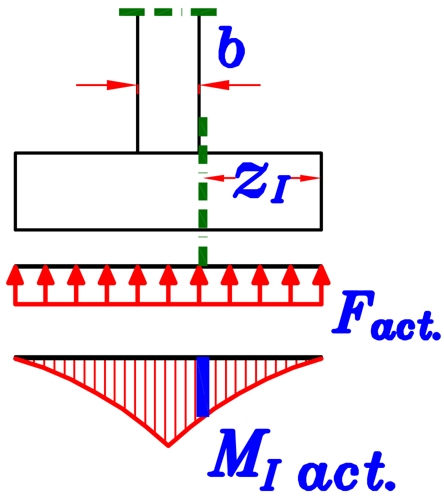
Direction I

$$z_I = \frac{L_{R.C.} - b}{2} \quad (m)$$

Force = Stress * Area

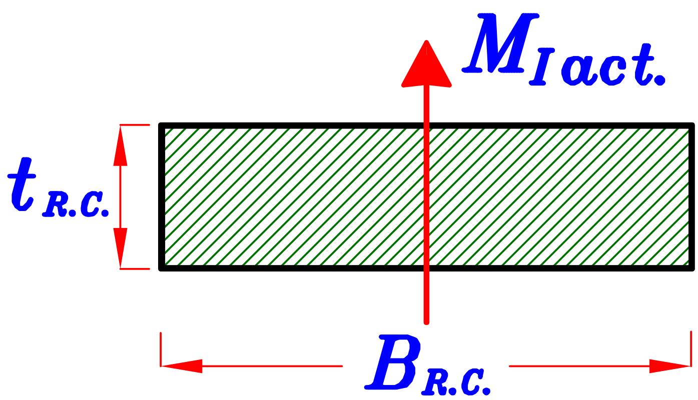
$$Force = F_{act.} * z_I * B_{R.C.}$$

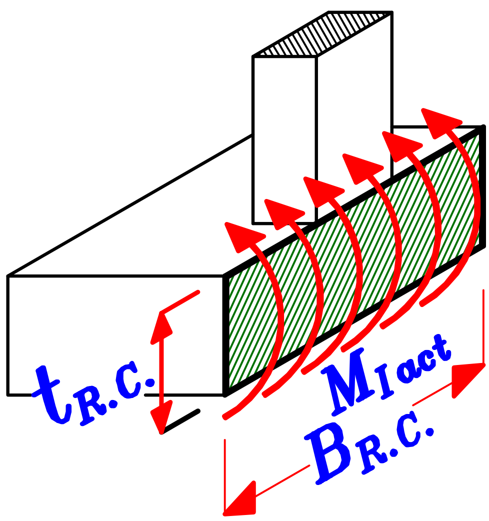
Moment = Force * Distance



$$M_{I\,act.} = (F_{act.} * z_I * B_{R.C.}) \; \frac{z_I}{2}$$

$(kN.m/B)$





$$d_{I}\,(mm) = C_1 \sqrt{\frac{M_{I\,act.}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * B_{R.C.}\,(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

Get $d_I = \checkmark\checkmark\ (mm)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده Rigid

Take $cover = 70\ mm$

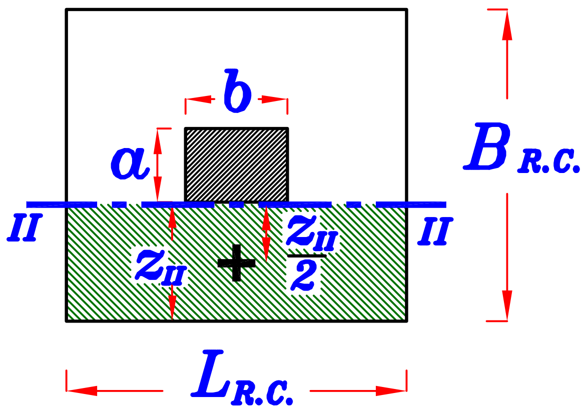
يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصداء.

$$t_{R.C.} = d_I + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

Direction II

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

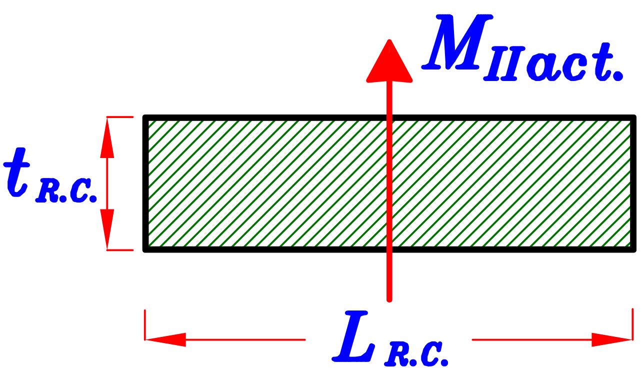


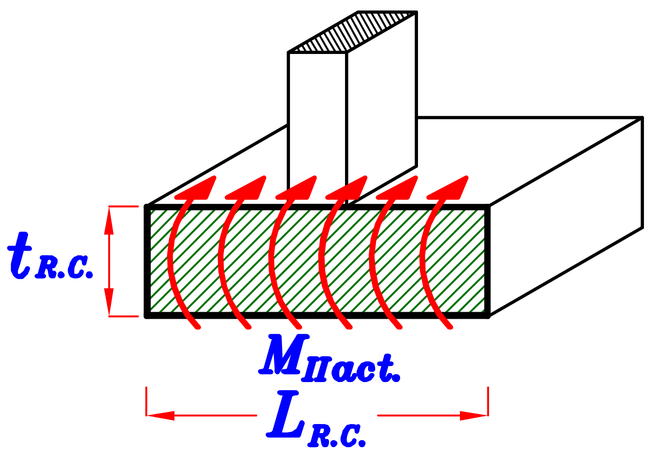
$$Force = Stress * Area$$

$$Force = F_{act.} * Z_{II} * L_{R.C.}$$

$$Moment = Force * Distance$$

$$M_{II\,act.} = (F_{act.} * Z_{II} * L_{R.C.})\ \frac{Z_{II}}{2} \quad (kN.m/L)$$





$$d_{II}\,(mm) = C_1 \sqrt{\frac{M_{II\,act.}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * L_{R.C.}\,(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده **Rigid**

Get $d_{II} = \checkmark\checkmark\,(mm)$

Take $cover = 70\ mm$

يفضل أن يكون الـ **cover** فى القواعد كبير
لحمايه الحديد من الصداء .

$$t_{II\,R.C.} = d_{II} + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

نأخذ الاكبر من $t_{II\,R.C.}$ & $t_{I\,R.C.}$ تكون هى $t_{R.C.}$

ملحوظه

اذا حافظنا على الشرط $L_{P.C.} - B_{P.C.} = b - a$

فيكون $z_I = z_{II}$ و بالتالى سيكون $\frac{M_{II}}{L} = \frac{M_I}{B}$ و من ثم سيكون $d_I = d_{II}$

أى انه يمكن أن ندرس أتجاه واحد فقط و يكون الاخر بالمثل .

3 – Check Shear.

Critical section of shear at R.C. Footing.

حمل العمود يتوزع من أعلى الى أسفل داخل القاعده بميل $(1:1)$ أى بزاويه ميل 45^o

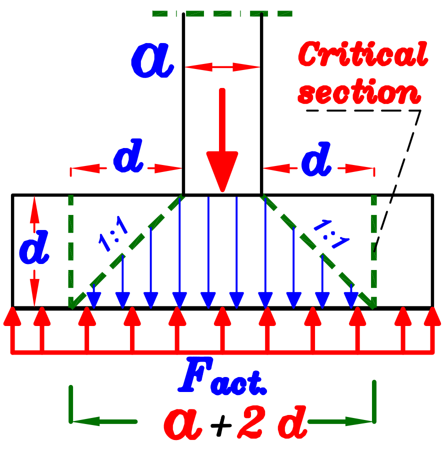
أى يكون تأثيره على القاعده على عرض $(b+2d)$ & $(a+2d)$

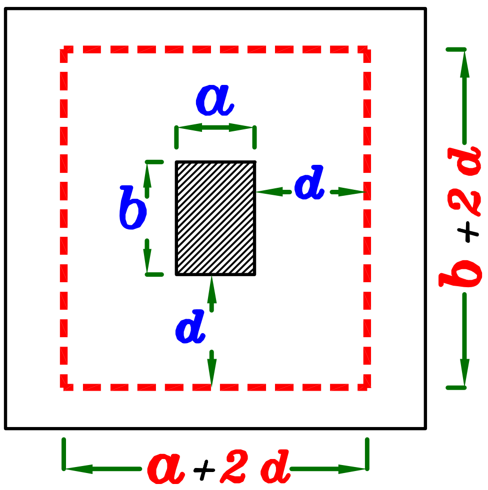
فتكون المساحه $(b+2d) * (a+2d)$ في منتصف القاعده عليها أقل اجهادات قص

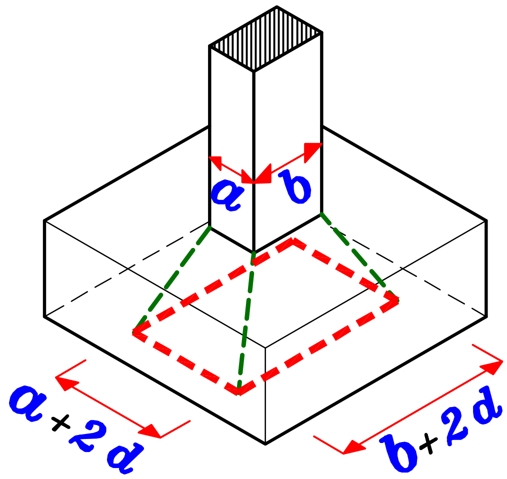
حيث تكون قيمته تساوى رد فعل التربه على القاعده $F_{act.}$ مطروحا منه حمل العمود $P_{U.L.}$

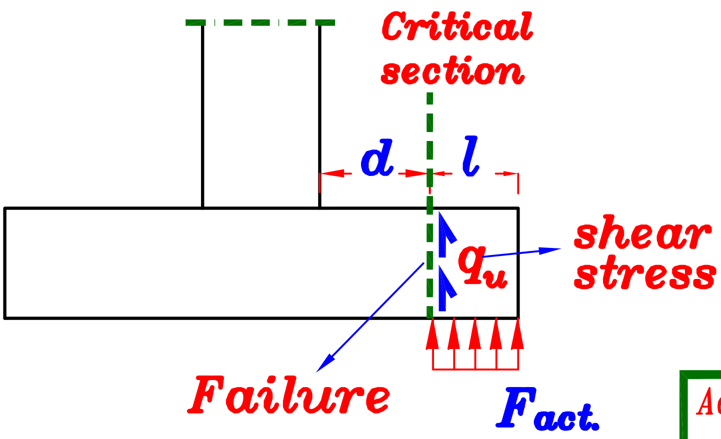
فيكون القطاع الحرج الذى عليه أكبر اجهادات قص على بعد d من وش العمود من أى جهه

لانه أول قطاع عليه رد فعل الارض فقط و بالتالى يكون عليه أكبر **Shear stress** .









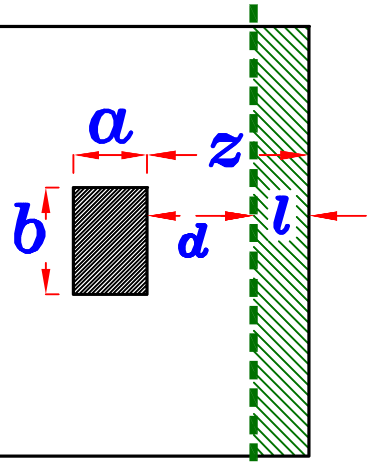
[Shear Failure]

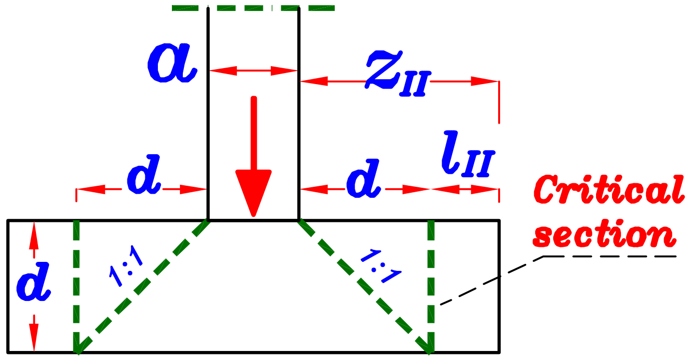
لذلك يجب التحقق من أن اجهاد القص

على جانب السطح المتوقع للانفصال

لا يتعدى مقاومه الخرسانه فى القص

Actual Shear stress	≤	Allowable Shear stress
q_u	$\le$	q_{su}





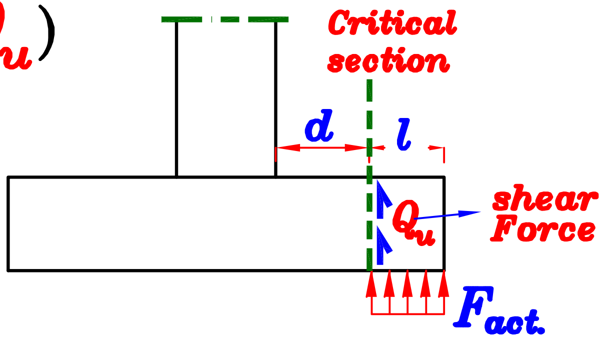
* Calculate $l = z - d$ (m)

z الاكبر من z_I , z_{II}

* Calculate Actual shear Force. (Q_u)

نحسب ل – ١,٠ م طولى من القاعده

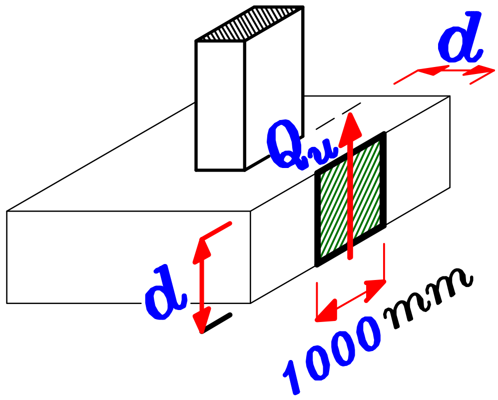
$$Q_u = F_{act.} * l * 1.0\ m \quad (kN)$$



* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d}$$

$$q_u = \frac{Q_u (kN) * 10^3}{1000 (mm) * d (mm)} \quad (N/mm^2)$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

لاحظ أنه فى القواعد نعتمد فقط
على مقاومه الخرسانه فى القص
لانه لا توجد كانات حيث يصعب
تشكيلها بالابعاد الضخمه للقواعد .

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su} \longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_u > q_{su} \longrightarrow$ UnSafe shear stresses
We have to increase dimensions.

IF UnSafe shear stresses increase $t_{R.C.}$ by 100 mm

then Calculate:

$$d = t_{R.C.} - 70 \ mm$$

$$l = z - d \quad (m)$$

$$Q_u = F_{act.} * l * 1.0 \ m \quad (kN)$$

$$q_u = \frac{Q_u (kN) * 10^3}{1000 (mm) * d (mm)} \quad (N/mm^2)$$

then ReCheck:

Actual shear stress (q_u) & Allowable shear stress (q_{su})

4 – Check Punching Shear. القص الثاقب .

يجب التأكد من أن العمود لن يخترق القاعده .

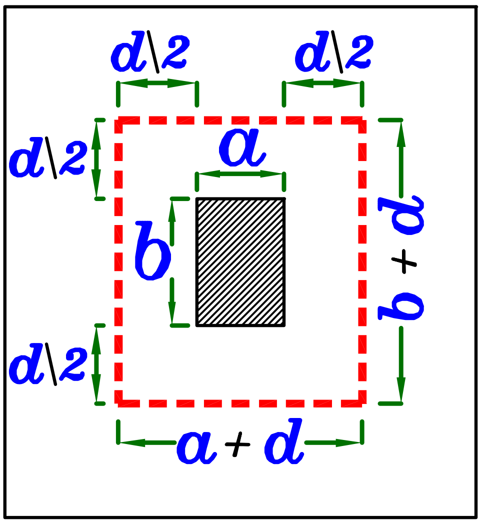
و للتأكد من ذلك نحسب q_{pu} و هو اجهاد القص الذى سينتج عن ثقب العمود للقاعده .

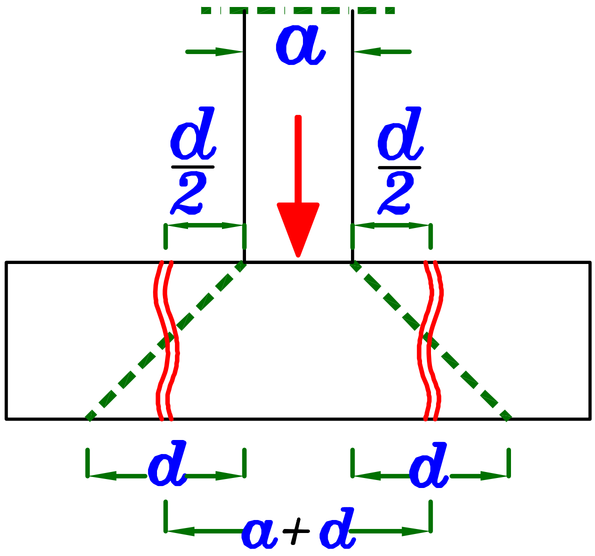
و نحسب q_{pcu} و هى مقاومه الخرسانه للقص الناتج عن ثقب القاعده .

The concrete area which resist punching shear.

تحديد مساحه الخرسانه المقاومه للقص الثاقب .

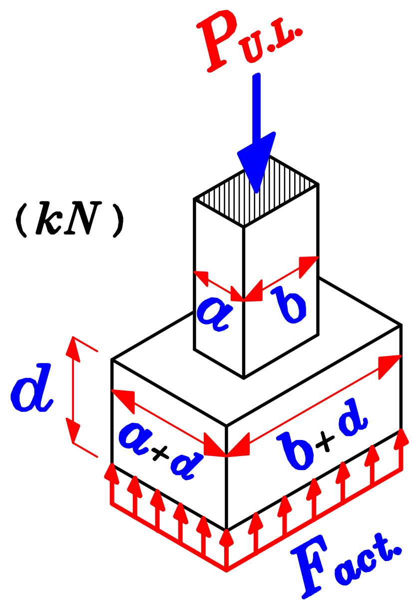
القطاع الحرج فى القص الثاقب عباره عن محيط يحيط بالعمود على مسافه $\frac{d}{2}$ من وش العمود من كل جهه .





*** Calculate Punching Force. (Q_p)**

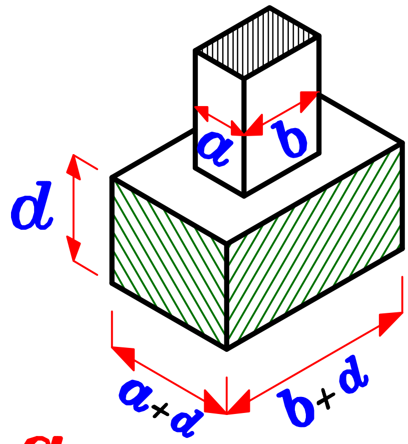
$$Q_p = P_{U.L.} - (F_{act.}) \left[(a+d)(b+d)\right] \quad (kN)$$



* Calculate Punching shear area. (A_p)

المحيط العمق

$$A_p = [2(a+d)+2(b+d)]*d \quad (mm^2)$$



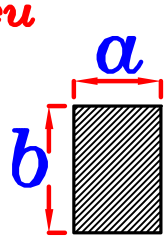
* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{\text{Punching Force}}{\text{Punching area}}$$

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

* Calculate allowable Punching shear stress. q_{pcu}

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



IF $(0.5+\frac{a}{b}) \leq 1.0$ Take → $q_{pcu} = 0.316 \sqrt{\frac{F_{cu}}{\delta_c}} \quad (N/mm^2)$

---

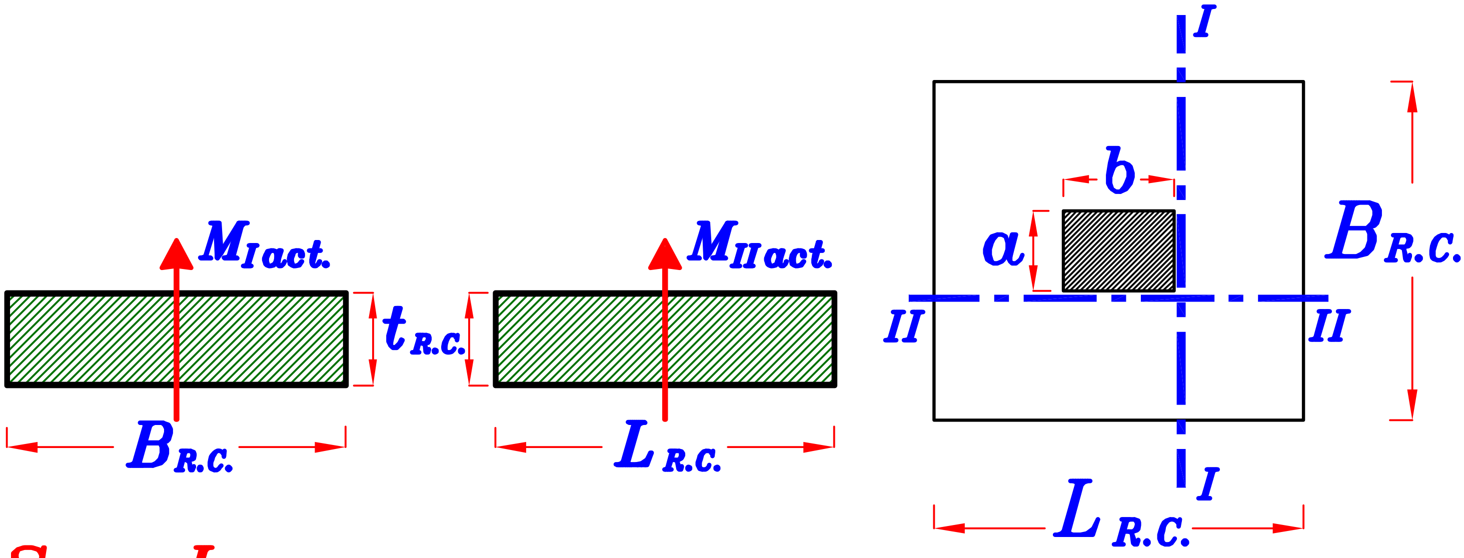
* Compare between

Actual punching shear stress (q_{pu}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu} \leq q_{pcu}$ → Safe punching shear. No need to increase dimensions.

* IF $q_{pu} > q_{pcu}$ → UnSafe punching shear. We have to increase dimensions.

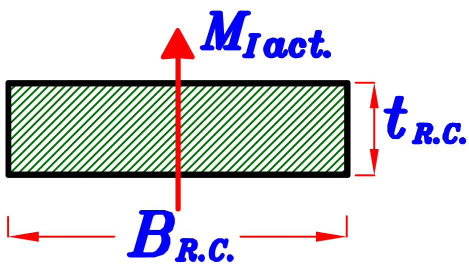
5- Reinforcement of the Footing.



Sec. I

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$



Get

$$A_{sI} = \frac{M_{I\,act.}}{J\,F_y\,d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{Bmatrix} 1.5\,d\ (mm) \\ 5\,\phi\,12\,/m' \end{Bmatrix} \text{الأكبر}$$

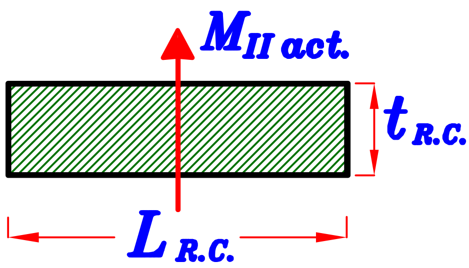
IF $A_{sI} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{sI} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

Sec. II

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$



Get $$A_{sII} = \frac{M_{II\,act.}}{J\,F_y\,d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\,d\ (mm) \\ 5\,\phi\,12/m' \end{cases}$$ الأكبر

IF $A_{sII} \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_{sII} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

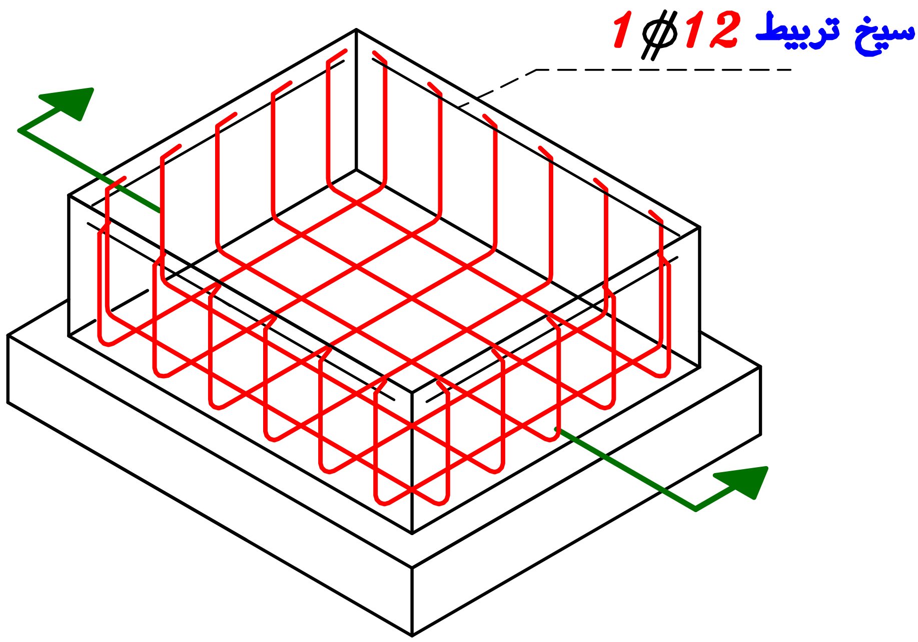
ملحوظه

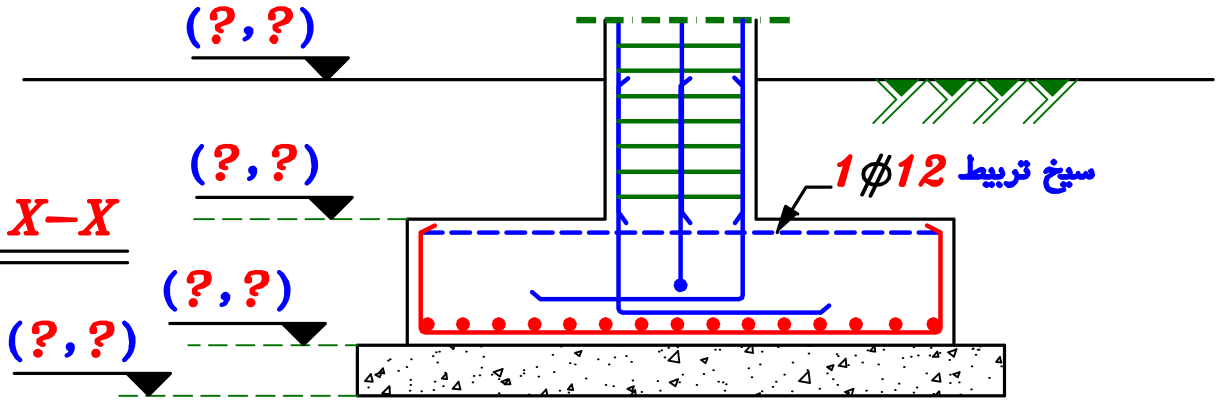
فى حاله تحقيق الشرط $L - B = b - a$

سيكون $\frac{M_{II\,act.}}{L} = \frac{M_{I\,act.}}{B}$ و بالتالى من الممكن حساب A_s فى اتجاه

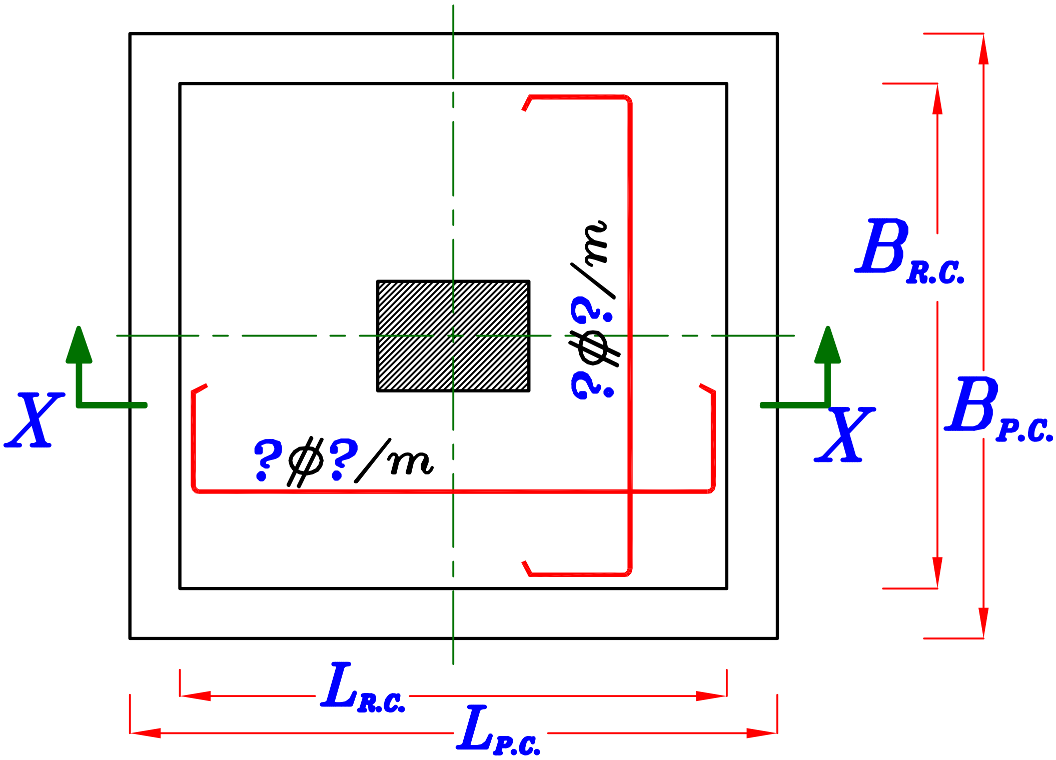
واحد فقط و يكون الاتجاه الاخر نفس القيمه $A_{sI} = A_{sII}$

6 – Details of Reinforcement.





Sec X–X



Plan

Example.

It is required to design a rectangular Footing to Support a R.C column of thickness (30 * 80) cm.
The column working load is 1900 kN , and the allowable net bearing capacity in the Footing site is 120 kN/m^2. (F_{cu} = 30 N/mm^2, F_y = 400 N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given:

column dimensions (300 * 800) mm

$P_{col.}$ (working) = 1900 kN $P_{col.}$ (U.L.) = 1900 * 1.5 = 2850 kN

Bearing capacity of the soil = q_{all} = 120 kN/m^2

F_{cu} = 30 N/mm^2 F_y = 400 N/mm^2

1– Calculate the Footing area (Width & Length of R.C. Footing.)

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

$$L_{P.C.} - B_{P.C.} = b - a = 0.80 - 0.30 = 0.50\ m$$

$$L_{P.C.} = B_{P.C.} + 0.50\ m \quad \text{------} (1)$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1900\ (kN)}{120\ (kN/m^2)} = 15.83\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 15.83\ m^2 \quad \text{-----} (2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.50) = 15.83 \ m^2$$

$$B_{P.C.} = 3.73 \ m$$

$$\boxed{B_{P.C.} = 3.80 \ m} \qquad \boxed{L_{P.C.} = 4.30 \ m}$$

$$\boxed{B_{R.C.} = 3.20 \ m} \qquad \boxed{L_{R.C.} = 3.70 \ m}$$

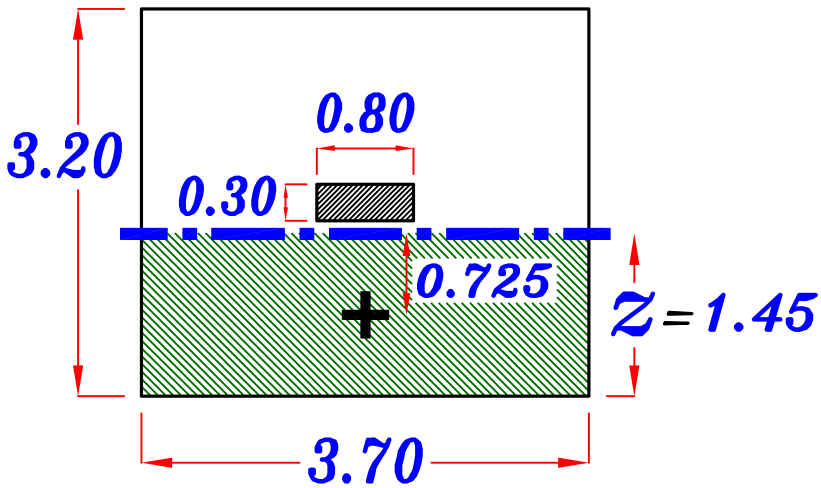
2– *Design the critical sections For moment.* (*Depth of R.C. Footing.*)

– ***Actual Normal stress on R.C. Footing* (U.L.)**

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{2850}{3.20 * 3.70} = 240.7 \ kN/m^2$$

$$Z = \frac{B_{R.C.} - a}{2} = \frac{3.20 - 0.30}{2}$$

$$= 1.45 \ m$$



ملحوظه

اذا حافظنا على الشرط $\boxed{L_{P.C.} - B_{P.C.} = b - a}$

فيكون $Z_I = Z_{II}$ و بالتالى سيكون $\frac{M_I}{B} = \frac{M_{II}}{L}$ و من ثم سيكون $d_I = d_{II}$

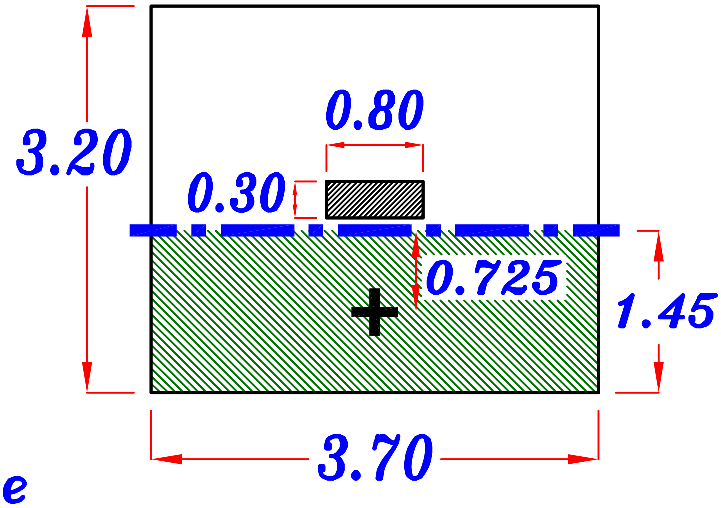
أى انه يمكن أن ندرس أتجاه واحد فقط و يكون الاخر بالمثل .

$$Force = Stress * Area$$

$$Force = F_{act.} * Z * B$$

$$= 240.7 * 1.45 * 3.70$$

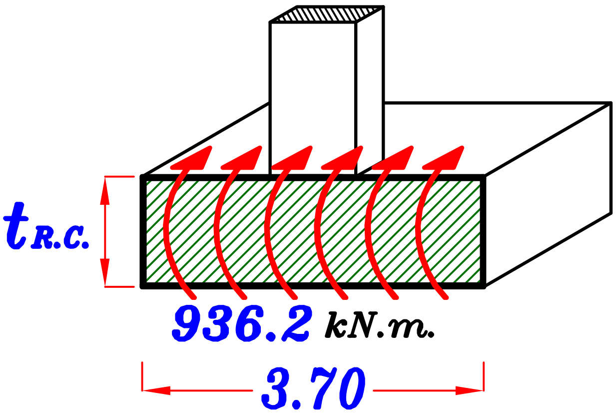
$$= 1291.4 \ kN$$

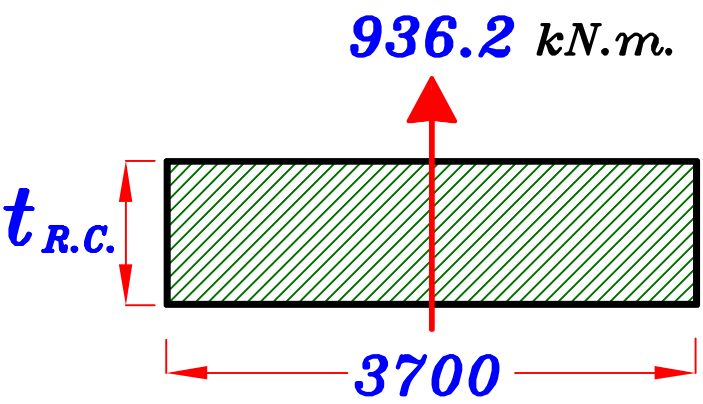


$$moment = Force * Distance$$

$$M_{act.} = (F_{act.} * Z * B_{R.C.}) \frac{Z}{2}$$

$$= (240.7 * 1.45 * 3.70) \frac{1.45}{2} = 936.2 \ kN.m$$





$$\because \ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \ d = 5.0 \sqrt{\frac{936.2 * 10^6}{30 * 3700}} = 459.2 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 459.2 + 70 = 529.2 \ mm$$

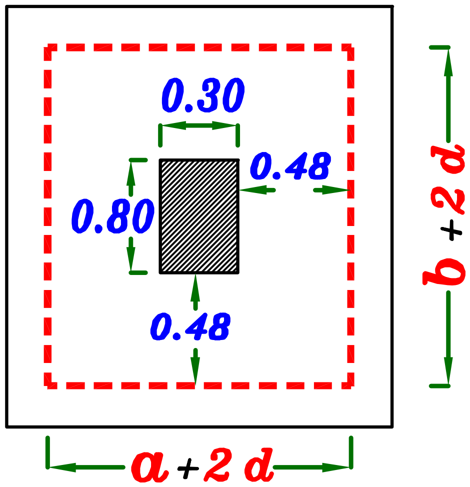
$$t_{R.C.} = 550 \ mm$$

$$d = 480 \ mm$$

3 – Check Shear.

$a + 2d = 0.30 + 2 * 0.48 = 1.26\ m$

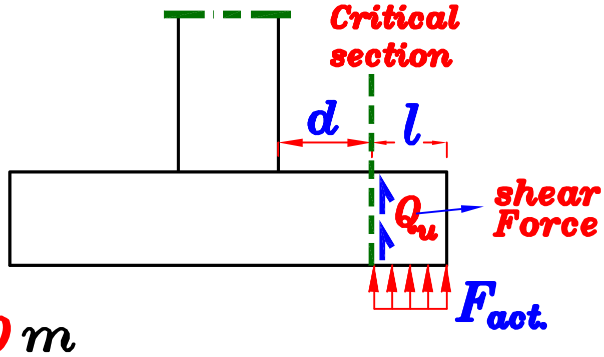
$b + 2d = 0.80 + 2 * 0.48 = 1.76\ m$



* Critical section For Shear.

$l = z - d$

$l = 1.45 - 0.48 = 0.97\ m$

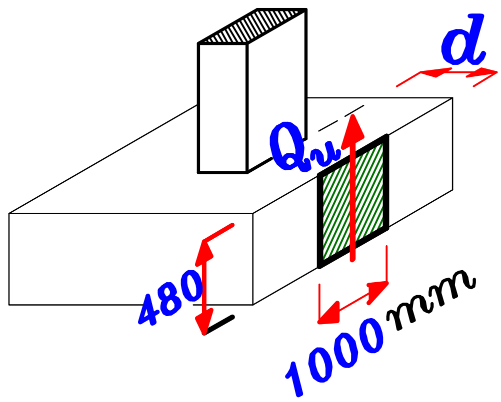


* Actual shear Force. (Q_u) For 1.0 m

$Q_u = F_{act.} * l * 1.0\ m = 240.7 * 0.97 * 1.0\ m = 233.48\ kN$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{233.48 * 10^3}{1000 * 480} = 0.486\ N/mm^2$$



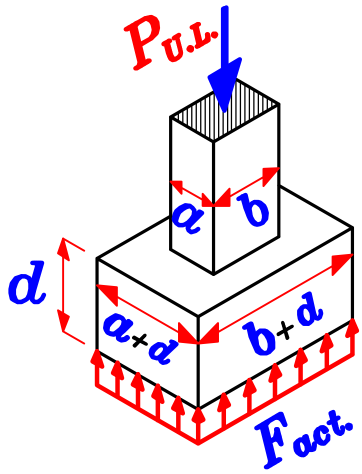
* Allowable shear stress. (q_{su})

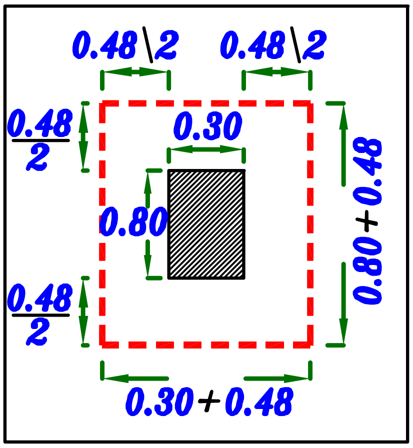
$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{30}{1.5}} = 0.715\ N/mm^2$$

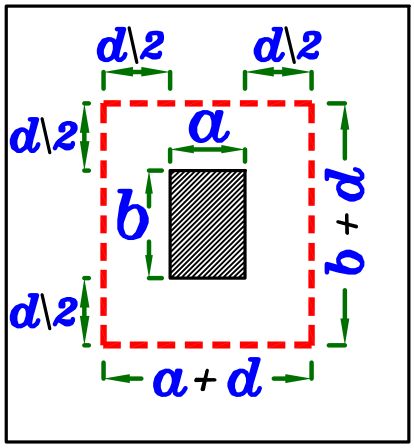
$q_u < q_{su}$ ⟶ Safe shear stresses

No need to increase dimensions.

4 – Check Punching Shear.







$$a + d = 0.30 + 0.48 = 0.78\, m$$

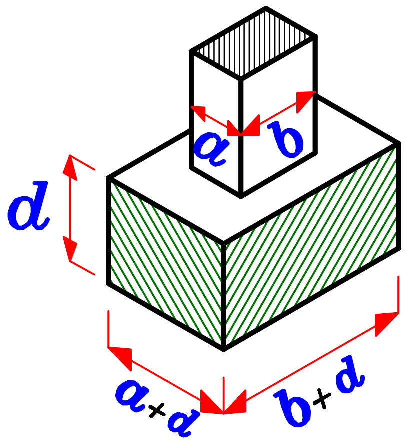
$$b + d = 0.80 + 0.48 = 1.28\, m$$

* **Calculate Punching Force.** (Q_p)

$$Q_p = P_{U.L.} - (F_{act.})\left[(a+d)(b+d)\right]$$

$$Q_p = 2850 - 240.7\left[0.78 * 1.28\right] = 2609.7\ kN$$

* **Calculate Punching shear area.** (A_p)



$$A_p = \left[2(a+d) + 2(b+d)\right] * d$$

$$A_p = \left[2(300+480) + 2(800+480)\right] * 480$$

$$A_p = 1977600\ mm^2$$

* **Calculate Actual Punching shear stress.** q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)] * d}$$

$$q_{pu} = \frac{2609.7 * 10^3}{1977600} = 1.319 \ N/mm^2$$

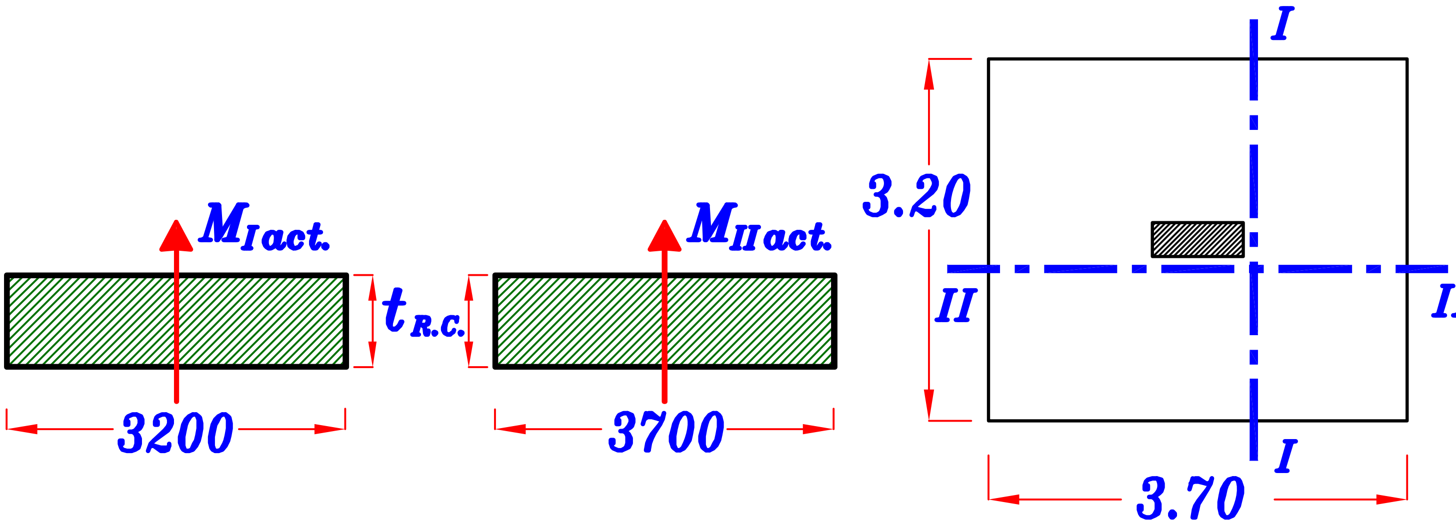
* **Calculate allowable Punching shear stress.** q_{pcu}

$$(0.5 + \frac{a}{b}) = (0.5 + \frac{0.30}{0.80}) = 0.875 \leqslant 1.0$$

$$q_{pcu} = 0.316 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316 \sqrt{\frac{30}{1.5}} = 1.413 \ N/mm^2$$

$q_{pu} \leqslant q_{pcu}$ ⟶ **Safe punching shear.** No need to increase dimensions.

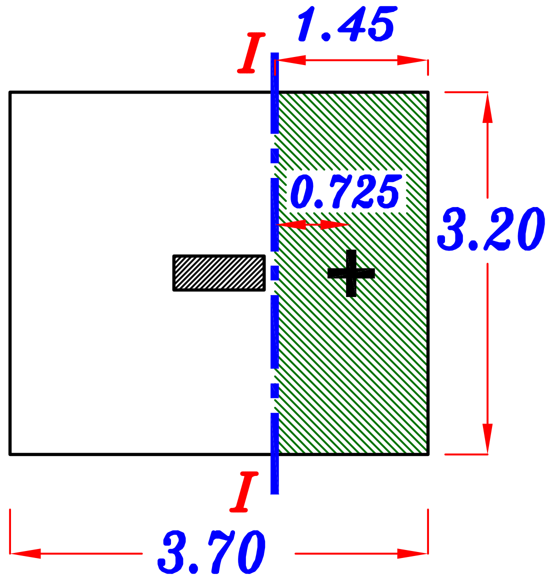
5- Reinforcement of the Footing.



$$M_{I\,act.} = (F_{act.} * Z * B_{R.C.})\frac{Z}{2}$$

$$= (240.7 * 1.45 * 3.20)\frac{1.45}{2}$$

$$= 809.7 \text{ kN.m}$$



$$J = 0.826$$

$$A_s = \frac{M_{I\,act.}}{J\,F_y\,d} = \frac{809.7 * 10^6}{0.826 * 400 * 480} = 5105.5 \text{ mm}^2$$

$$A_s\,(mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{5105.5}{3.20} = 1595.5 \text{ mm}^2/m'$$

Check $A_{s\,min}$

$$A_{s\,min} = \begin{cases} 1.5\,d = 1.5 * 480 = 720 \\ 5\phi 12/m' = 565 \end{cases} 720 \text{ mm}^2$$

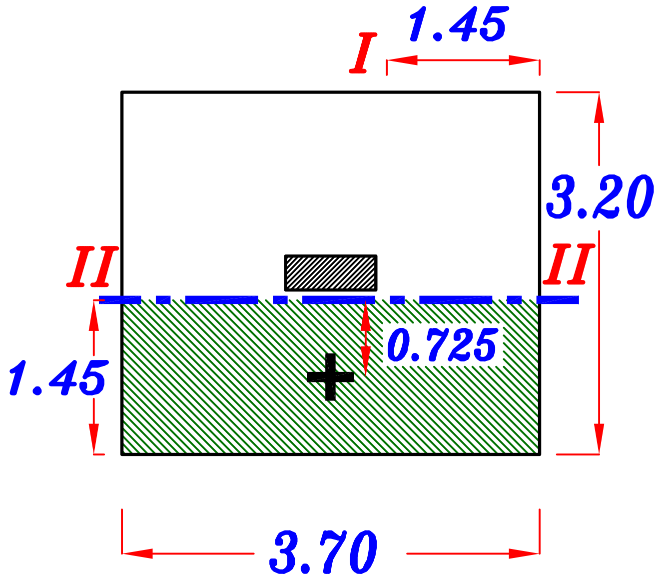
$$\therefore A_s > A_{s\,min} \longrightarrow o.k.$$

$$A_s = 1595.5 \text{ mm}^2 \qquad \boxed{5\phi 22/m'}$$

$$M_{II\,act.} = \left(F_{act.} * Z * L_{R.C.}\right) \frac{Z}{2}$$

$$= \left(240.7 * 1.45 * 3.70\right) \frac{1.45}{2}$$

$$= 936.2 \ kN.m$$



$$J = 0.826$$

$$A_s = \frac{M_{II\,act.}}{J\,F_y\,d} = \frac{936.2 * 10^6}{0.826 * 400 * 480} = 5903.2 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{5903.2}{3.70} = 1595.5 \ mm^2/m'$$

Check $A_{s\,min}$

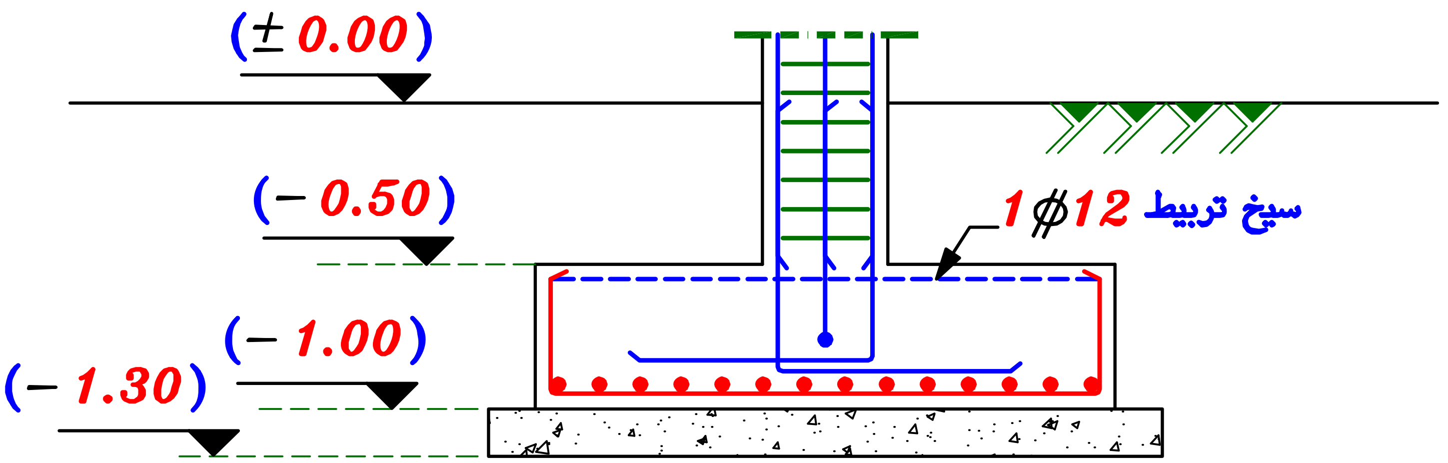
$$A_{s\,min} = \begin{cases} 1.5\,d = 1.5 * 480 = 720 \\ 5 \phi 12/m' = 565 \end{cases} \quad 720 mm^2$$

$$\therefore \ A_s > A_{s\,min} \longrightarrow o.k.$$

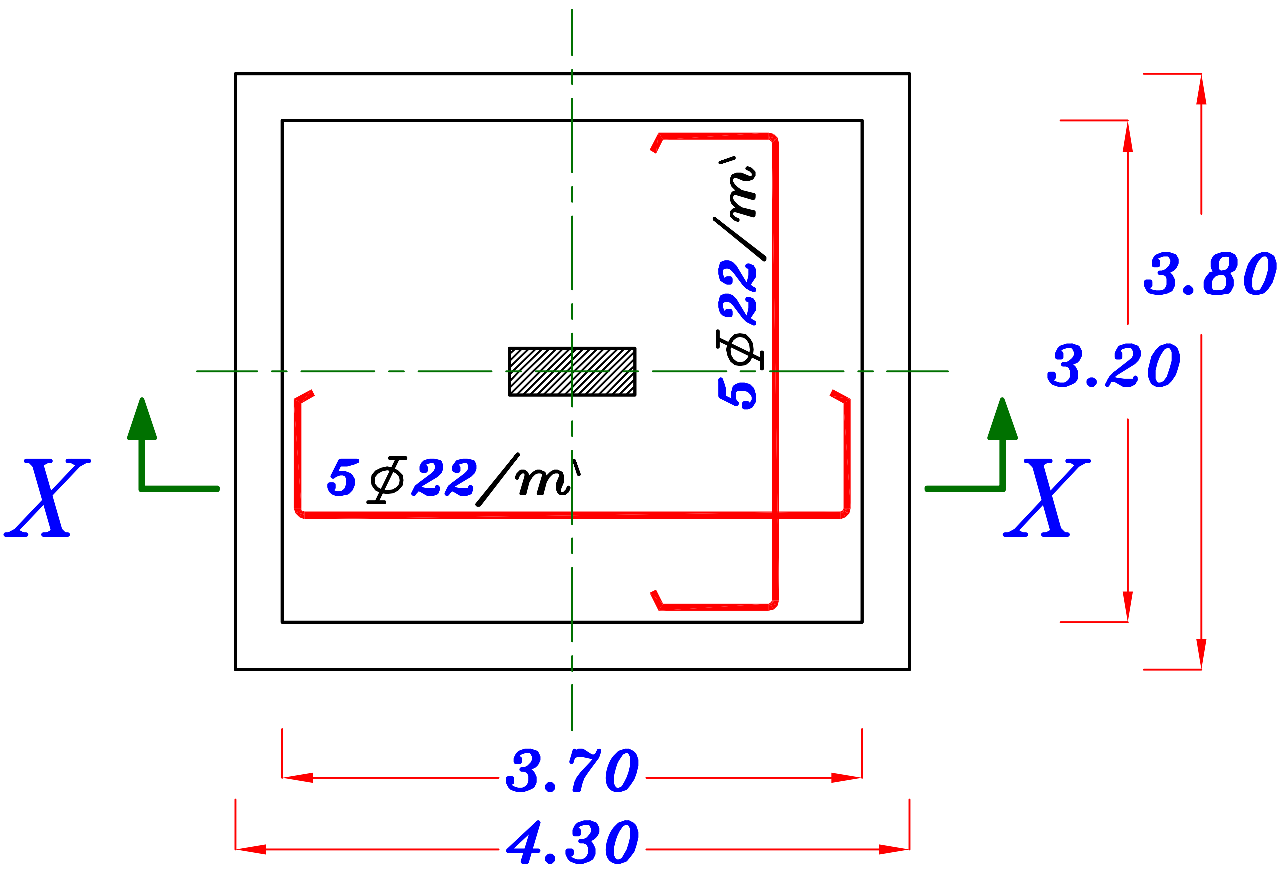
$$A_s = 1595.5 \ mm^2$$

$5 \phi 22/m'$

6 – Details of Reinforcement.



Sec X–X



Important Notes. ملاحظات هامه .

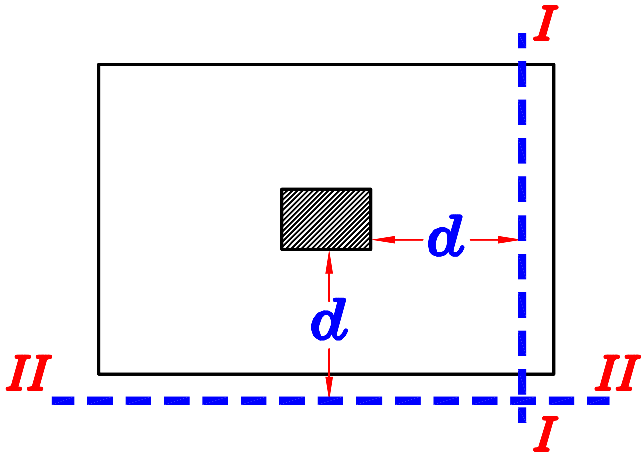
١ – فى حاله عمل **check shear**

و وقوع مستوى ال **critical section** (الذى يبعد مسافه d من وش العمود)

خارج القاعده المسلحه فانه لا يكون عليه أجهاد قص

$$Q_{SI} = q_u * l * 1.0m$$

$$Q_{SII} = Zero$$



٢ – فى حاله عمل **check punching**

و وقوع مستوى ال **critical section** (الذى يبعد مسافه $\frac{d}{2}$ من وش العمود)

خارج القاعده المسلحه .

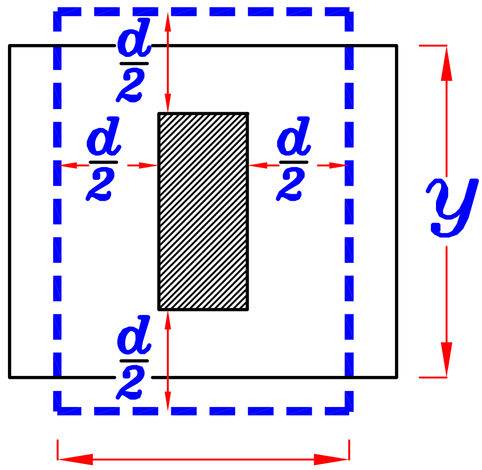
$$A_p = 2\,y * d$$

$$Q_p = P_{U.L.} - (F_{act.})\,[X * Y]$$

$$q_{pu} = \frac{Q_p}{2\,y * d}$$

الجانب y فقط هو الذى يحدث

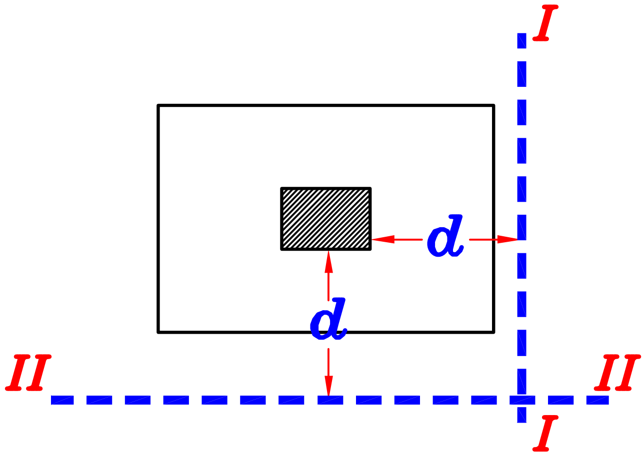
عليه الانفصال عن القاعده



$$X = a + d$$

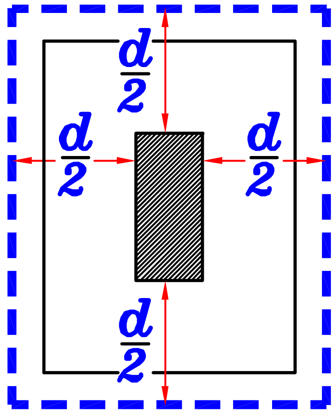
٣ـ اذا وقعت كل مستويات check shear خارج القاعده المسلحه

No need to check shear



اذا وقعت كل مستويات check punching خارج القاعده المسلحه

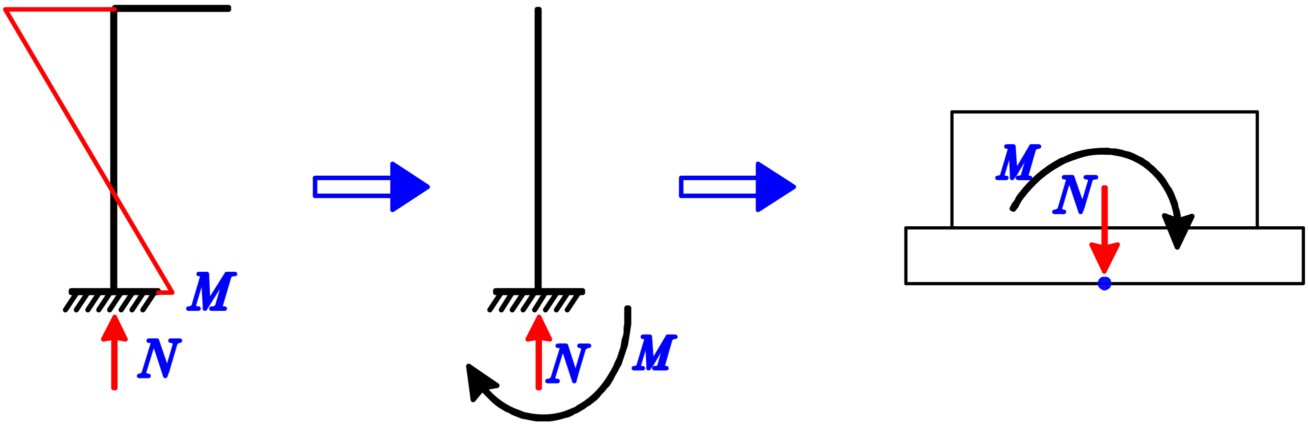
No need to check punching



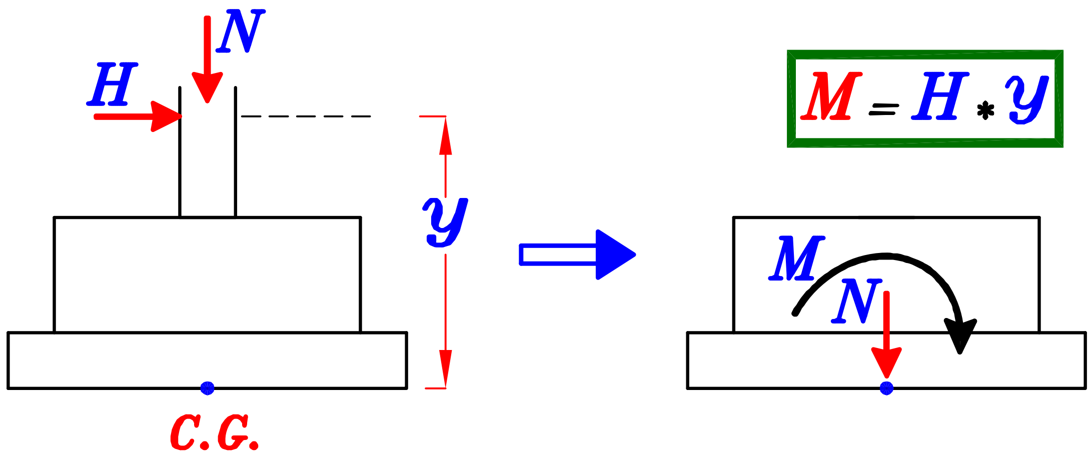
4 Design of Isolated Footing subjected to Moment and Normal M & N

تتولد عزوم على القواعد من أسباب عده منها :

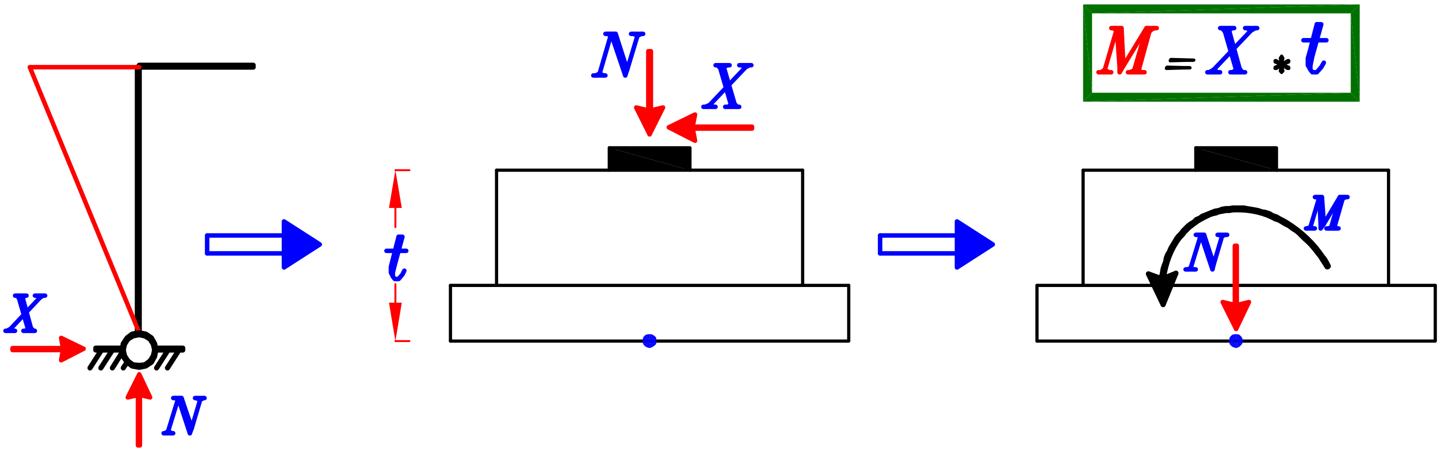
١- عزم صريح على العمود . (مثل الاعمده فى ال *Fixed Frames*) .



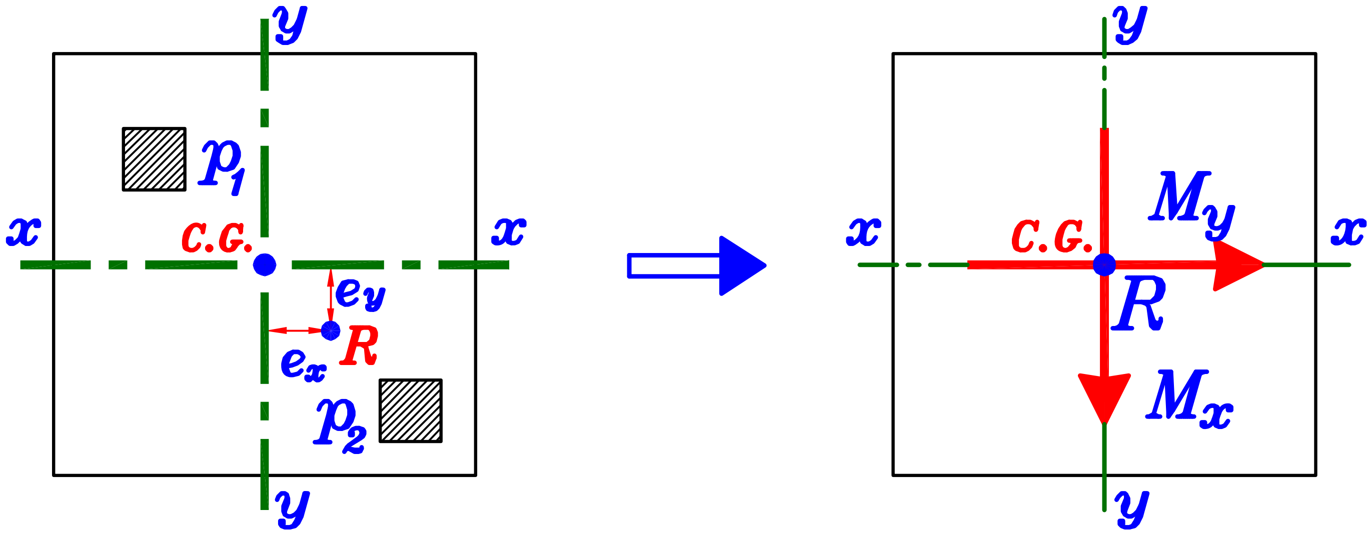
٢- وجود قوه أفقيه دائمه تؤثر على العمود على مسافه من *C.G.* القاعده .



٣- و جود قاعده *Hinged* يوجد عليها رد فعل أفقى دائم قيمته *X*



٤ ـ ال C.M. للاحمال (أي مركز الاحمال Center of Mass)
لا ينطبق على C.G. للقاعده فيسبب eccentricity مما يسبب عزوم دائمه .



$$R = P_1 + P_2$$

$$M_x = R * e_x$$

$$M_y = R * e_y$$

Types of moments on Footings.

أنواع العزوم التى من الممكن أن تؤثر على القواعد .

1- Permanent Moment. العزوم الدائمه .

و هى العزوم الناتجه عن الاحمال الدائمه مثل **Gravity loads & Dead loads**

و هى عزوم تكون ثابته المقدار و الاتجاه .

و يفضل إلغائها عن طريق ترحيل القاعده **مسافه** e عكس اتجاه ال **moment** .

2- Temporary Moment. العزوم المتغيره أو الغير دائمه .

و هى العزوم الناتجه عن الاحمال المتغيره مثل

L.L. , Wind load & Earth quake loads.

و هى عزوم متغيره الاتجاه ↻ or ↺ و لكن بقيمه ثابته .

و يتم تصميم القاعده بحيث يكون الاجهاد أسفل القاعده يساوى :-

$$F_{act} = \frac{N}{A} \pm \frac{M\,y}{I}$$

1- Design of isolated Footings subjected to permanent moment.

تصميم القواعد المنفصله المعرضه لعزوم ثابته المقدار و الاتجاه .

يفضل ترحيل القاعده **مسافه e** عكس اتجاه ال **moment** و ذلك لإلغاء ال **moment** .

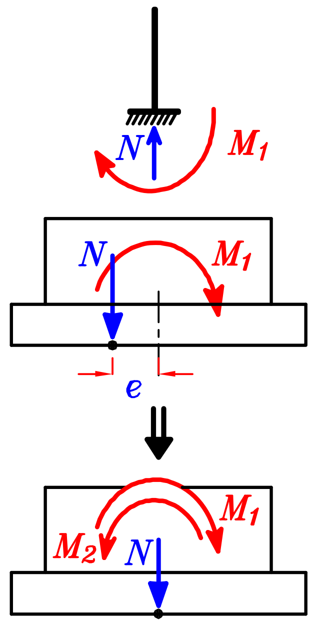
ترحيل القواعد

قيمه (**Normal stress**) على التربه تحسب من المعادله التاليه

$$F = -\frac{N}{A} \pm \frac{My}{I}$$

و من المفضل عدم عمل شد (**Tension**) على التربه .

فى حاله ترحيل القاعده عكس ال B.M.



تعمل N عزم قيمته $M_2 = N * e$

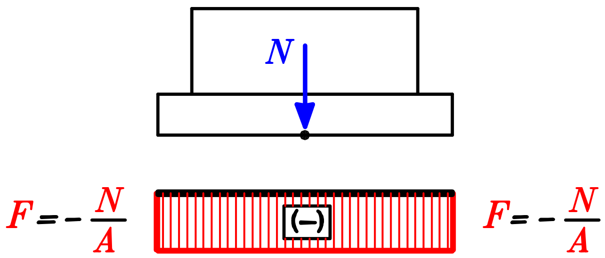
معاكس لـ M_1 اذا أخذنا قيمه لـ e

بحيث تكون $M_2 = M_1$ فلن يكون هناك عزم

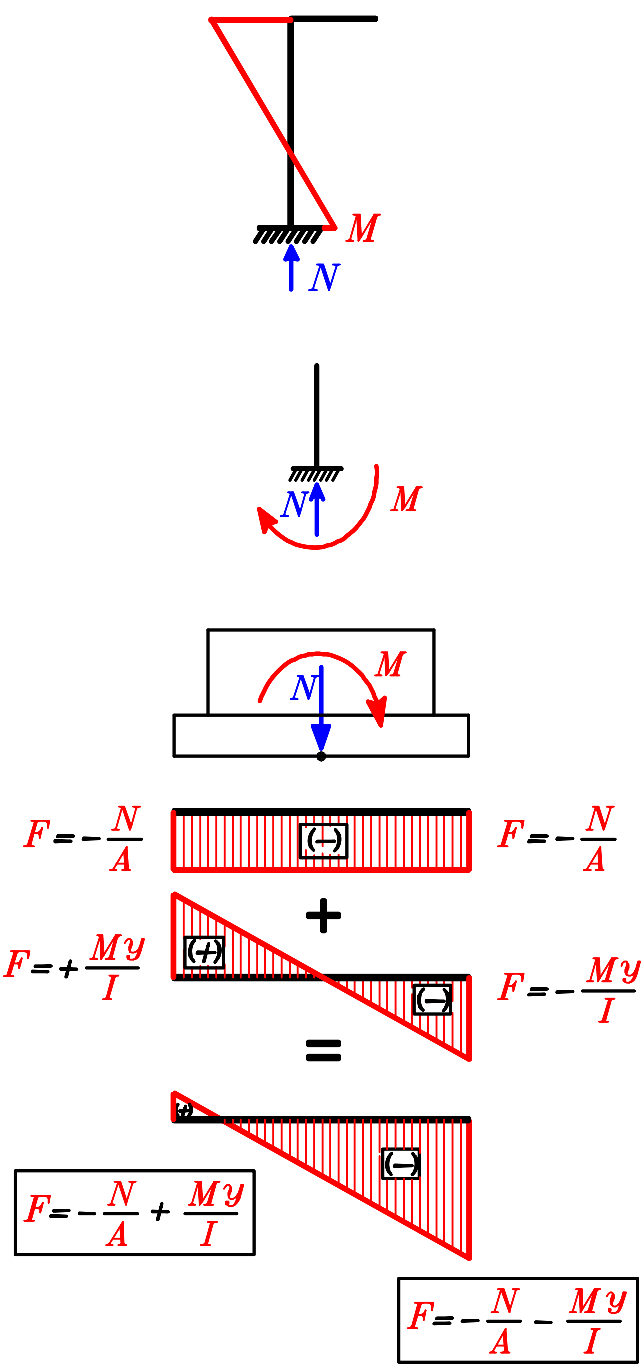
و تكون قوى ضغط فقط

و تكون قيمه $F = -\frac{N}{A}$ (*Normal stress*)

فنضمن أن ال *stress* كله *compression*



اذا لم يتم ترحيل القاعده

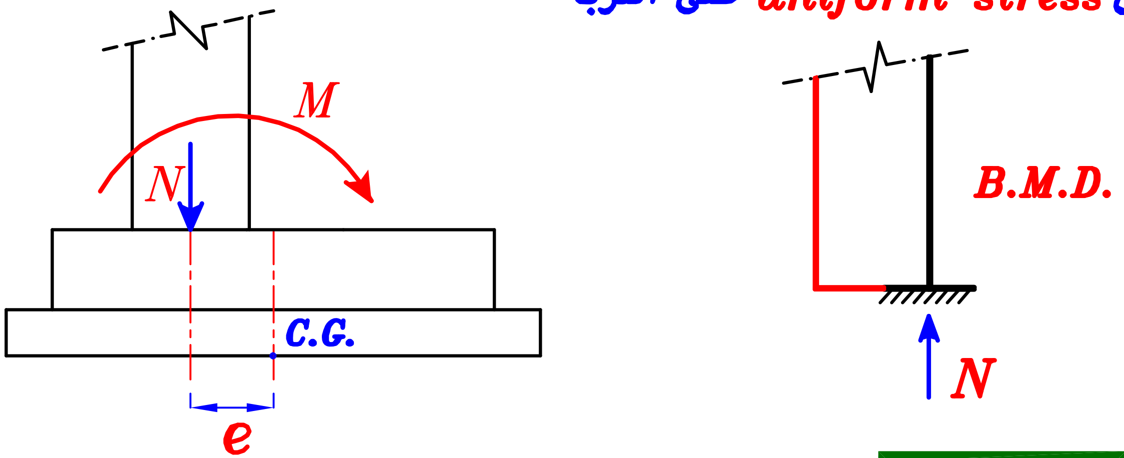


العزم من اتجاه واحد فقط.

أ ـ القاعده التى يوجد عليها Reactions فى إتجاه N و M معاً

ترحل القاعدة عكس إتجاه الـ Moment فى رسمة الـ B.M.D. مسافة (e)

لعمل uniform stress على التربه



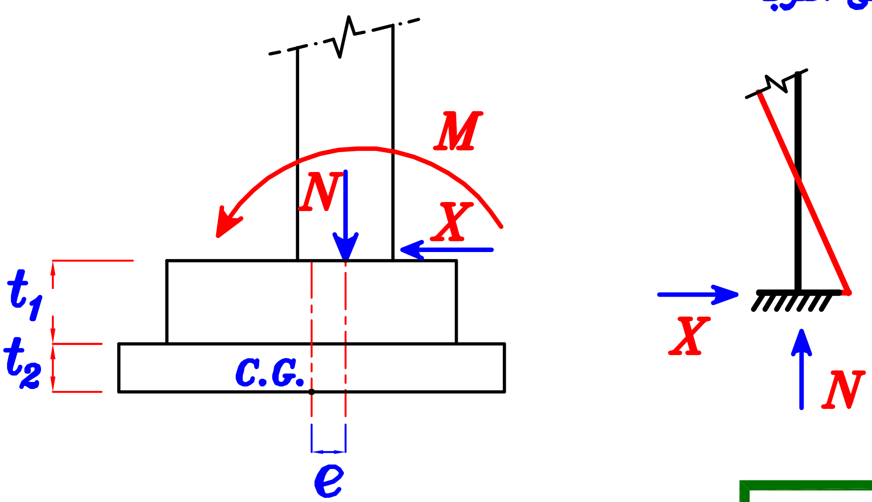
$\because \sum M_{C.G.} = Zero \qquad \therefore M - N(e) = Zero$

$$e = \frac{M}{N}$$

ب ـ القاعده التى يوجد عليها Reactions فى إتجاه X و N و M معاً

ترحل القاعدة عكس اتجاه الـ Moment فى رسمه الـ B.M.D. مسافه (e)

لعمل uniform stress على التربه



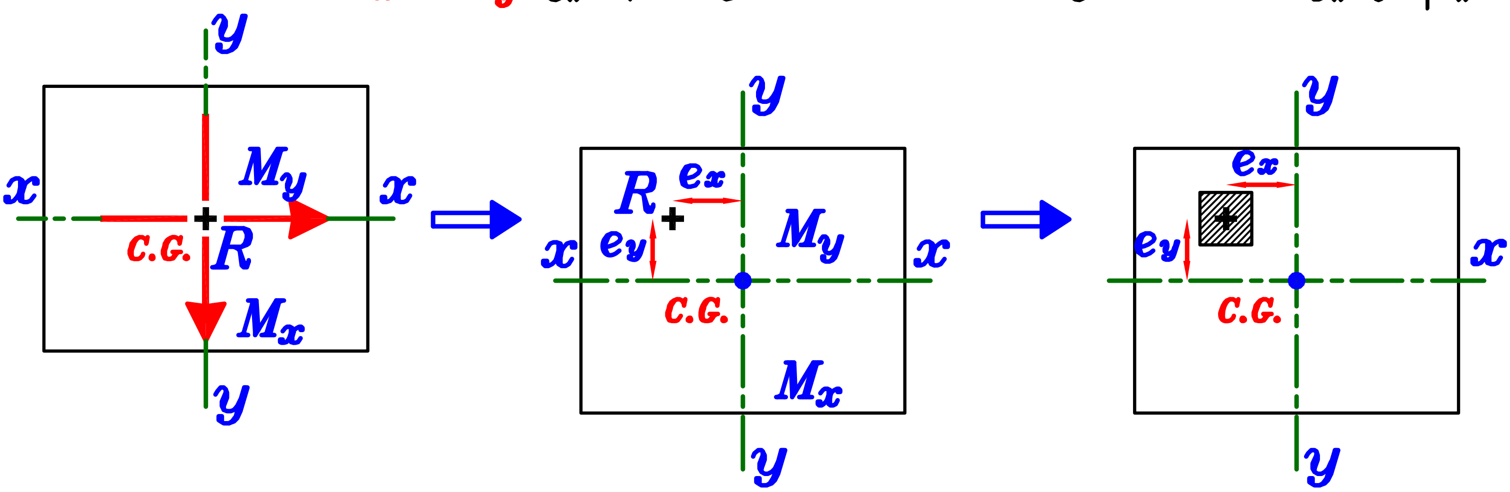
$\because \sum M_{C.G.} = Zero$

$\therefore X(t_1+t_2)+M - N(e) = Zero \qquad \therefore$

$$e = \frac{X(t_1+t_2)+M}{N}$$

العزم من الاتجاهين .

يتم ترحيل القاعده عكس الـ **Moment** فى الاتجاهين e_x & e_y



ملحوظه هامه يتم ترحيل القاعده و ليس ترحيل العمود .

ملحوظه هامه

يتم ترحيل القاعده عكس اتجاه الـ **Moment** أى جهه رأس السهم .

حتى تكون محصله الـ **Moment** النهائيه عند **C.G.** القاعده يساوى صفر .

$$e_x = \frac{M_x}{N} \qquad e_y = \frac{M_y}{N}$$

$$M_{at\ C.G.\ of\ the\ Footing} = Zero$$

ثم يتم تصميم القاعده على N فقط .

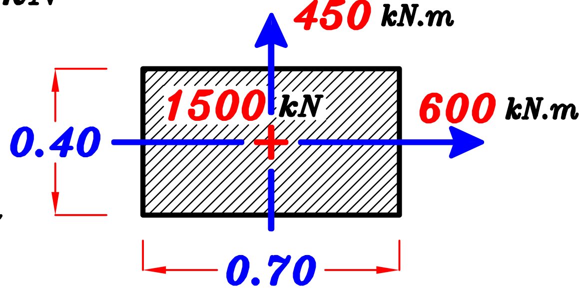
Example.

*It is required to design a rectangular Footing to Support a R.C column of thickness (40 * 70) cm.*

The column working load is 1500 kN

and permanent moment ↑ M_x = 450 kN.m

and permanent moment → M_y = 600 kN.m



The allowable net bearing capacity in the Footing site is 150 kN/m². (F_{cu} = 25 N/mm², F_y = 360 N/mm²).

and draw details of RFT. to scale 1:50

Solution.

Data given: Column dimensions (400 * 700) mm

$P_{col.}$ (working) = 1500 kN $\qquad$ $P_{col.}$ (U.L.) = 1500 * 1.5 = 2250 kN

M_x = 450 kN.m $\qquad$ M_y = 600 kN.m

Bearing capacity of the soil = q_{all} = 150 kN/m²

F_{cu} = 25 N/mm² $\qquad$ F_y = 360 N/mm²

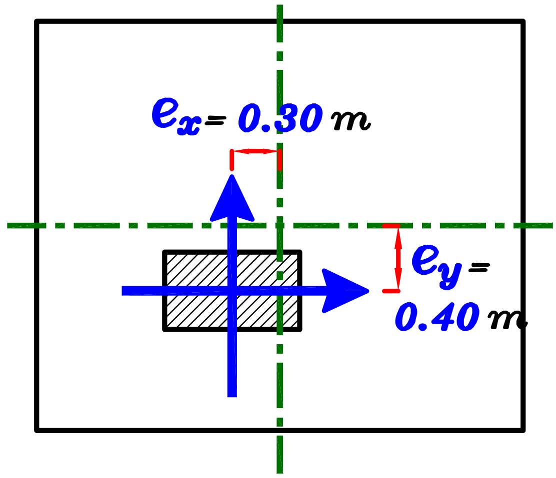
لان العزوم *permanent moment*

ممكن لالغاء تأثير العزوم على القاعده يتم ترحيل القاعده عكس العزوم

$$e_x = \frac{M_x}{N} = \frac{450}{1500} = 0.30 \ m$$

$$e_y = \frac{M_y}{N} = \frac{600}{1500} = 0.40 \ m$$

عند ترحيل القاعده عكس ال moment
سيتم الغاء تأثير ال moment
و بالتالى يكون ال stresses على التربه متساوى
أى يكون على التربه uniform stresses
ثم يتم تصميم القاعده بالطريقه السابقه .



1– Calculate the Footing area (Width & Length of R.C. Footing.)

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

$$L_{P.C.} - B_{P.C.} = b - a = 0.70 - 0.40 = 0.30\ m$$

$$L_{P.C.} = B_{P.C.} + 0.30\ m \quad \text{------} (1)$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1500\ (kN)}{150\ (kN/m^2)} = 10.0\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 10.0\ m^2 \quad \text{-----} (2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.30) = 10.0\ m^2$$

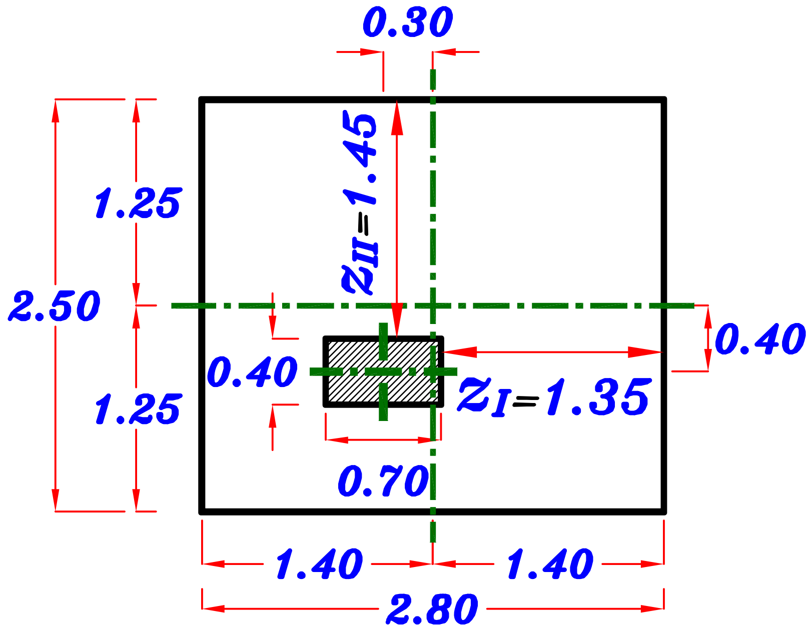
$$B_{P.C.} = 3.01\ m$$

$B_{P.C.} = 3.10\ m$ $\qquad$ $L_{P.C.} = 3.40\ m$

$B_{R.C.} = 2.50\ m$ $\qquad$ $L_{R.C.} = 2.80\ m$

$$Z_I = 2.8 - 1.4 + 0.3 - 0.35 = 1.35\ m$$

$$Z_{II} = 2.5 - 1.25 + 0.4 - 0.2 = 1.45\ m$$

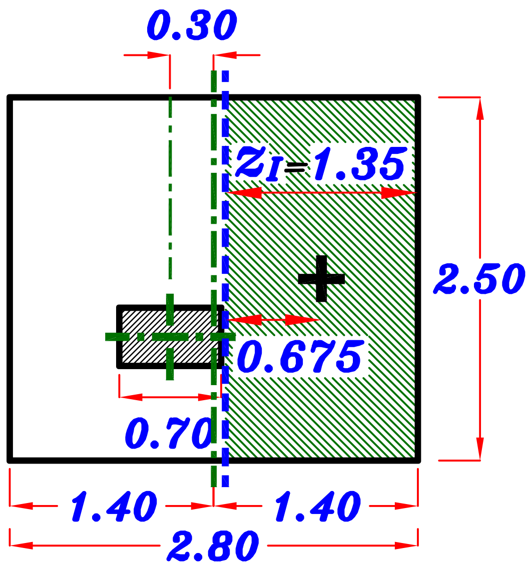


2– *Design the critical sections For moment.* (*Depth of R.C. Footing.*)

– *Actual Normal stress on R.C. Footing* (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{2250}{2.50 * 2.80} = 321.4\ kN/m^2$$

Direction I



$$Z_I = \frac{2.80}{2} + 0.30 - \frac{0.70}{2} = 1.35\ m$$

Force = Stress * Area

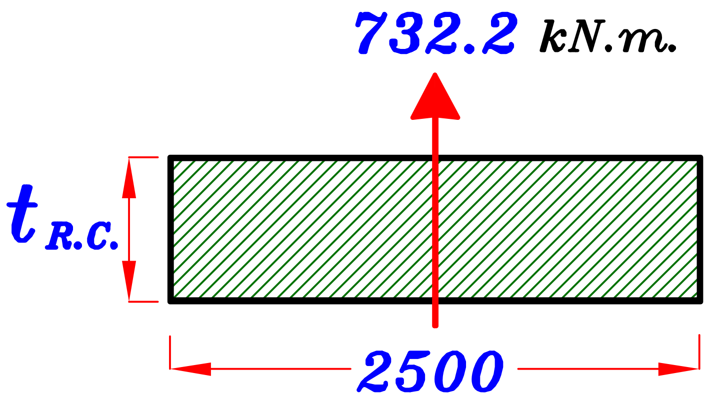
$$Force = F_{act.} * Z_I * B_{R.C.}$$

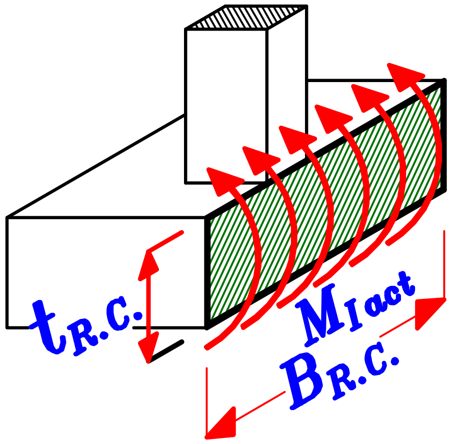
$$= 321.4 * 1.35 * 2.50 = 1084.7\ kN$$

moment = Force * Distance

$$M_{I\ act.} = (F_{act.} * Z_I * B_{R.C.})\ \frac{Z_I}{2}$$

$$= (321.4 * 1.35 * 2.50)\ \frac{1.35}{2} = 732.2\ kN.m$$





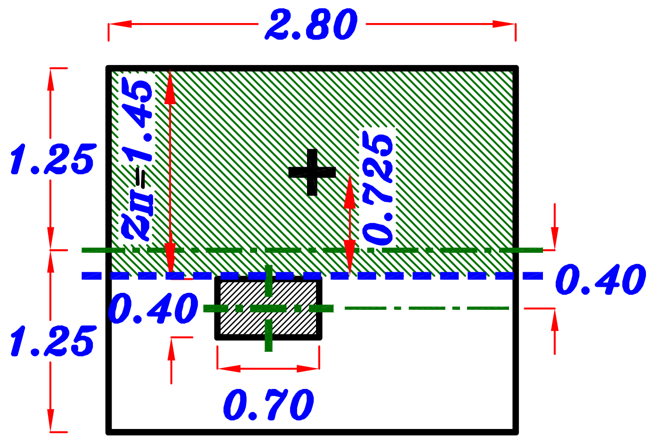
$$\because \; d_I = C_1 \sqrt{\frac{M_{I\,act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \; d_I = 5.0 \sqrt{\frac{732.2 * 10^6}{25 * 2500}} = 541.2 \text{ mm}$$

Direction II

$$Z_{II} = \frac{2.50}{2} + 0.40 - \frac{0.40}{2} = 1.45 \text{ m}$$



$$Force = Stress * Area$$

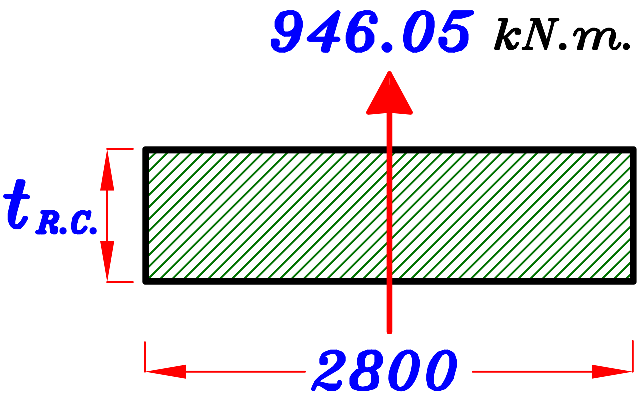
$$Force = F_{act.} * Z_{II} * B_{R.C.}$$

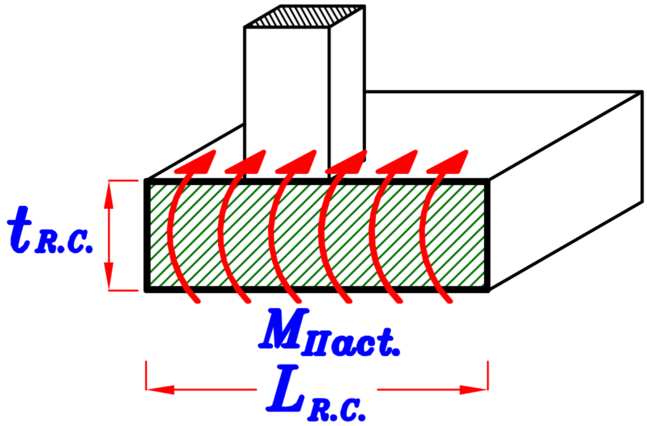
$$= 321.4 * 1.45 * 2.80 = 1304.9 \text{ kN}$$

$$moment = Force * Distance$$

$$M_{II\,act.} = (F_{act.} * Z_{II} * B_{R.C.}) \frac{Z_{II}}{2}$$

$$= (321.4 * 1.45 * 2.80) \frac{1.45}{2} = 946.05 \text{ kN.m}$$





$\because\ d_{II} = C_1 \sqrt{\frac{M_{II\,act.}}{F_{cu} * b}}$ Choose $C_1 = 5.0$

$\therefore\ d_{II} = 5.0 \sqrt{\frac{946.05 * 10^6}{25 * 2800}} = 581.2\ mm$

Take d The bigger of d_I & $d_{II} = 581.2\ mm$

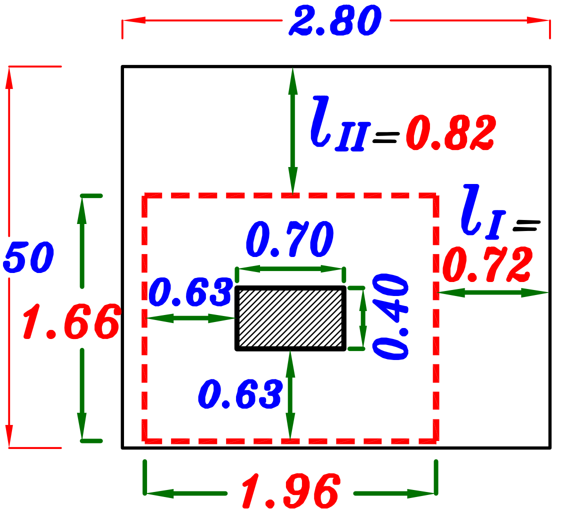
$t_{R.C.} = d + 70\ mm = 581.2 + 70 = 651.2\ mm$

$t_{R.C.} = 700\ mm$ $d = 630\ mm$

3 – Check Shear.

$a + 2d = 0.40 + 2 * 0.63 = 1.66\ m$

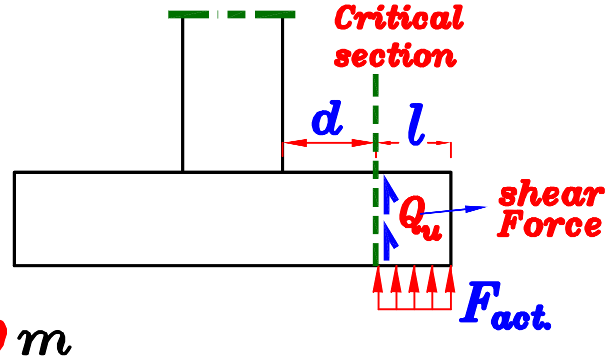
$b + 2d = 0.70 + 2 * 0.63 = 1.96\ m$



∗ Critical section For Shear.

Take l The bigger of l_I & l_{II}

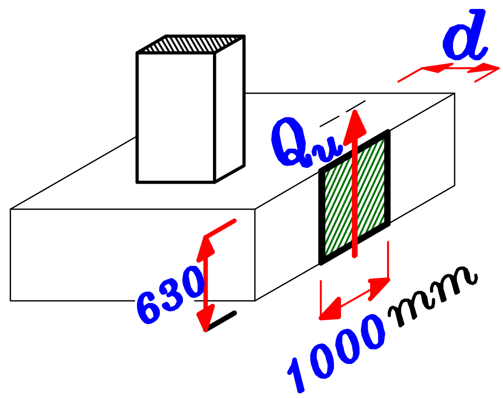
$$l = 0.82\ mm$$



∗ Actual shear Force. (Q_u) For 1.0 m

$$Q_u = F_{act.} * l * 1.0\ m = 321.4 * 0.82 * 1.0\ m = 263.55\ kN$$

∗ Calculate Actual shear stress. (q_u)



$$q_u = \frac{Q_u}{b * d} = \frac{263.55 * 10^3}{1000 * 630} = 0.418\ N/mm^2$$

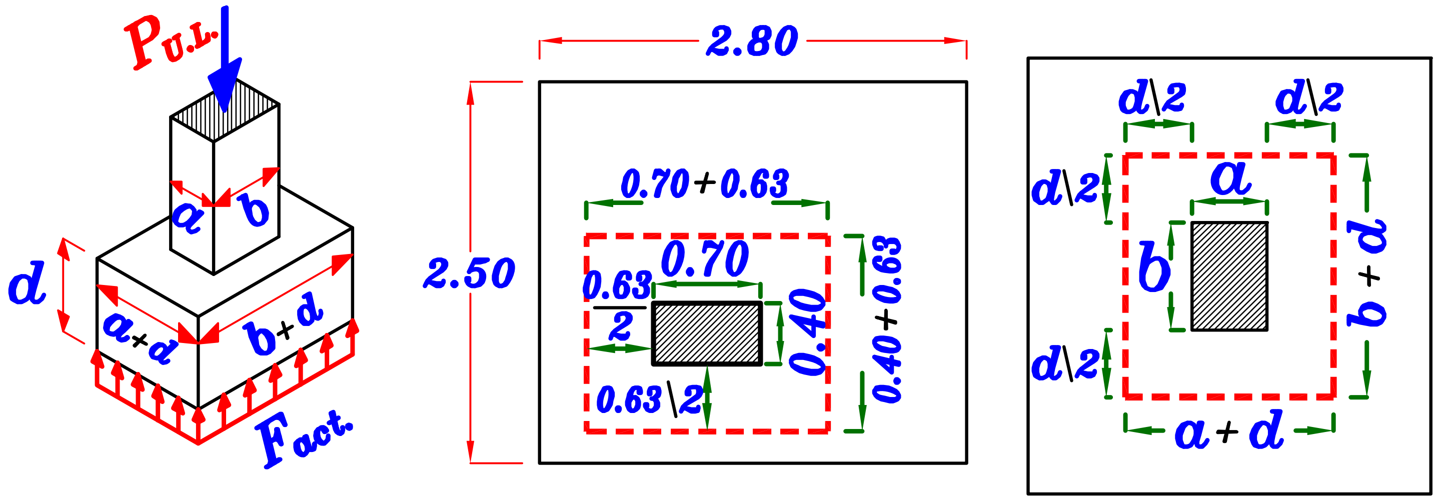
∗ Allowable shear stress. (q_{su})

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

$$q_u < q_{su}$$ → Safe shear stresses

No need to increase dimensions.

4 – Check Punching Shear.



$$a + d = 0.40 + 0.63 = 1.03 \, m$$

$$b + d = 0.70 + 0.63 = 1.33 \, m$$

* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{act.}) \left[(a+d)(b+d) \right]$$

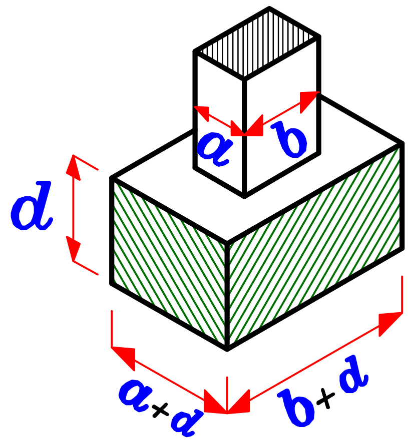
$$Q_p = 2250 - 321.4 \left[1.03 * 1.33 \right] = 1809.7 \; kN$$

* Calculate Punching shear area. (A_p)

$$A_p = \left[2(a+d) + 2(b+d) \right] * d$$

$$A_p = \left[2(400 + 630) + 2(700 + 630) \right] * 630$$

$$A_p = 2973600 \; mm^2$$



* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)]*d}$$

$$q_{pu} = \frac{2250*10^3}{2973600} = 0.756 \ N/mm^2$$

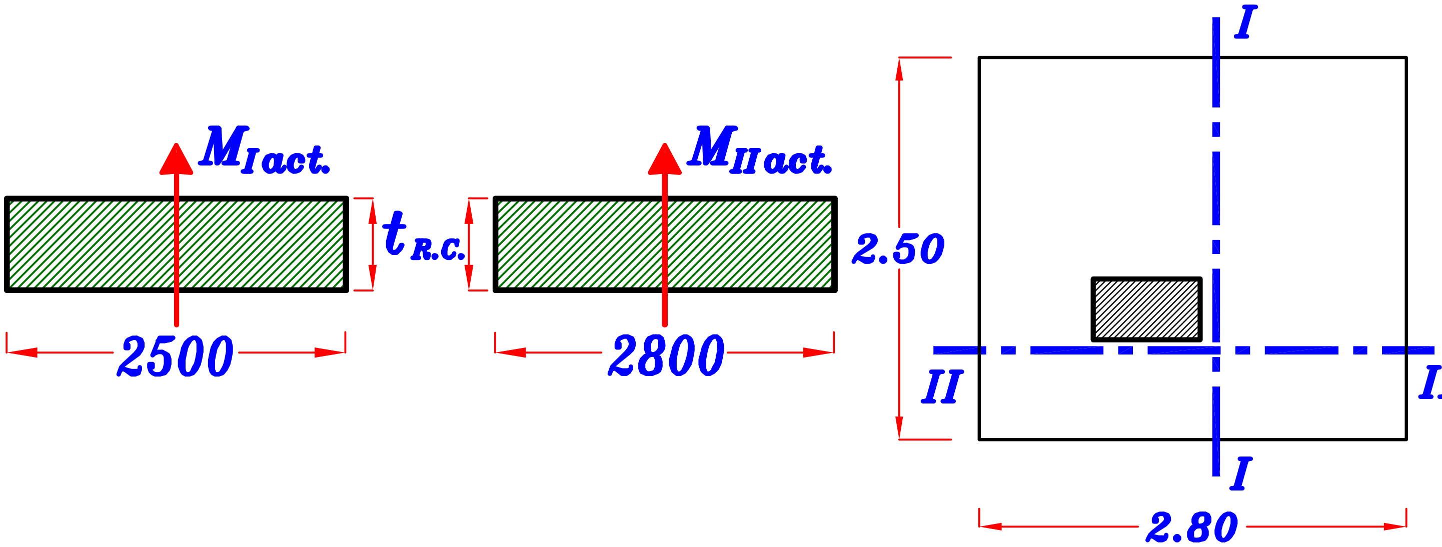
* Calculate allowable Punching shear stress. q_{pcu}

$$q_{pcu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\delta_c}} =$$

$$q_{pcu} = 0.316\left(0.5+\frac{0.40}{0.70}\right)\sqrt{\frac{25}{1.5}} = 1.38 \ N/mm^2$$

$q_{pu} \leqslant q_{pcu}$ ⟶ Safe punching shear.
No need to increase dimensions.

5- Reinforcement of the Footing.

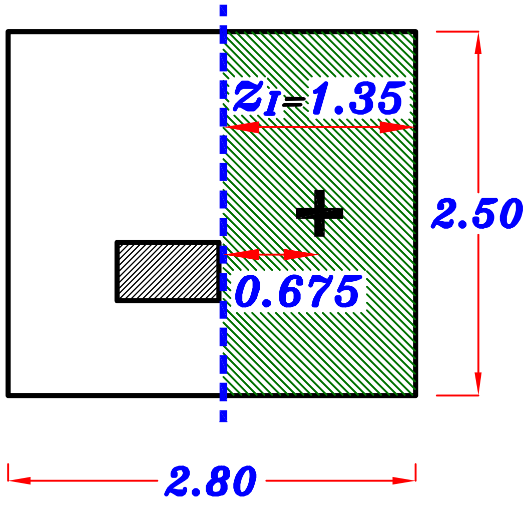


Direction I

$$M_{I\,act.} = (F_{act.} * Z_I * B_{R.C.}) \frac{Z_I}{2}$$

$$= (321.4 * 1.35 * 2.50) \frac{1.35}{2}$$

$$= 732.2 \text{ kN.m}$$



$$J = 0.826$$

$$A_s = \frac{M_{I\,act.}}{J\,F_y\,d} = \frac{732.2 * 10^6}{0.826 * 360 * 630} = 3908.5 \text{ mm}^2$$

$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{3908.5}{2.50} = 1563.4 \text{ mm}^2/m'$$

Check $A_{s\,min}$

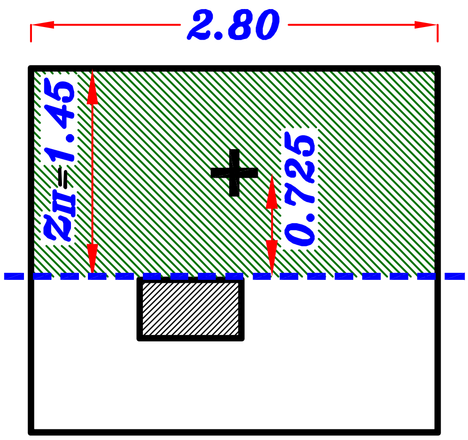
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 630 = 954 \\ 5\phi 12/m' = 565 \end{array} \right\} 945 \text{ mm}^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow o.k.$$

$$A_s = 1563.4 \text{ mm}^2$$

$7\phi 18/m'$

Direction II



$$M_{II\,act.} = (F_{act.} * Z_{II} * B_{R.C.}) \frac{Z_{II}}{2}$$

$$= (321.4 * 1.45 * 2.80) \frac{1.45}{2}$$

$$= 946.05 \ kN.m$$

$$J = 0.826$$

$$A_S = \frac{M_{II\,act.}}{J\,F_y\,d} = \frac{946.05 * 10^6}{0.826 * 360 * 630} = 5050 \ mm^2$$

$$A_S\ (mm^2/m) = \frac{A_S}{B_{R.C.}} = \frac{5050}{2.80} = 1803.6 \ mm^2/m'$$

Check $A_{S\,min}$

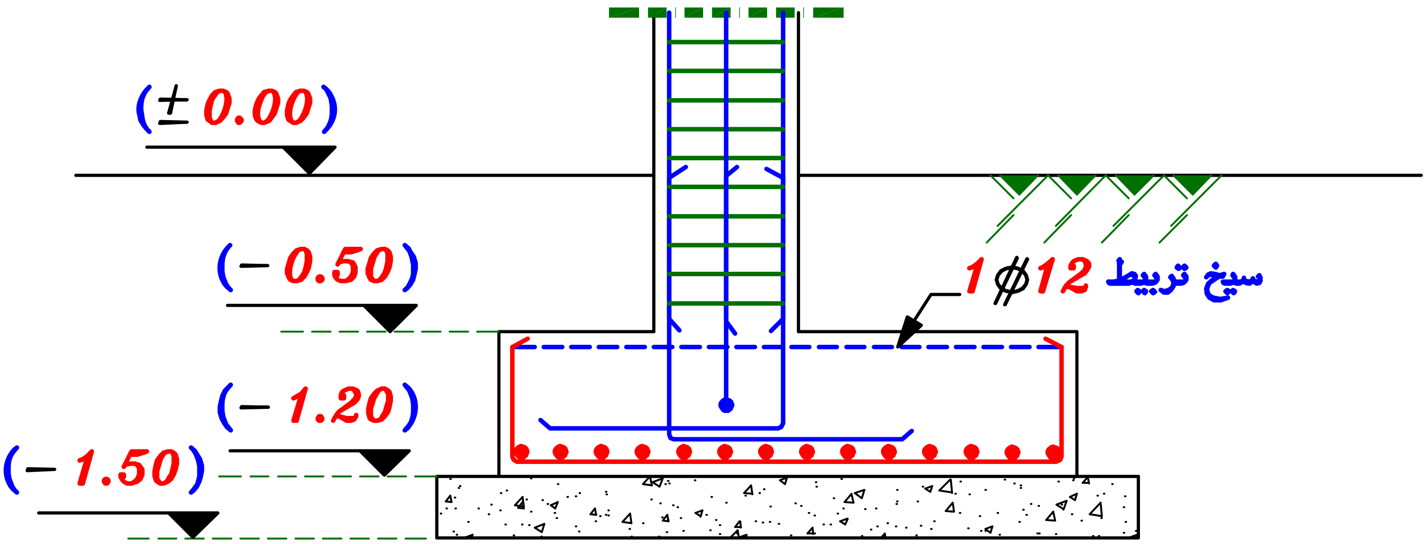
$$A_{S\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 630 = 954 \\ 5 \phi 12/m' = 565 \end{array} \right\} 954\,mm^2$$

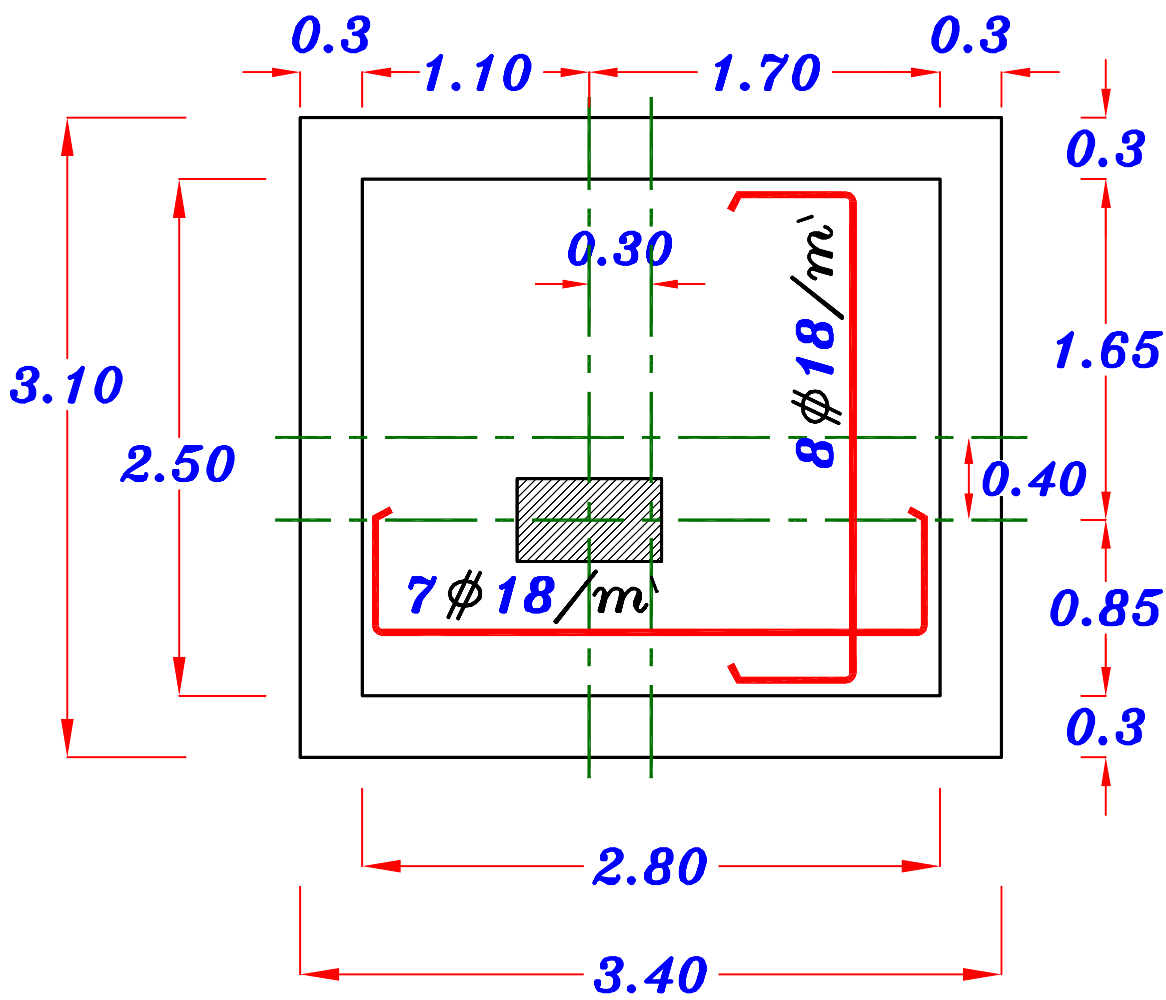
$$\therefore A_S > A_{S\,min} \longrightarrow o.k.$$

$$A_S = 1803.6 \ mm^2$$

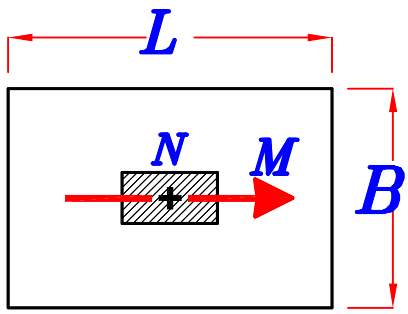
$8 \phi 18/m'$

6 – Details of Reinforcement.





2-Design of isolated Footings subjected to temporary moment.
تصميم القواعد المنفصله المعرضه لعزوم متغيره أو غير دائمه .

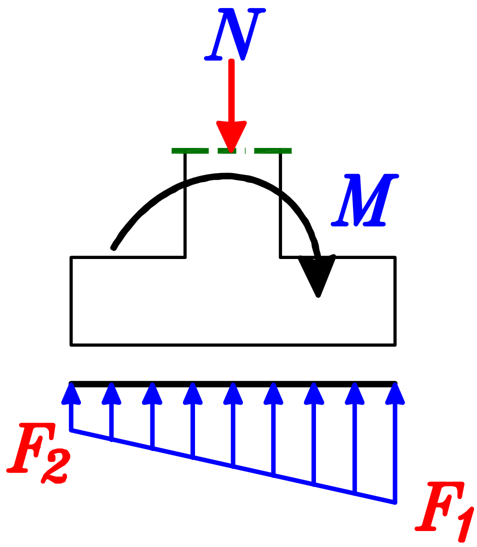


العزوم الناتجه عن الاحمال المتغيره مثل

L.L. , Wind load

& Earth quake loads.

Case of single moment.



فى حاله وجود عزم واحد *variable* على القاعده

يوضع فى أى اتجاه ↷ أو ↶

و يفضل وضع أبعاد القاعده بحيث يكون

العرض الكبير للقاعده موازى لاتجاه ال *moment*

و يؤخذ تأثير العزم عند حساب الاجهادات على التربه .

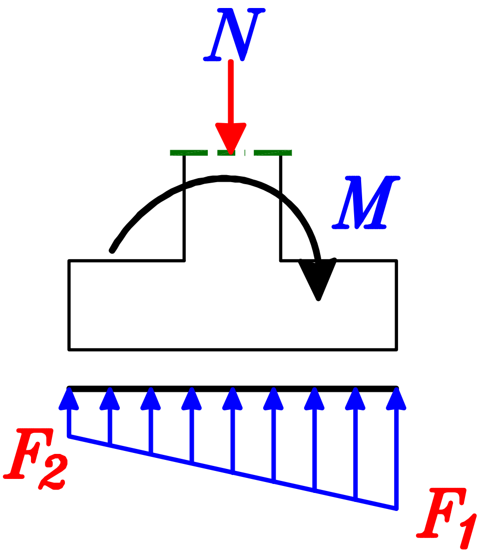
$$F_1 = \frac{N}{A} + \frac{M\,y}{I}$$

$$F_2 = \frac{N}{A} - \frac{M\,y}{I}$$

$(+Ve) \longrightarrow$ *Compression stress.*

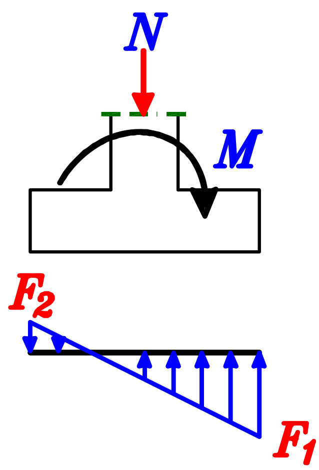
$(-Ve) \longrightarrow$ *Tension stress.*

و يتم اختيار أبعاد القاعده B , L



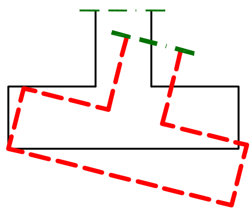
لتحقيق الشروط التاليه :

1 $F_1 \leqslant$ *Allowable bearing capacity* q_{all}



2 $F_2 > Zero$ لكى لا يوجد شد على التربه

No Tension on soil.



3 $F_2 \simeq \frac{F_1}{2}$ يفضل

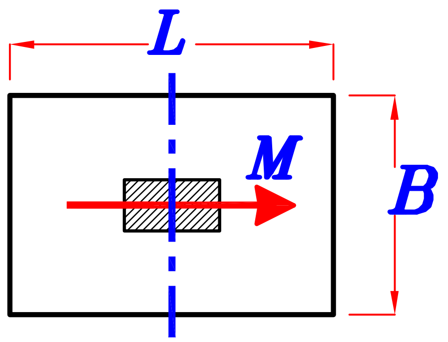
لكى نضمن عدم دوران القاعده

to avoid tilting of the Footing.

4 $L - B = b - a$ مع محاوله الحفاظ على الشرط

Steps of design Footing subjected to M , N

For rectangular Footing.



و يفضل وضع أبعاد القاعده بحيث يكون
العرض الكبير للقاعده موازى لاتجاه ال moment

Area of the Footing = $A = B*L$

Moment of Inertia For the Footing = $I = \frac{B*L^3}{12}$

Stresses on soil.

$$\therefore \quad F = \frac{N}{A} \pm \frac{M\,y}{I}$$

$A = B*L$ $\quad$ $I = \frac{B*L^3}{12}$ $\quad$ $y = \frac{L}{2}$ عند طرف القاعده

$$\therefore \quad F = \frac{N}{B*L} \pm \frac{M*L\backslash 2}{B*L^3\backslash 12}$$

$$\therefore \quad F = \frac{N}{B*L} \pm \frac{6\,M}{B*L^2}$$ عند طرف القاعده

1- Calculate the Footing area. (*Width & Length of R.C. Footing.*)

IF $t_{P.C.} \geq 20\ cm$

get $B_{P.C.}$, $L_{P.C.}$ From

$$L_{P.C.} - B_{P.C.} = b - a \quad \text{------} (1) \quad B_{P.C.} , L_{P.C.}$$

Actual Normal stress on soil = Bearing Capacity of soil.

$$F_1 = \frac{N}{B_{P.C.} * L_{P.C.}} + \frac{6\ M}{B_{P.C.} * L_{P.C.}^2} = q_{all} \quad \text{---} (2) \quad B_{P.C.} , L_{P.C.}$$

يتم حل معادلتين في مجهولين و تحديد قيمه كلا من $B_{P.C.}$, $L_{P.C.}$

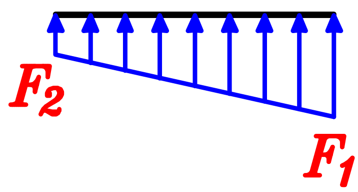
بعد حساب $B_{P.C.}$ & $L_{P.C.}$ يقربا لاقرب ٥٠ مم بالزياده

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

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

Check .

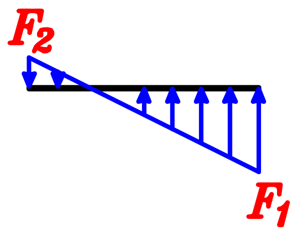
$$F_2 = \frac{N}{B_{P.C.} * L_{P.C.}} - \frac{6\ M}{B_{P.C.} * L_{P.C.}^2} > Zero$$



حتى لا يكون هناك tension على التربه .

IF $F_2 < Zero$ ⟶ . أي tension على التربه

Increase $B_{P.C.}$, $L_{P.C.}$



IF $t_{P.C.} < 20\ cm$

get $B_{R.C.}$, $L_{R.C.}$ From

$$L_{R.C.} - B_{R.C.} = b - a \quad \text{------} (1) \quad B_{R.C.} , L_{R.C.}$$

Actual Normal stress on soil = Bearing Capacity of soil.

$$F_1 = \frac{N}{B_{R.C.} * L_{R.C.}} + \frac{6M}{B_{R.C.} * L_{P.C.}^2} = q_{all} \quad \text{---} (2) \quad B_{R.C.} , L_{R.C.}$$

يتم حل معادلتين في مجهولين و تحديد قيمه كلا من $B_{R.C.}$, $L_{R.C.}$

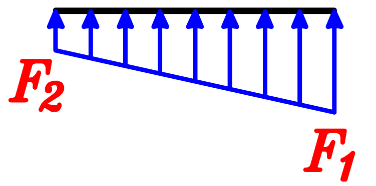
بعد حساب $B_{R.C.}$ & $L_{R.C.}$ يقربا لاقرب ٥٠ مم بالزياده

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

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

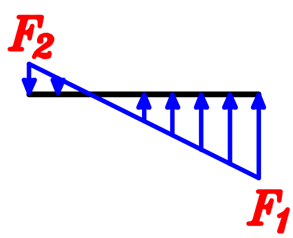
Check .

$$F_2 = \frac{N}{B_{R.C.} * L_{R.C.}} - \frac{6M}{B_{R.C.} * L_{R.C.}^2} > Zero$$



حتى لا يكون هناك tension على التربة .

IF $F_2 < Zero$ ⟶ . أي tension على التربة



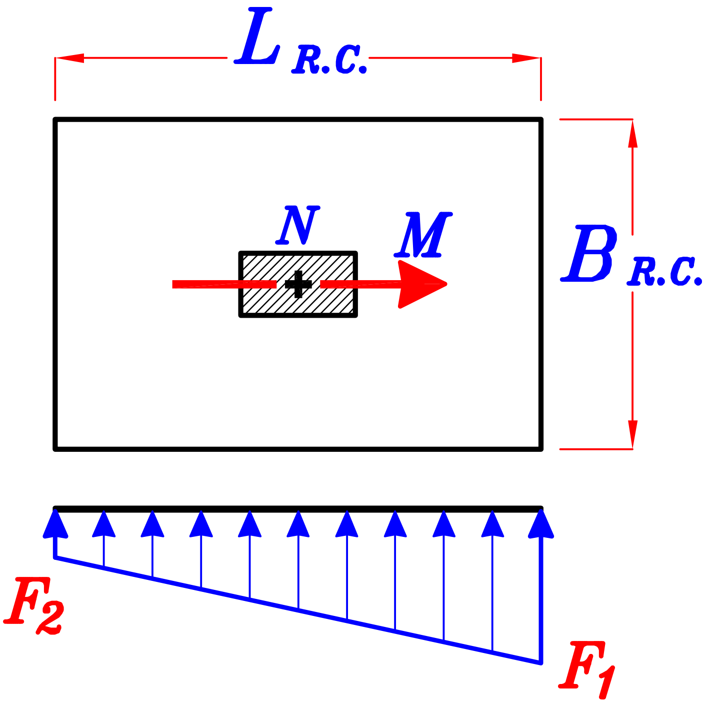
Increase $B_{R.C.}$, $L_{R.C.}$

2– Design the critical sections For moment. (Depth of R.C. Footing.)

The actual ultimate limits stresses on R.C. concrete.

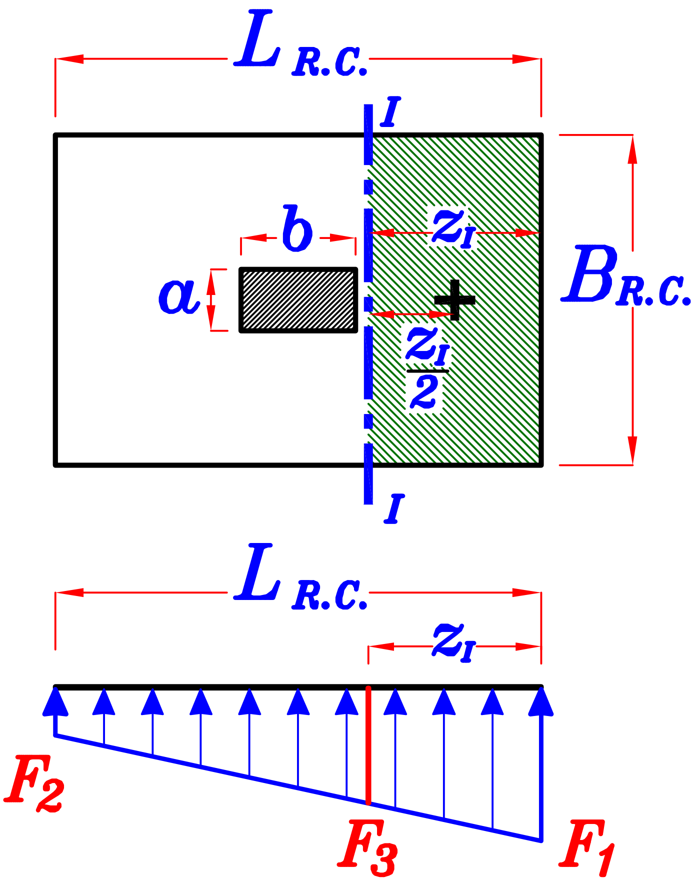
$$F_1 = \frac{N_{U.L.}}{B_{R.C.} * L_{R.C.}} + \frac{6\, M_{U.L.}}{B_{R.C.} * L_{R.C.}^2}$$

$$F_2 = \frac{N_{U.L.}}{B_{R.C.} * L_{R.C.}} - \frac{6\, M_{U.L.}}{B_{R.C.} * L_{R.C.}^2}$$



Direction I

$$z_I = \frac{L_{R.C.} - b}{2} \quad (m)$$

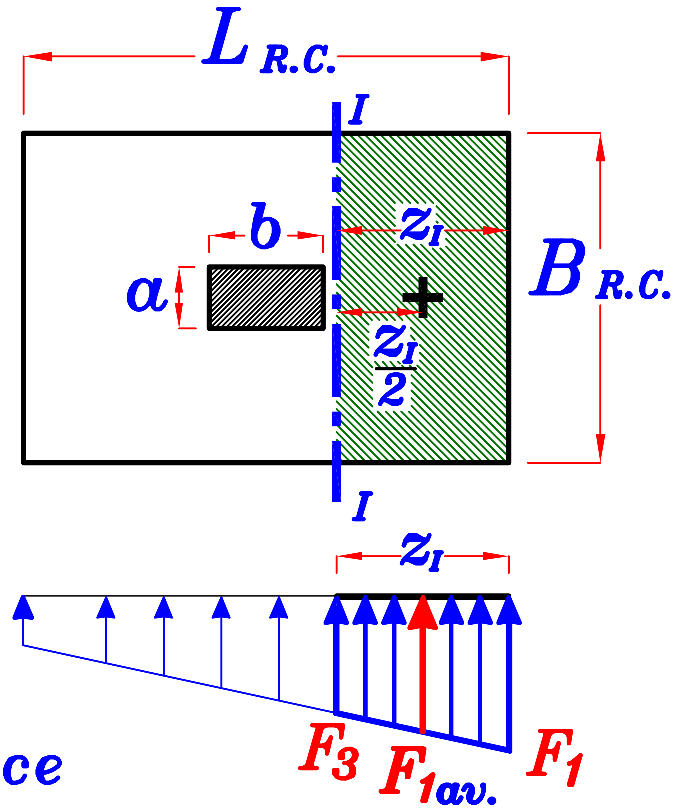


Calculate F_3 من تشابه المثلثات

$$F_3 = \frac{L_{R.C.} - z_I}{L_{R.C.}} * (F_1 - F_2) + F_2$$

Get the average stress $F_{1av.}$

$$F_{1av.} = \frac{F_1 + F_3}{2}$$

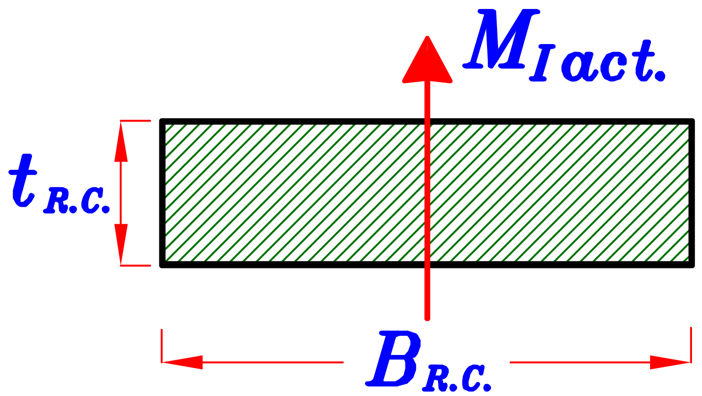


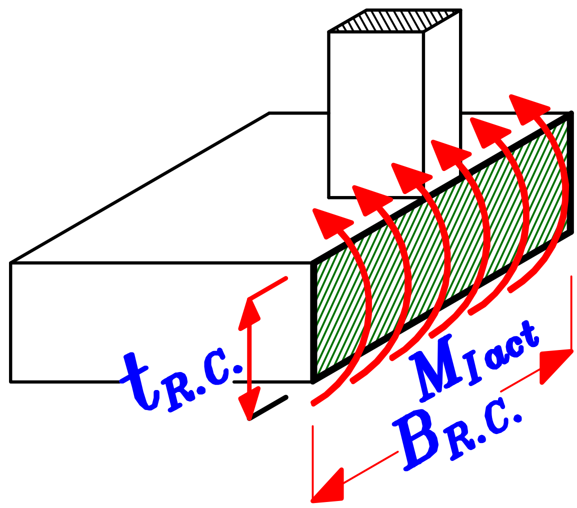
$$Force = Stress * Area$$

$$Force = F_{1av.} * z_I * B_{R.C.}$$

$$Moment = Force * Distance$$

$$M_{I\,act.} = (F_{1av.} * z_I * B_{R.C.}) \; \frac{z_I}{2} \qquad (kN.m/B)$$





$$d_{I\,(mm)} = C_1 \sqrt{\frac{M_{I\,act.}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * B_{R.C.}\,(mm)}}$$

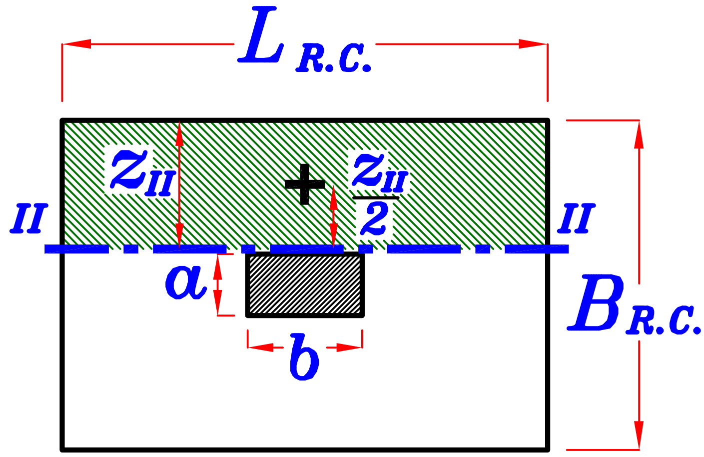
Choose $C_1 = (3.5 \rightarrow 5.0)$ Get $d_I = \checkmark\checkmark$ (mm)

Take cover = 70 mm

$t_{I\,R.C.} = d_I + cover\ (70\ mm)$ تقرب لاقرب ٥٠ مم بالزياده

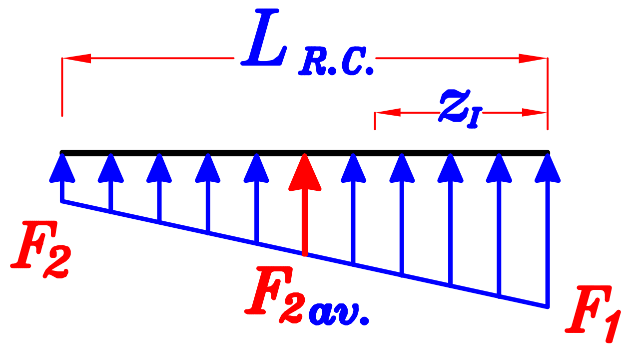
Direction II

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



Get the average stress $F_{2av.}$

$$F_{2av.} = \frac{F_1 + F_2}{2}$$

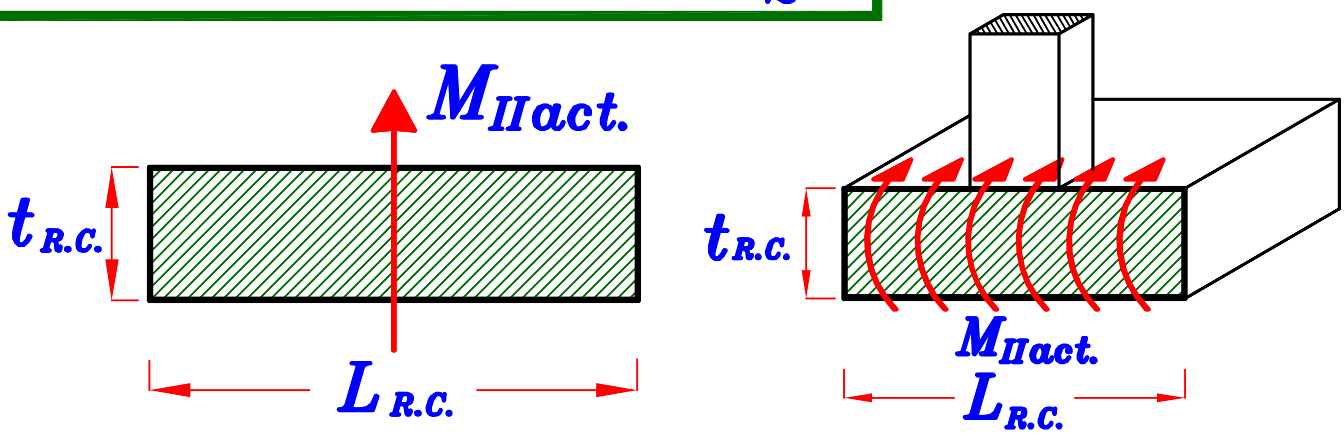


Force = Stress * Area

Force = $F_{2av.} * Z_{II} * L_{R.C.}$

Moment = Force * Distance

$$M_{II\,act.} = (F_{2av.} * Z_{II} * L_{R.C.}) \frac{Z_{II}}{2} \quad (kN.m/L)$$



$$d_{II} \ (mm) = C_1 \sqrt{\frac{M_{II\,act.} * 10^6}{F_{cu} * L_{R.C.}}}$$

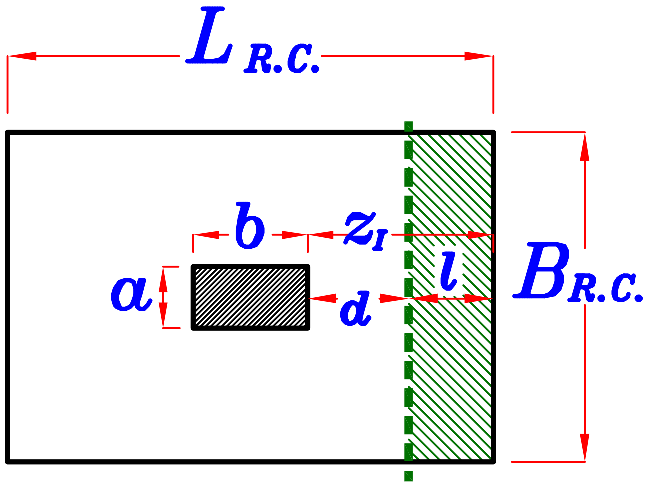
Choose $C_1 = (3.5 \rightarrow 5.0)$

Get $d_{II} = ✓✓$ (mm) Take cover = 70 mm

$t_{II\,R.C.} = d_{II} + cover$ (70 mm) تقرب لاقرب ٥٠ مم بالزياده

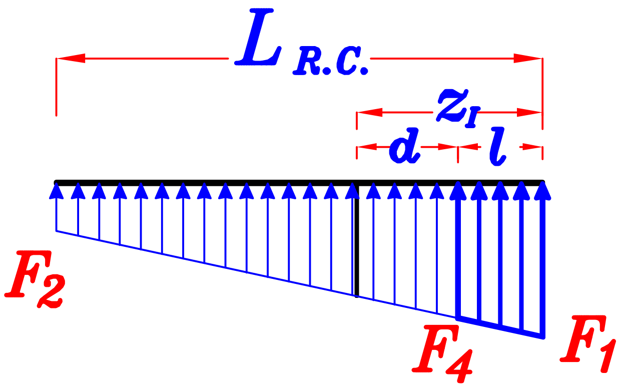
$t_{R.C.}$ تكون هى $t_{I\,R.C.}$ & $t_{II\,R.C.}$ نأخذ الاكبر من

3 – Check Shear.



* Calculate $l = z_I - d$ (m)

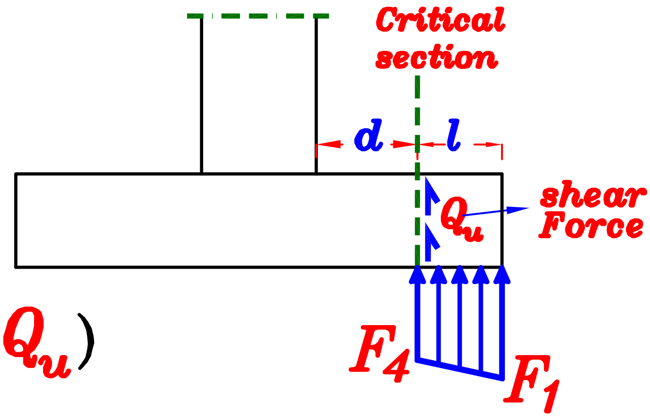
* Calculate the shear stress at critical section.



$$F_4 = \frac{L_{R.C.} - l}{L_{R.C.}} * (F_1 - F_2) + F_2$$

Get the average stress $F_{3av.}$

$$F_{3av.} = \frac{F_1 + F_4}{2}$$



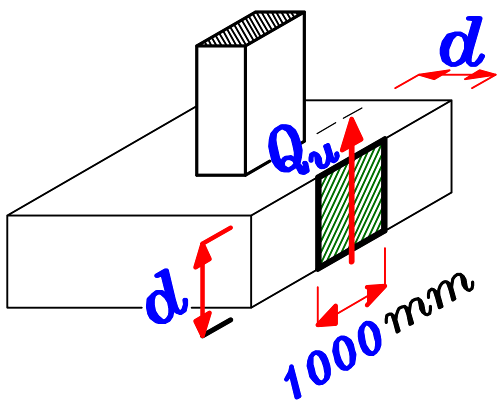
* Calculate Actual shear Force. (Q_u)

نحسب ل – ١,٠ م طولي من القاعده

$$Q_u = F_{3av.} * l * 1.0\ m \quad (kN)$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d}$$



$$q_u = \frac{Q_u\,(kN) * 10^3}{1000\,(mm) * d\,(mm)} \quad (N/mm^2)$$

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ ⟶ Safe shear stresses
  No need to increase dimensions.

* IF $q_u > q_{su}$ ⟶ UnSafe shear stresses
  We have to increase dimensions.

IF UnSafe shear stresses increase $t_{R.C.}$ by 100 mm

then ReCheck:

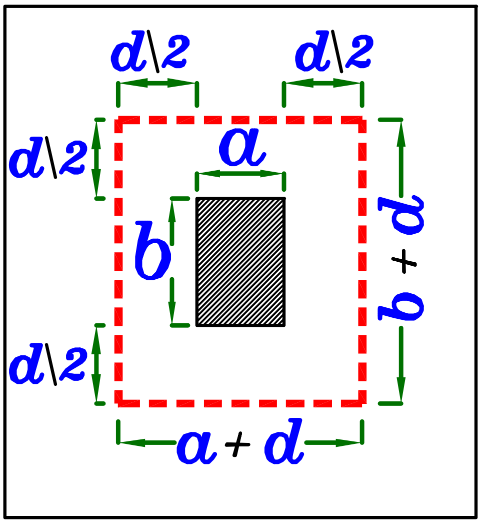
Actual shear stress (q_u) & Allowable shear stress (q_{su})

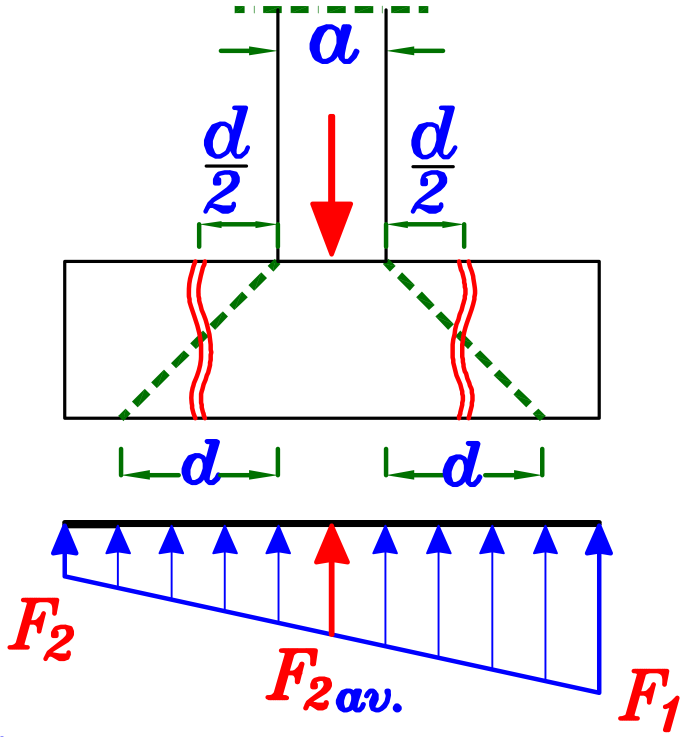
4 – Check Punching Shear. القص الثاقب .

The concrete area which resist punching shear.

تحديد مساحه الخرسانه المقاومه للقص الثاقب .

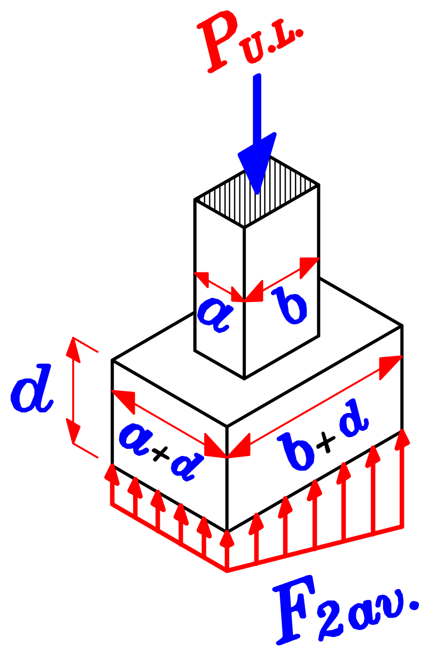
القطاع الحرج فى القص الثاقب عباره عن محيط يحيط بالعمود على مسافه $\frac{d}{2}$ من وش العمود من كل جهه .





Get the average stress $F_{2av.}$

$$F_{2av.} = \frac{F_1 + F_2}{2}$$



* **Calculate Punching Force.** (Q_p)

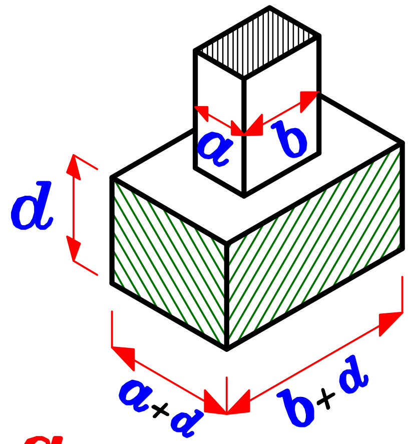
$$Q_p = P_{U.L.} - (F_{2av.})\left[(a+d)(b+d)\right]$$

(kN)

* Calculate Punching shear area. (A_p)

المحيط   العمق

$$A_p = \left[2(a+d)+2(b+d)\right] * d \quad (mm^2)$$



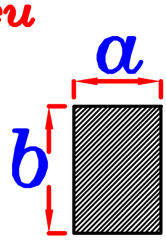
* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{\text{Punching Force}}{\text{Punching area}}$$

$$q_{pu} = \frac{Q_p\,(kN) * 10^3}{\left[2(a+d)+2(b+d)\right] * d \quad (mm^2)} \quad (N/mm^2)$$

* Calculate allowable Punching shear stress. q_{pcu}

$$q_{pcu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\delta_c}} \quad (N/mm^2)$$



IF $\left(0.5+\frac{a}{b}\right) \leq 1.0$ Take → $q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\delta_c}} \quad (N/mm^2)$

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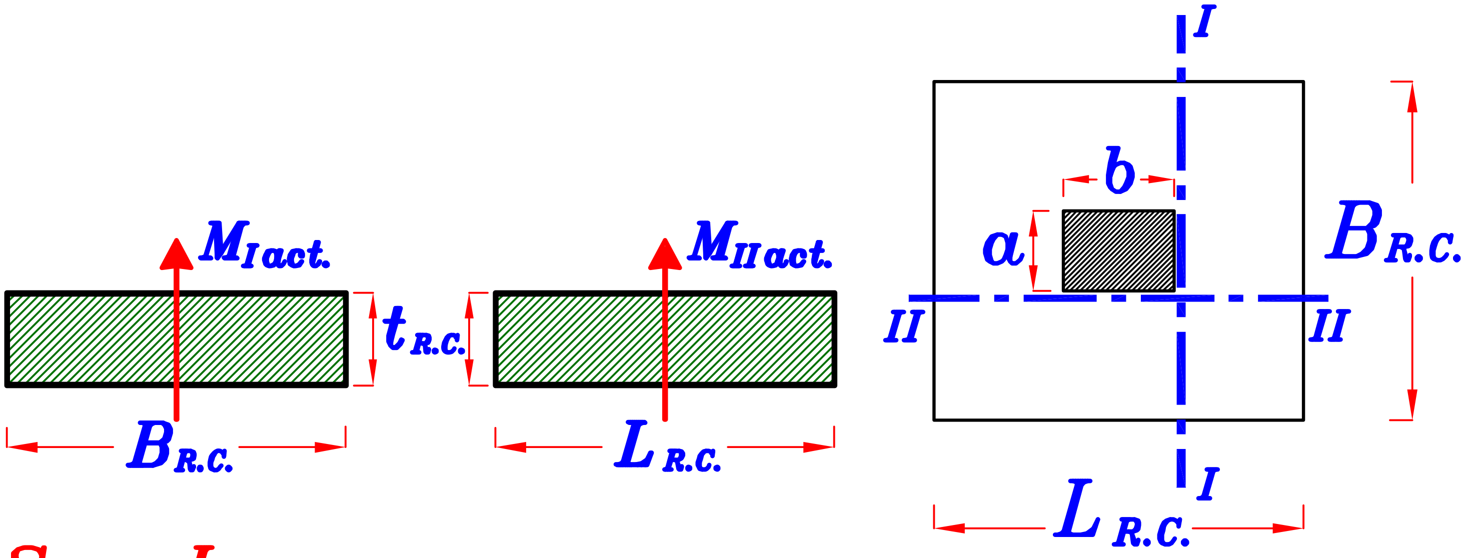
* Compare between

Actual punching shear stress (q_{pu}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu} \leq q_{pcu}$ → Safe punching shear. No need to increase dimensions.

* IF $q_{pu} > q_{pcu}$ → UnSafe punching shear. We have to increase dimensions.

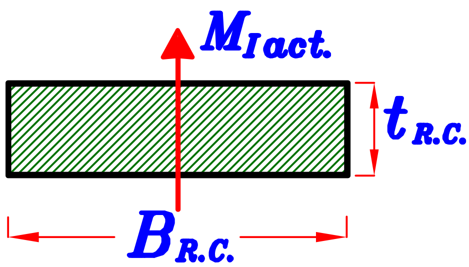
5- Reinforcement of the Footing.



Sec. I

From Step (2) We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$



Get
$$A_{sI} = \frac{M_{I\,act.}}{J\, F_y\, d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min} \; (mm^2/m') = \left\{ \begin{array}{l} 1.5\, d \;(mm) \\ 5 \phi 12 / m' \end{array} \right\} \text{الأكبر}$$

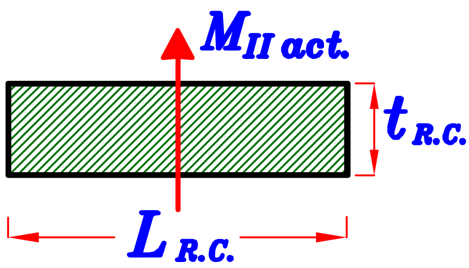
IF $A_{sI} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{sI} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

Sec. II

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$



Get $$A_{sII} = \frac{M_{II\,act.}}{J\, F_y\, d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{Bmatrix} 1.5\, d\ (mm) \\ 5\phi 12/m' \end{Bmatrix} \text{الأكبر}$$

IF $A_{sII} \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_{sII} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

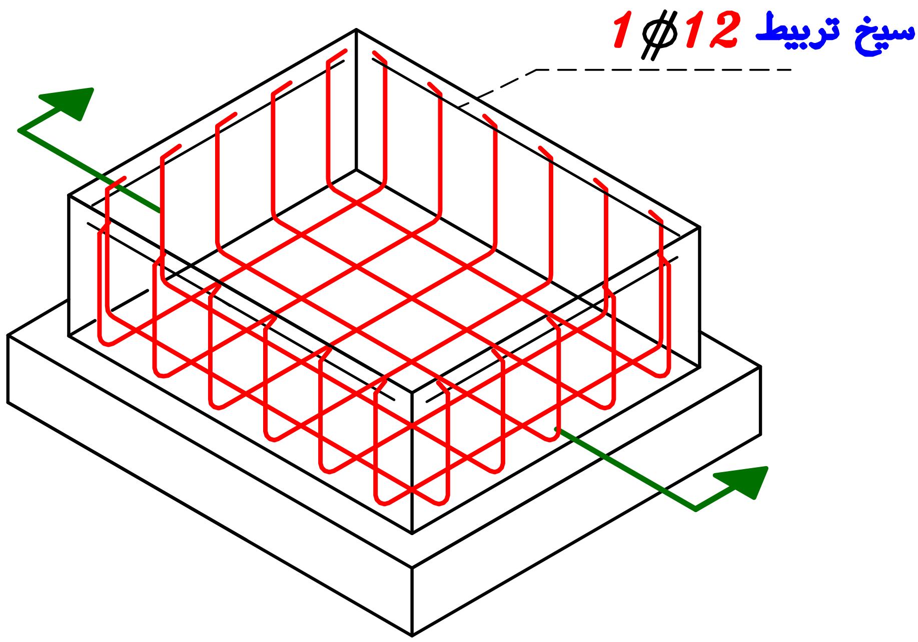
ملحوظة

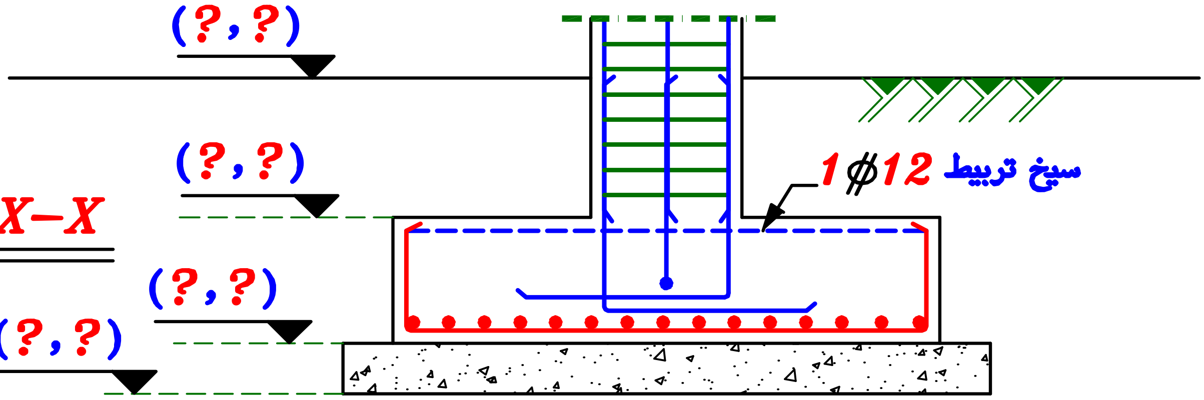
فى حالة تحقيق الشرط $L - B = b - a$

سيكون $\frac{M_{II\,act.}}{L} = \frac{M_{I\,act.}}{B}$ و بالتالى من الممكن حساب A_s فى اتجاه

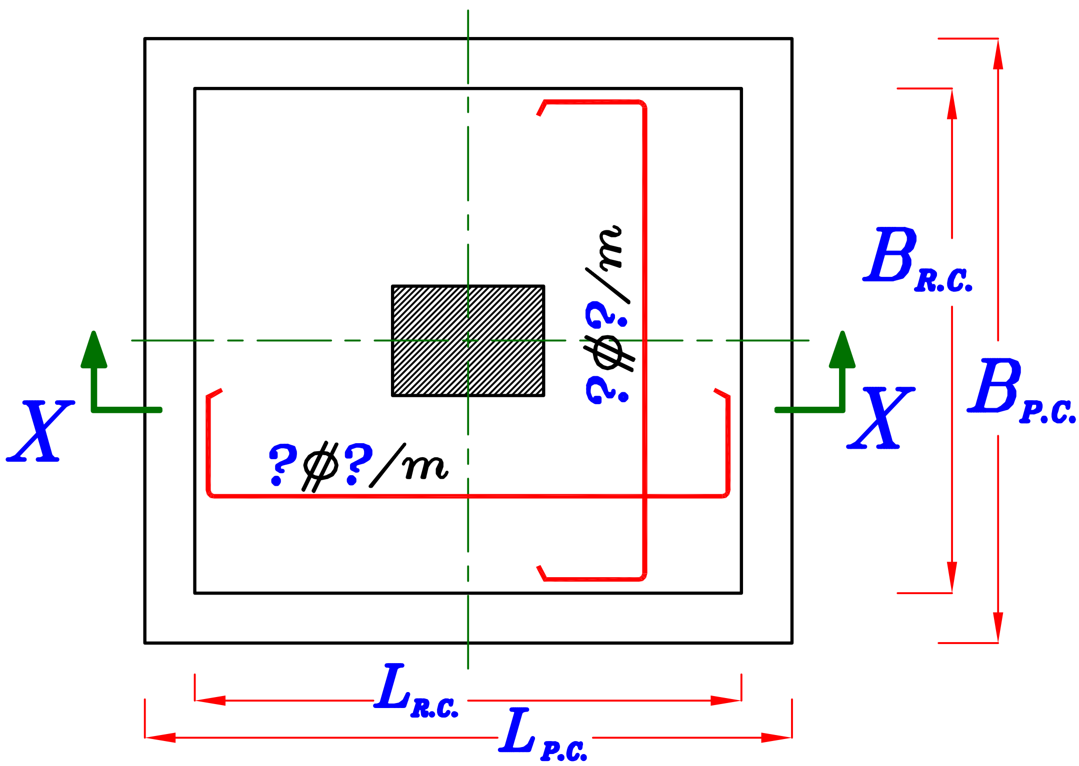
واحد فقط و يكون الاتجاه الاخر نفس القيمه $A_{sI} = A_{sII}$

6 – Details of Reinforcement.





Sec X–X

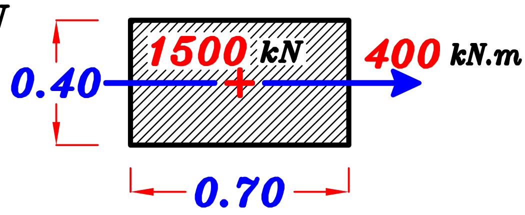


Plan

Example.

It is required to design a rectangular Footing to Support a R.C column of thickness (40 * 70) cm.

The column working load is 1500 kN and temporary moment → $M_y = 400$ kN.m



The allowable net bearing capacity in the Footing site is 150 kN/m². ($F_{cu} = 25$ N/mm², $F_y = 360$ N/mm²).
and draw details of RFT. to scale 1:50

Solution.

Data given: Column dimensions (400 * 700) mm

$P_{col.}$ (working) = 1500 kN $P_{col.}$ (U.L.) = 1500 * 1.5 = 2250 kN

$M_y = 400$ kN.m M_y (U.L.) = 400 * 1.5 = 600 kN.m

Bearing capacity of the soil = $q_{all} = 150$ kN/m²

$F_{cu} = 25$ N/mm² $F_y = 360$ N/mm²

1– Calculate the Footing area (Width & Length of R.C. Footing.)

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

$$L_{P.C.} - B_{P.C.} = b - a = 0.70 - 0.40 = 0.30 \text{ m}$$

$$L_{P.C.} = B_{P.C.} + 0.30 \text{ m} \quad \text{------} (1)$$

Actual Normal stress on soil = Bearing Capacity of soil.

$$F_1 = \frac{N}{B_{P.C.} * L_{P.C.}} + \frac{6\,M}{B_{P.C.} * L^2_{P.C.}} = q_{all} \quad ---(2)$$

$$\frac{1500}{B_{P.C.} * L_{P.C.}} + \frac{6 * 400}{B_{P.C.} * L^2_{P.C.}} = 150 \quad ---(2)$$

$$\therefore \frac{1500}{B_{P.C.} * (B_{P.C.} + 0.30)} + \frac{6 * 400}{B_{P.C.} * (B_{P.C.} + 0.30)^2} = 150$$

$$B_{P.C.} = 3.607\ m$$

$B_{P.C.} = 3.70\ m$	$L_{P.C.} = 4.0\ m$
$B_{R.C.} = 3.10\ m$	$L_{R.C.} = 3.40\ m$

Check.

$$F_1 = \frac{N}{B_{P.C.} * L_{P.C.}} + \frac{6\,M}{B_{P.C.} * L^2_{P.C.}} < q_{all} = 150$$

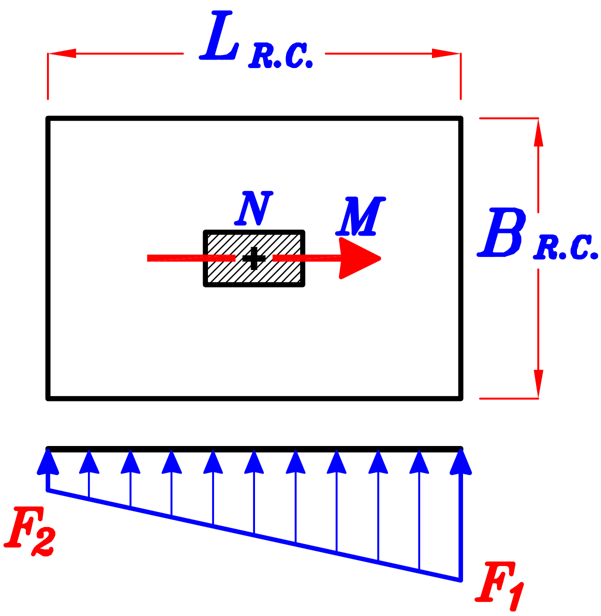
$$F_1 = \frac{1500}{3.70 * 4.0} + \frac{6 * 400}{3.70 * (4.0)^2} = 141.9\ kN/m^2 < q_{all} \quad \text{o.k.}$$

$$F_2 = \frac{N}{B_{P.C.} * L_{P.C.}} - \frac{6\,M}{B_{P.C.} * L^2_{P.C.}} > Zero$$

$$F_2 = \frac{1500}{3.70 * 4.0} - \frac{6 * 400}{3.70 * (4.0)^2} = 60.81\ kN/m^2 > Zero \quad \text{o.k.}$$

2– Design the critical sections For moment. (Depth of R.C. Footing.)

The actual ultimate Limits stresses on R.C. concrete.

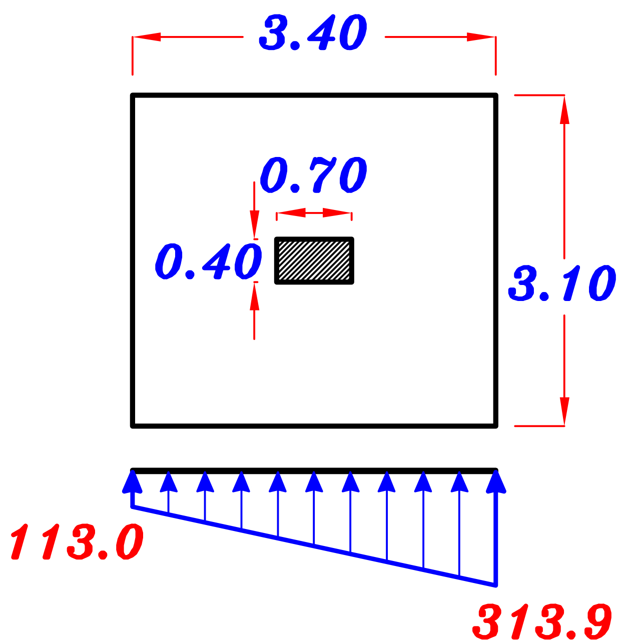


$$F_1 = \frac{N_{U.L.}}{B_{R.C.} * L_{R.C.}} + \frac{6\,M_{U.L.}}{B_{R.C.} * L_{R.C.}^2}$$

$$F_1 = \frac{2250}{3.10 * 3.40} + \frac{6 * 600}{3.10 * (3.40)^2} = 313.9 \ kN/m^2$$

$$F_2 = \frac{N_{U.L.}}{B_{R.C.} * L_{R.C.}} - \frac{6\,M_{U.L.}}{B_{R.C.} * L_{R.C.}^2}$$

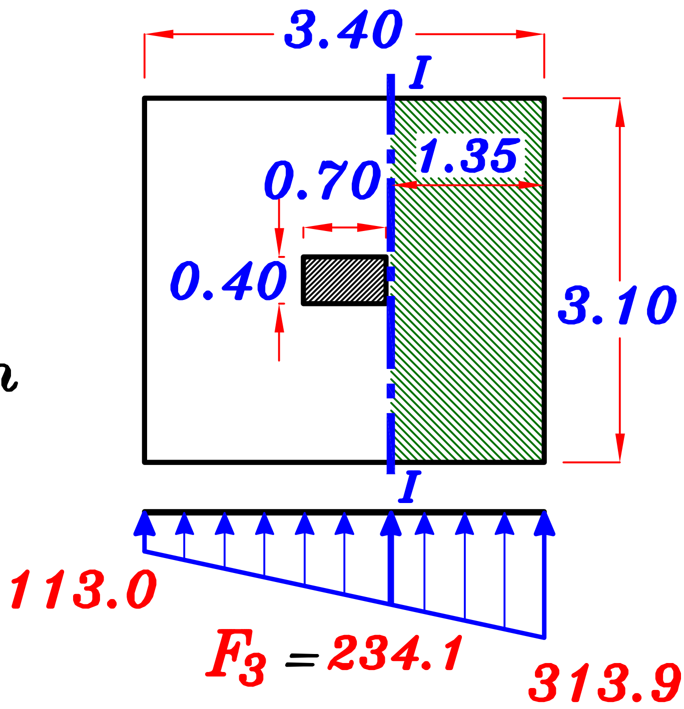
$$F_2 = \frac{2250}{3.10 * 3.40} - \frac{6 * 600}{3.10 * 3.40^2} = 113.0 \ kN/m^2$$



Direction I

$$z_I = \frac{L_{R.C.} - b}{2} =$$

$$z_I = \frac{3.40 - 0.70}{2} = 1.35\ m$$

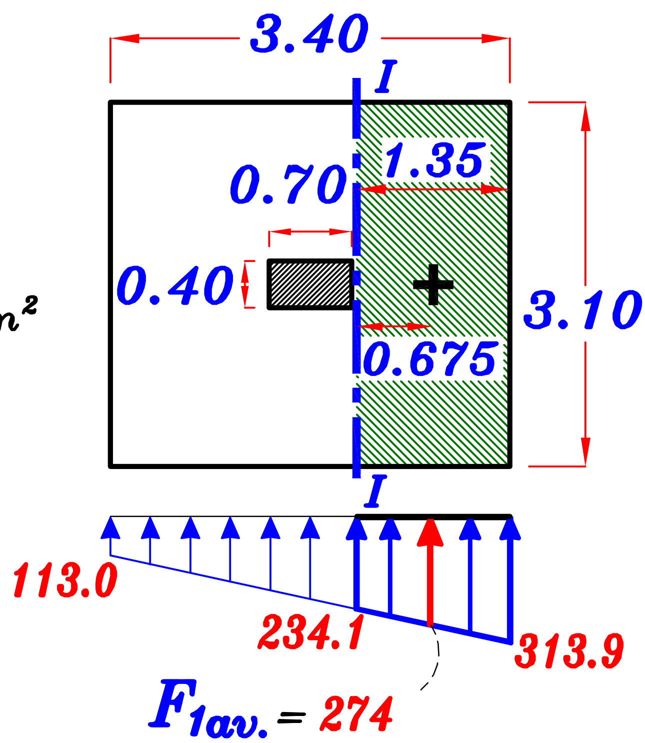


$$F_3 = \frac{L_{R.C.} - z_I}{L_{R.C.}} * (F_1 - F_2) + F_2$$

$$F_3 = \frac{3.40 - 1.35}{3.40} * (313.9 - 113.0) + 113.0 = 234.1\ kN/m^2$$

$$F_{1av.} = \frac{F_1 + F_3}{2}$$

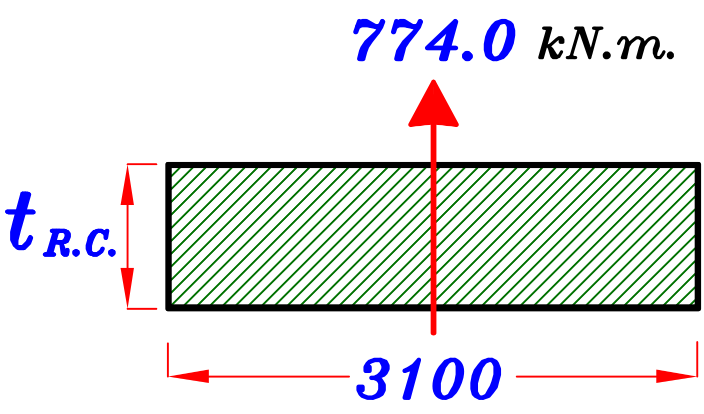
$$F_{1av.} = \frac{313.9 + 234.1}{2} = 274.0\ kN/m^2$$

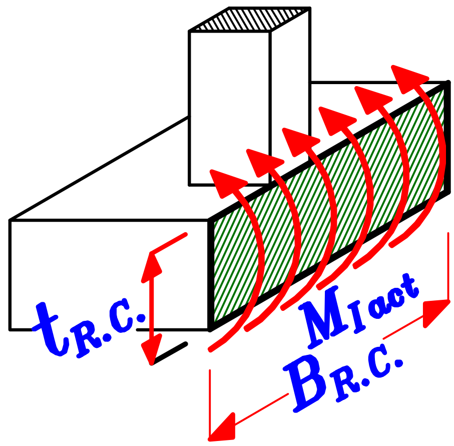


moment = Force * Distance

$$M_{I\,act.} = (F_{1av.} * z_I * B_{R.C.})\ \frac{z_I}{2}$$

$$M_{I\,act.} = (274.0 * 1.35 * 3.10)\ \frac{1.35}{2} = 774.0\ kN.m$$





$$\because\ d_I = C_1 \sqrt{\frac{M_{I\,act.}}{F_{cu} * b}}$$

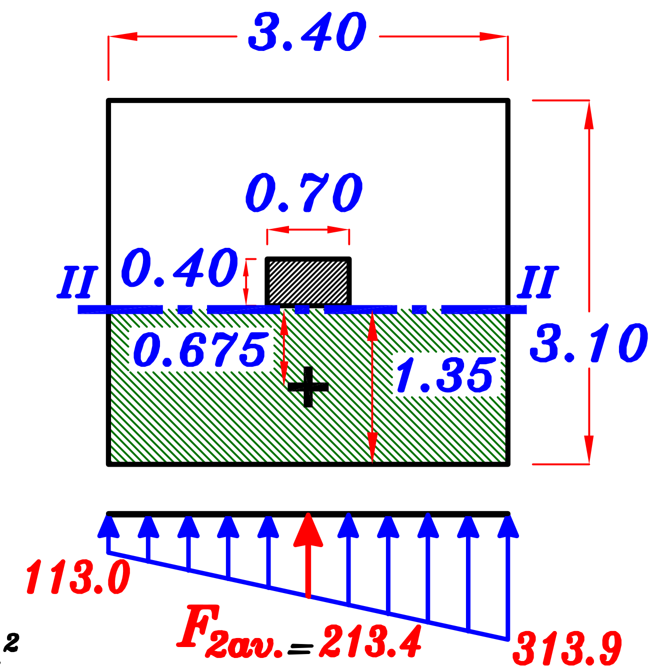
Choose $C_1 = 5.0$

$$\therefore\ d_I = 5.0 \sqrt{\frac{774.0 * 10^6}{25 * 3100}} = 499.6\ mm$$

Direction II

$$Z_{II} = \frac{b_{R.C.} - a}{2} =$$

$$Z_{II} = \frac{3.10 - 0.40}{2} = 1.35\ m$$

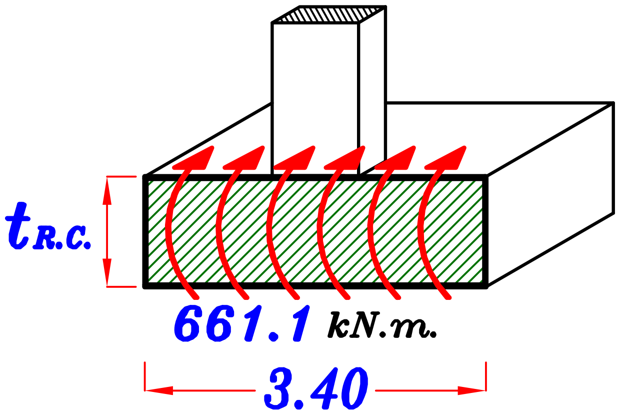


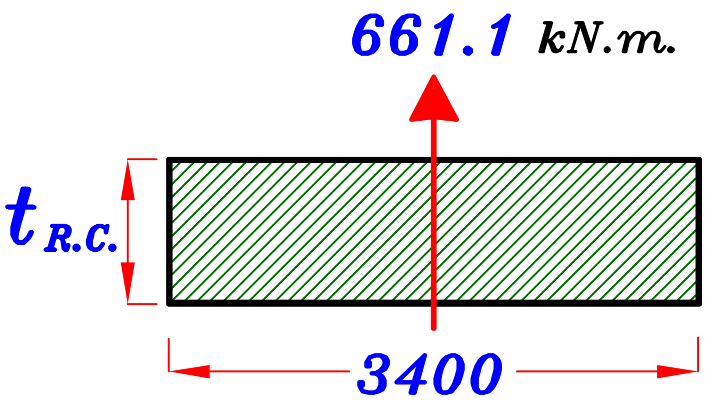
$$F_{2av.} = \frac{F_1 + F_2}{2}$$

$$F_{2av.} = \frac{313.9 + 113.0}{2} = 213.4\ kN/m^2$$

$$M_{II\,act.} = (F_{2av.} * Z_{II} * L_{R.C.})\ \frac{Z_{II}}{2}$$

$$M_{II\,act.} = (213.4 * 1.35 * 3.40)\ \frac{1.35}{2} = 661.1\ kN.m$$





$$\because \quad d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \quad d = 5.0 \sqrt{\frac{661.1 * 10^6}{25 \quad * 3400}} = 440.9 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 499.6 + 70 = 569.6 \ mm$$

$t_{R.C.} = 600 \ mm$ **$d = 530 \ mm$**

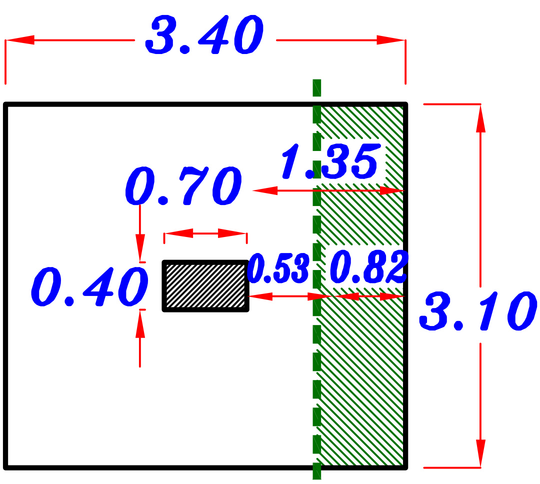
3- Check Shear.

*Critical section For Shear.

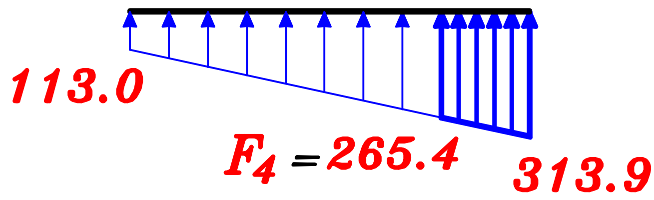
$$l = Z_I - d$$

$$l = 1.35 - 0.53 = 0.82 \ m$$

* Calculate the shear stress at critical section.

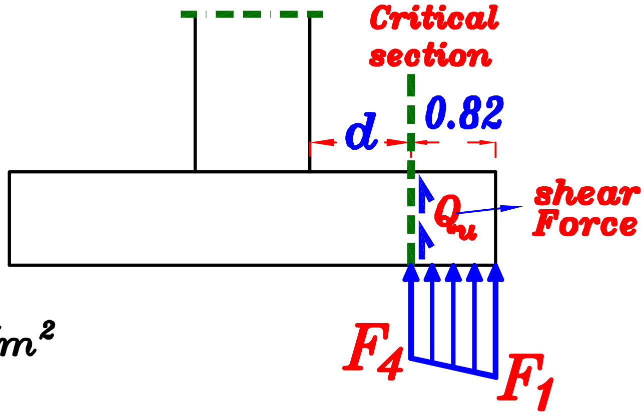


$$F_4 = \frac{L_{R.C.} - l}{L_{R.C.}} * (F_1 - F_2) + F_2$$



$$F_4 = \frac{3.40 - 0.82}{3.40} * (313.9 - 113.0) + 113.0 = 265.4 \ kN/m^2$$

Get the average stress $F_{3av.}$



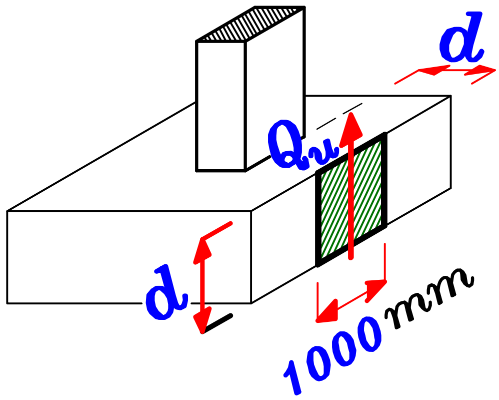
$$F_{3av.} = \frac{F_1 + F_4}{2}$$

$$F_{3av.} = \frac{313.9 + 265.4}{2} = 289.6 \text{ kN/m}^2$$

* **Calculate Actual shear Force.** (Q_u)

$$Q_u = F_{3av.} * l * 1.0\,m = 289.6 * 0.82 * 1.0\,m = 237.47 \text{ kN}$$

* **Calculate Actual shear stress.** (q_u)



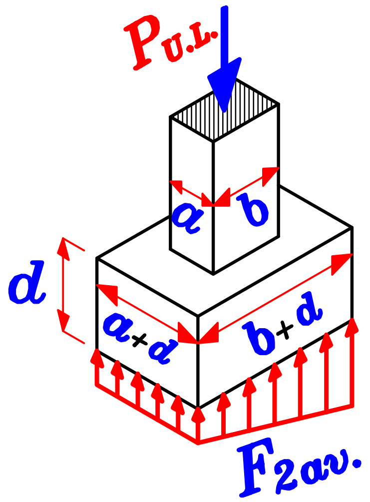
$$q_u = \frac{Q_u}{b * d} = \frac{237.47 * 10^3}{1000 * 530} = 0.448 \text{ N/mm}^2$$

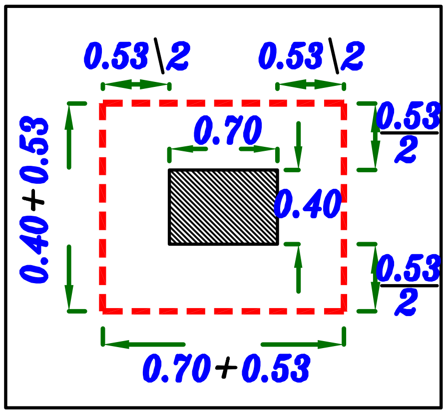
* **Allowable shear stress.** (q_{su})

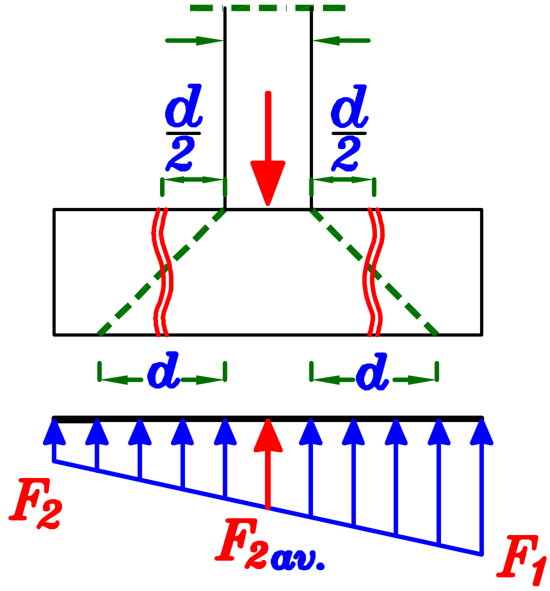
$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

$q_u < q_{su}$ ⟶ **Safe shear stresses**
No need to increase dimensions.

4 – Check Punching Shear.







$$F_{2av.} = \frac{F_1 + F_2}{2} = \frac{313.9 + 113.0}{2} = 213.4 \text{ kN/m}^2$$

$$a + d = 0.40 + 0.53 = 0.93 \text{ m}$$

$$b + d = 0.70 + 0.53 = 1.23 \text{ m}$$

* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{2av}) \left[(a+d)(b+d)\right]$$

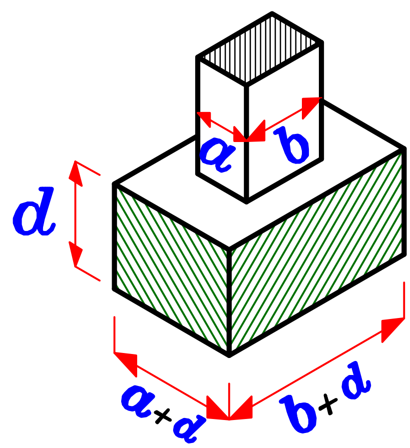
$$Q_p = 2250 - 213.4 \left[0.93 * 1.23\right] = 2005.9 \text{ kN}$$

* Calculate Punching shear area. (A_p)

$$A_p = \left[2(a+d) + 2(b+d)\right] * d$$

$$A_p = \left[2(400+530) + 2(700+530)\right] * 530$$

$$A_p = 2289600 \text{ mm}^2$$



* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)] * d}$$

$$q_{pu} = \frac{2005.9 * 10^3}{2289600} = 0.876 \ N/mm^2$$

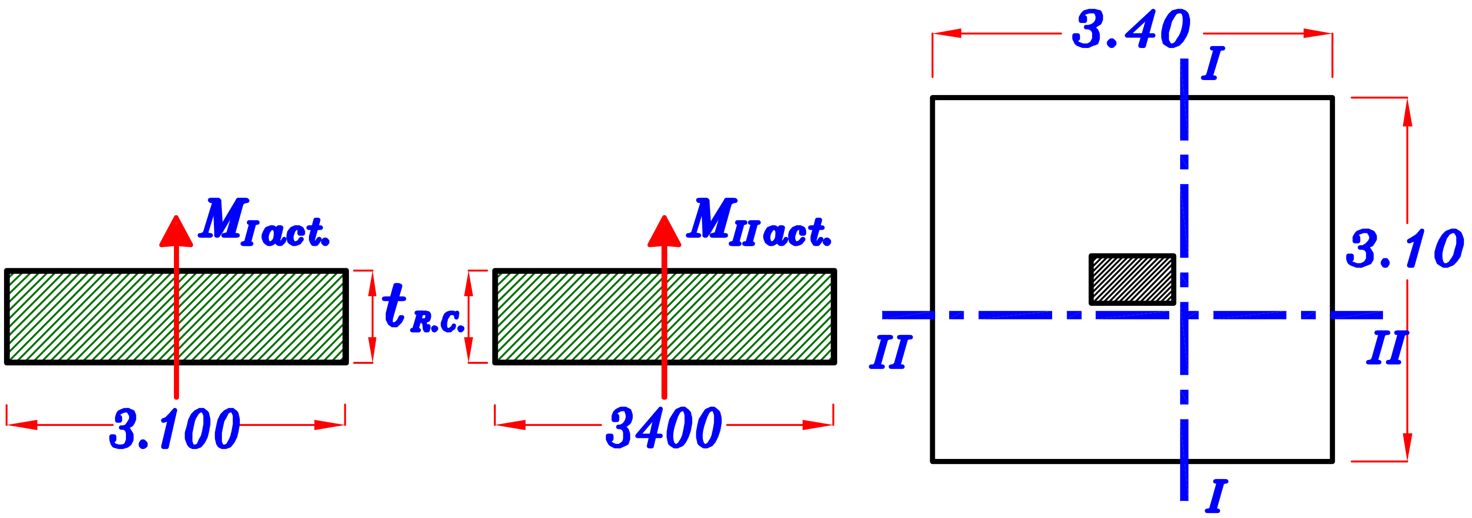
* Calculate allowable Punching shear stress. q_{pcu}

$$q_{pcu} = 0.316 \left(0.5 + \frac{a}{b}\right) \sqrt{\frac{F_{cu}}{\gamma_c}} =$$

$$q_{pcu} = 0.316 \left(0.5 + \frac{0.40}{0.70}\right) \sqrt{\frac{25}{1.5}} = 1.38 \ N/mm^2$$

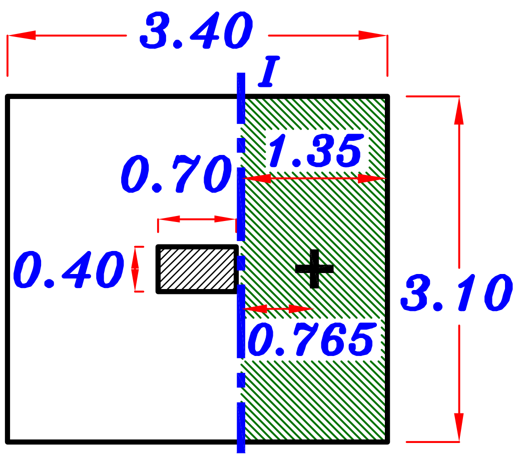
$q_{pu} \leqslant q_{pcu}$ ⟶ Safe punching shear.
No need to increase dimensions.

5- Reinforcement of the Footing.



$$M_{I\,act.} = 774.0 \ kN.m$$

$$J = 0.826$$



$$A_s = \frac{M_{I\,act.}}{J\,F_y\,d} = \frac{774.0 * 10^6}{0.826 * 360 * 530} = 4911.1 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{4911.1}{3.10} = 1584.2 \ mm^2/m'$$

Check $A_{s\,min}$

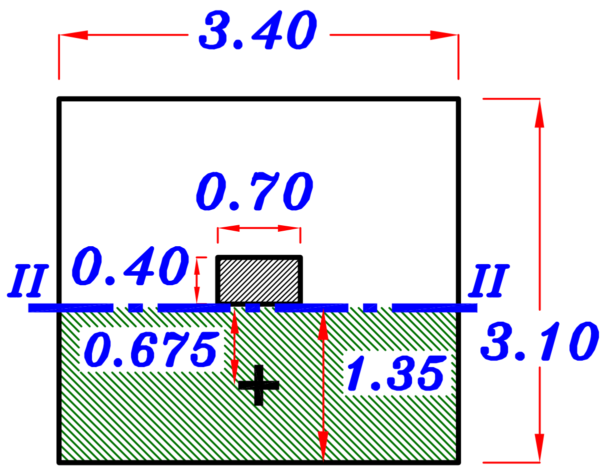
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 530 = 790 \\ 5\phi 12/m' = 565 \end{array} \right\} 790 \ mm^2$$

$$\therefore \ A_s > A_{s\,min} \longrightarrow o.k.$$

$$A_s = 1584.2 \ mm^2 \qquad \boxed{7\phi 18/m'}$$

$$M_{II\,act.} = 661.1 \ kN.m$$

$$J = 0.826$$



$$A_s = \frac{M_{II\,act.}}{J\,F_y\,d} = \frac{661.1 * 10^6}{0.826 * 360 * 530} = 4194.7 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{4194.7}{3.40} = 1233.7 \ mm^2/m'$$

Check $A_{s\,min}$

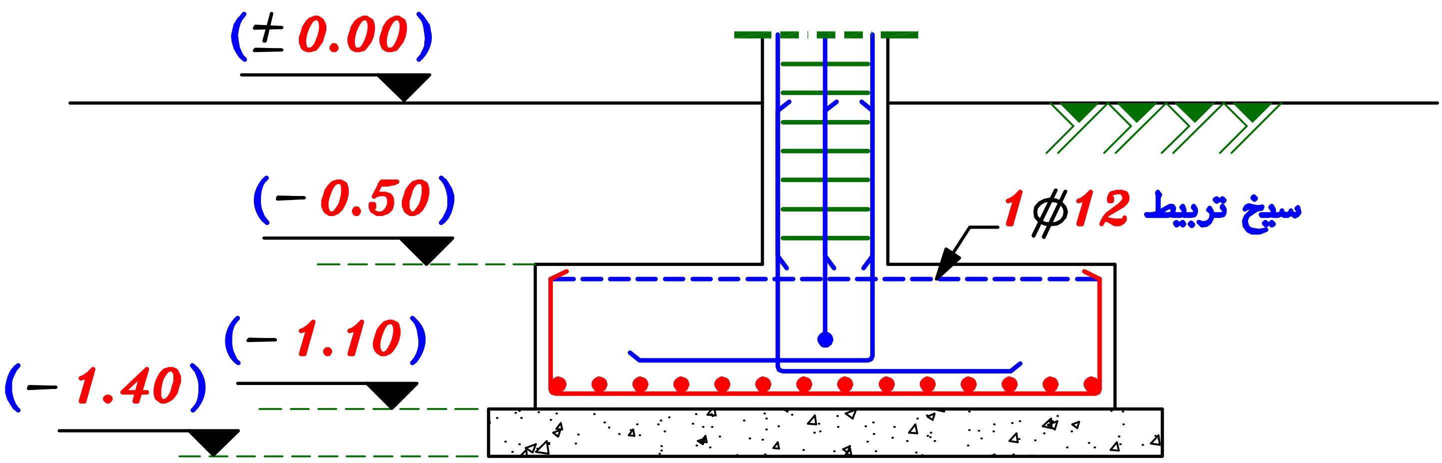
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 530 = 790 \\ 5 \phi 12/m' = 565 \end{array} \right\} 790 \, mm^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow o.k.$$

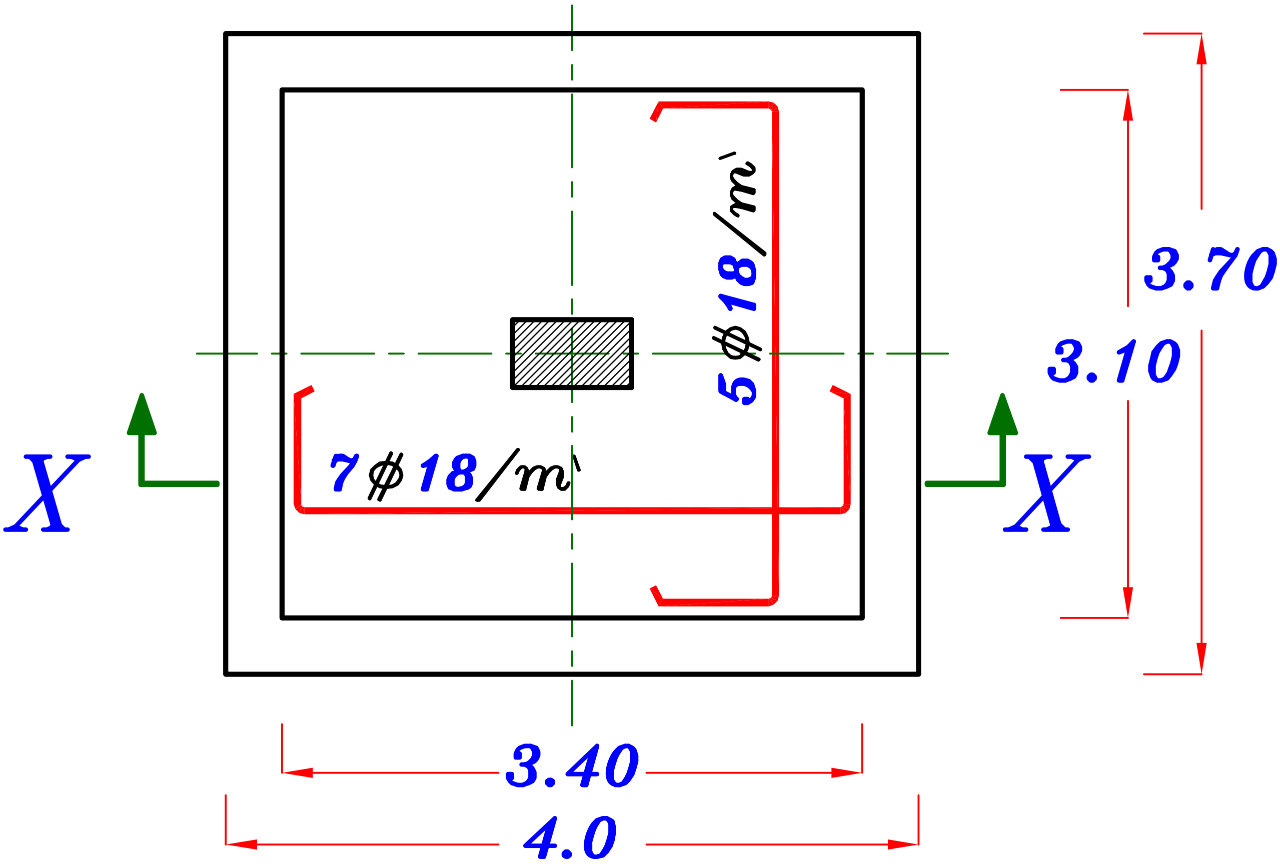
$$A_s = 1233.7 \ mm^2$$

$$5 \phi 18/m'$$

6 – Details of Reinforcement.



Sec X–X

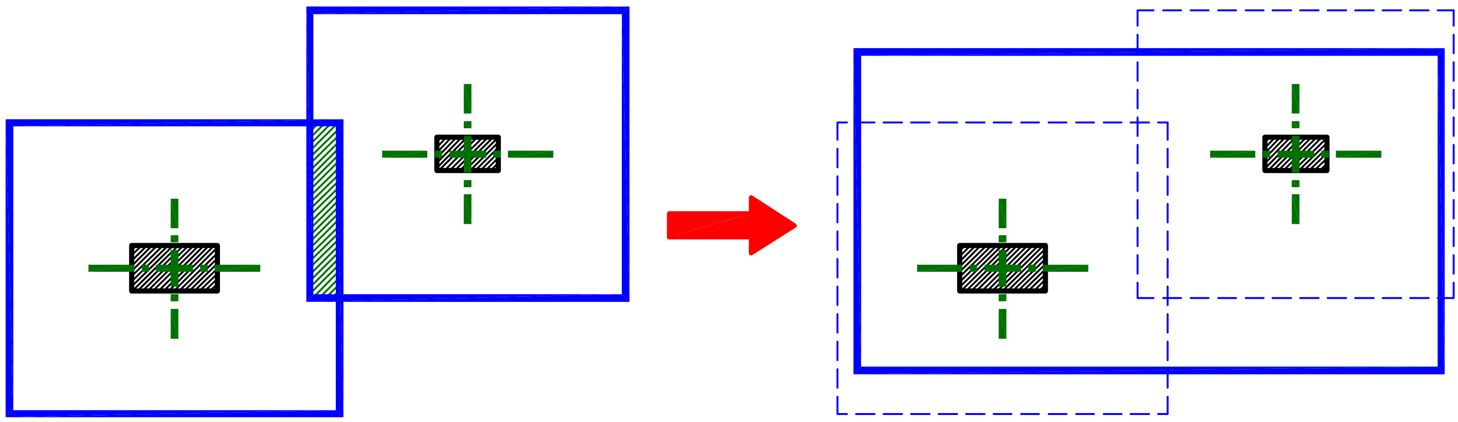


5 *Design of Combined Footings.*

تصميم القواعد المشتركه .

- القاعده المشتركه (*Combined Footing*) هى عباره عن قاعده واحده كبيره تحمل أكثر من عمود واحد و غالبا يكون شكلها مستطيل .

- عاده نحتاج لعمل قواعد مشتركه عند تداخل أكثر من قاعده منفصله .
أى عند تحديد أبعاد الـ *R.C.* لقاعدتين منفصلتين لعمودين متجاورين و وجد أن القاعدتين سوف يتداخلان معا و هو ما لا يمكن تنفيذه لذلك نلجاء لاستبدال القاعدتين المنفصلتين بقاعده واحده كبيره مشتركه بين العمودين .



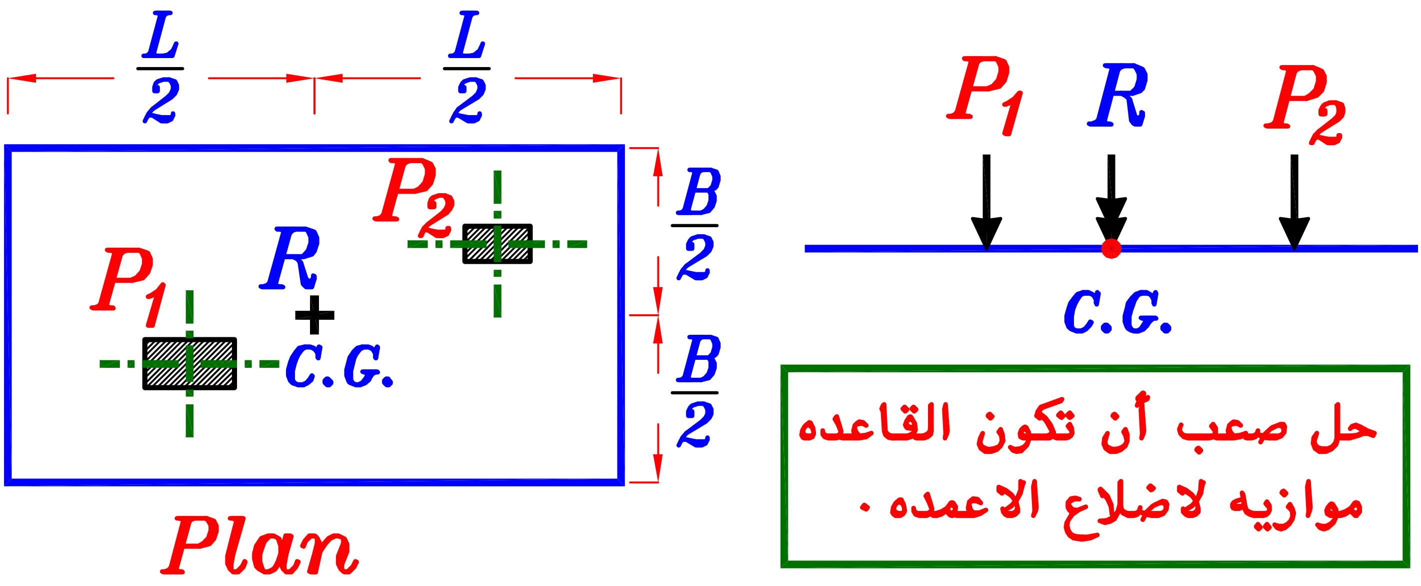
R.C. Isolated Footings *R.C. Combined Footing*

المبدأ الرئيسى لتصميم القواعد المشتركه .

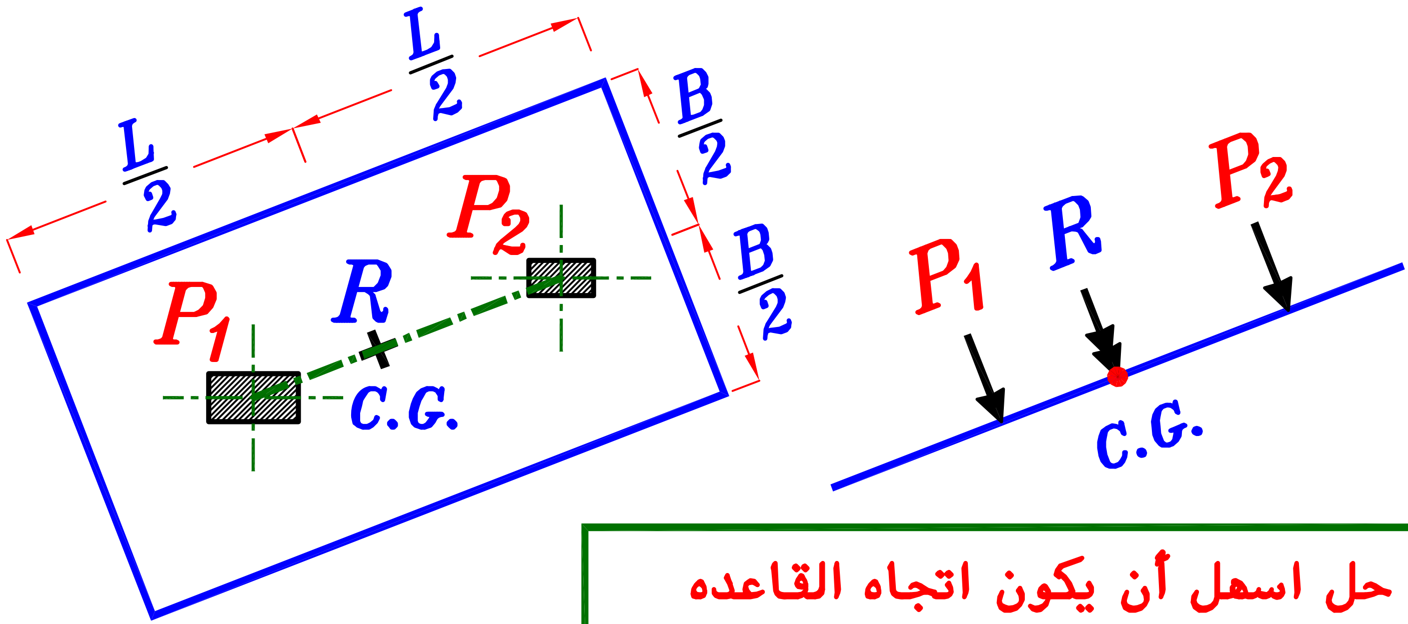
نحاول قدر المستطاع أن يكون مركز الاحمال

يقع تماما عند .C.G القاعده المسلحه .

حتى يكون على التربه اجهادات منتظمه Uniform stresses



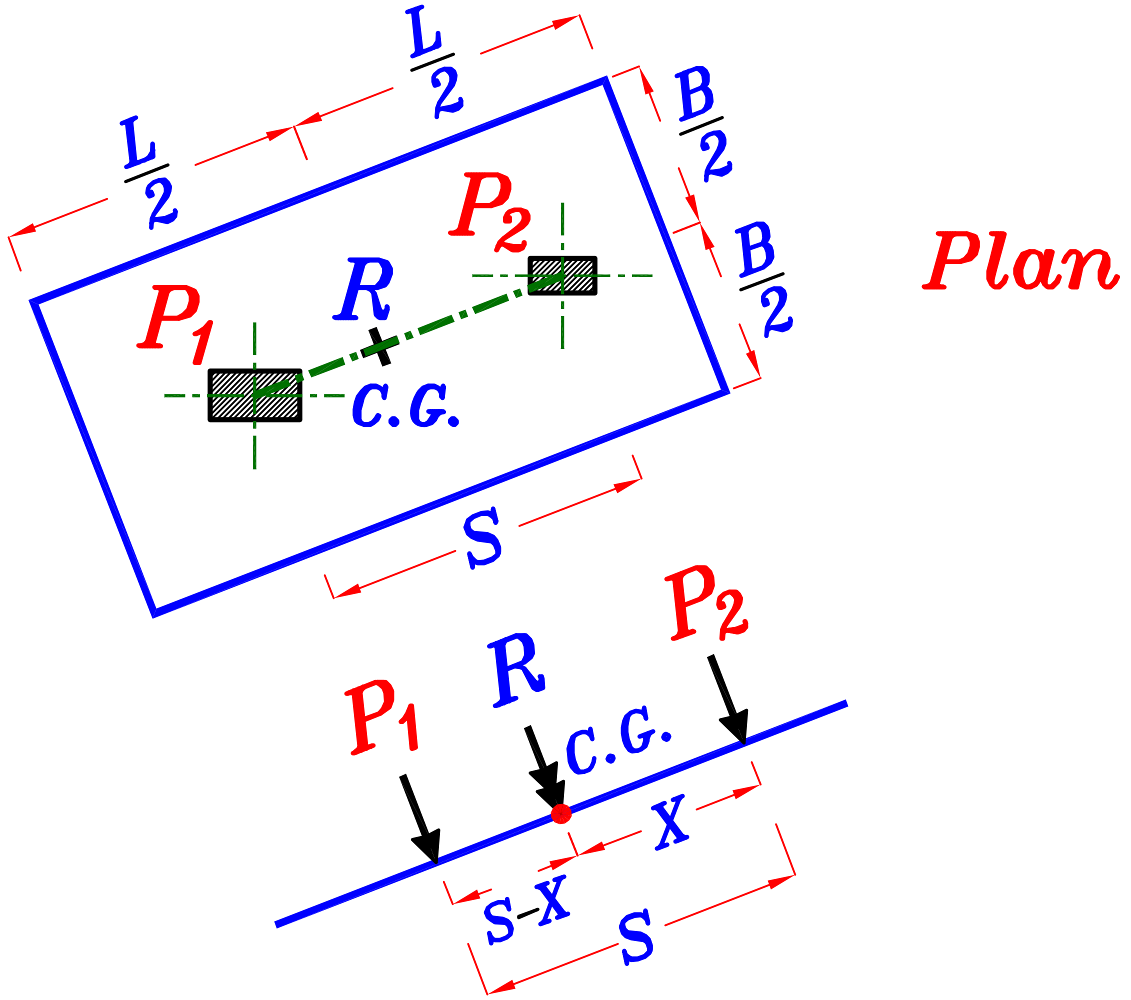
حل صعب أن تكون القاعده موازيه لاضلاع الاعمده .



حل اسهل أن يكون اتجاه القاعده موازى للخط الواصل بين العمودين .

Steps of design of rectangular combined Footing.

1- Calculate the Footing area. (Width & Length of R.C. Footing.)



$$R = P_1 + P_2$$

يتم حساب قيمه محصله الاحمال R

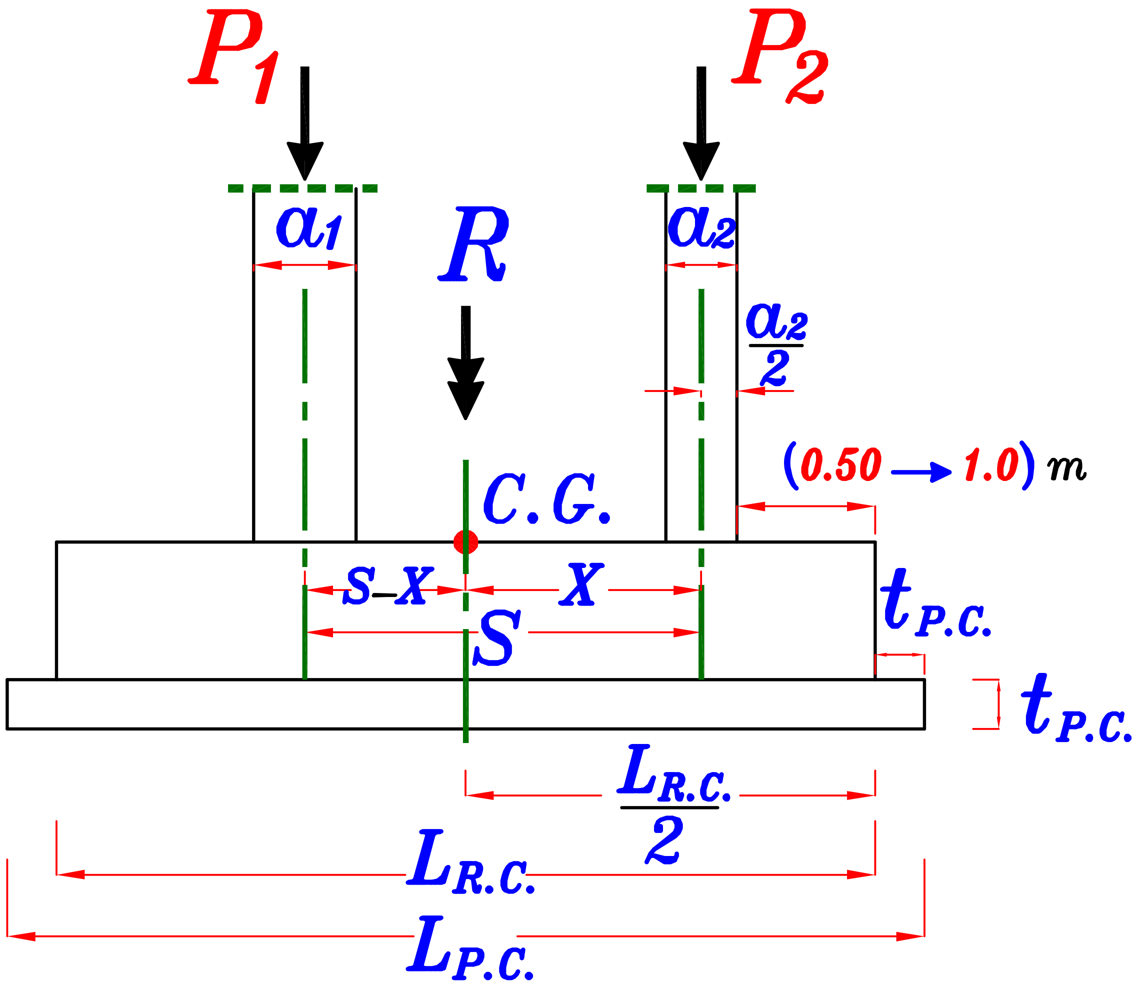
يتم تحديد مكان محصله الاحمال X

$$R * X = P_1 * S \longrightarrow X = \frac{P_1}{R} * S$$

نأخذ طول القاعده المسلحه بحيث تكون نهايتها بعد وش العمود الخارجى

بمسافه $(0.50\,m \longrightarrow 1.0\,m)$ من جهه الحمل الاصغر .

مثلا فى هذا المثال P_2 هو الاصغر .



$$\frac{L_{R.C.}}{2} = (X) + \frac{a_2}{2} + (0.50 \longrightarrow 1.0)\,m \longrightarrow \boxed{L_{R.C.} = \checkmark}$$

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

Calculate the width of the Footing. B

IF $t_{P.C.} \geq 20$ cm get $B_{P.C.}$ From

$$A_{P.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = B_{P.C.} * L_{P.C.} \rightarrow \boxed{B_{P.C.} = \checkmark}$$

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

IF $t_{P.C.} < 20$ cm get $B_{R.C.}$ From

$$A_{R.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = B_{R.C.} * L_{R.C.} \rightarrow \boxed{B_{R.C.} = \checkmark}$$

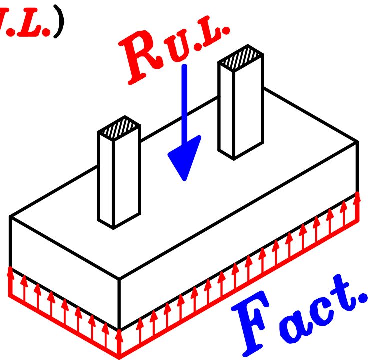
$$\boxed{B_{P.C.} = B_{R.C.} + 2\ t_{P.C.}}$$

2- Design the critical sections For moment. (Depth of R.C. Footing.)

$$P_{1\,U.L.} = 1.5 * P_{1w}\ ,\ P_{2\,U.L.} = 1.5 * P_{2w}\ ,\ R_{U.L.} = 1.5 * R_w$$

- **Actual Normal stress on R.C. Footing (U.L.)**

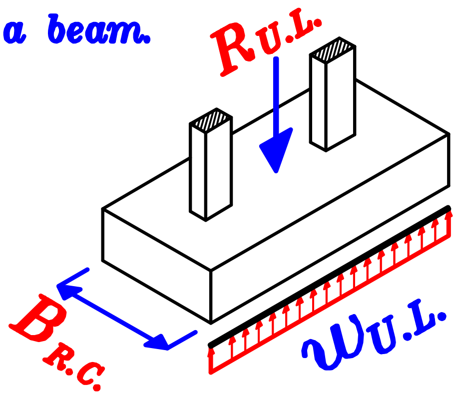
$$\boxed{F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}}} \quad (kN/m^2)$$



- **Actual Uniform Load on R.C. Footing (U.L.) as a beam.**

$B_{R.C.}$ نعتبر أن القاعده عباره عن كمره بعرض

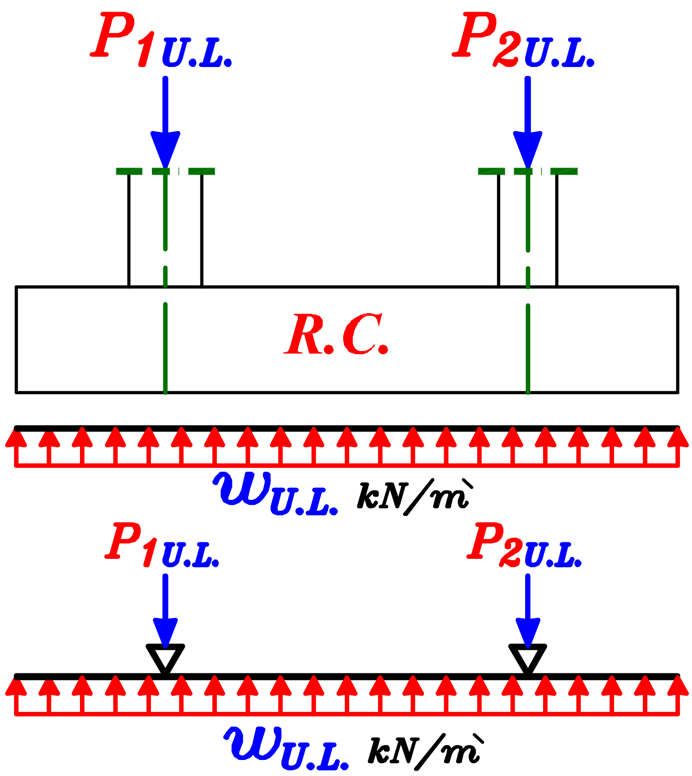
$$\boxed{w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}}} \quad (kN/m`)$$



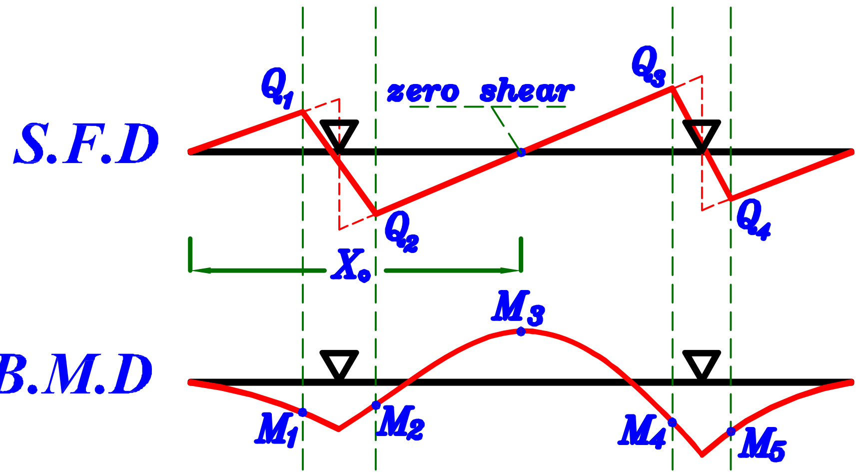
Longitudinal direction.

نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$

يتم رسم B.M.D. , S.F.D. للقاعده كلها كأنها كمره بعرض $B_{R.C.}$



و يتم حساب قيم B.M. , S.F. على وش الاعمده .



لتحديد أكبر moment فى منتصف القاعده M_3

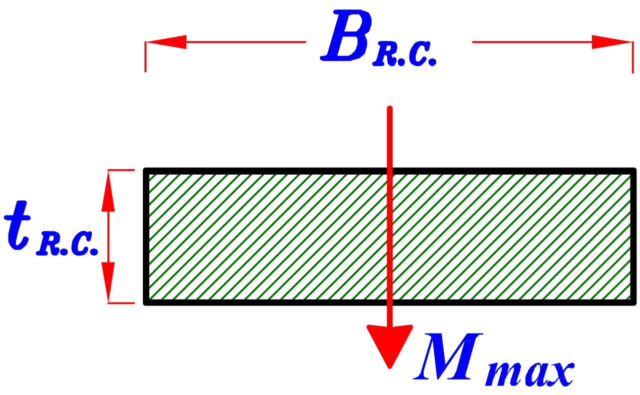
يتم تحديد مكان نقطه zero shear أى حساب المسافه X_o

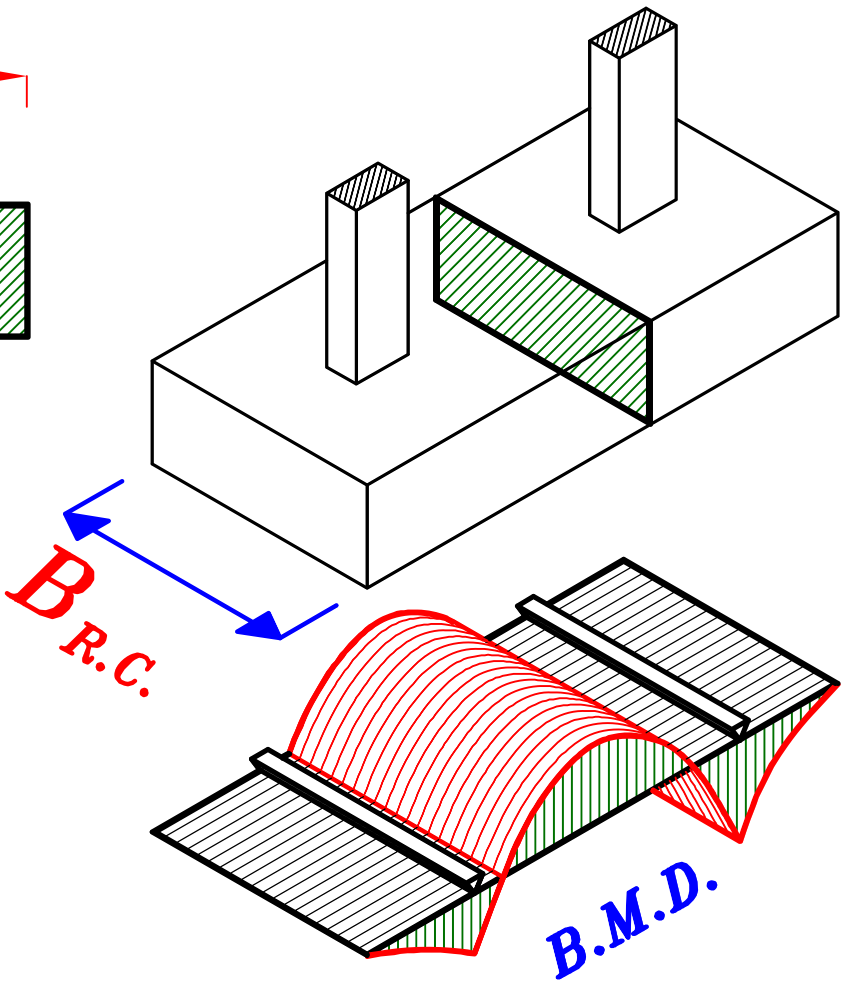
$P_{1\,U.L.} = w_{U.L.} * X_o$ → $X_o = ✓$ → $M_3 = ✓$

Get M_{max}

نحسب أكبر moment على القاعده كلها . M_{max}

M_{max} is the biggest moment of M_1, M_2, M_3, M_4, M_5





$$d\ (mm) = C_1 \sqrt{\frac{M_{max}\ (kN.m) * 10^6}{F_{cu}\ (N/mm^2) * B_{R.C.}\ (mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده Rigid

Get $d = \checkmark\checkmark$ (mm)

Take cover = 70 mm

يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصداء .

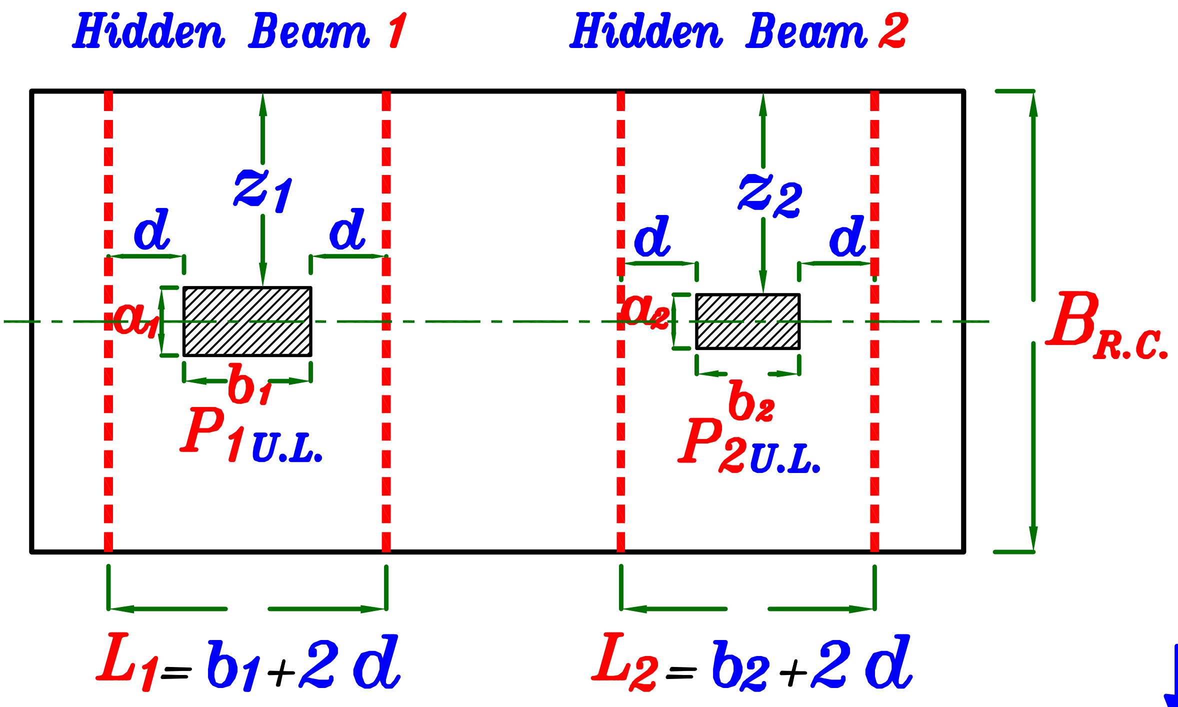
$t_{R.C.} = d + cover\ (70\ mm)$

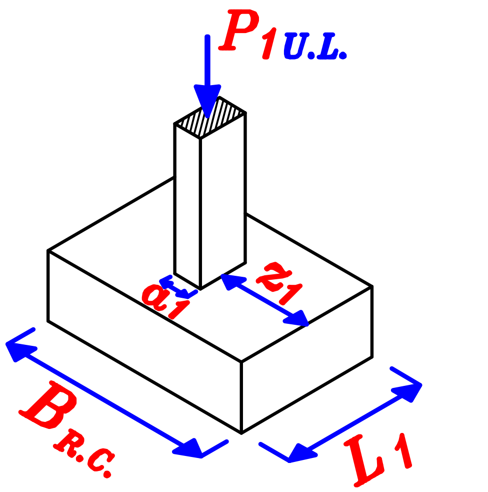
تقرب لاقرب ٥٠ مم بالزياده

As a Hidden Beam.

نعتبر القاعده أسفل كل عمود كأنها كمره مدفونه (Hidden Beam)

أبعادها أسفل العمود $L * B_{R.C.}$





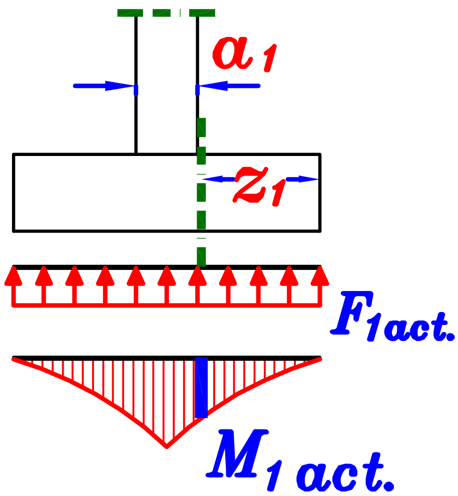
Hidden Beam 1

$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} \quad (kN/m^2)$$

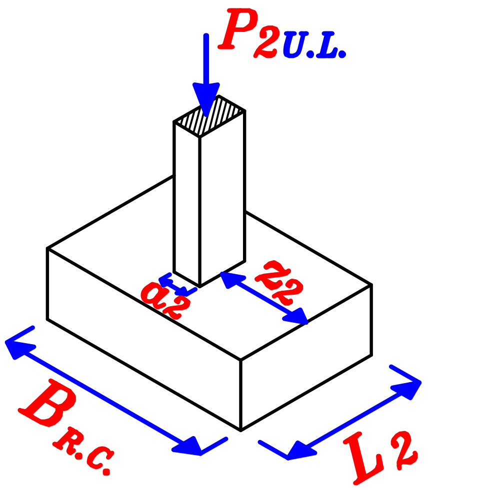
$$Z_1 = \frac{B_{R.C.} - a_1}{2} \quad (m)$$

$$M_{1act.} = (F_{1act.} * Z_1 * 1.0\,m)\ \frac{Z_1}{2}$$

$(kN.m/1.0\,m)$



Hidden Beam 2

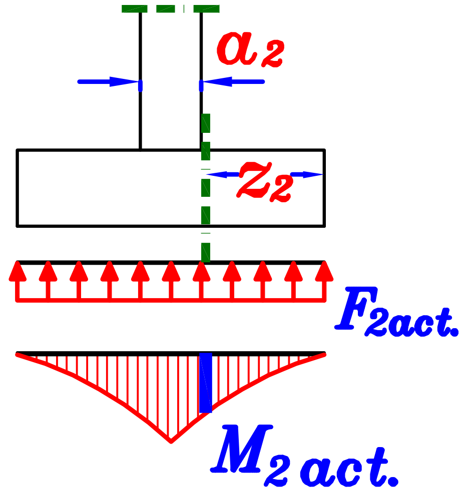


$$F_{2act.} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} \quad (kN/m^2)$$

$$Z_2 = \frac{B_{R.C.} - a_2}{2} \quad (m)$$

$$M_{2act.} = (F_{2act.} * Z_2 * 1.0\,m)\ \frac{Z_2}{2}$$

$(kN.m/1.0\,m)$



Choose M_{bigger} The bigger value of $M_{1act.}$ & $M_{2act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{Get} C_1$$

Then Check on $C_1 \nless 3.0$

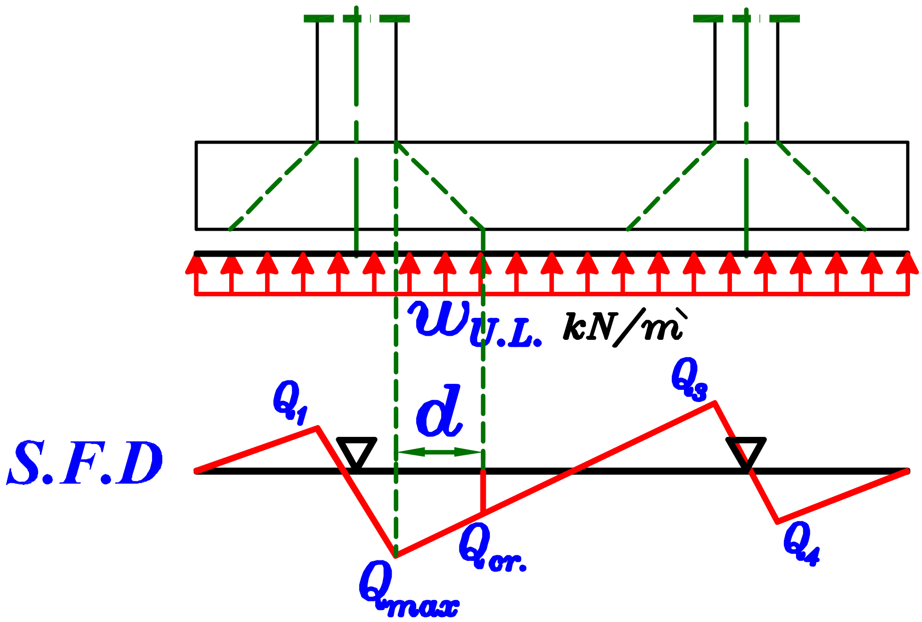
IF $C_1 < 3.0 \longrightarrow$ Increase d

and Recheck the transverse direction.

3 – Check Shear. at long direction

Critical section For Shear.

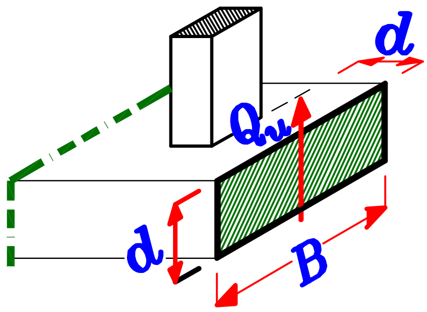
على بعد d من وش العمود اللى عنده $Q_{max.}$



$$Q_{cr.} = Q_{max.} - w_{U.L.} * d$$

* **Calculate Actual shear stress.** (q_u)

$$q_u = \frac{Q_{cr.}\,(kN) * 10^3}{B\,(mm) * d\,(mm)} \quad (N/mm^2)$$



* **Calculate Allowable shear stress.** (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\delta_c}} \quad (N/mm^2)$$

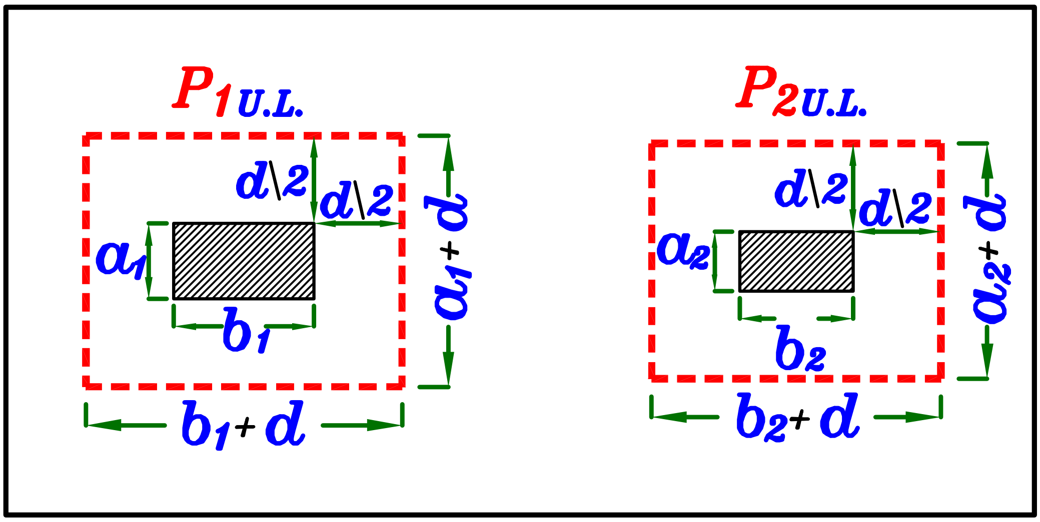
* **Compare between**

Actual shear stress (q_u) & **Allowable shear stress** (q_{su})

* IF $q_u \leqslant q_{su}$ ⟶ **Safe shear stresses**
No need to increase dimensions.

* IF $q_u > q_{su}$ ⟶ **UnSafe shear stresses**
We have to increase dimensions.

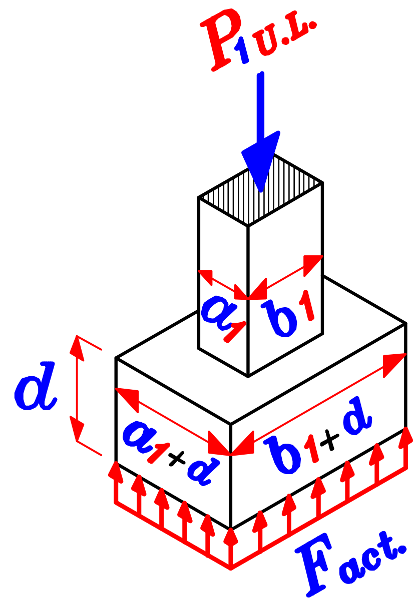
4 – Check Punching Shear. القص الثاقب .



Column 1

* Calculate Punching Force. (Q_{1p})

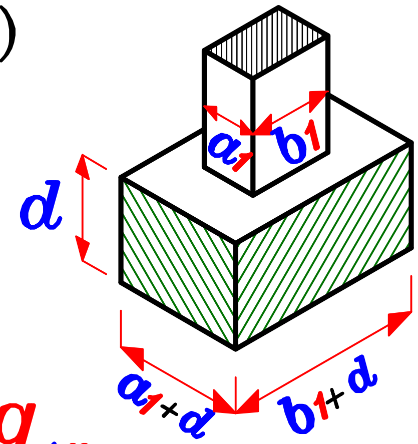
$$Q_{1p} = P_{1\,U.L.} - (F_{act.})\left[(a_1+d)(b_1+d)\right] \quad (kN)$$



* Calculate Punching shear area. (A_{1p})

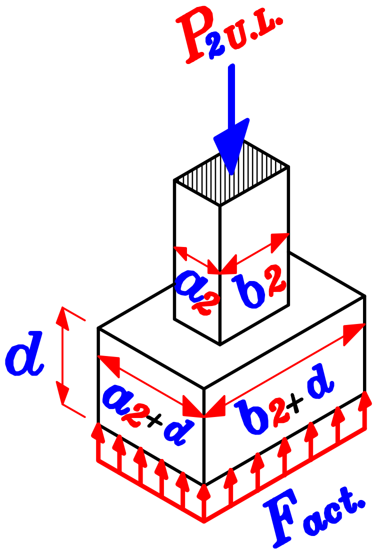
المحيط العمق

$$A_{1p} = \left[2(a_1+d) + 2(b_1+d)\right] * d \quad (mm^2)$$



* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{Q_{1p}\ (kN) * 10^3}{\left[2(a_1+d) + 2(b_1+d)\right] * d\ (mm^2)} \quad (N/mm^2)$$



* Calculate Punching Force. (Q_{2p})

$$Q_{2p} = P_{2\,U.L.} - (F_{act.})\left[(a_2+d)(b_2+d)\right]$$

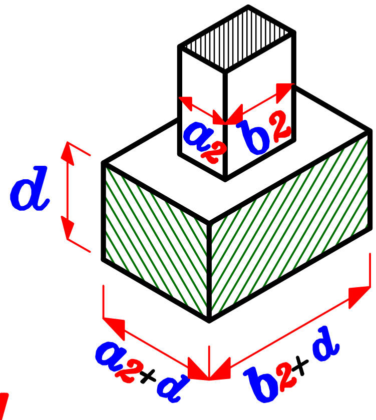
(kN)

* Calculate Punching shear area. (A_{2p})

المحيط   العمق

$$A_{2p} = \left[2(a_2+d)+2(b_2+d)\right] * d$$

(mm^2)



* Calculate Actual Punching shear stress. q_{2pu}

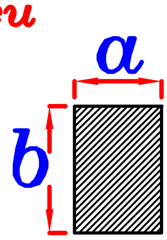
$$q_{2pu} = \frac{Q_{2p}\,(kN) * 10^3}{\left[2(a_2+d)+2(b_2+d)\right] * d\ (mm^2)} \quad (N/mm^2)$$

Choose q_{pumax} the bigger value of q_{1pu} & q_{2pu}

---

* Calculate allowable Punching shear stress. q_{pcu}

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



IF $\left(0.5+\frac{a}{b}\right) \leqslant 1.0$ Take → $q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}}$ (N/mm^2)

* Compare between

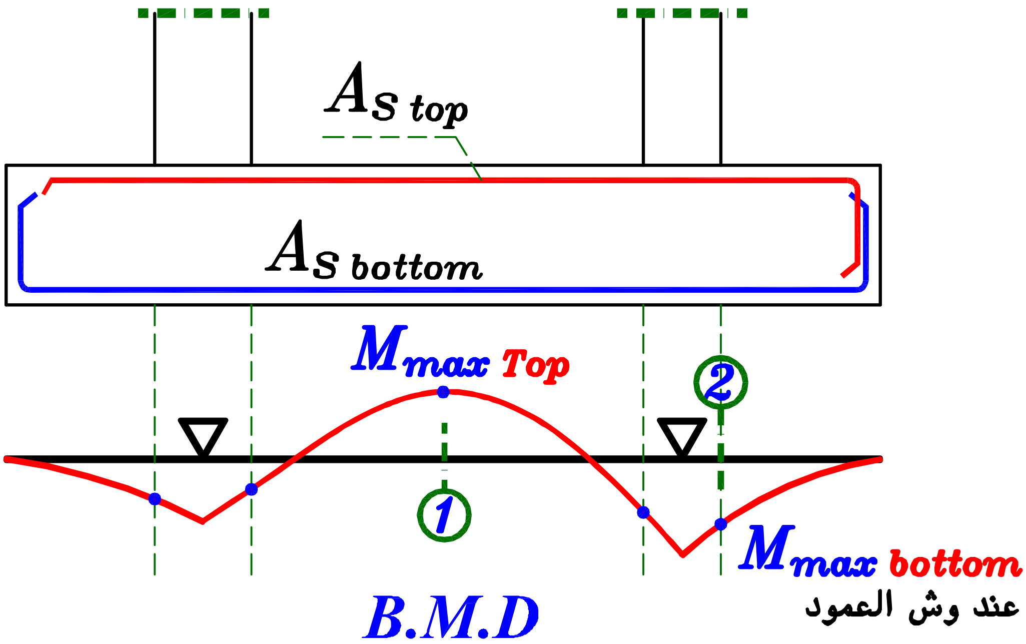
Actual punching shear stress (q_{pumax}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pumax} \leqslant q_{pcu}$ ⟶ Safe punching shear. No need to increase dimensions.

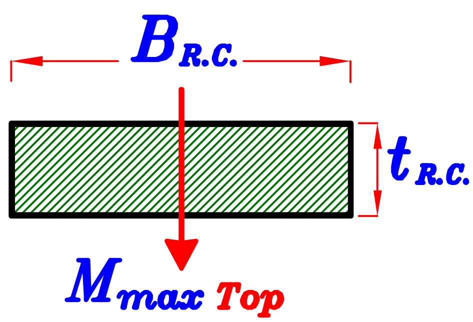
* IF $q_{pumax} > q_{pcu}$ ⟶ UnSafe punching shear. We have to increase dimensions.

5- Reinforcement of the Footing.

Longitudinal direction.



Sec. 1



From $d = C_1 \sqrt{\frac{M_{max\ Top}}{F_{cu} * B_{R.C.}}}$ $\xrightarrow{Get}$ $C_1 \longrightarrow J$

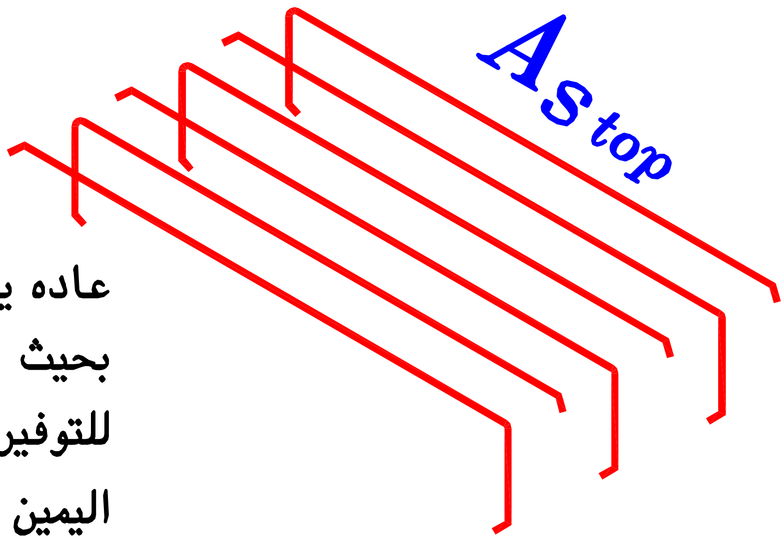
Get $$A_{s\,top} = \frac{M_{max\,Top}}{J\,F_y\,d}\ (mm^2)$$

Check $A_{s\,min}$

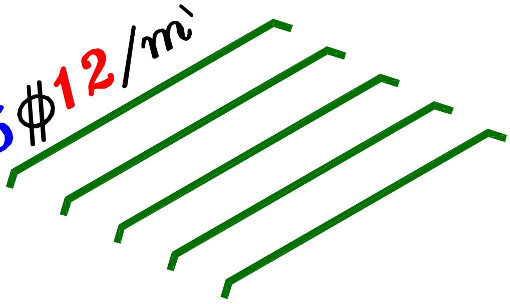
$$A_{s\,min}\ (mm^2/m) = \begin{Bmatrix} 1.5\,d\ (mm) \\ 5\phi 12/m' \end{Bmatrix} \text{الأكبر}$$

IF $A_{s\,top} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{s\,top} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

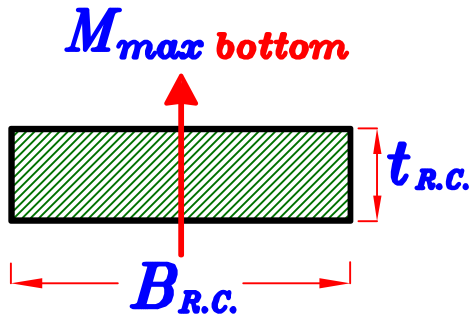


عاده يتم رص الحديد العلوى فى القواعد
بحيث يتم عمل ركبه من جهه واحده فقط
للتوفير بحيث تكون الركبه مره من جهه
اليمين  و السيخ التالى تكون
الركبه جهه اليسار 



يوضع تسليح علوى ثانوى قيمته $5\phi 12/m'$

Sec. ②



From $d = C_1 \sqrt{\dfrac{M_{max\ bottom}}{F_{cu} * B_{R.C.}}}$

$\xrightarrow{Get} C_1 \longrightarrow J$

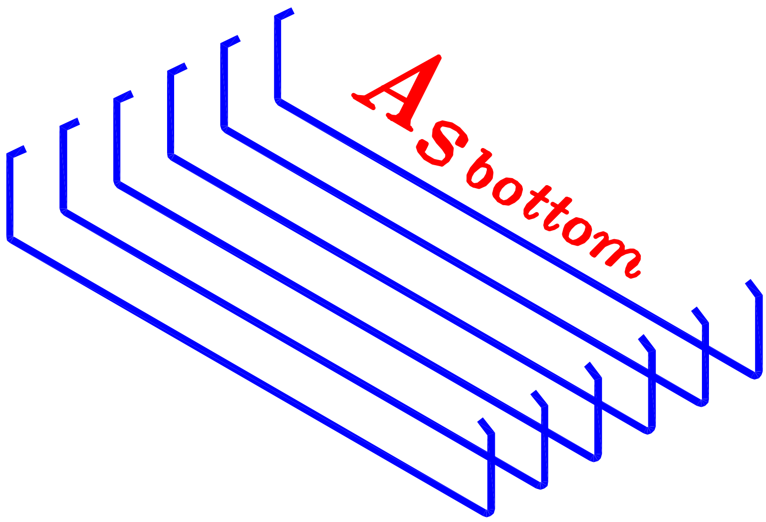
Get $$A_{s\ bottom} = \frac{M_{max\ bottom}}{J\ F_y\ d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\, d\ (mm) \\ 5\phi 12/m' \end{cases} \text{الأكبر}$$

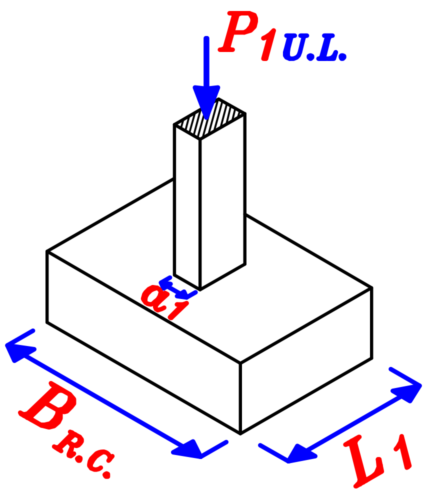
IF $A_{s\,top} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{s\,top} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$



الحديد السفلى فى القواعد
يفضل أن يتم عمل ركبه من الجهتين

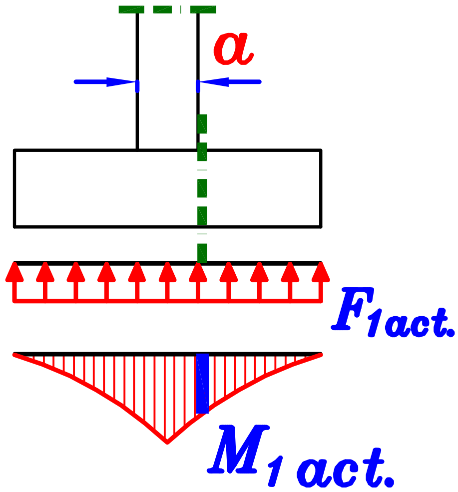
Transverse direction. Short direction.



Hidden Beam 1

From $d = C_1 \sqrt{\dfrac{M_{1\,act.}}{F_{cu} * 1000}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



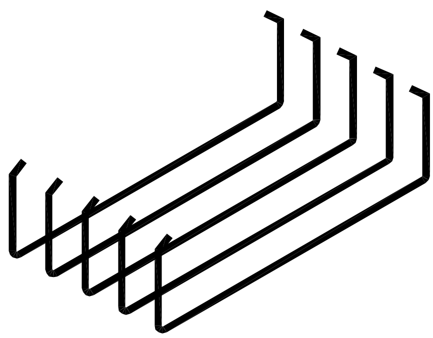
Get $$A_{s1} = \frac{M_{1\,act.}}{J\,F_y\,d} \quad (mm^2/m')$$

Check $A_{s\,min}$

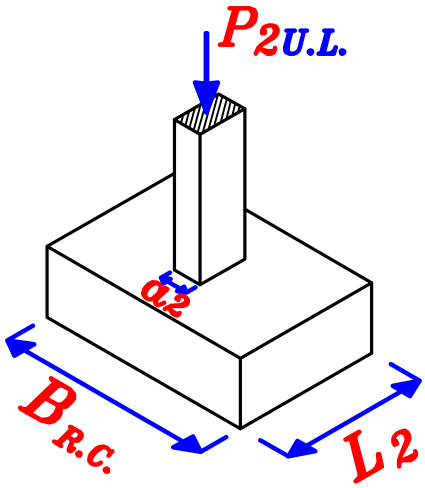
$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\,d\ (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

IF $A_{s1} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{s1} < A_{s\,min} \longrightarrow$ Take $A_{s1} = A_{s\,min}$

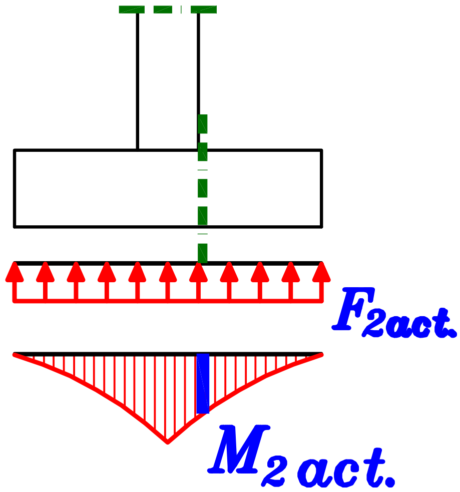


Hidden Beam 2



From $d = C_1 \sqrt{\dfrac{M_{2act.}}{F_{cu} * 1000}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



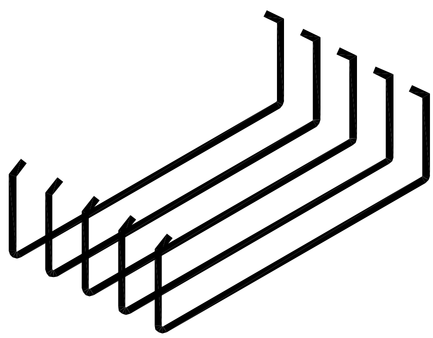
Get $\boxed{A_{s2} = \dfrac{M_{2act.}}{J\ F_y\ d}}$ $(mm^2/m`)$

Check $A_{s\,min}$

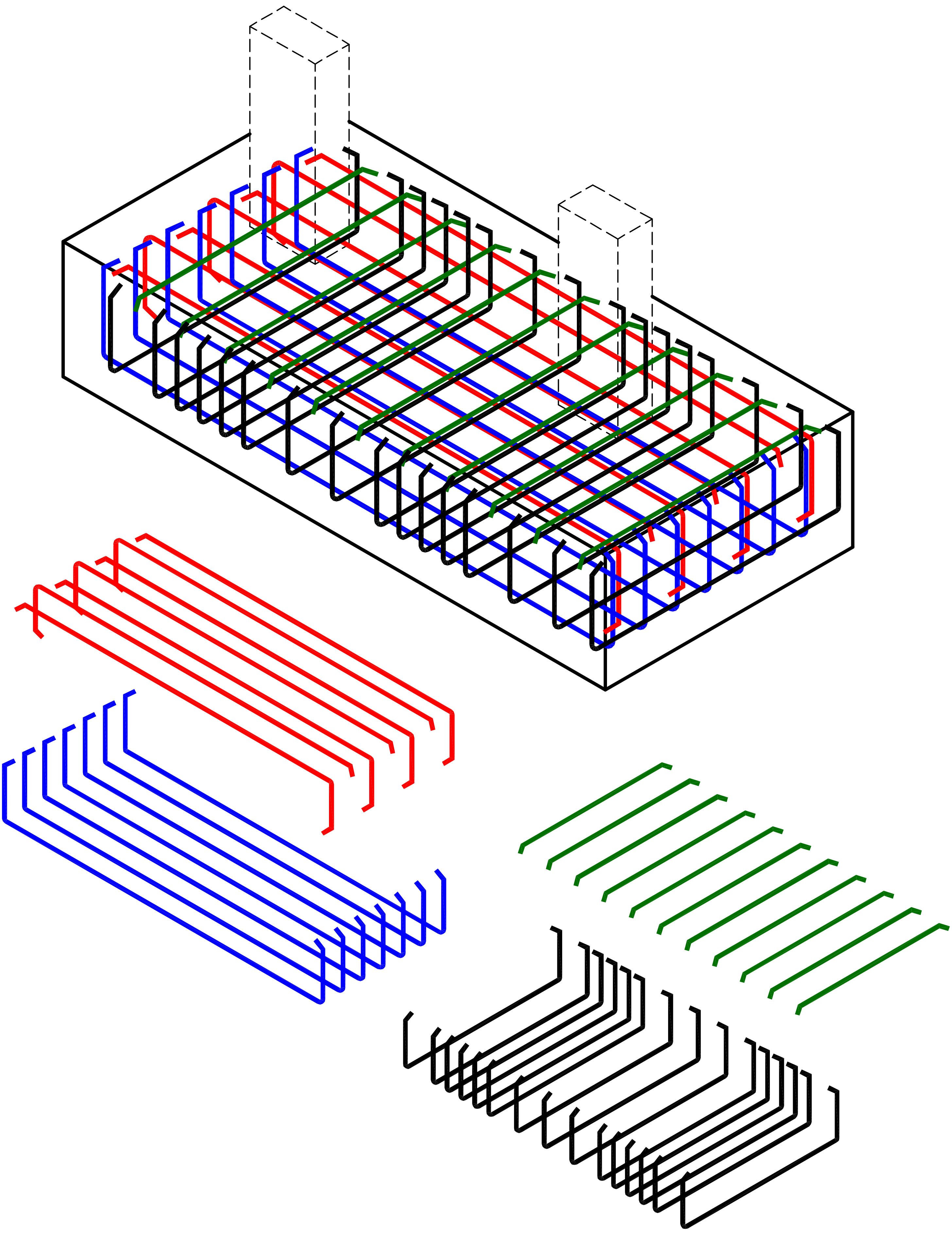
$$\boxed{A_{s\,min}\ (mm^2/m) = \left\{ \begin{array}{l} 1.5\,d\ (mm) \\ 5\,\phi\,12\,/m` \end{array} \right\} \text{الأكبر}}$$

IF $A_{s2} \geqslant A_{s\,min} \longrightarrow$ o.k.

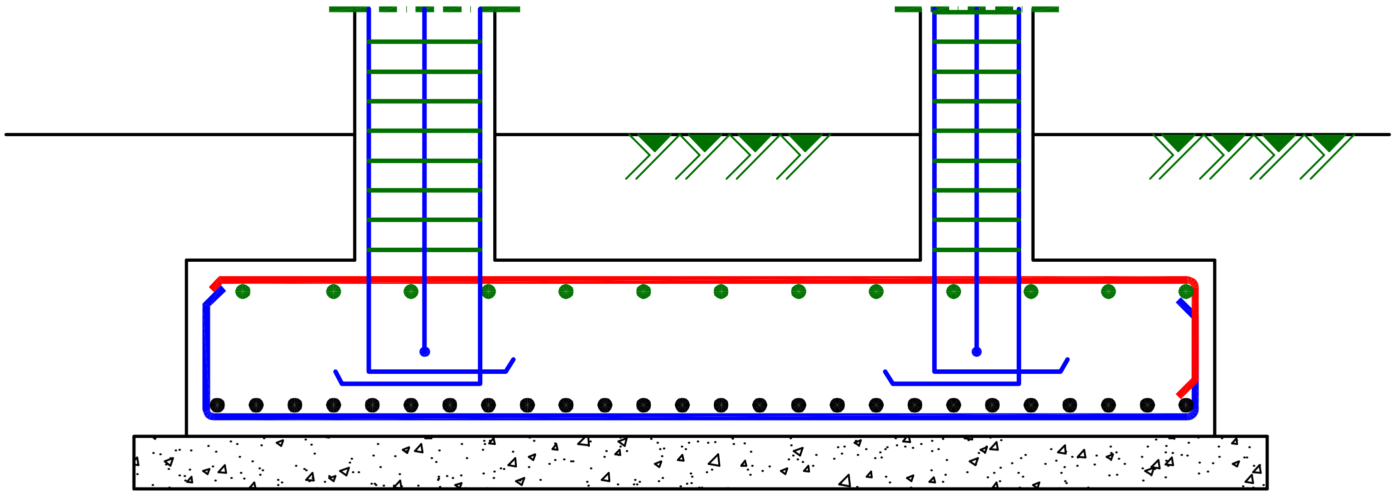
IF $A_{s2} < A_{s\,min} \longrightarrow$ Take $A_{s2} = A_{s\,min}$



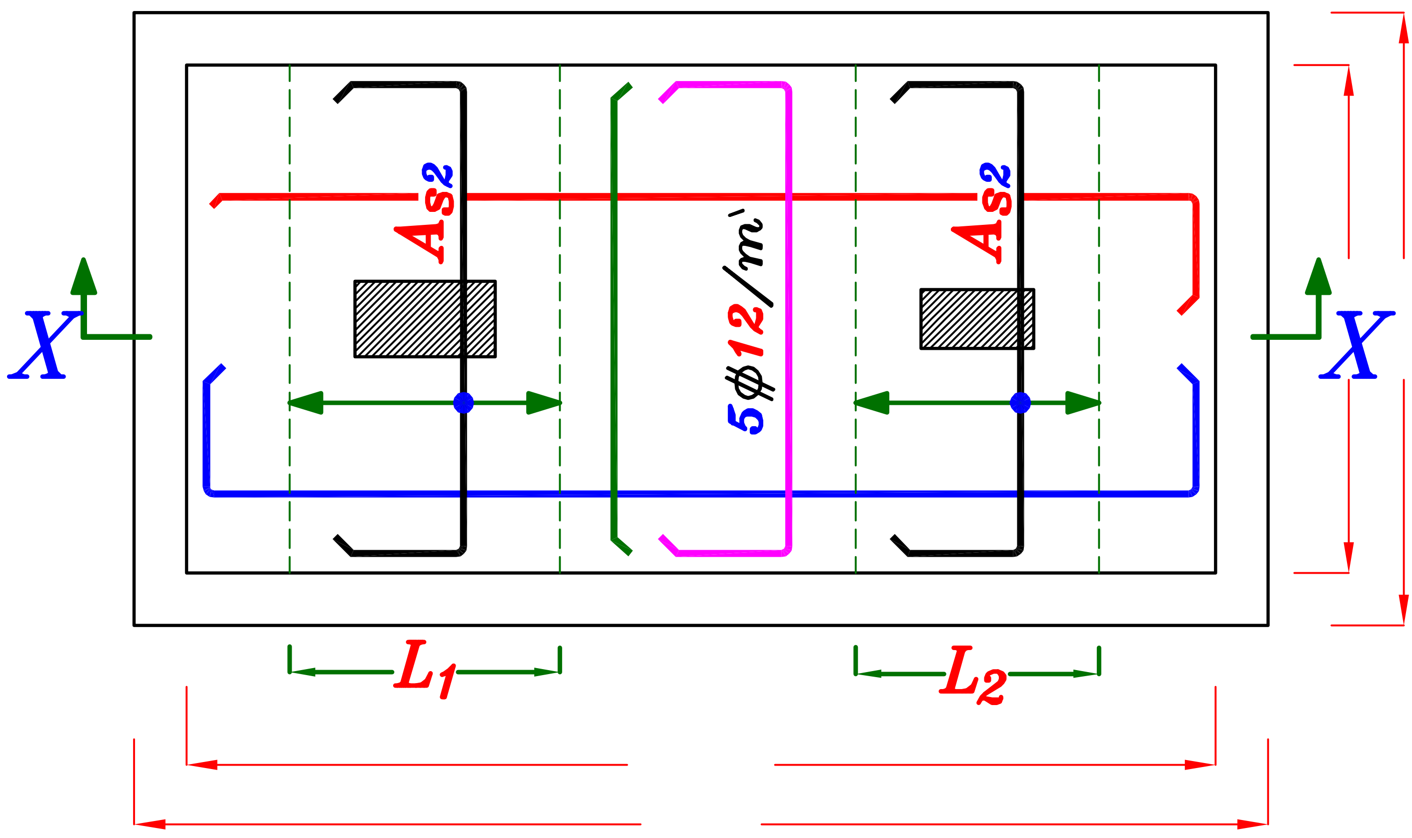
6 – *Details of Reinforcement.*



6 – Details of Reinforcement.



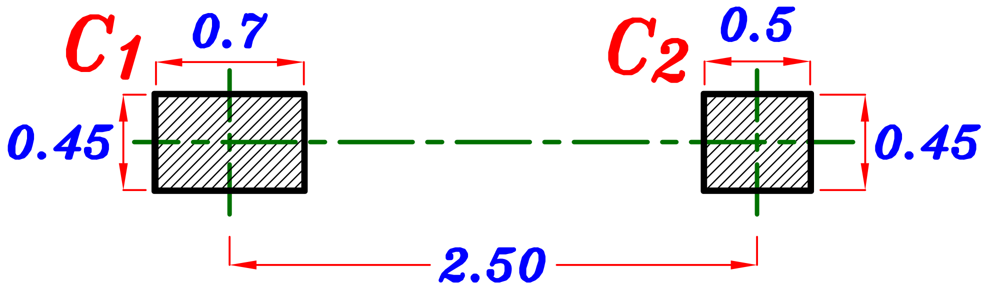
Sec X–X



Plan

Example.

It is required to design Footings to support a R.C. column C_1 $(45 * 70)$ cm. and carrying working load 2400 kN and column C_2 $(45 * 50)$ cm. and carrying working load 1800 kN the spacing between the C.L. of the two columns is 2.50 m as shown



and the allowable net bearing capacity in the Footing site is 150 kN/m^2. ($F_{cu} = 25$ N/mm^2, $F_y = 360$ N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given:

Column C_1 dimensions $(450 * 700)$ mm

P_1 (working) $= 2400$ kN $\qquad$ P_1 (U.L.) $= 2400 * 1.5 = 3600$ kN

Column C_2 dimensions $(450 * 500)$ mm

P_2 (working) $= 1800$ kN $\qquad$ P_2 (U.L.) $= 1800 * 1.5 = 2700$ kN

$R_{(working)} = P_1 + P_2 = 4200$ kN

$R_{(U.L.)} = 1.5 * 4200 = 6300$ kN

Bearing capacity of the soil $= q_{all} = 150$ kN/m^2

$F_{cu} = 25$ N/mm^2 $\qquad$ $F_y = 360$ N/mm^2

Use Isolated Footing. First.

1 – Calculate the Footing area. (Width & Length of R.C. Footing.)

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

Column. C_1 $(450 * 700)$ mm P_1 (working) $= 2400$ kN

$$L_{P.C.} - B_{P.C.} = b - a = 0.70 - 0.45 = 0.25\ m$$

$$L_{P.C.} = B_{P.C.} + 0.25\ m \quad \text{------} (1)$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{2400\ (kN)}{150\ (kN/m^2)} = 16.0\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 16.0\ m^2 \quad \text{-----} (2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.25) = 16.0\ m^2$$

$$B_{P.C.} = 3.87\ m$$

$B_{P.C.} = 3.90\ m$	$L_{P.C.} = 4.15\ m$
$B_{R.C.} = 3.30\ m$	$L_{R.C.} = 3.55\ m$

Column. C_2 $(450 * 500)$ mm P_2 (working) $= 1800$ kN

$$L_{P.C.} - B_{P.C.} = b - a = 0.50 - 0.45 = 0.05\ m$$

$$L_{P.C.} = B_{P.C.} + 0.05\ m \quad \text{------} (1)$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1800\ (kN)}{150\ (kN/m^2)} = 12.0\ m^2$$

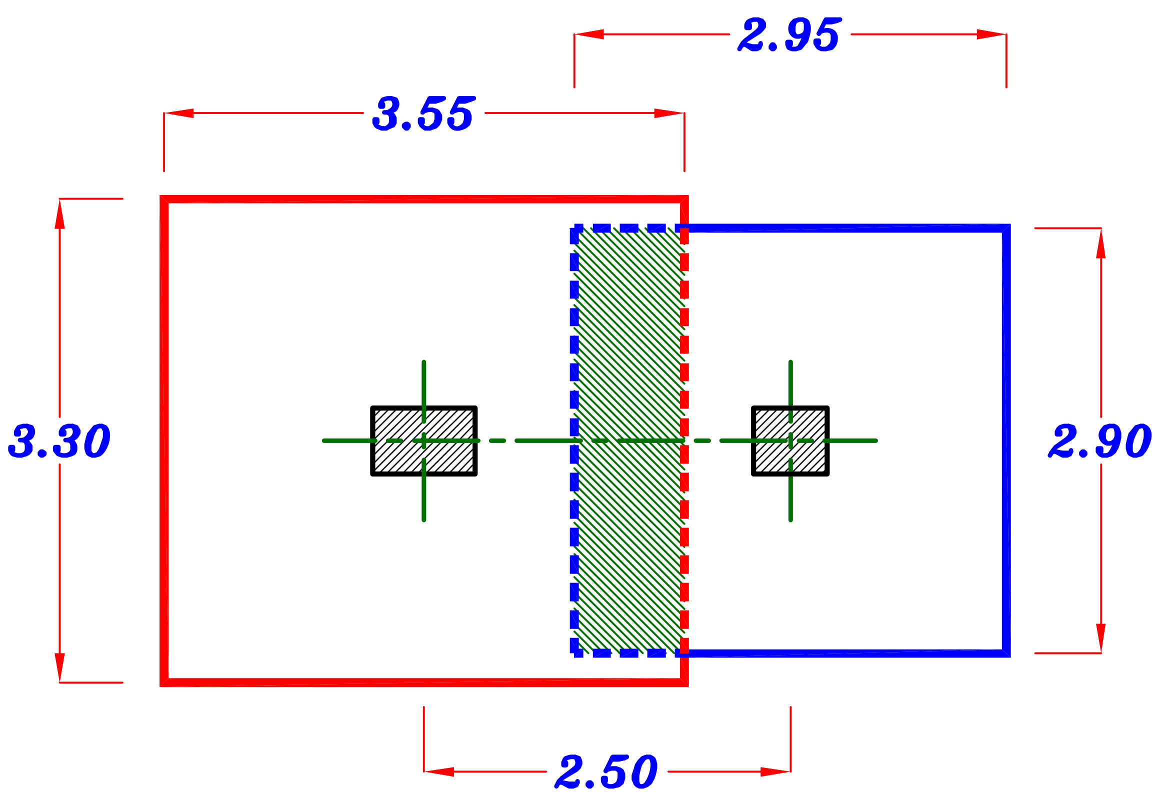
$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 12.0 \quad m^2 \quad \text{-----} (2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.05) = 12.0 \quad m^2$$

$$B_{P.C.} = 3.43 \, m$$

$$\boxed{B_{P.C.} = 3.50 \, m} \qquad \boxed{L_{P.C.} = 3.55 \, m}$$

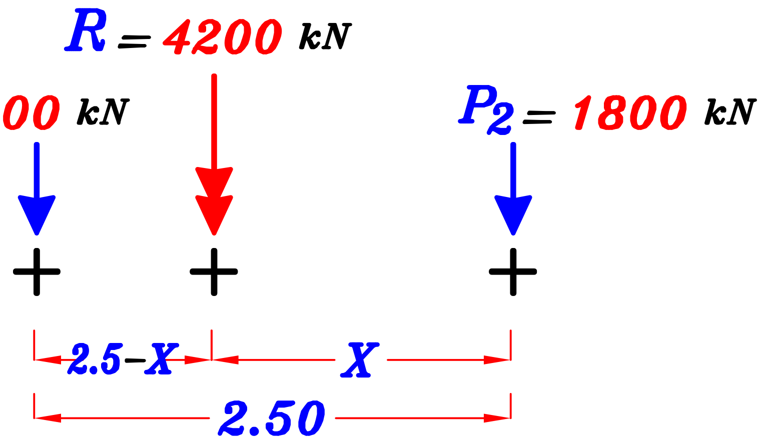
$$\boxed{B_{R.C.} = 2.90 \, m} \qquad \boxed{L_{R.C.} = 2.95 \, m}$$



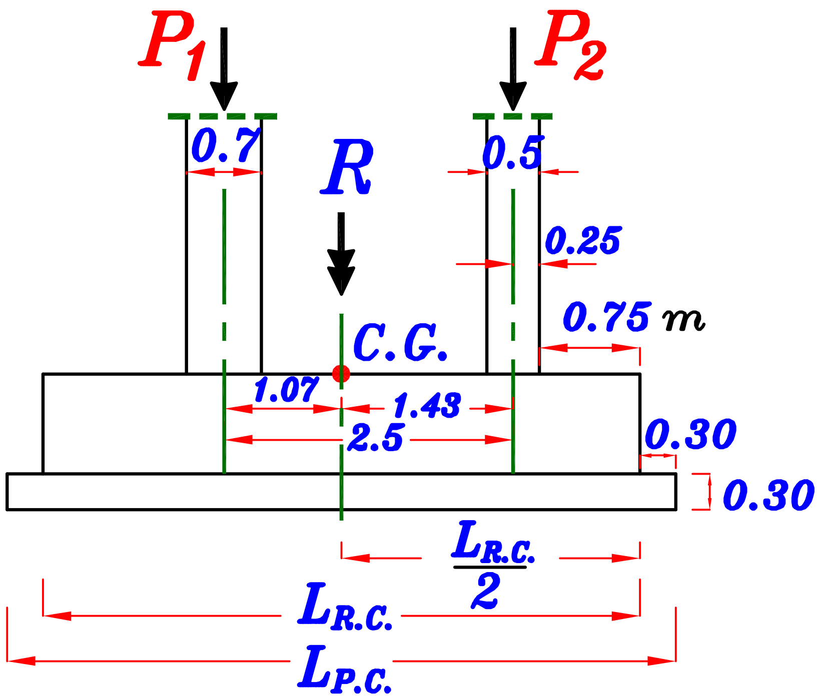
اذا استخدمنا قواعد منفصله سيحدث تداخل فى القواعد المسلحه
لذا سنحتاج لعمل قاعده واحده مشتركه . ***Combined Footing***

Use Combined Footing.

1– Calculate the Footing area. (Width & Length of R.C. Footing.)



$$X = \frac{P_1}{R} * S = \frac{2400}{4200} * 2.5 = 1.43 \; m$$



$$\frac{L_{R.C.}}{2} = (X) + \frac{a_2}{2} + (0.50 \rightarrow 1.0) \; m$$

$$\frac{L_{R.C.}}{2} = (1.43) + \frac{0.5}{2} + 0.75 \longrightarrow L_{R.C.} = 4.86$$

$$\boxed{L_{R.C.} = 4.90 \; m}$$

$$L_{P.C.} = L_{R.C.} + 2\,t_{P.C.} = 4.90 + 2(0.3) = 4.80 \; m$$

$$\boxed{L_{P.C.} = 5.50 \; m}$$

Calculate the width of the Footing. B

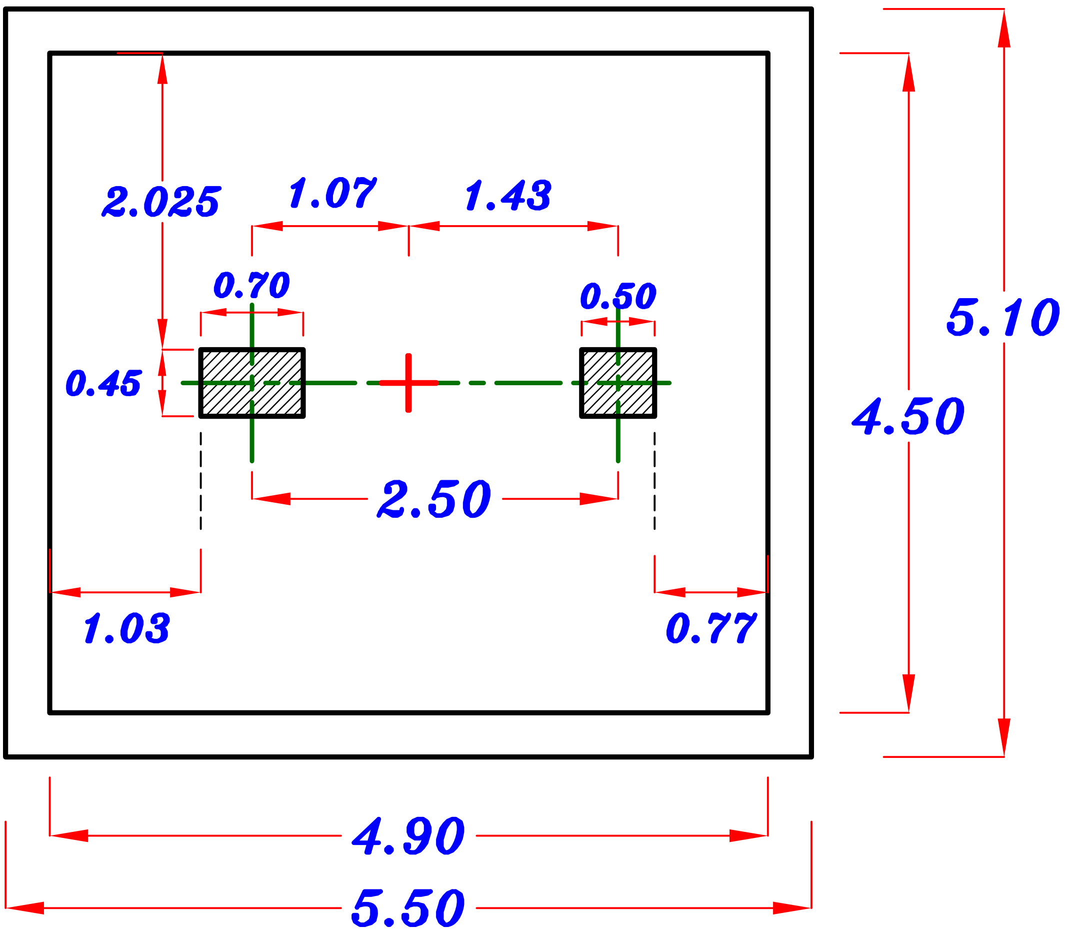
$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{4200}{150} = 28.0 \ m^2$$

$$A_{P.C.} = 28.0 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 5.50 \longrightarrow B_{P.C.} = 5.09 \ m$$

$$B_{P.C.} = 5.10 \ m$$

$$B_{P.C.} = 5.10 \ m \qquad L_{P.C.} = 5.50 \ m$$

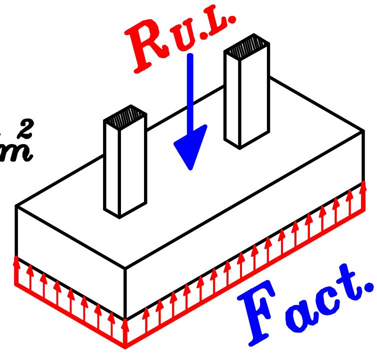
$$B_{R.C.} = 4.50 \ m \qquad L_{R.C.} = 4.90 \ m$$



2– Design the critical sections For moment. (Depth of R.C. Footing.)

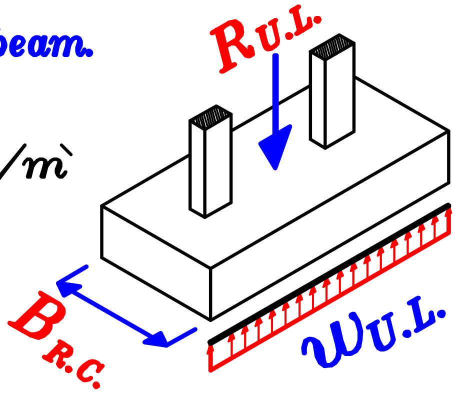
– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{6300}{4.5 * 4.9} = 285.7 \; kN/m^2$$



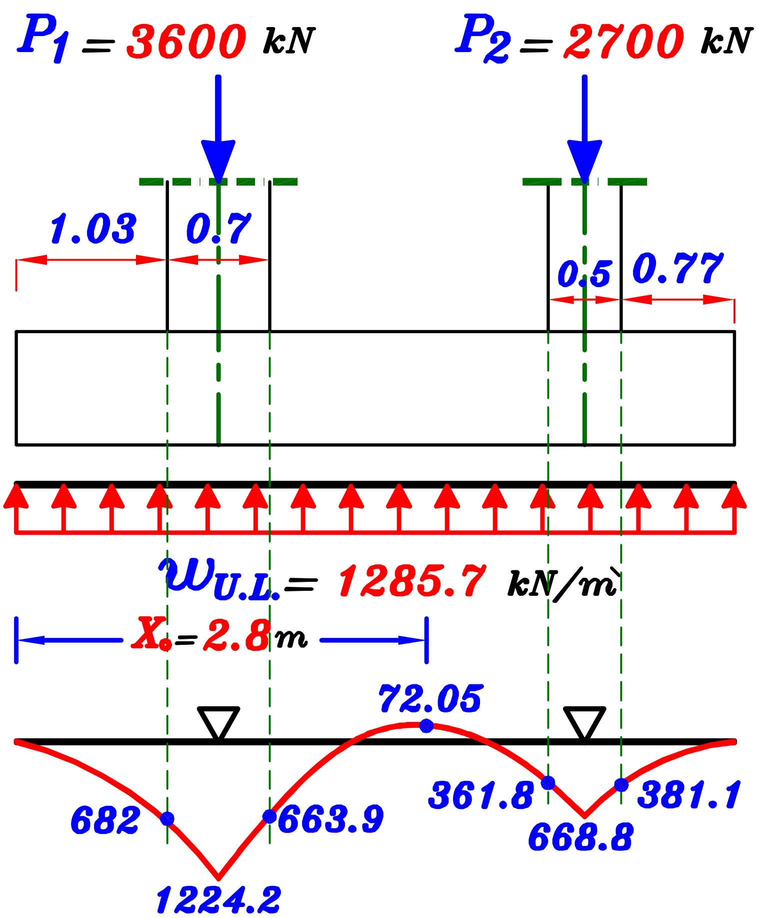
– Actual Uniform Load on R.C. Footing (U.L.) as a beam.

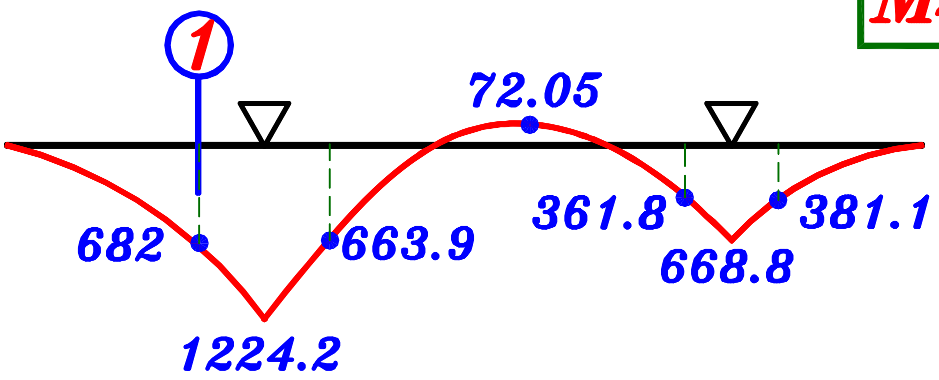
$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} = \frac{6300}{4.9} = 1285.7 \; kN/m'$$



Drawing U.L. B.M.D. on all R.C. Footing. Longitudinal direction.

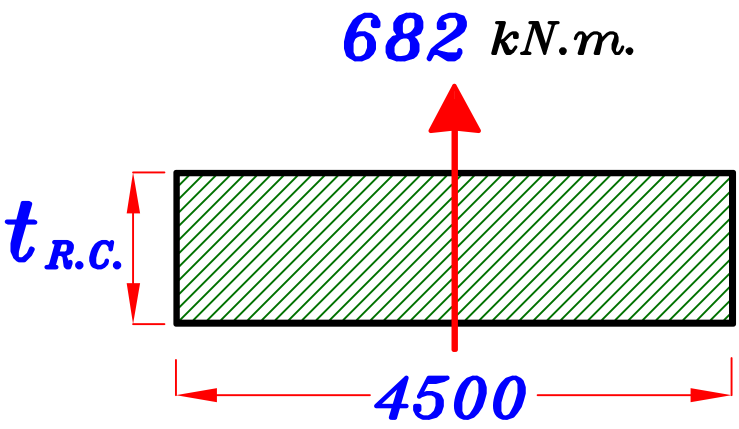
Point of Zero Shear $(X_o) = \frac{3600}{1285.7} = 2.80 \; m$

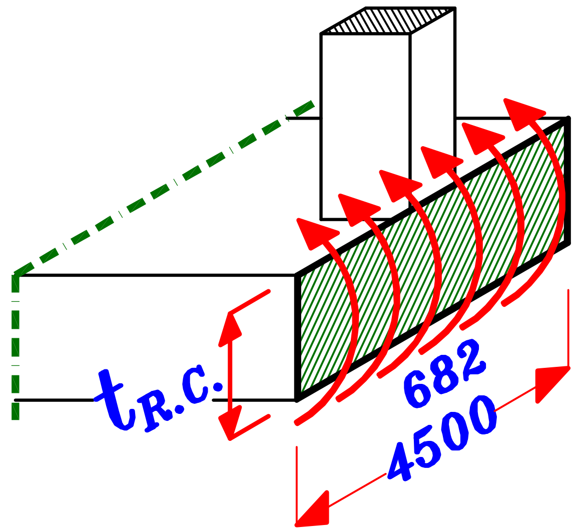




$M_{max.} = 682 \; kN.m$

عند وش العمود





$$\because \; d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \; d = 5.0 \sqrt{\frac{682 * 10^6}{25 * 4500}} = 389.3 \; mm$$

$$t_{R.C.} = d + 70 \; mm = 389.3 + 70 = 459.3 \; mm$$

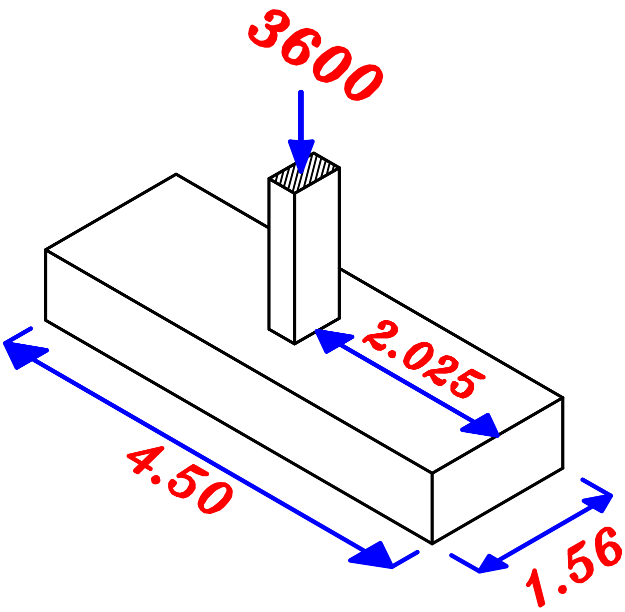
$t_{R.C.} = 500 \; mm$

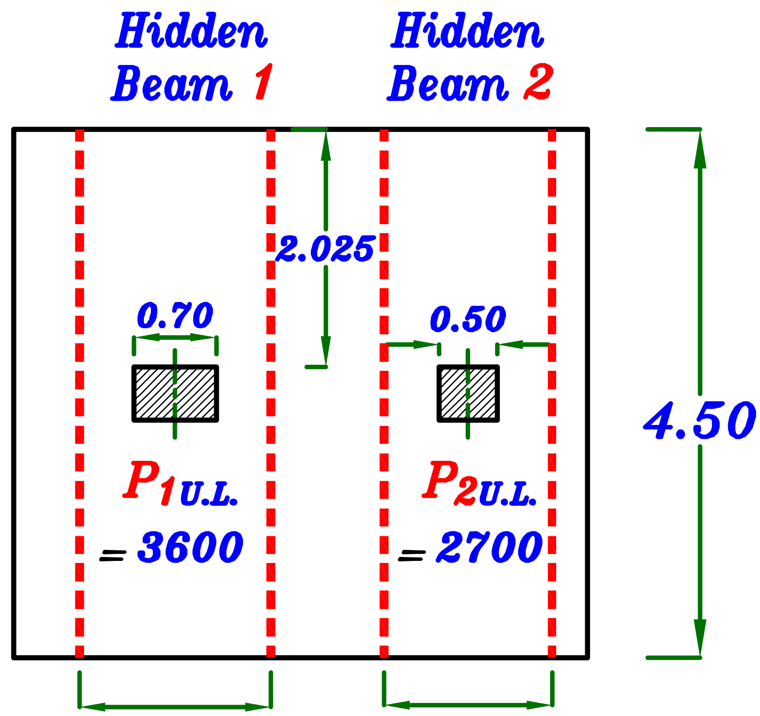
$d = 430 \; mm$

Check depth in Transverse direction.

As a Hidden Beam.

Hidden Beam 1





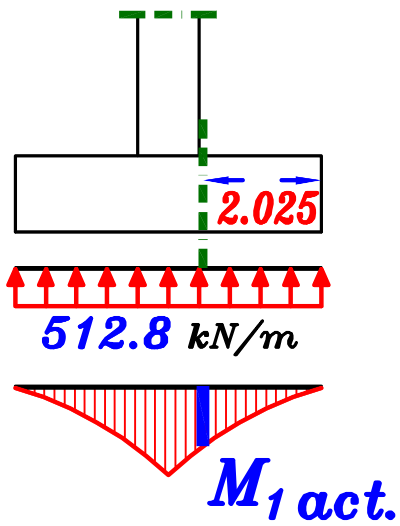
$$L_1 = b_1 + 2\,d = 0.7 + 2(0.43) = 1.56\ m$$

$$L_2 = b_2 + 2\,d = 0.5 + 2(0.43) = 1.36\ m$$

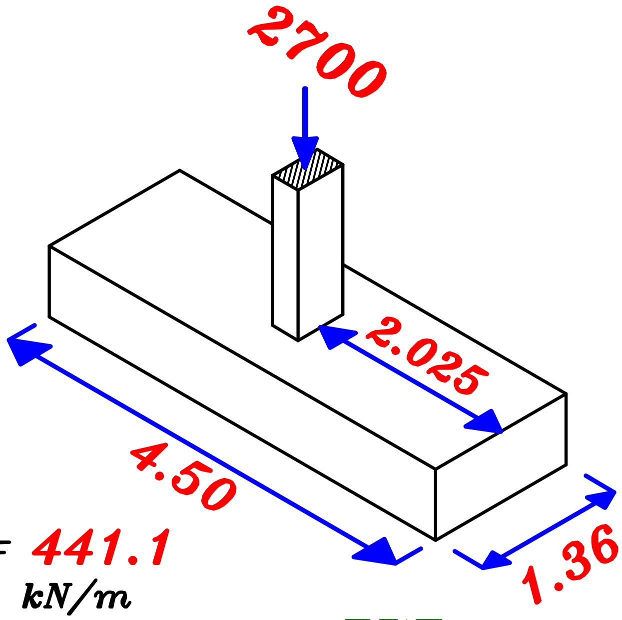
$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} = \frac{3600}{4.5 * 1.56} = 512.8\ kN/m$$

$$M_{1act.} = (512.8 * 2.025 * 1.0m)\ \frac{2.025}{2}$$

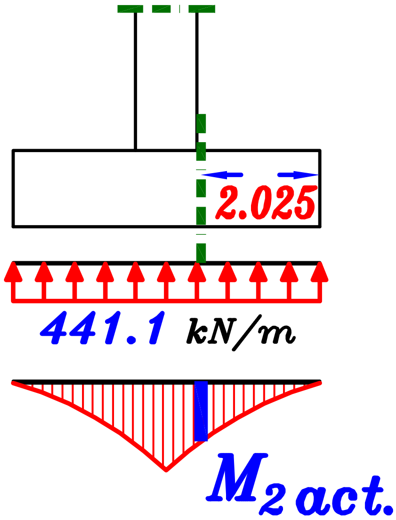
$$M_{1act.} = 1051.4\ kN.m/m$$



Hidden Beam 2



$$F_{2act.} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} = \frac{2700}{4.5 * 1.36} = 441.1 \ kN/m$$



$$M_{2act.} = (441.1 * 2.025 * 1.0m) \frac{2.025}{2}$$

$$\boxed{M_{2act.} = 904.4 \ kN.m/m}$$

M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$\boxed{M_{bigger} = 1051.4 \ kN.m/m}$$

$$430 = C_1 \sqrt{\frac{1051.4 * 10^6}{25 * 1000}} \longrightarrow C_1 = 2.09 < 3.0$$

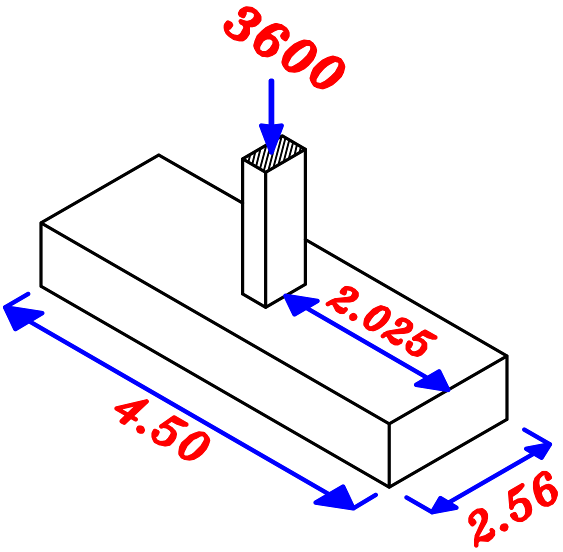
$\therefore$ **We have to increase the depth**

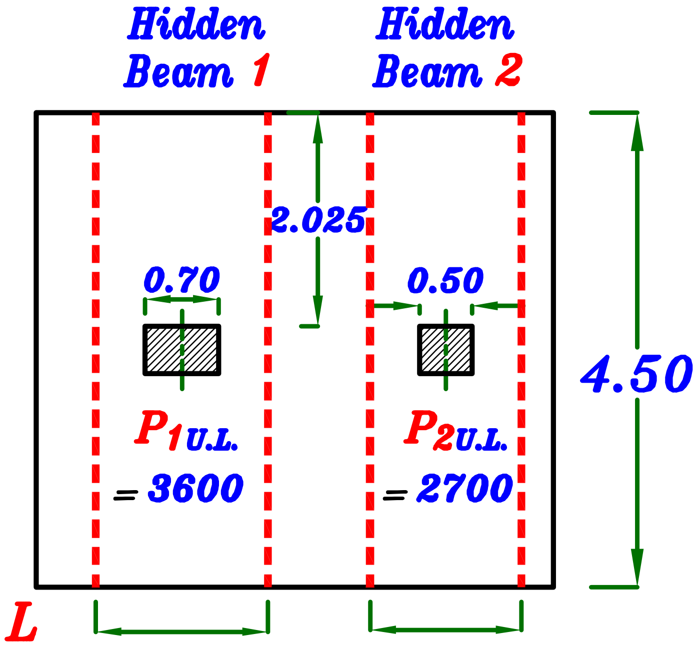
$$\therefore d = 4.5 \sqrt{\frac{1051.4 * 10^6}{25 * 1000}} = 922.8 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 922.8 + 70 = 992.8 \ mm$$

$$\boxed{t_{R.C.} = 1000 \ mm} \qquad \boxed{d = 930 \ mm}$$

Hidden Beam 1





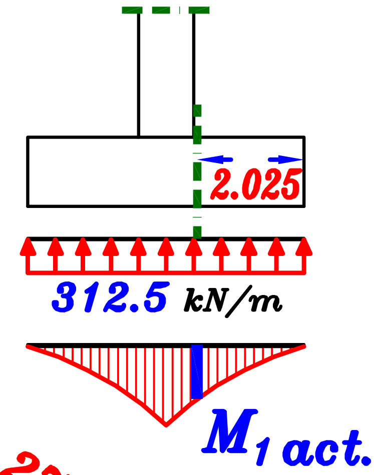
$L_1 = b_1 + 2\,d$
$= 0.7 + 2(0.93)$
$= 2.56\ m$

$L_2 = b_2 + 2\,d$
$= 0.5 + 2(0.93)$
$= 2.36\ m$

$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1}$$

$$= \frac{3600}{4.5 * 2.56} = 312.5 \ \ kN/m$$

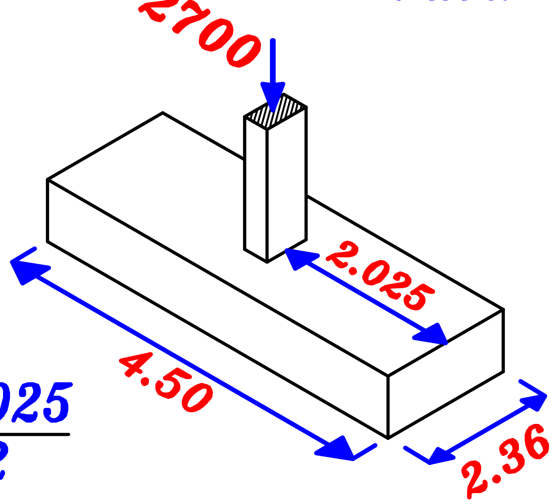
$$M_{1act.} = (312.5 * 2.025 * 1.0m)\ \frac{2.025}{2}$$



$$M_{1act.} = 640.7 \ \ kN.m/m$$

Hidden Beam 2

$$F_{2act.} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} = \frac{2700}{4.5 * 2.36} = 254.2 \ \ kN/m$$

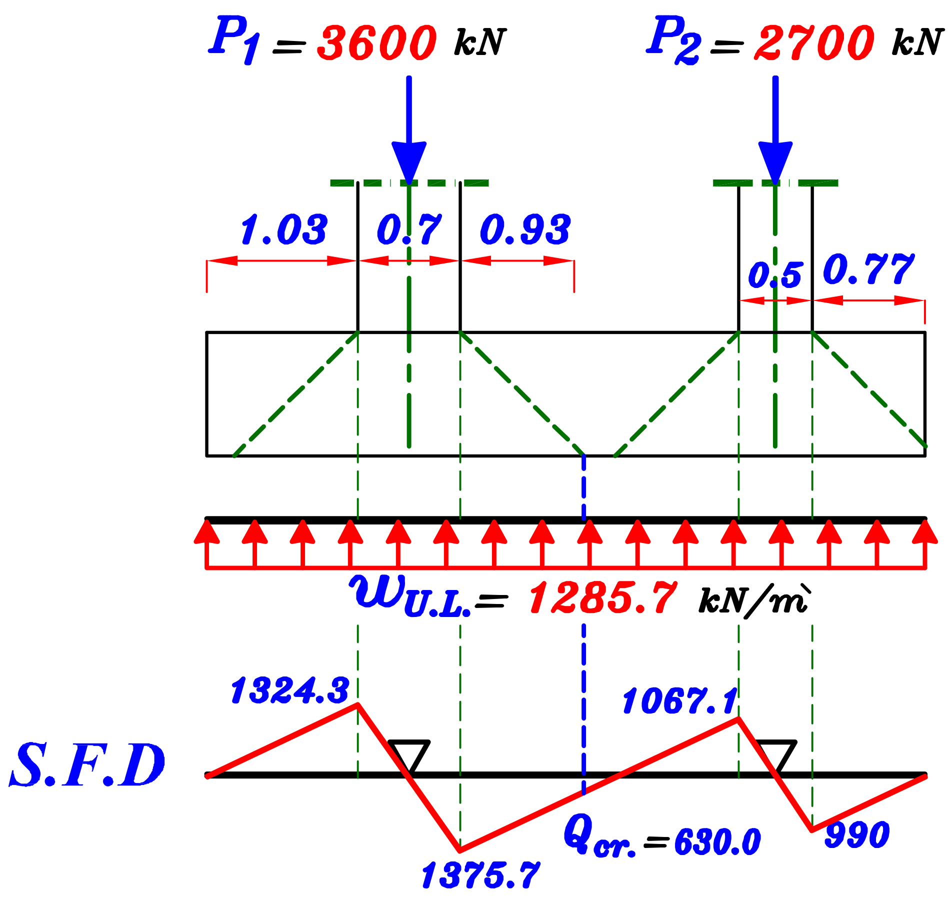


$$M_{2act.} = (254.2 * 2.025 * 1.0m)\ \frac{2.025}{2}$$

$$M_{2act.} = 521.2 \ \ kN.m/m$$

3 – Check Shear. at long direction

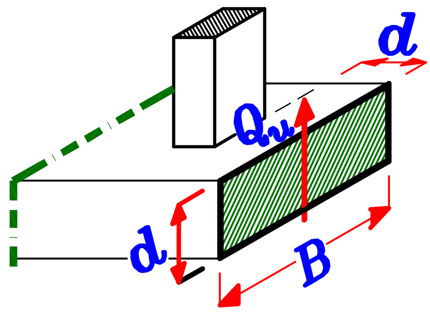
Critical section For Shear.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * d = 1375.7 - 1285.7 * 0.93 = 180 \text{ kN}$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}}{B * d} = \frac{180.0 * 10^3}{4500 * 930} = 0.043 \text{ kN/m}^2$$

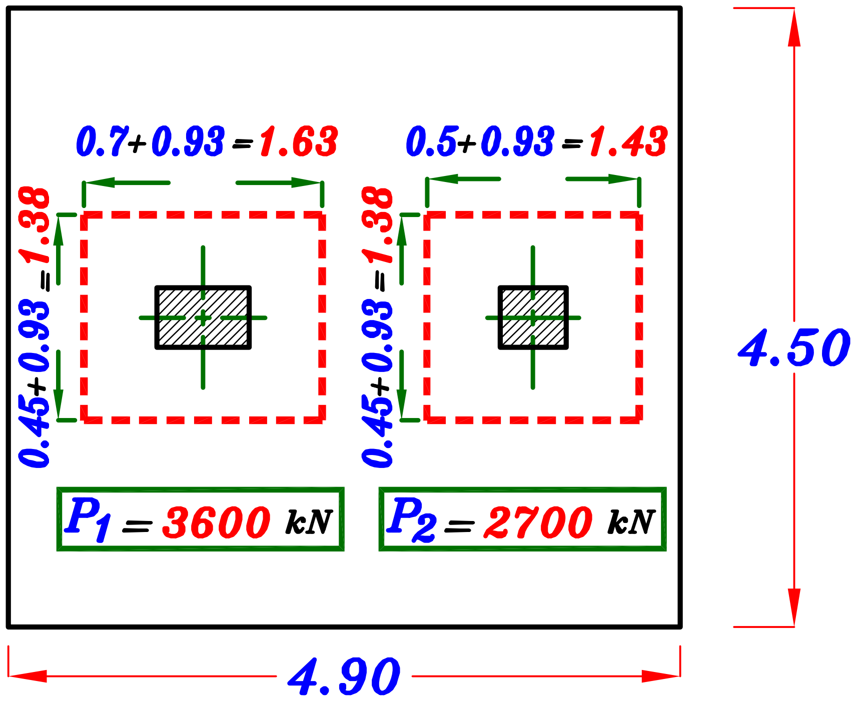


* Allowable shear stress. (q_{su})

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

$q_u < q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

4 – Check Punching Shear. القص الثاقب .

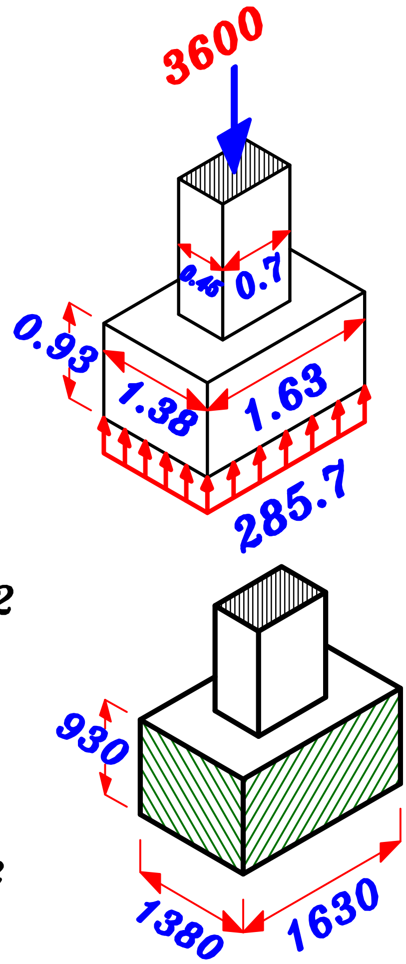


Column 1

* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = 3600 - 285.7 \; (1.38 * 1.63)$$

$$= 2957.3 \; kN$$



$$A_{1p} = [2(1380) + 2(1630)] * 930$$

$$= 5598600 \; mm^2$$

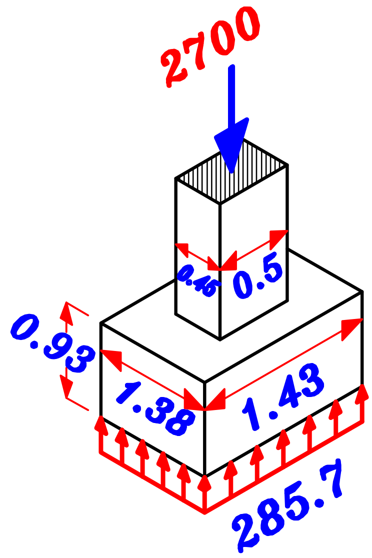
* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{2957.3 * 10^3}{5598600} = 0.528 \; N/mm^2$$

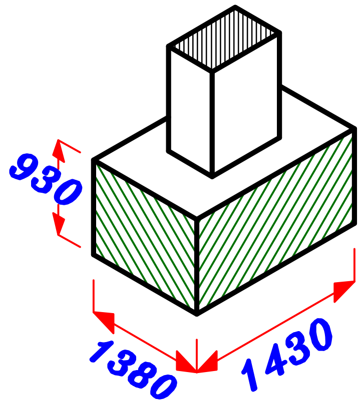
Column 2

* Calculate Punching Force. (Q_{2p})

$$Q_{2p} = 2700 - 285.7\ (1.38 * 1.43)$$
$$= 2136.2\ kN$$



$$A_{2p} = [2(1380) + 2(1430)] * 930$$
$$= 5226600\ mm^2$$



* Calculate Actual Punching shear stress. q_{1pu}

$$q_{2pu} = \frac{2136.2 * 10^3}{5226600} = 0.408\ N/mm^2$$

q_{pumax} the bigger q_{1pu} & $q_{2pu} = 0.528\ N/mm^2$

* Calculate allowable Punching shear stress. q_{pcu}

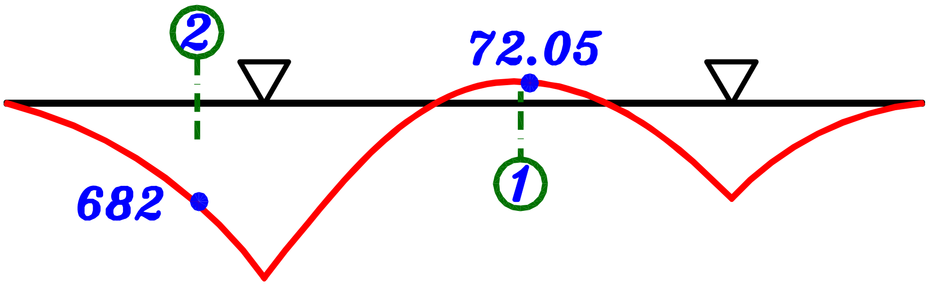
$$q_{pcu} = 0.316\ (0.5 + \frac{a}{b}) \sqrt{\frac{F_{cu}}{\gamma_c}} =$$

$$q_{pcu} = 0.316\ (0.5 + \frac{0.45}{0.70}) \sqrt{\frac{25}{1.5}} = 1.47\ N/mm^2$$

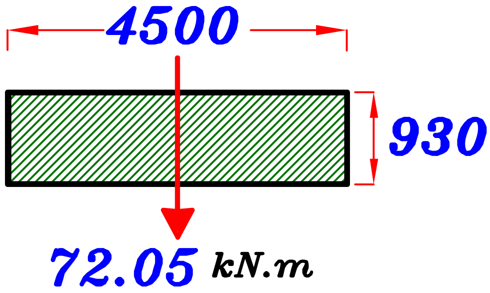
$q_{pu} \leq q_{pcu}$ ⟶ Safe punching shear.
No need to increase dimensions.

5 – Reinforcement of the Footing.

Longitudinal direction.



Sec. ①



$$930 = C_1 \sqrt{\frac{72.05 * 10^6}{25 \; * 4500}}$$

$$\longrightarrow C_1 = 36.7 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \; F_y \; d} = \frac{72.05 * 10^6}{0.826 * 360 * 930} = 260.53 \; mm^2$$

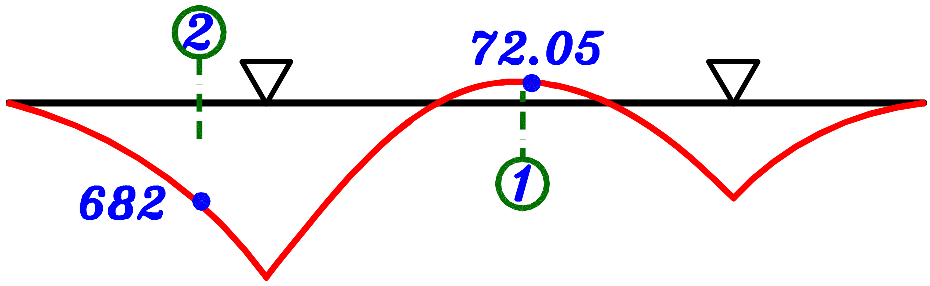
$$A_s \; (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{260.53}{4.50} = 57.9 \; mm^2/m'$$

Check $A_{s_{min}}$

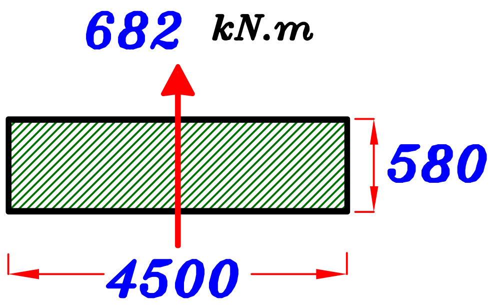
$$A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{cases} \quad 1395 \; mm^2$$

$$\therefore \; A_s < A_{s_{min}} \longrightarrow \text{Take} \; A_s = 1395 \; mm^2$$

$$\boxed{7 \phi 16/m'}$$



Sec. 2



$$930 = C_1 \sqrt{\frac{682 * 10^6}{25 * 4500}}$$

$$\longrightarrow C_1 = 11.9 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\, F_y\, d} = \frac{682 * 10^6}{0.826 * 360 * 930} = 2466.1 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{2466.1}{4.50} = 548.0 \ mm^2/m'$$

Check $A_{s_{min}}$

$$A_{s_{min}} = \begin{cases} 1.5\, d = 1.5 * 930 = 1395 \\ 5 \phi 12 / m' = 565 \end{cases} \quad 1395 \ mm^2$$

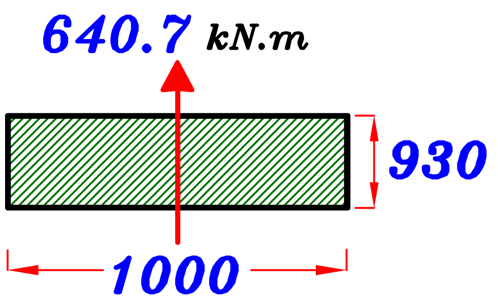
$$\therefore A_s < A_{s_{min}} \longrightarrow \text{Take } A_s = 1395 \ mm^2$$

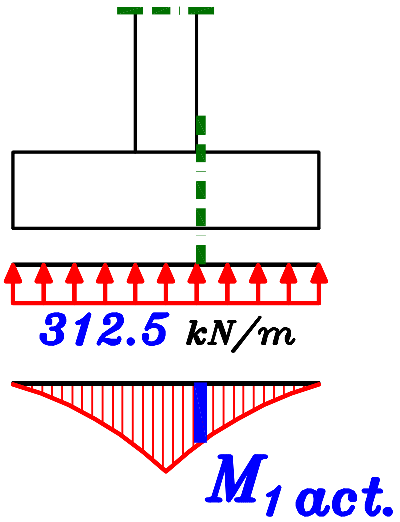
$$\boxed{7 \phi 16 / m'}$$

Transverse direction. Short direction.

Hidden Beam 1

$$M_{1act.} = 640.7 \ kN.m/m$$





$$930 = C_1 \sqrt{\frac{640.7 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 5.81 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \ F_y \ d} = \frac{640.7 * 10^6}{0.826 * 360 * 930} = 2316.8 \ mm^2/m`$$

Check $A_{s_{min}}$

$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m` = 565 \end{array} \right\} 1395 \ mm^2$$

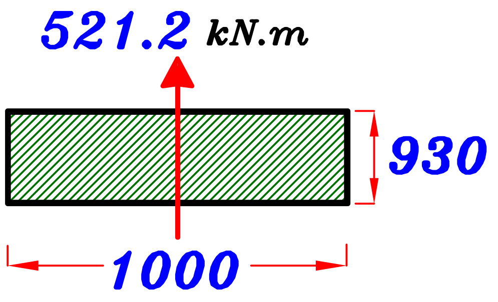
$$\therefore \ A_s > A_{s_{min}} \longrightarrow o.k.$$

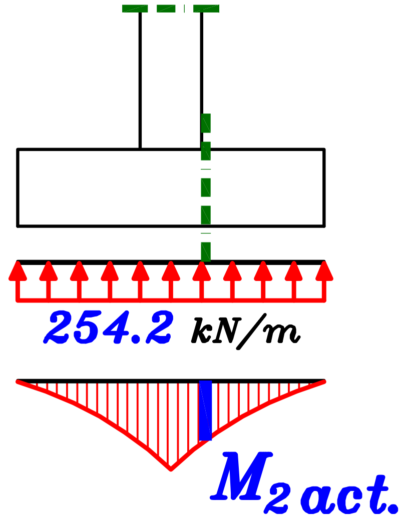
$$A_s = 2316.8 \ mm^2$$

$$7 \phi 22/m`$$

Hidden Beam 2

$$M_{2act.} = 521.2 \ kN.m/m$$





$$930 = C_1 \sqrt{\frac{521.2 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 6.44 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \ F_y \ d} = \frac{521.2 * 10^6}{0.826 * 360 * 930} = 1884.7 \ mm^2/m'$$

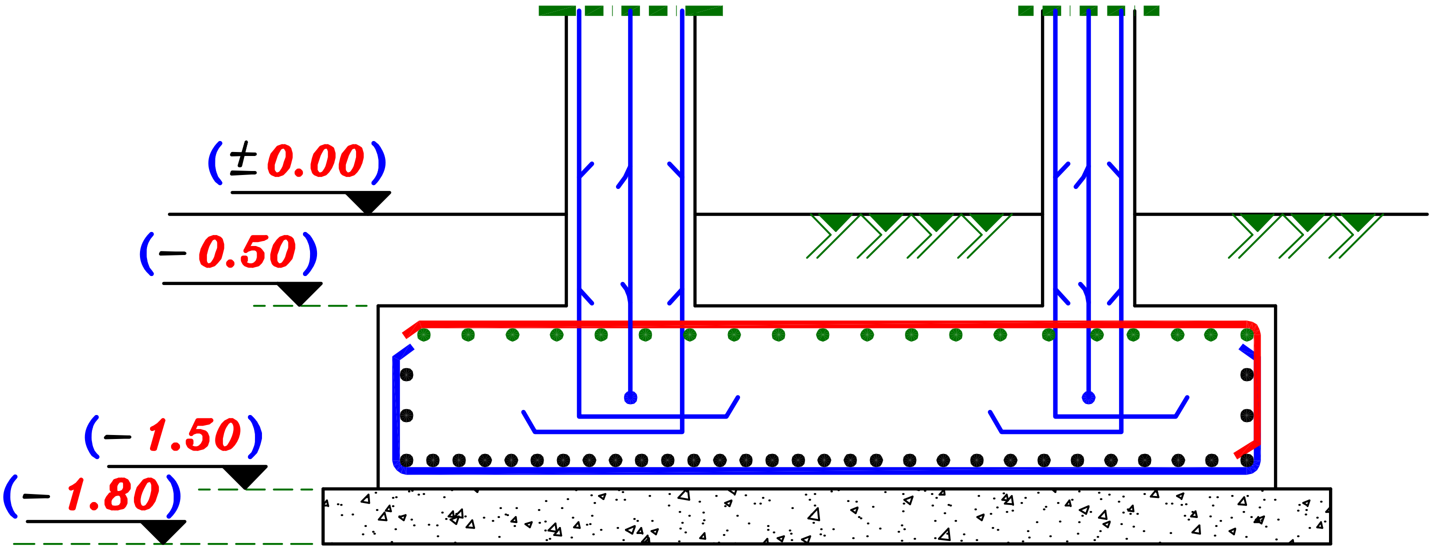
Check $A_{s_{min}}$

$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5 \, d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1395 \ mm^2$$

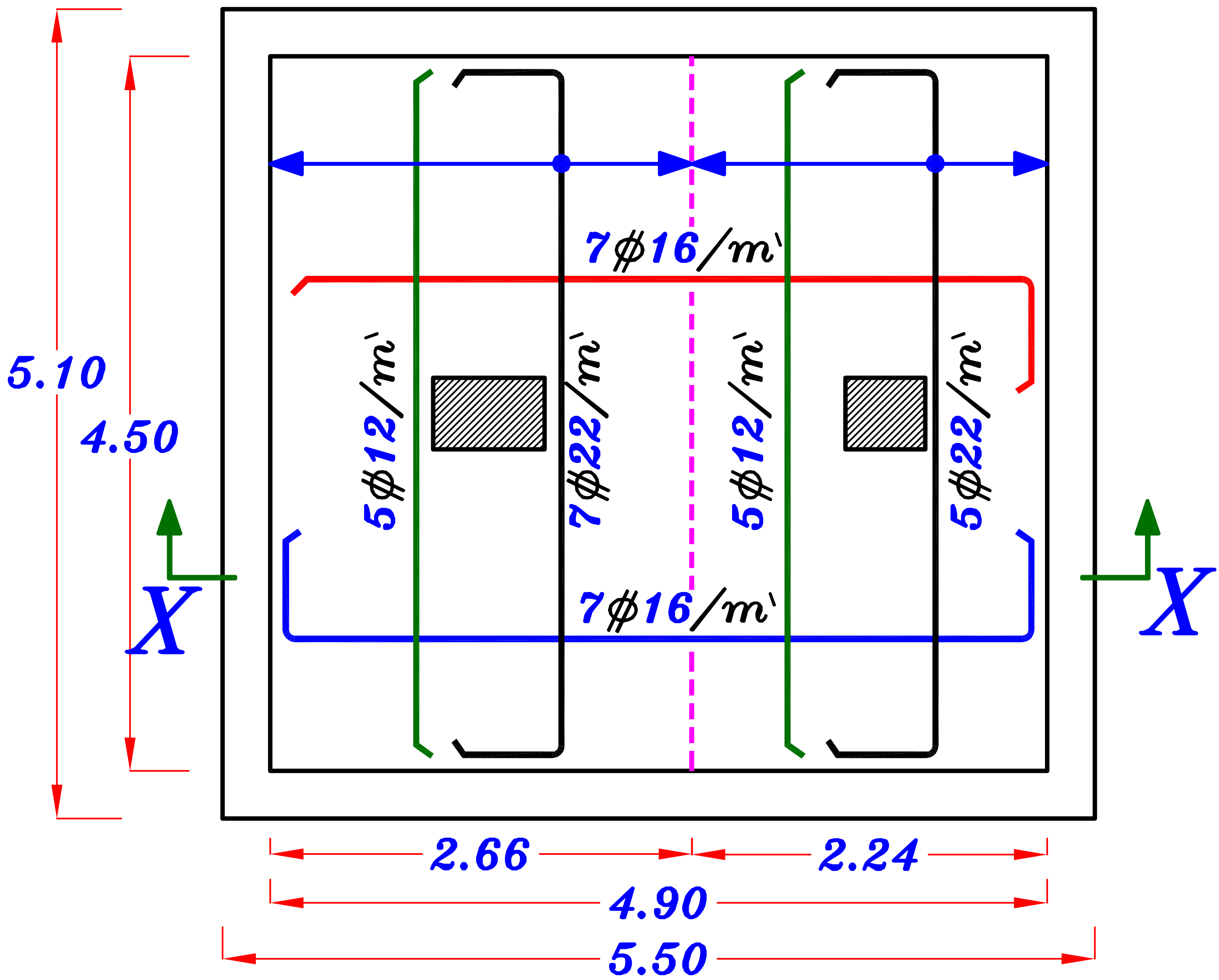
$$\therefore A_s > A_{s_{min}} \longrightarrow o.k.$$

$$A_s = 1884.7 \ mm^2 \qquad \boxed{5 \phi 22/m'}$$

6 – Details of Reinforcement.



Sec X–X

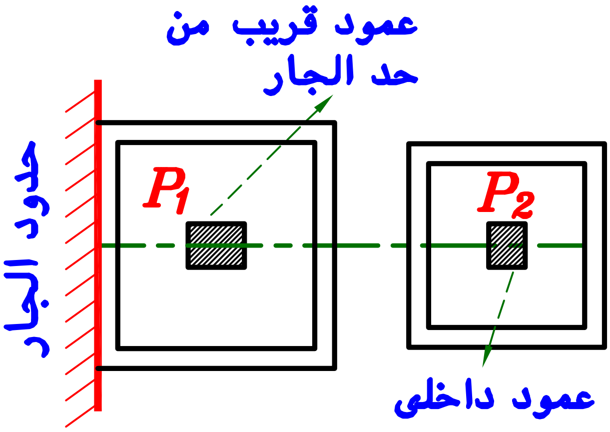


6 Design of Footings For column near an existing (property line)

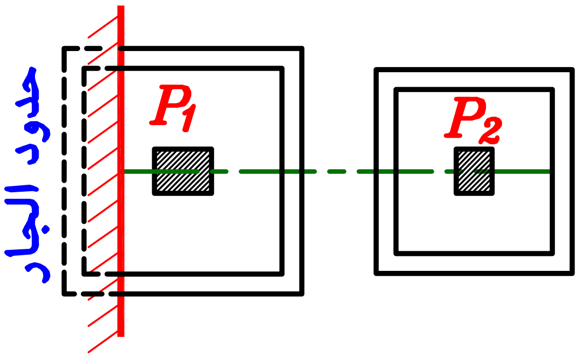
تصميم القواعد بجوار حد الجار .

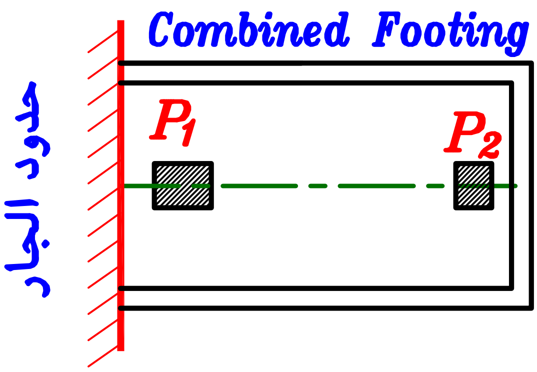
يتم عمل قواعد لاعمده حد الجار فى احدى الحالتان التاليتان :-

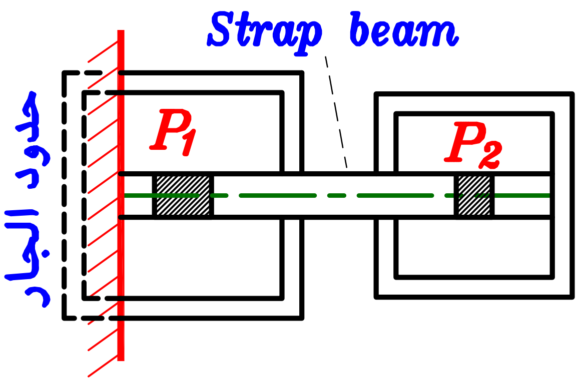
١- عند وجود عمود قريب من حد الجار نحاول أولا أن نعمل قاعده منفصله بأبعاد خاصه بحيث لا تدخل القاعده العاديه فى حدود الجار .



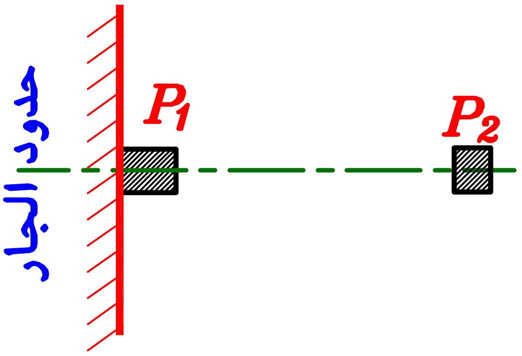
و لكن اذا زادت أبعاد القاعده و تعدت حدود الجار فيتم ربط عمود الجار بعمود داخلى مجاور اما عن طريق قاعده مشتركه
Combined Footing
أو كمره كبيره للتحزيم
Strap beam



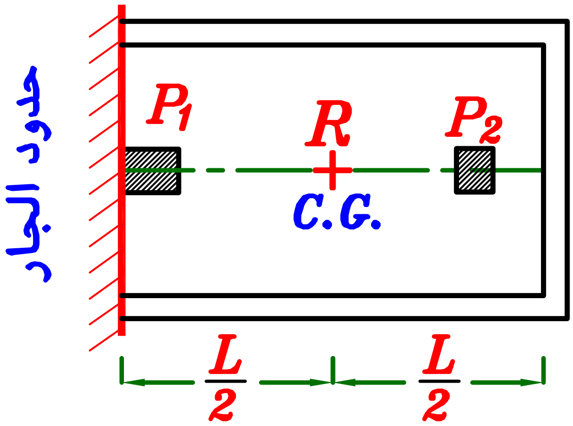




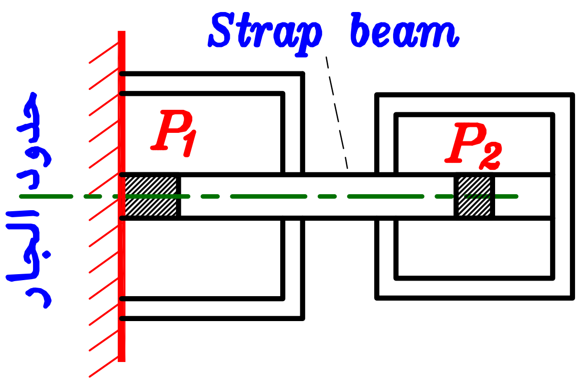
٢- عند وجود عمود عند حد الجار مباشره
يتم ربط عمود الجار بعمود داخلى
مجاور له



اما عن طريق قاعده مشتركه
Combined Footing
بحيث يكون مكان محصله الاحمال
هو نفس مكان *C.G.* القاعده



أو كمره كبيره للتحزيم
Strap beam



و يتوقف اختيار نوع القاعده التى سوف تربط عمود حد الجار بالعمود الداخلى على :

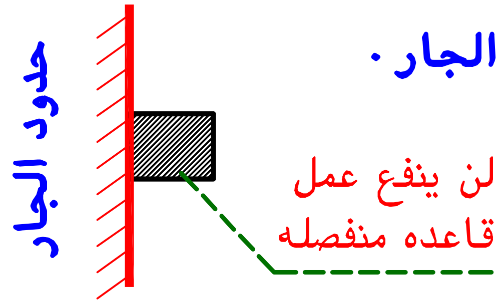
١ـ المسافه بين عمود حد الجار و العمود الداخلى المجاور . C_1 , C_2

٢ـ قيمه الاحمال الواقعه على العمودين . P_1 , P_2

٣ـ أكبر اجهاد تتحمله التربه *Bearing capacity of soil*

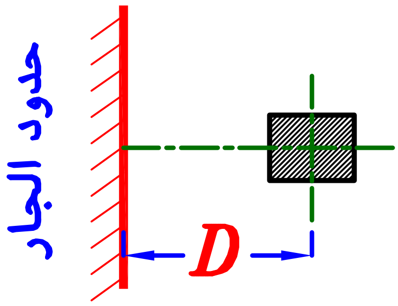
الحالات التى يمكن استخدام قاعده منفصله لعمود عند حد الجار .

١ـ يجب أن لا يكون العمود ملاصق تماما لحد الجار .



٢ـ يجب أن لا تقل المسافه من (*C.L.*) العمود

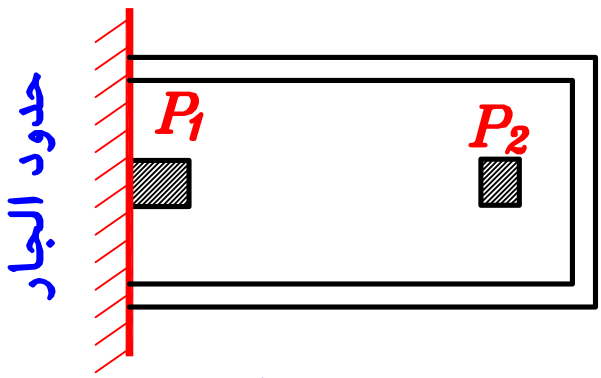
الى حد الجار مسافه (*D*)



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

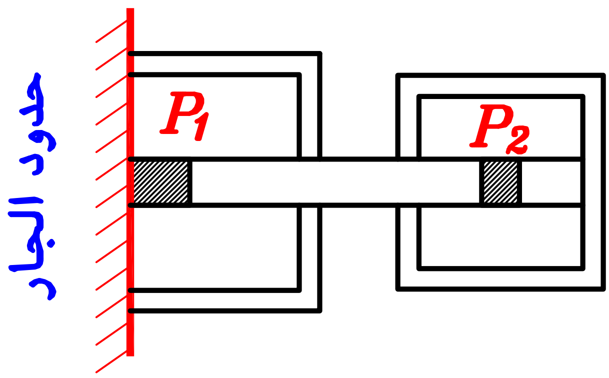
اذا لم تتحقق هذه الشروط لن نستطيع عمل قاعده منفصله

و نضطر لربط هذا العمود بالعمود الداخلى المجاور له



قاعده مشتركه

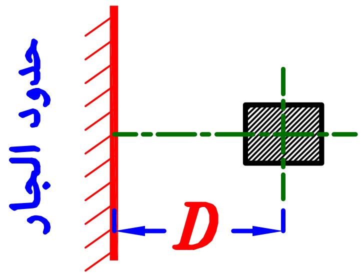
Combined Footing



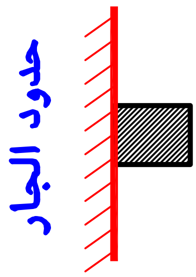
Strap beam

1 - Strap Beam. كمره تحزيم

اذا لم ينفع حل القواعد المنفصله لوجود احدى الاسباب التاليه .



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



العمود ملاصق تماما لحد الجار .

يتم التفكير فى استخدام **Strap Beam**

و لتحديد اذا كانت الـ **Strap Beam** تنفع أم لا

فيتم حساب أبعاد القواعد المنفصله F_1 , F_2

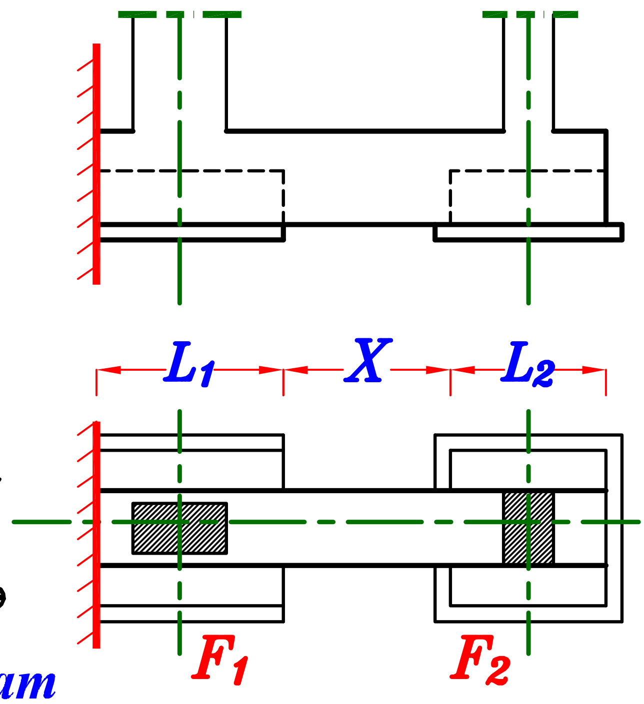
اذا حدث تداخل فى القواعد لن تنفع

الـ **Strap Beam** و نعمل **Combined Footing**

اذا كانت المسافه بين القواعد المسلحه X

أصغر من $\frac{L_2}{2}$ and $\frac{L_1}{2}$ لن تنفع **Strap Beam**

و نعمل **Combined Footing**

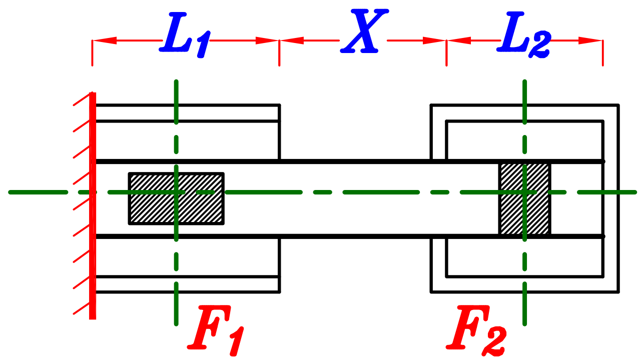


IF $X \geqslant \frac{L_1}{2}$ or $\frac{L_2}{2}$ $\longrightarrow$ *use strap beam*

أيهما أصغر

2 - Combined Footing. قاعده مشتركه

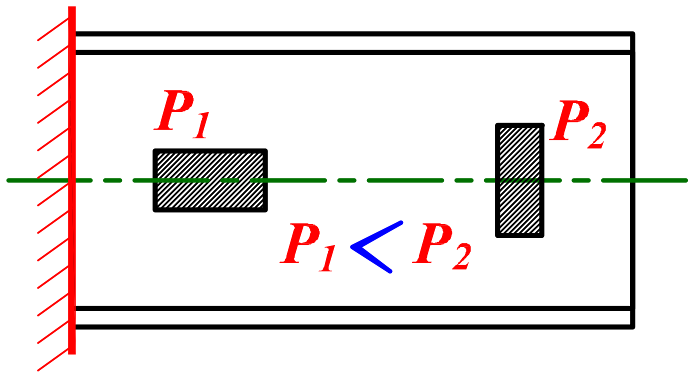
اذا لم ينفع حل ال **Strap Beam**



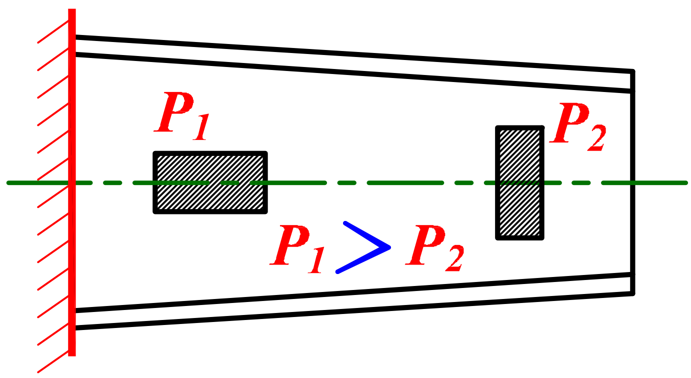
عندما تكون $IF\ X < \frac{L_1}{2}\ \&\ \frac{L_2}{2}$

يتم عمل قاعده مشتركه و يكون شكلها كالاتى :

1- IF $P_1 < P_2$ use **Rectangular** combined Footing.

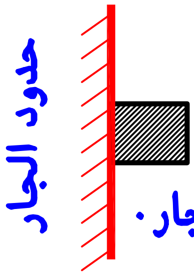


2- IF $P_1 > P_2$ use **Trapezoidal** combined Footing.

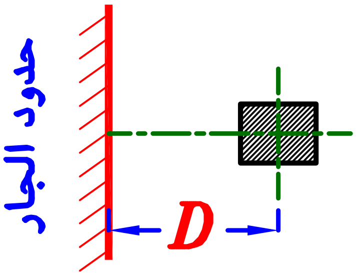


Design of Strap Beam.

اذا لم ينفع حل القواعد المنفصله للاسباب السابقه .



العمود ملاصق تماما لحد الجار.



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

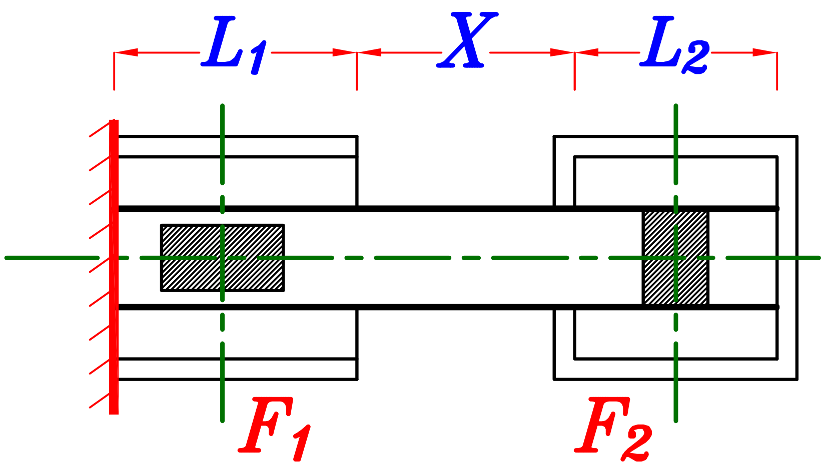
يتم التفكير أولا فى استخدام Strap Beam

و لتحديد اذا كانت الـ Strap Beam تنفع أم لا فيتم حساب أبعاد القواعد المنفصله F_1 , F_2

اذا حدث تداخل فى القواعد لن تنفع الـ Strap Beam و نعمل Combined Footing

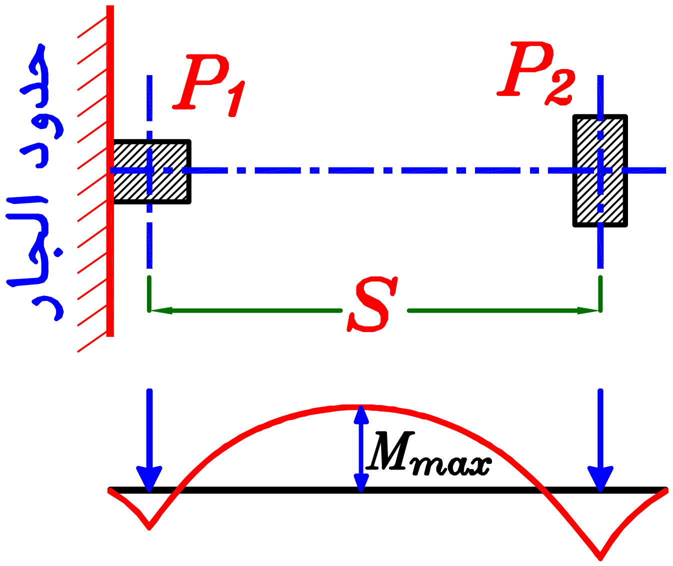
اذا كانت المسافه بين القواعد المسلحه X أصغر من $\frac{L_2}{2}$ and $\frac{L_1}{2}$

لن تنفع Strap Beam

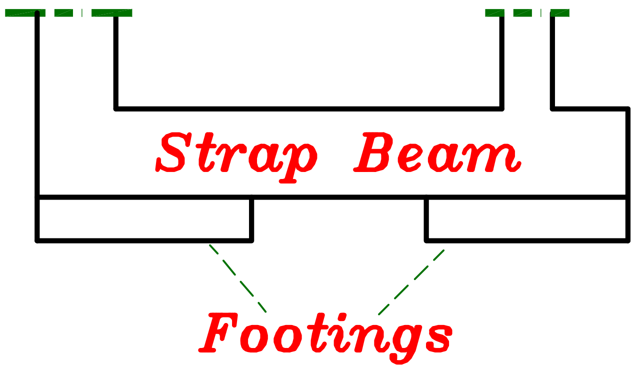


$$IF \; X \geqslant \frac{L_1}{2} \; or \; \frac{L_2}{2} \longrightarrow \text{use strap beam}$$

أيهما أصغر



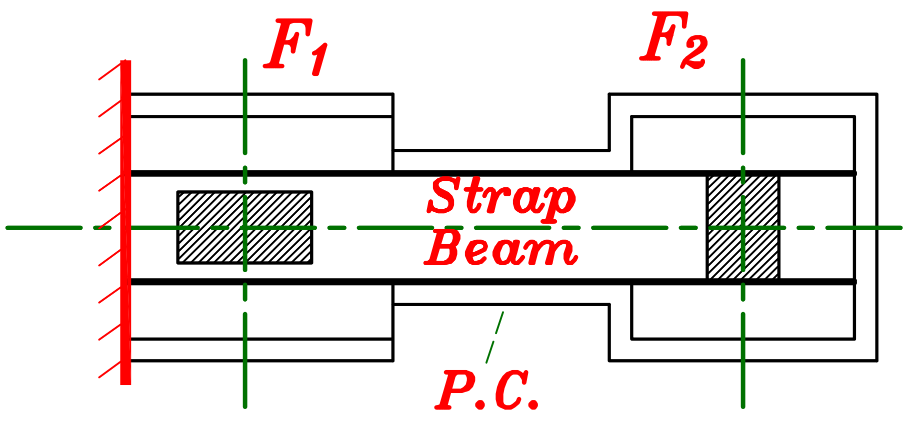
عندما تكون المسافه (S) بين العمود ناحيه الجار و العمود الداخلى كبيره و المفترض عمل قاعده مشتركه تربط بين العمودين معا فان طول هذه القاعده يكون كبير جدا و بالتالى يكون عليها عزم كبير جدا (M_{max}) .



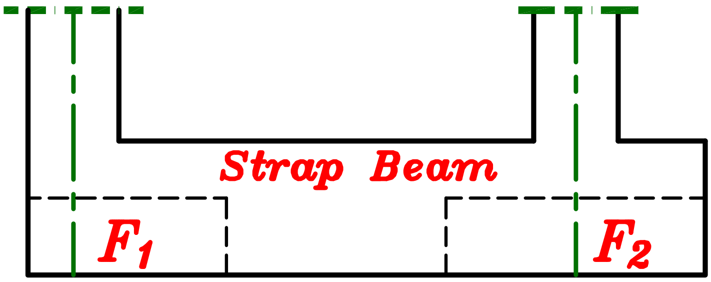
لذلك نلجاء لفكره الا *Strap Beam* و هى أن أحمال الاعمده تنزل أولا على كمره كبيره (ذات عرض و عمق كبيرين) ثم يتم عمل قاعدتين أسفل العمودين ليكونا بمثابه *supports* للكمره لنقل الا *reactions* الى التربه .

ترتيب نقل حمل العمود يكون كالاتى :

Columns → Strap Beam → 2 Footings → Soil

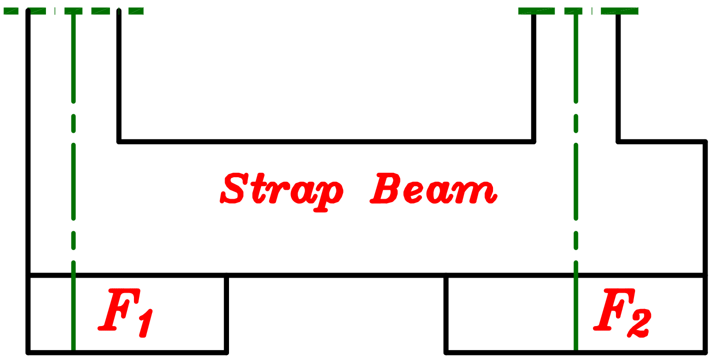


أشكال ال Strap Beam و القاعدتين.



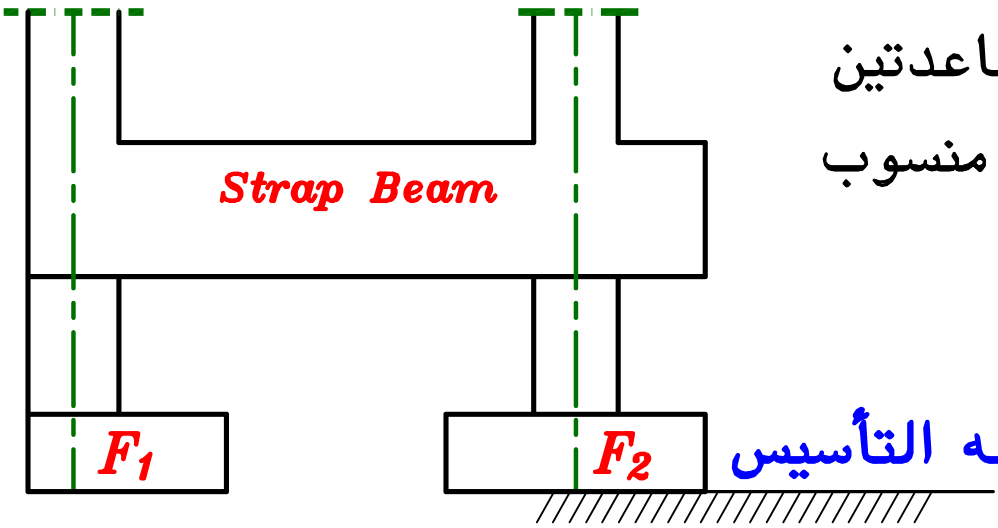
١- منسوب قاع القاعدتين
عند منسوب قاع الكمره

و هو الاكثر استخداما لانه أوفر فى عمق الحفر



٢- منسوب قاع القاعدتين
أسفل منسوب قاع الكمره

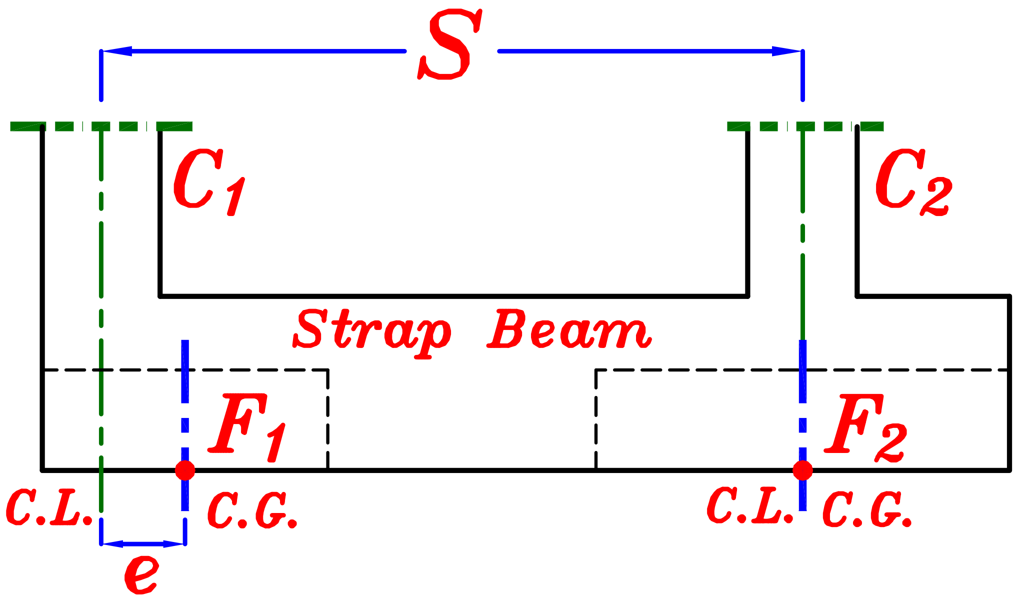
هذا الحل غير مفضل لانه يحتاج عمق حفر كبير .
و يتطلب معه أن يكون سُمك القاعدتين واحد .



٣- منسوب قاع القاعدتين
أسفل بكثير من منسوب
قاع الكمره .

هذا الحل نلجاء له عندما تكون طبقه التأسيس عميقه .

Important Notes. ملحوظه هامه .



١- مركز القاعده أسفل العمود الداخلى يكون أسفل محور العمود مباشره .

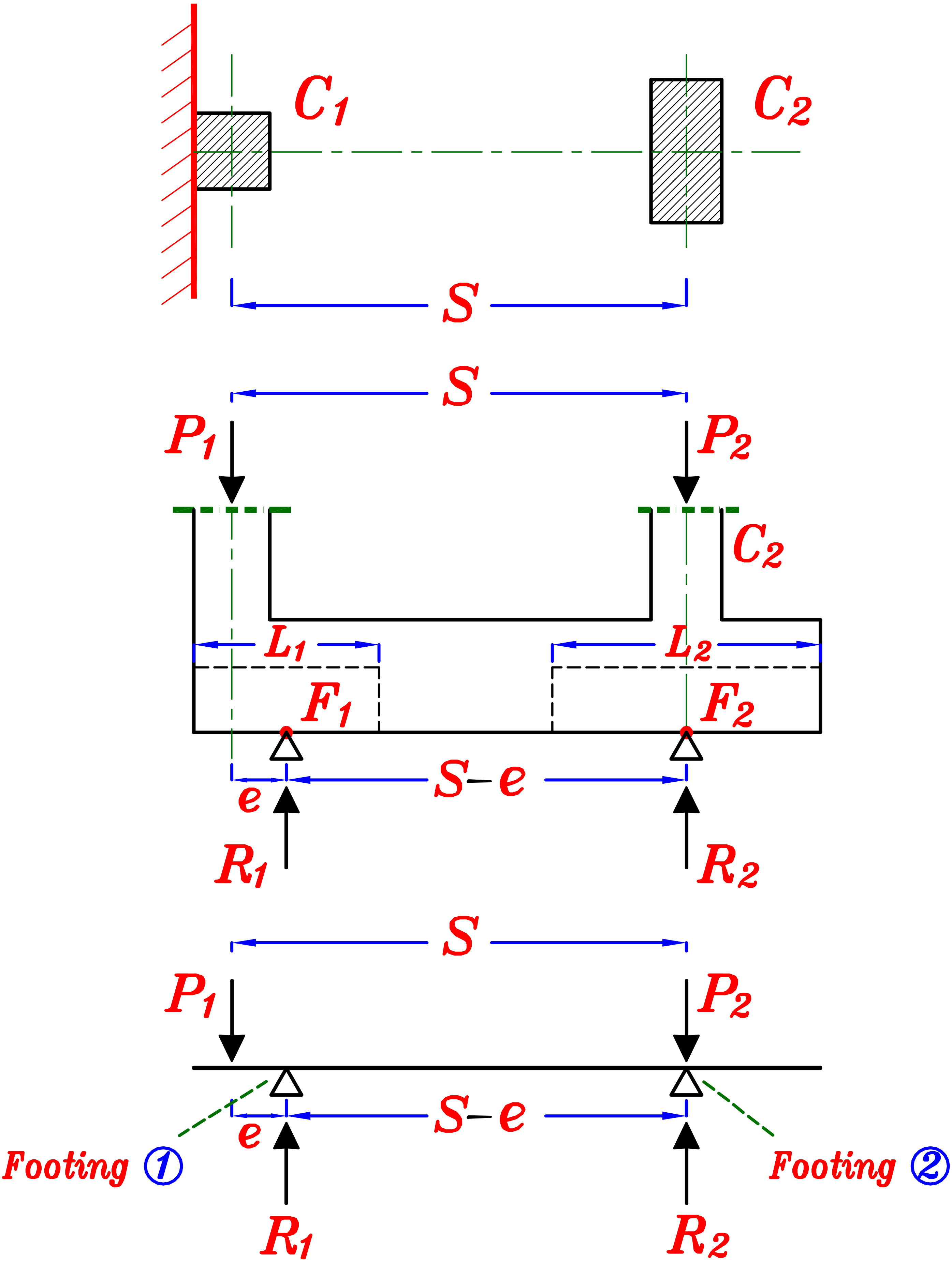
$C.G.$ القاعده F_2 تكون منطبقة مع $C.L.$ العمود C_2 .

٢- مركز القاعده F_1 أسفل عمود الجار C_1 يكون على بعد مسافه (e) من محور العمود .

$$e = 0.1 + 0.2\,(S)$$

و ذلك حتى لا تدخل القاعده F_1 فى منطقة الجار .

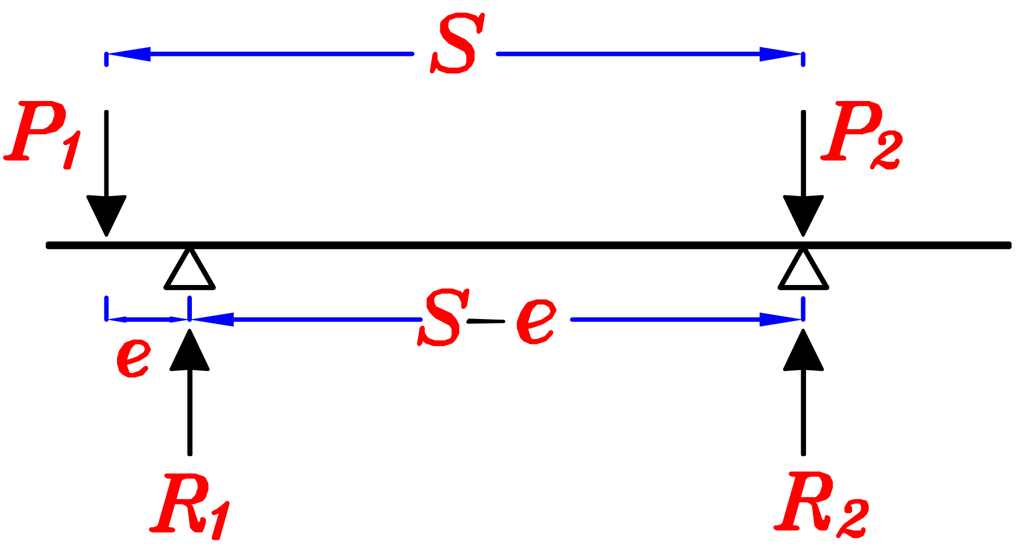
Design the Strap Beam and the two Footings.



1- Calculate the Footing area. (Width & Length of R.C. Footings.)

- Take $e = 0.1 + 0.2\,(S)$

- Calculate the reactions on Footings R_1, R_2



$$P_1 * S = R_1 * (S-e)$$

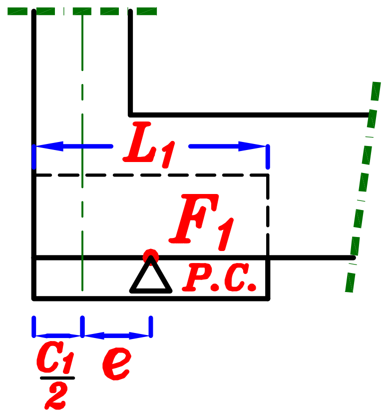
$$R_1 = \frac{P_1 * S}{S-e}$$

$$P_1 + P_2 = R_1 + R_2 \longrightarrow R_2 = R_1 - P_1 - P_2$$

Footing F_1

IF $t_{P.C.} > 20\ cm$

$$L_{1\,P.C.} = 2\left(e + \frac{C_1}{2}\right)$$



get $B_{1\,P.C.}$ From

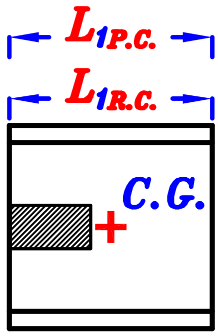
$$A_{P.C.} = \frac{R_1}{q_{all}} = \checkmark\checkmark\ m^2$$

$$A_{P.C.} = B_{1P.C.} * L_{1\,P.C.} \longrightarrow B_{1P.C.} = \checkmark$$

بعد حساب $B_{1\,P.C.}$
تقرب لاقرب ٥٠ مم بالزياده

$$B_{1R.C.} = B_{1P.C.} - 2\ t_{P.C.}$$

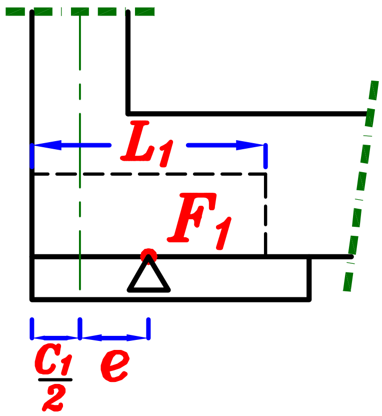
$$L_{1R.C.} = L_{1P.C.}$$



لا يوجد بروز للقاعده العاديه
حتى يكون C.G. للقاعده العاديه ينطبق على C.G. للقاعده المسلحه

IF $t_{P.C.} < 20\ cm$

$$L_{1\,R.C.} = 2\left(e + \frac{C_1}{2}\right)$$

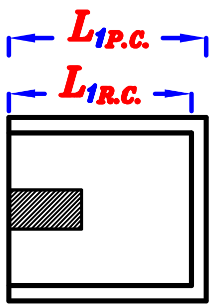


Get $B_{1\,R.C.}$ From $A_{R.C.} = \frac{R_1}{q_{all}} = \checkmark\checkmark\ m^2$

$$A_{R.C.} = B_{1R.C.} * L_{1\,R.C.} \longrightarrow B_{1R.C.} = \checkmark$$

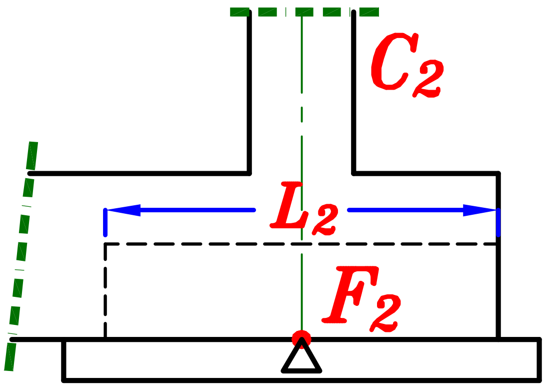
$$B_{1P.C.} = B_{1R.C.} + 2\ t_{P.C.}$$

$$L_{1P.C.} = L_{1R.C.} + t_{P.C.}$$



بروز من ناحيه واحده لان الناحيه الاخرى عندها حد الجار
لا يهم فى هذه الحاله أن ينطبق C.G. للقاعده العاديه و المسلحه
لان القاعده العاديه فى هذه الحاله فرشه نظافه .

Footing F_2



IF $t_{P.C.} > 20$ cm

get $B_{P.C.}$, $L_{P.C.}$ From

$$A_{P.C.} = \frac{R_2}{q_{all}} = ✓✓ \ m^2 = B_{2\,P.C.} * L_{2\,P.C.} \text{------} (1)$$

$$L_{2\,P.C.} - B_{2\,P.C.} = b - a \text{------} (2)$$

بعد حساب $B_{2\,P.C.}$ & $L_{2\,P.C.}$ يقربا لاقرب ٥٠ مم بالزياده

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

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

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

get $B_{R.C.}$, $L_{R.C.}$ From

$$A_{R.C.} = \frac{R_2}{q_{all}} = ✓✓ \ m^2 = B_{2\,R.C.} * L_{2\,R.C.} \text{------} (1)$$

$$L_{2\,R.C.} - B_{2\,R.C.} = b - a \text{------} (2)$$

بعد حساب $B_{2\,R.C.}$ & $L_{2\,R.C.}$ يقربا لاقرب ٥٠ مم بالزياده

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

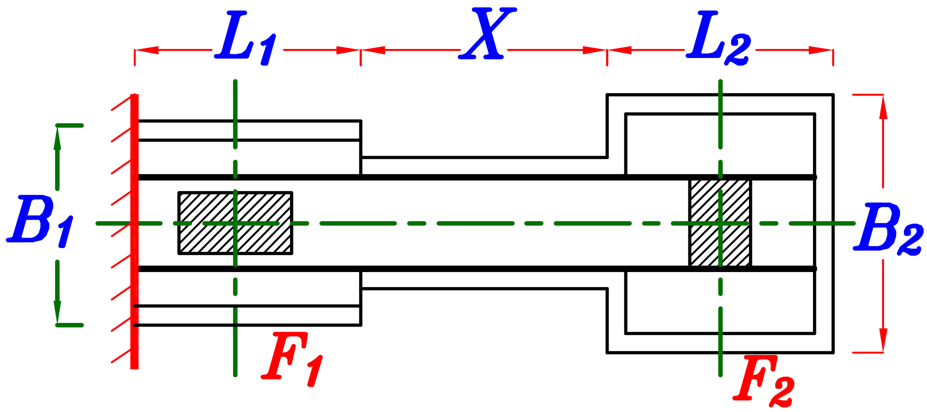
$$L_{2\,P.C.} = L_{2\,R.C.} + 2\,t_{P.C.}$$

2– *Check the validity of using Strap Beam .*

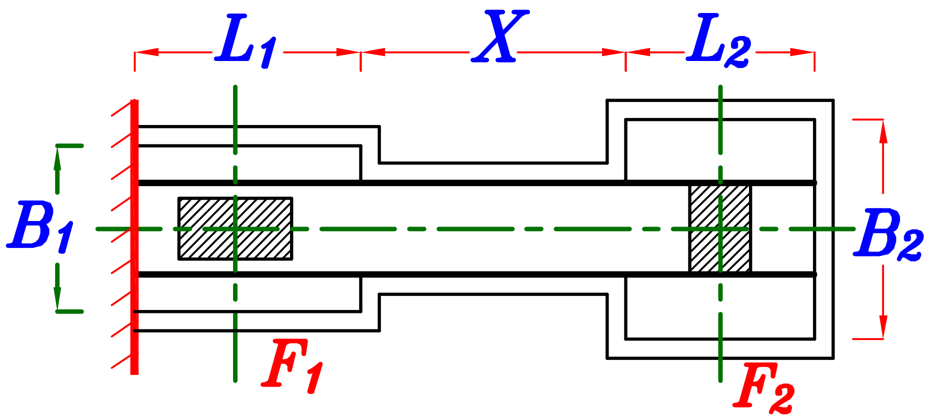
تأكد من سماحيه عمل *Strap Beam* أم لا .

نرسم **sketch** للقاعدتين F_2 , F_1 و نحدد عليه أبعاد كل قاعده .

IF $t_{P.C.} > 20\ cm$



IF $t_{P.C.} < 20\ cm$

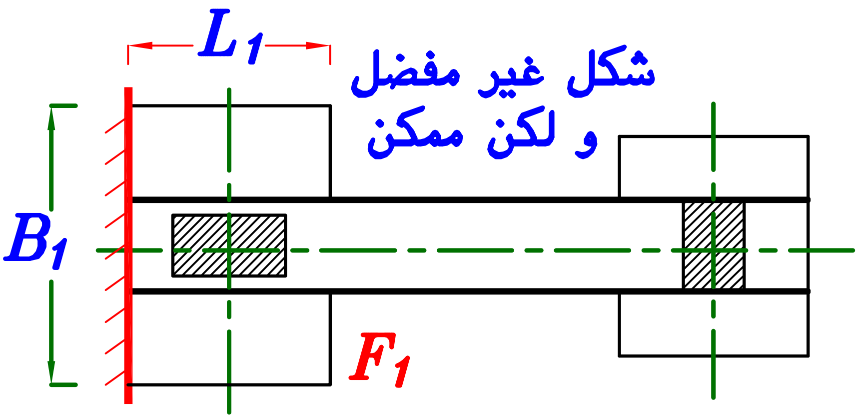


شروط استخدام الـ *Strap Beam* .

١- عدم حدوث تداخل بين القاعدتين F_1 , F_2

٢- أن لا تقل المسافه X عن الاصغر من $\frac{L_2}{2}$ and $\frac{L_1}{2}$

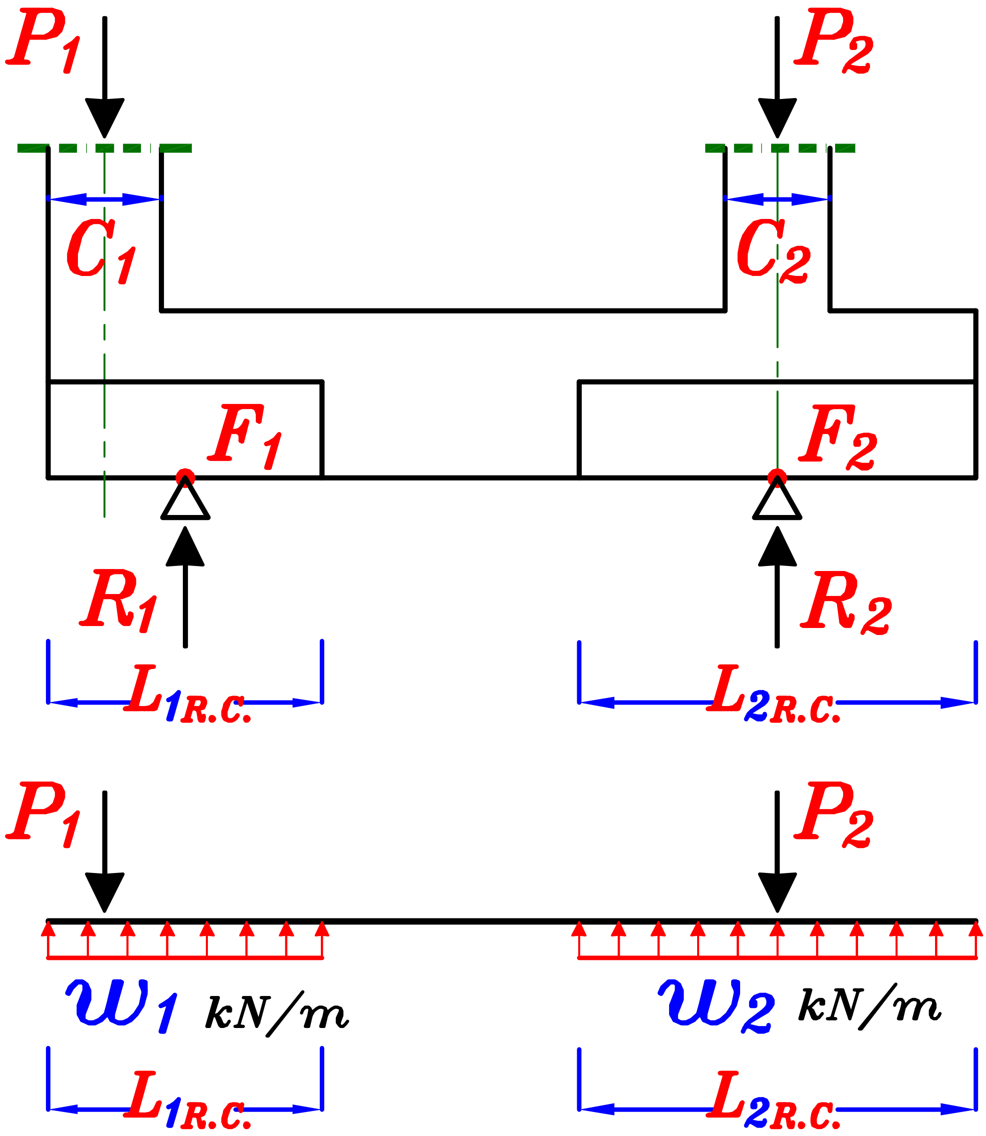
٣- أن تكون أبعاد القاعده F_1 لها الاستطاله الاكبر فى اتجاه حد الجار .



$L_1 \geqslant B_1$

اذا لم يتحقق أيا من الشروط السابقه نضطر لعمل **Combined Footing**

3 – Dimensions of the Strap Beam. (Width & depth)

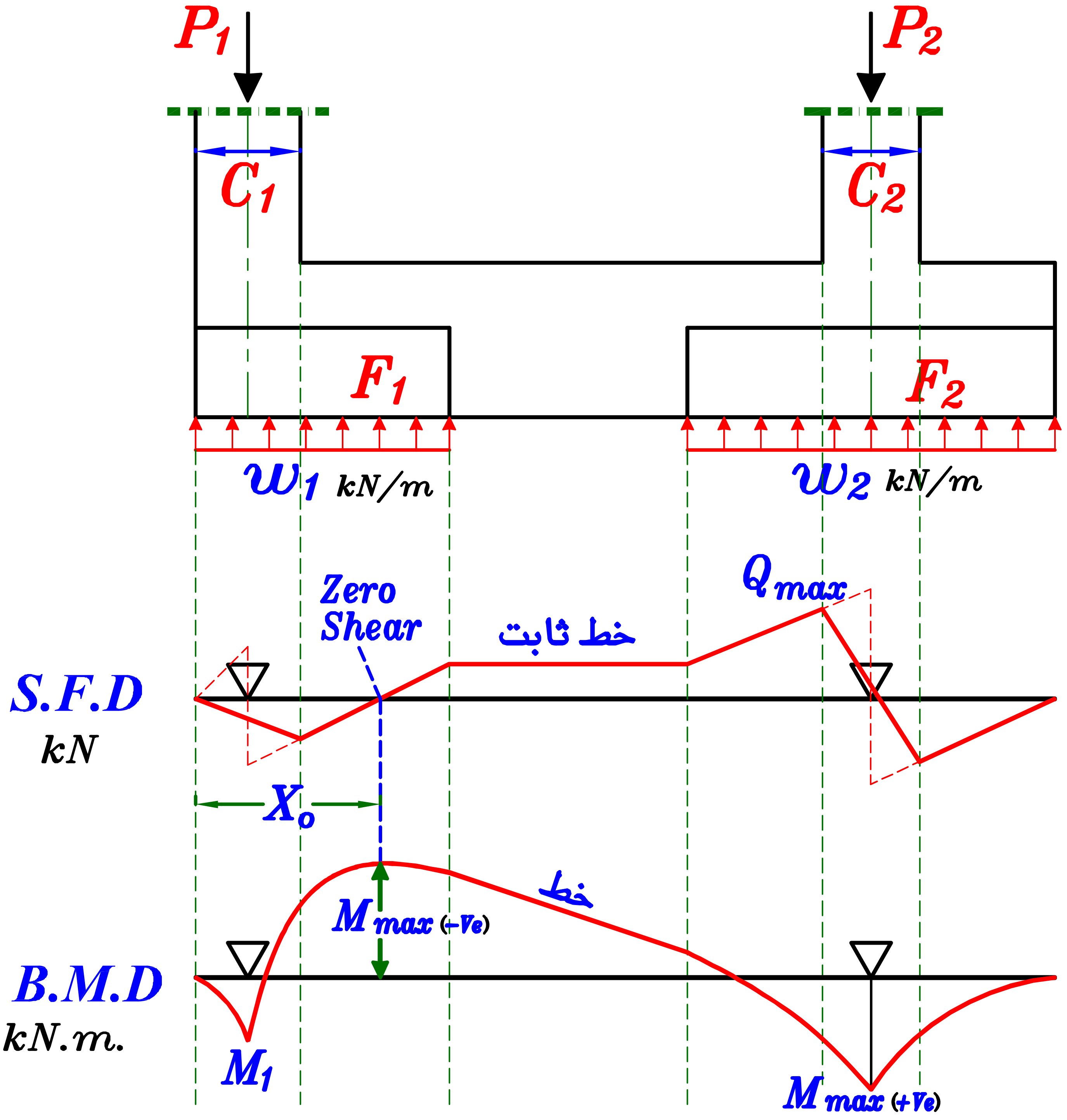


Stresses on Footings.

$$w_1 = \frac{R_1 \text{ (U.L.)}}{L_{1\,R.C.}} \quad (kN/m)$$

$$w_2 = \frac{R_2 \text{ (U.L.)}}{L_{2\,R.C.}} \quad (kN/m)$$

Drawing B.M.D. & S.F.D. For the Beam.



To Calculate the point of Zero Shear.

$$w_1 = P_1 (X_o) \longrightarrow X_o = \checkmark$$

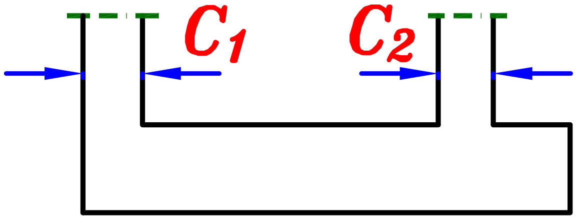
To Calculate the max (-Ve) Moment.

$$M_{max\,(-Ve)} = P_1 \left(X_o - \frac{C_1}{2}\right) - w_1 \frac{(X_o)^2}{2}$$

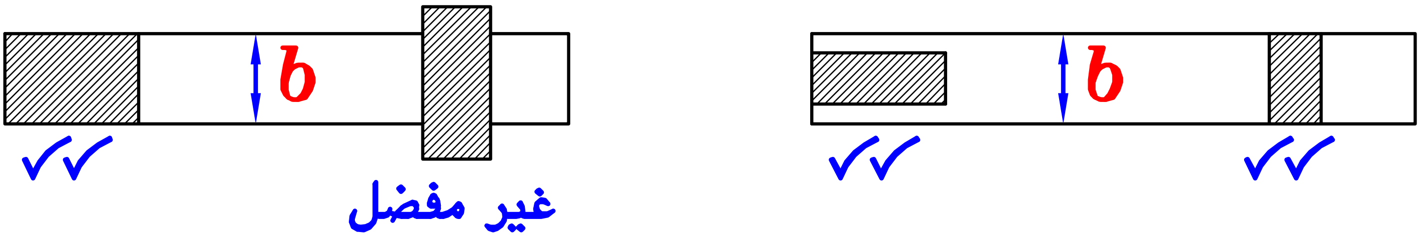
M_{max} the bigger From $M_{max\,(-Ve)}$ & $M_{max\,(+Ve)}$

Choose $b = (400 \rightarrow 1000)$ mm

$b \not< C_1$ or C_2



لا يقل عرض الكمره عن عرض العمود العمودى عليها



Recommended $b \simeq \dfrac{d}{2}$

$$d\,(mm) = C_1 \sqrt{\frac{M_{max}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * b\,(mm)}}$$

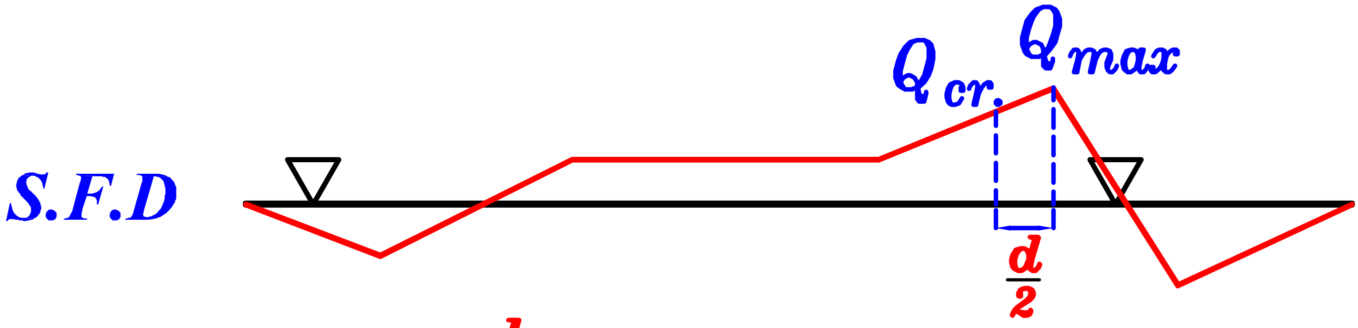
Choose $C_1 = (3.5 \rightarrow 5.0)$

Get $d = ✓✓$ (mm)

Take cover = 70 mm

$t = d + cover\ (70\ mm)$ تقرب لاقرب ٥٠ مم بالزياده

4 – Check Shear For Strap Beam. as beams.



$Q_{cr.}$ على بعد $\frac{d}{2}$ من وش العمود

$$Q_{cr.} = Q_{max.} - w\left(\frac{d}{2}\right)$$

① **Calculate Allowable Shear Stresses.**

$$q_{cu} = 0.24 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad N\backslash mm^2$$

$$q_{max.} = 0.70 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad N\backslash mm^2$$

② **Calculate Actual Shear Stress.**

$$q_U = \frac{Q_{cr.}}{b\,d} \quad N\backslash mm^2$$

③ **IF** IF q_U

- $q_U \leqslant q_{cu}$
  Use min. Stirrups.
  5 ϕ 10 \ m'
  4 branches
- $q_{cu} < q_U \leqslant q_{Umax.}$
  We need Stirrups
  More Than 5 ϕ 10 \ m'
- $q_U > q_{Umax.}$
  Increase Dim.
  b or d

* IF $q_{cu} < q_U < q_{U\,max.}$

We need Stirrups more than $5\phi 8 \backslash m'$

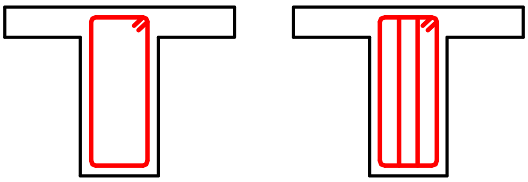
$$q_{su} = q_u - \frac{q_{cu}}{2} = \frac{n\, A_s\, (F_y \backslash \gamma_s)}{b\; S}$$

Where : q_{su} = Shear Stress Taken by Stirrups only.

q_u = Actual Shear Stress.

$\frac{q_{cu}}{2}$ = Shear Stress Taken by Concrete only.

- n = No. of Branches.



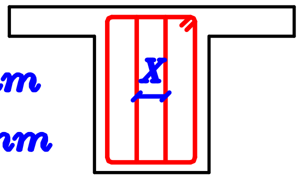
$n = 2$ $n = 4$

ملحوظه IF $b \geqslant 400$ mm OR $b > t$

Take $n = 4$

$X \nless 50$ mm

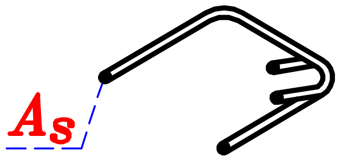
$X \ngtr 250$ mm



- A_s مساحه سطح السيخ الواحد من الكانه

IF using $\phi 8 \longrightarrow A_s = 50.3\ mm^2$

IF using $\phi 10 \longrightarrow A_s = 78.5\ mm^2$



- $F_y = 240\ N \backslash mm^2$ Mild Steel

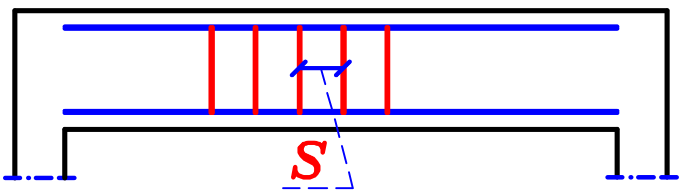
$F_y = 360\ N \backslash mm^2$ H.T.Steel

- S = Spacing between stirrups in the Long Direction.

المسافات بين الكانات فى الإتجاه الطولى

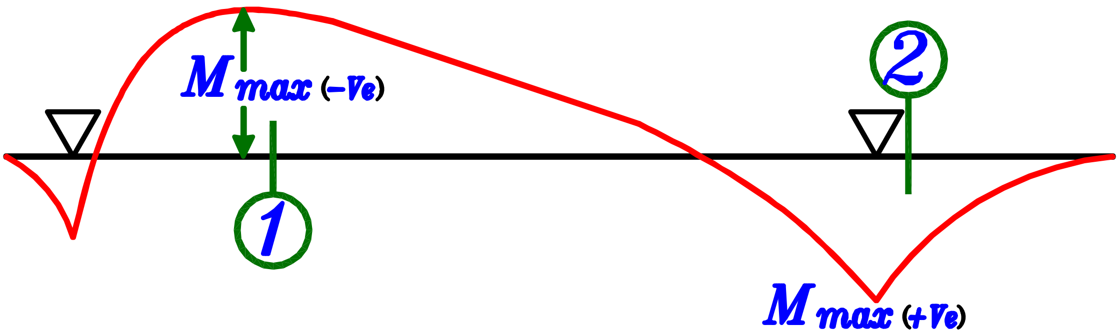
$S_{min} = 100$ mm

$S_{max.} = 200$ mm



5 – Reinforcement of Strap Beam.

B.M.D



Sec. ①

$$d = C_1 \sqrt{\frac{M_{max\,(-Ve)}}{F_{cu} * b}} \longrightarrow C_1 \longrightarrow J$$

Get

$$A_{s\,Top} = \frac{M_{max\,(-Ve)}}{J\, F_y\, d} \quad (mm^2)$$

Check

$$A_{s\,min} = \left.\left.\begin{matrix} \frac{1.1}{F_y}\, b\, d \\ 1.3\, A_{s\,req.} \end{matrix}\right\} \text{الأقل} \quad \begin{matrix} \\ \frac{0.15}{100}\, b\, d \end{matrix}\right\} \text{الأكبر}$$

Sec. ②

$$d = C_1 \sqrt{\frac{M_{max\,(+Ve)}}{F_{cu} * b}} \longrightarrow C_1 \longrightarrow J$$

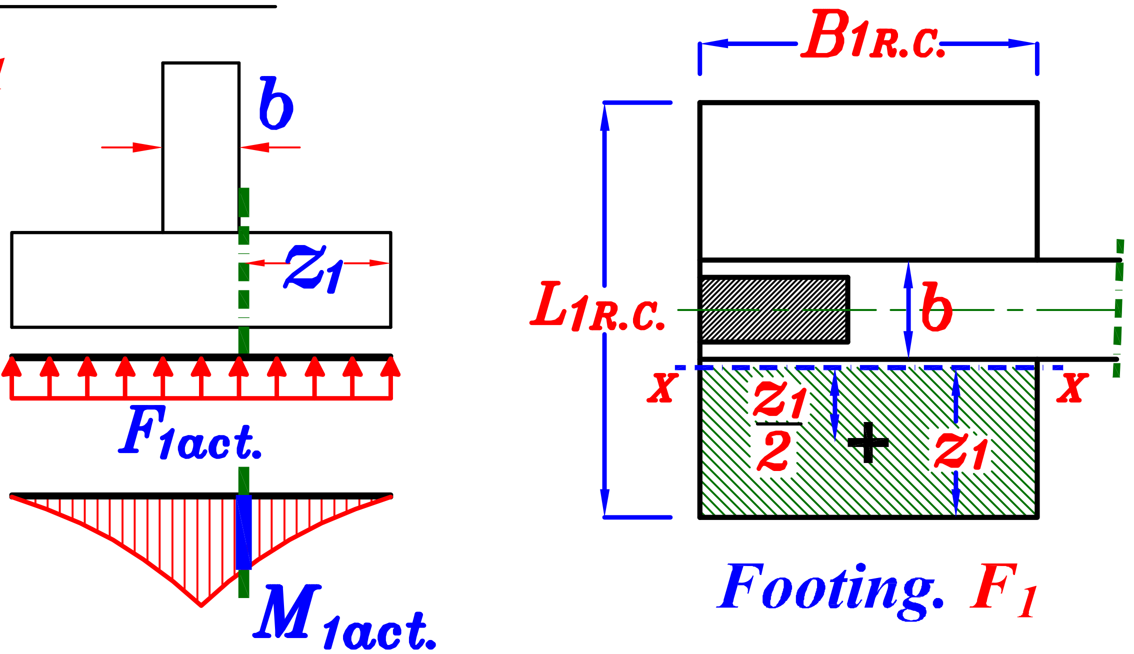
Get

$$A_{s\,bott} = \frac{M_{max\,(+Ve)}}{J\, F_y\, d} \quad (mm^2)$$

Check $A_{s\,min}$

6 – Design of Footings. *as a strip Footing.*

Footing. F_1



– Actual Normal stress on R.C. Footing (U.L.)

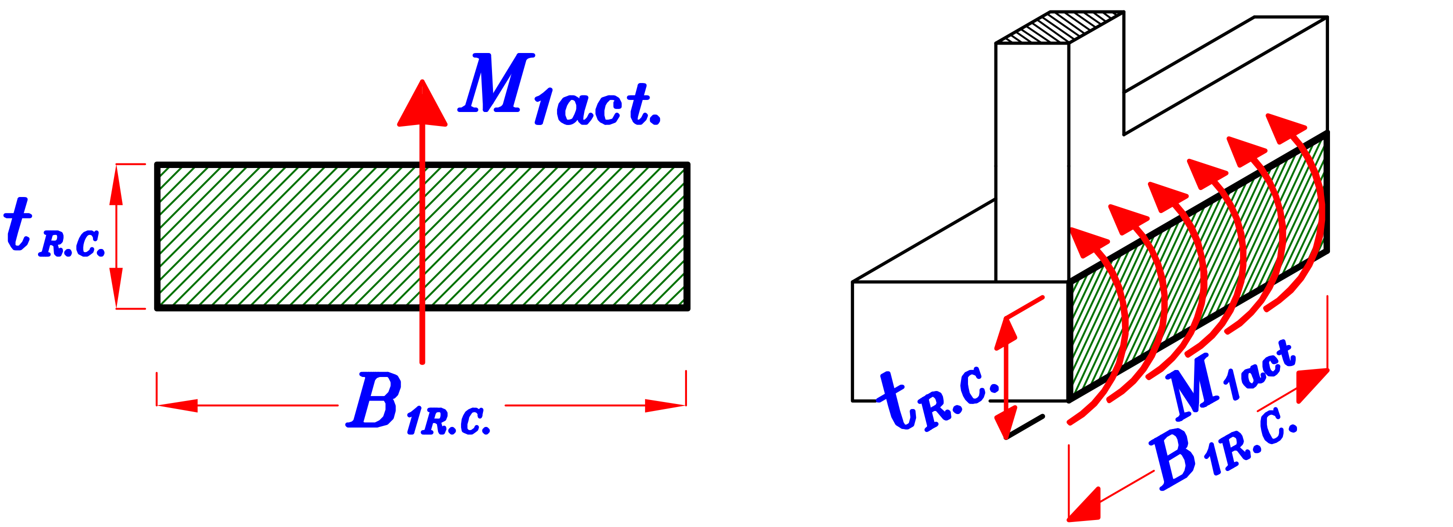
$$F_{1act.} = \frac{R_{1U.L.}}{B_{1R.C.} * L_{1R.C.}} \quad (kN/m^2)$$

– Critical section of bending at R.C. Footing.

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

– moment = Force * Distance

$$M_{1act.} = (F_{1act.} * Z_1 * B_{1R.C.}) \frac{Z_1}{2} \quad (kN.m)$$



$$d_1 = C_1 \sqrt{\frac{M_{1act.}}{F_{cu} * B_{1R.C.}}}$$

Take $C_1 = (3.5 \rightarrow 5.0)$

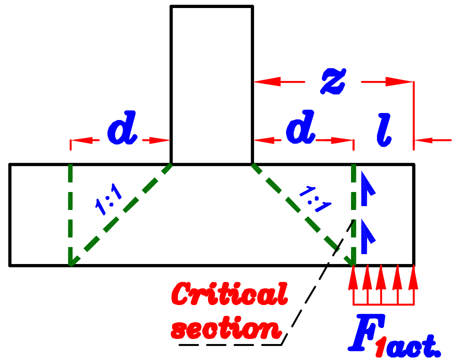
Get $d_1 = ✓✓$ (mm)

Take cover = 70 mm

$t_{1\,R.C.} = d_1 + cover\ (70\ mm)$ — تقرب لاقرب ٥٠ مم بالزياده

Check Shear.

* Calculate $l_1 = z_1 - d$ (m)

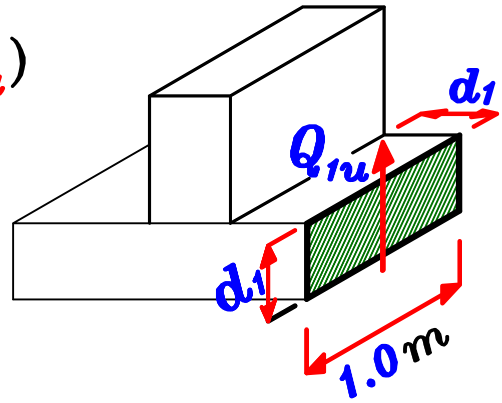


* Calculate Actual shear Force. (Q_u)

$$Q_{1u} = F_{act.} * l_1 * 1.0\,m \quad (kN)$$

* Calculate Actual shear stress. (q_u)

$$q_{u1} = \frac{Q_{1u}}{b * d_1} = \frac{Q_{1u}\,(kN) * 10^3}{1000 * d_1\,(mm)}$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}}$$

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_{u1} \leqslant q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

* IF $q_{u1} > q_{su}$ ⟶ UnSafe shear stresses
We have to increase dimensions.

Reinforcement of the Footing.

From $C_1 \xrightarrow{Get} J$

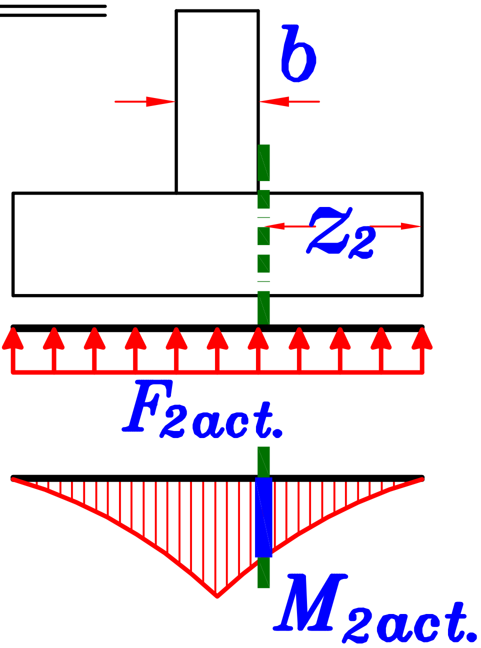
Get $$A_{s1} = \frac{M_{1act.}}{J\, F_y\, d_1} \quad (mm^2)$$

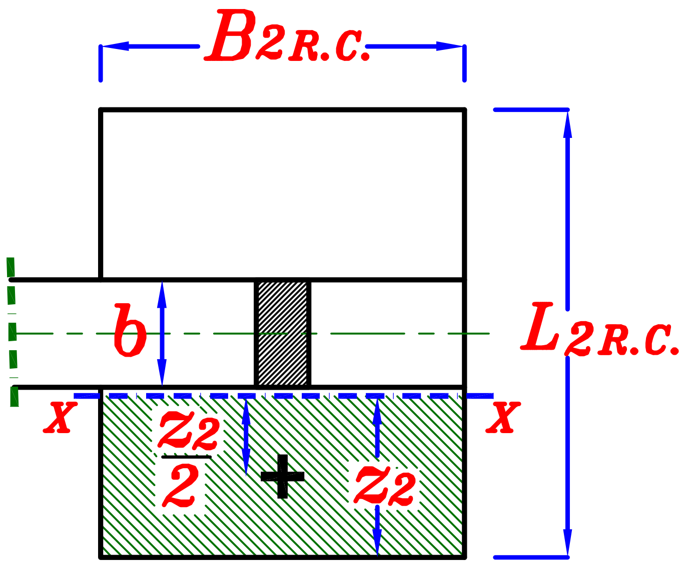
Check $$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\, d \ (mm) \\ 5\phi 12/m' \end{cases} \text{الأكبر}$$

IF $A_{s1} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{s1} < A_{s\,min} \longrightarrow$ Take $A_{s1} = A_{s\,min}$

Footing. F_2





Footing. F_2

- Actual Normal stress on R.C. Footing (U.L.)

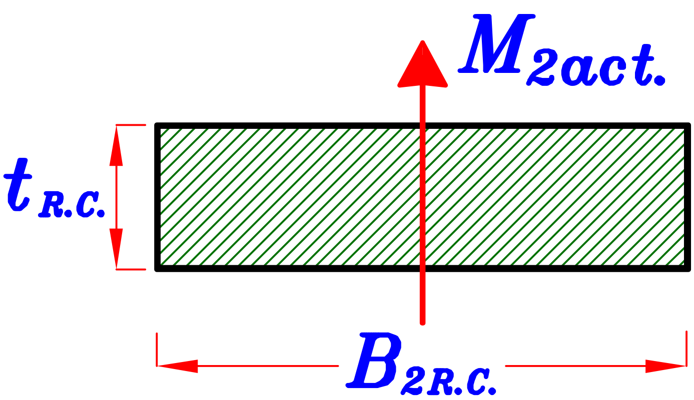
$$F_{2act.} = \frac{R_{2U.L.}}{B_{2R.C.} * L_{2R.C.}} \quad (kN/m^2)$$

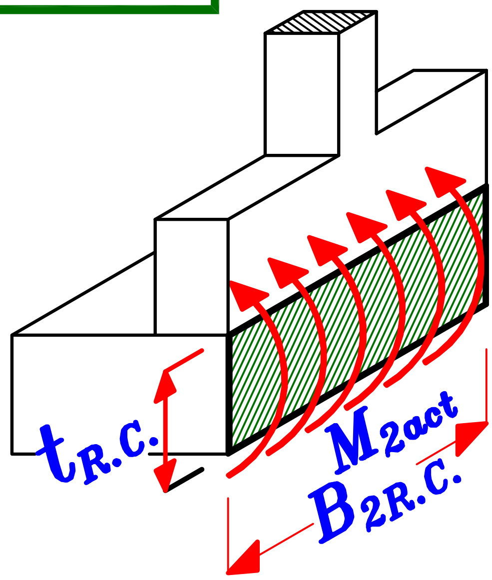
- Critical section of bending at R.C. Footing.

$$Z_2 = \frac{L_{2R.C.} - b}{2} \quad (m)$$

- moment = Force * Distance

$$M_{2act.} = (F_{2act.} * Z_2 * B_{2R.C.}) \frac{Z_2}{2} \quad (kN.m)$$





$$d_2 = C_1 \sqrt{\frac{M_{2act.}}{F_{cu} * B_{1R.C.}}}$$

Take $C_1 = (3.5 \rightarrow 5.0)$

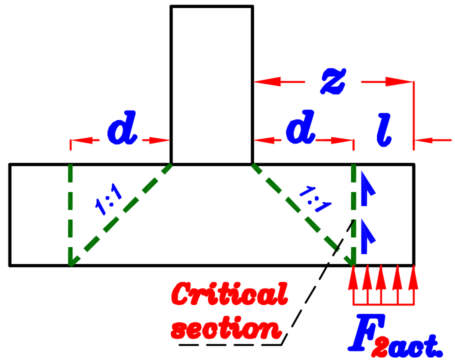
Get $d_2 = \checkmark\checkmark$ (mm)

Take cover = 70 mm

$t_{2\,R.C.} = d_2 + cover$ (70 mm) تقرب لاقرب ٥٠ مم بالزياده

Check Shear.

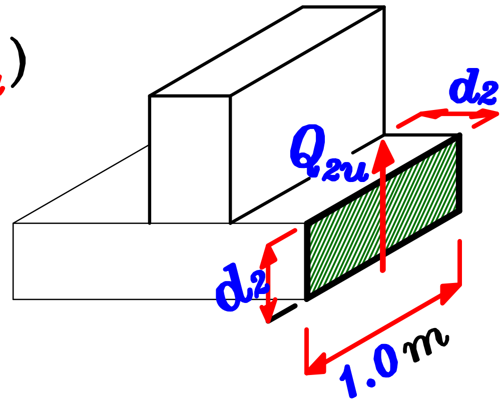
* Calculate $l_2 = z_2 - d$ (m)



* Calculate Actual shear Force. (Q_u)

$$Q_{2u} = F_{act.} * l_2 * 1.0\ m \quad (kN)$$

* Calculate Actual shear stress. (q_u)



$$q_{2u} = \frac{Q_{2u}}{b * d_2} = \frac{Q_{2u}\,(kN) * 10^3}{1000 * d_2\,(mm)}$$

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}}$$

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_{u2} \leqslant q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

* IF $q_{u2} > q_{su}$ ⟶ UnSafe shear stresses
We have to increase dimensions.

Reinforcement of the Footing.

From $C_1 \xrightarrow{Get} J$

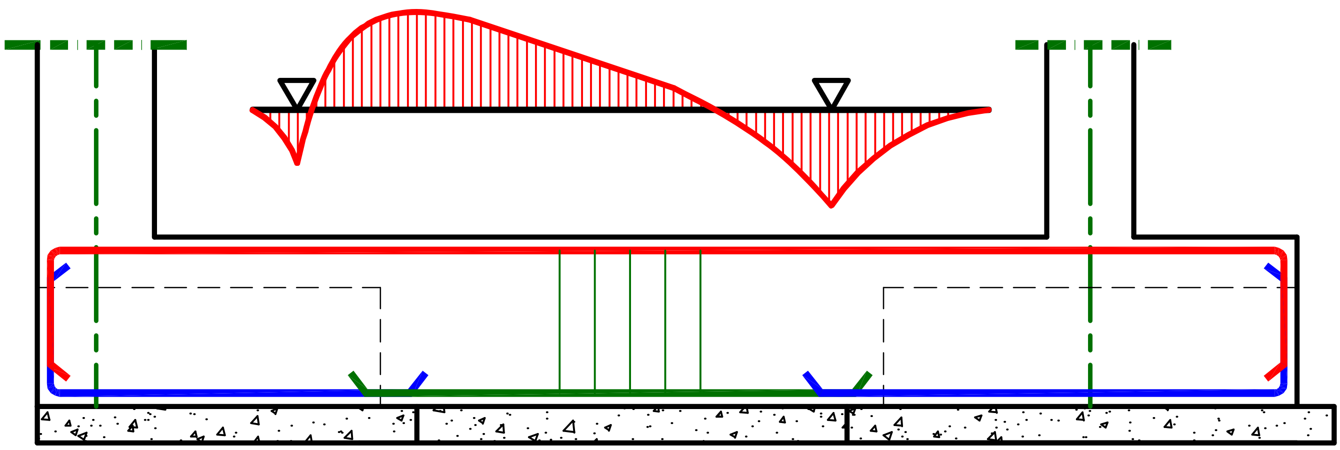
Get
$$A_{s2} = \frac{M_{2act.}}{J\ F_y\ d_2} \quad (mm^2)$$

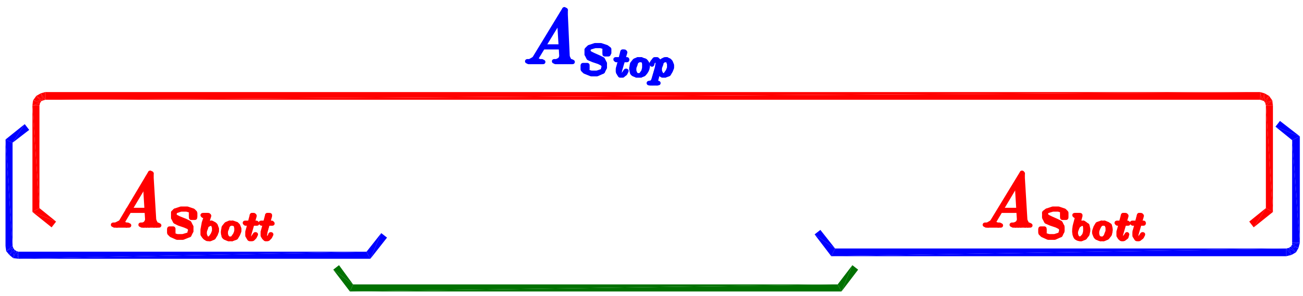
Check
$$A_{s\,min}\ (mm^2/m) = \left\{ \begin{array}{l} 1.5\ d\ (mm) \\ 5\ \phi\ 12/m' \end{array} \right\} \text{الأكبر}$$

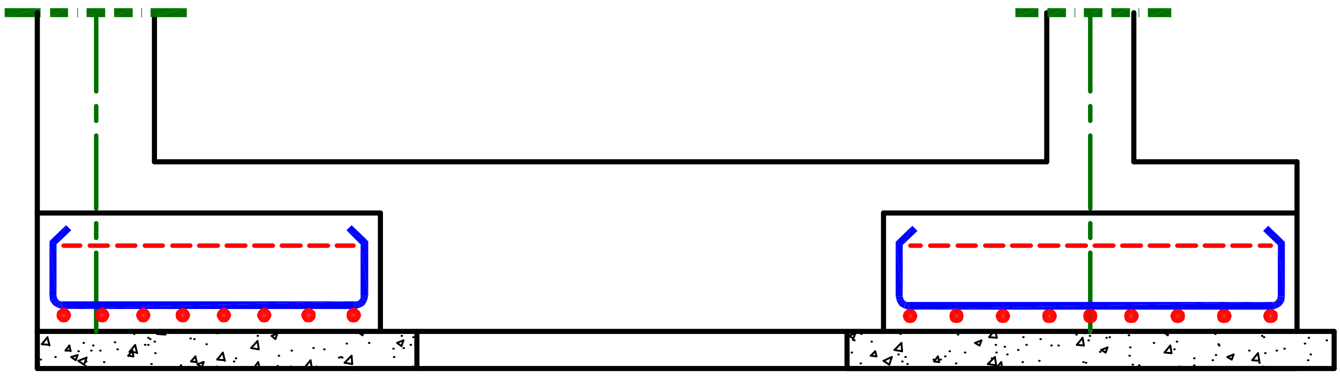
IF $A_{s2} \geq A_{s\,min} \longrightarrow$ o.k.

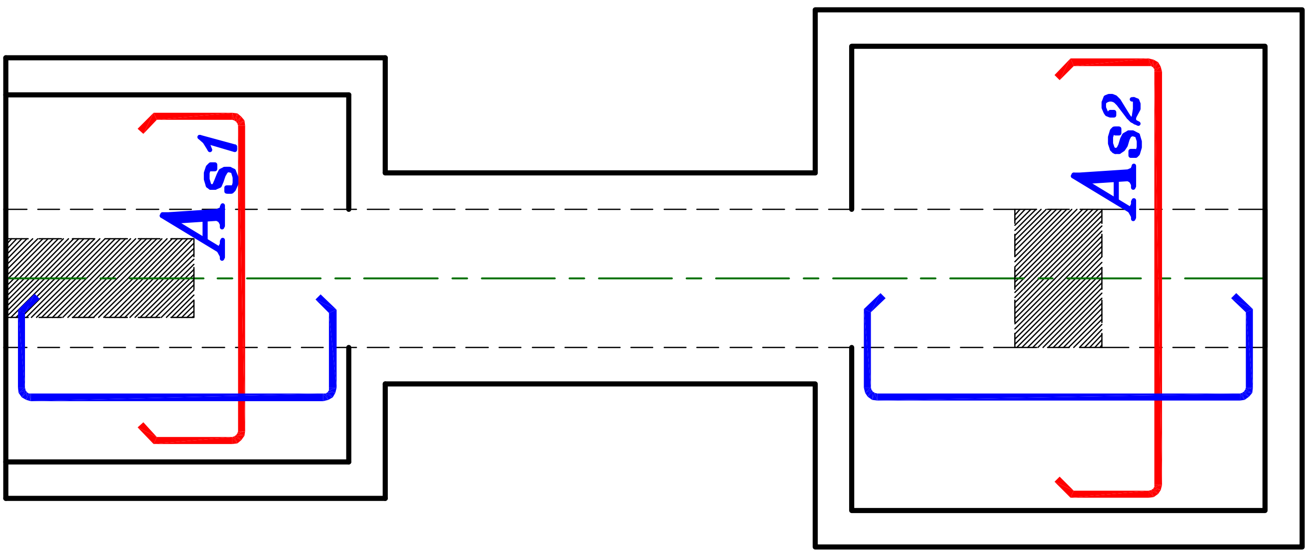
IF $A_{s2} < A_{s\,min} \longrightarrow$ Take $A_{s1} = A_{s\,min}$

7 – Details of Reinforcement.



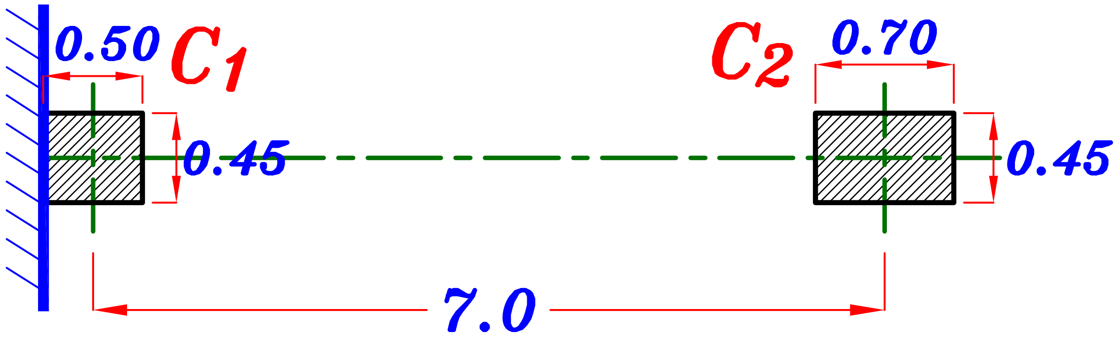






Example.

It is required to design Footings to support a proterty line column C_1 (45 * 50) cm. and carrying working load 1000 kN and interior column C_2 (45 * 70) cm. and carrying working load 2200 kN the spacing between the C.L. of the two columns is 7.0 m as shown



and the allowable net bearing capacity in the Footing site is 200 kN/m^2. (F_{cu} = 25 N/mm^2, F_y = 360 N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given:

Column C_1 dimensions (450 * 500) mm

P_1 (working) = 1000 kN P_1 (U.L.) = 1000 * 1.5 = 1500 kN

Column C_2 dimensions (450 * 700) mm

P_2 (working) = 2200 kN P_2 (U.L.) = 2200 * 1.5 = 3300 kN

R (working) $= P_1 + P_2$ = 3200 kN

R (U.L.) = 1.5 * 3200 = 4800 kN

Bearing capacity of the soil = q_{all} = 200 kN/m^2

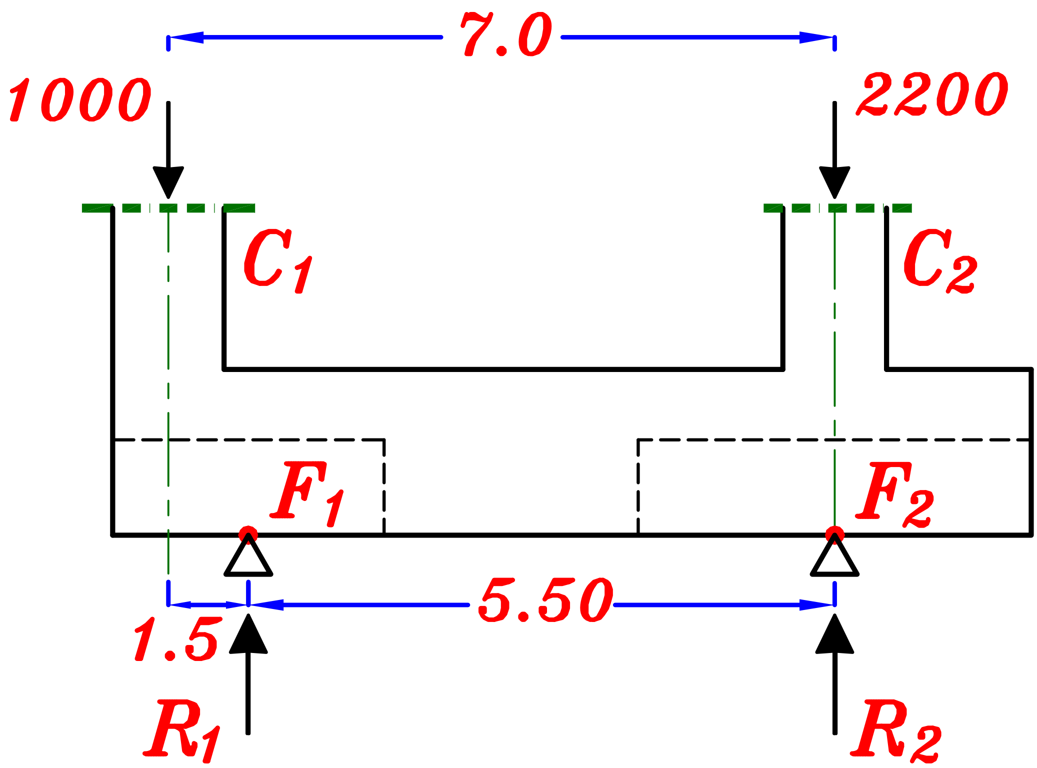
F_{cu} = 25 N/mm^2 F_y = 360 N/mm^2

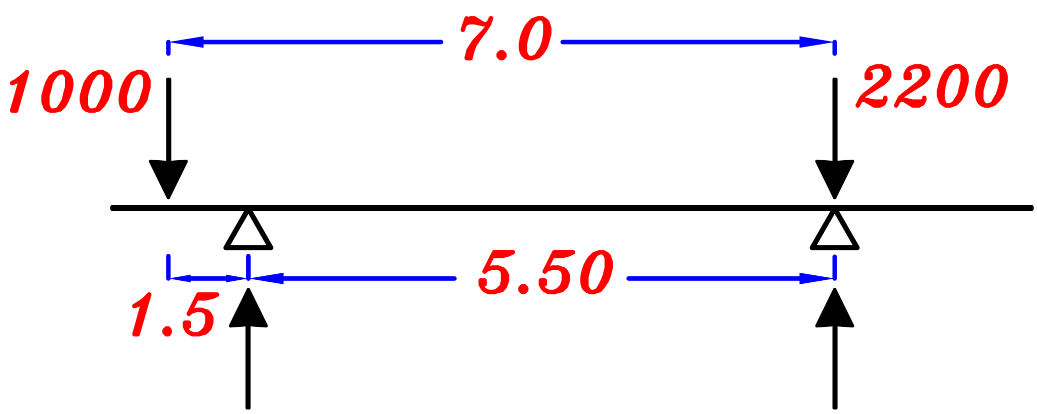
For property line use
Strap Beam or Combined Footing.

Start with Strap Beam.

1– Calculate the Footing area. (*Width & Length of R.C. Footings.*)

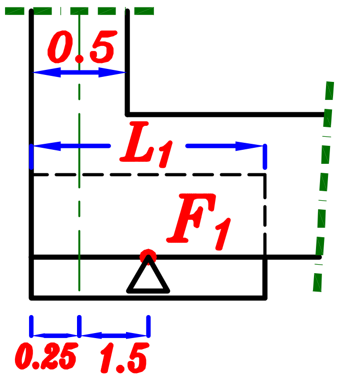
Take $e = 0.1 + 0.2\,(S) = 0.1 + 0.2\,(7.0) = 1.50$ m





$R_1 = 1272.7$ kN $\qquad R_2 = 1927.3$ kN

Footing F_1



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

$$L_{1\,P.C.} = 2\left(e + \frac{C_1}{2}\right) = 2\,(1.5 + 0.25) = 3.50\ m$$

get $B_{1\,P.C.}$ From $A_{P.C.} = \dfrac{R_1}{q_{all}} = A_{P.C.} = B_{1P.C.} * L_{1P.C.}$

$$A_{P.C.} = \frac{1272.7}{200} = B_{1P.C.} * 3.50 \longrightarrow B_{1P.C.} = 1.82\ m$$

$B_{1P.C.} = 1.90\ m$	$L_{1P.C.} = 3.50\ m$
$B_{1R.C.} = 1.30\ m$	$L_{1R.C.} = 3.50\ m$

Footing F_2

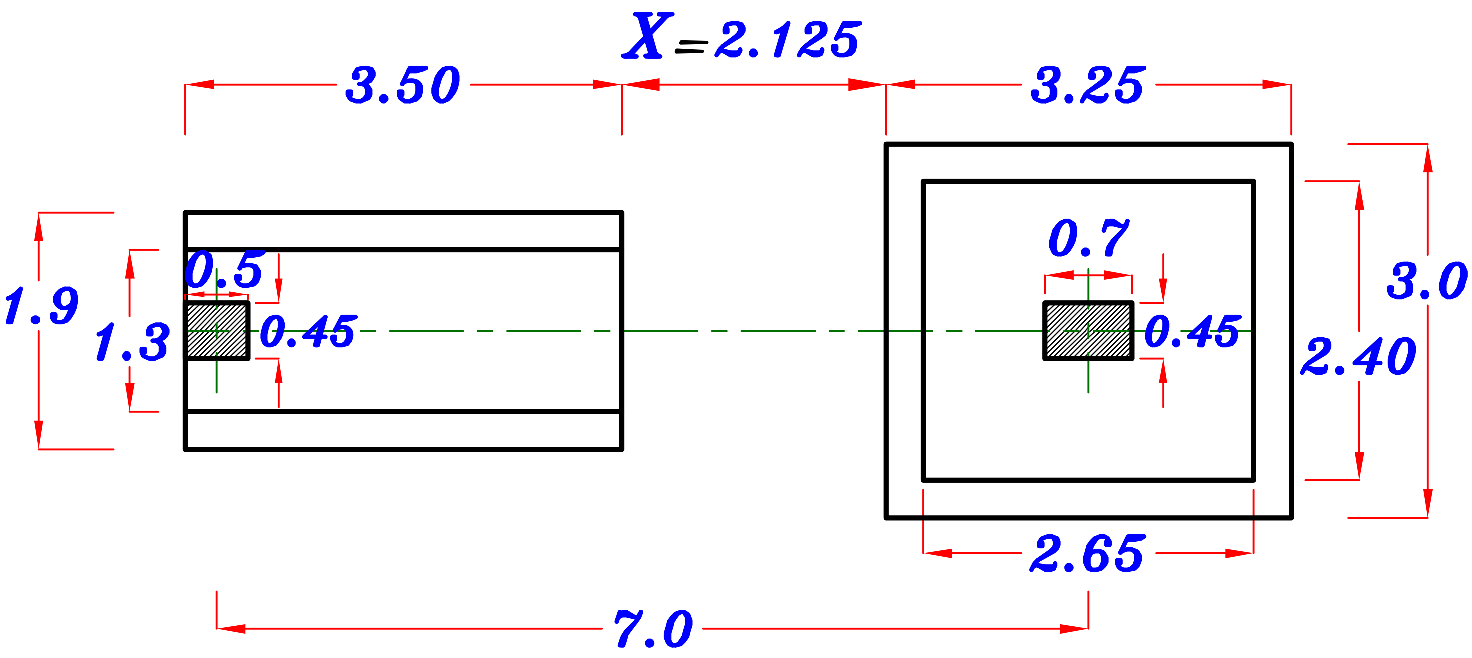
$$L_{2P.C.} - B_{2P.C.} = b - a = 0.70 - 0.45 = 0.25\ m$$

$$L_{2P.C.} = B_{2P.C.} + 0.25\ m \quad \text{------} (1)$$

$$A_{2P.C.} = \frac{R_2}{q_{all}} = \frac{1927.3\ (kN)}{200\ \ (kN/m^2)} = 9.63\ \ m^2$$

$$A_{2P.C.} = B_{2P.C.} * L_{2P.C.} = 9.63\ \ m^2 \quad \text{-----} (2)$$

$B_{2P.C.} = 3.0\ m$	$L_{2P.C.} = 3.25\ m$
$B_{2R.C.} = 2.40\ m$	$L_{2R.C.} = 2.65\ m$



$X > \frac{L_1}{2}$ and $\frac{L_2}{2}$ ∴ use **Strap Beam.**

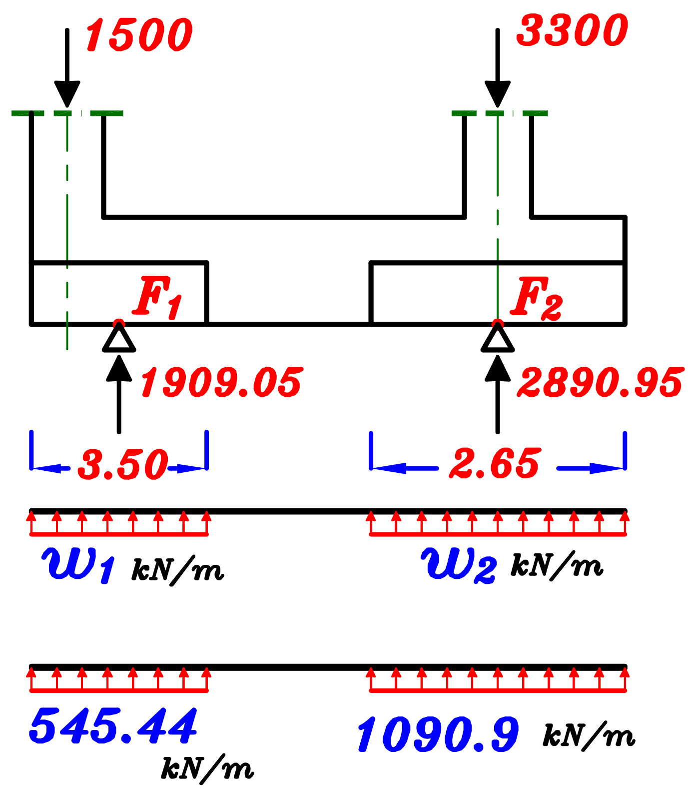
3 – Dimensionsof the Strap Beam. (Width & depth)

$$w_1 = \frac{R_1 \, (U.L.)}{L_{1\,R.C.}}$$

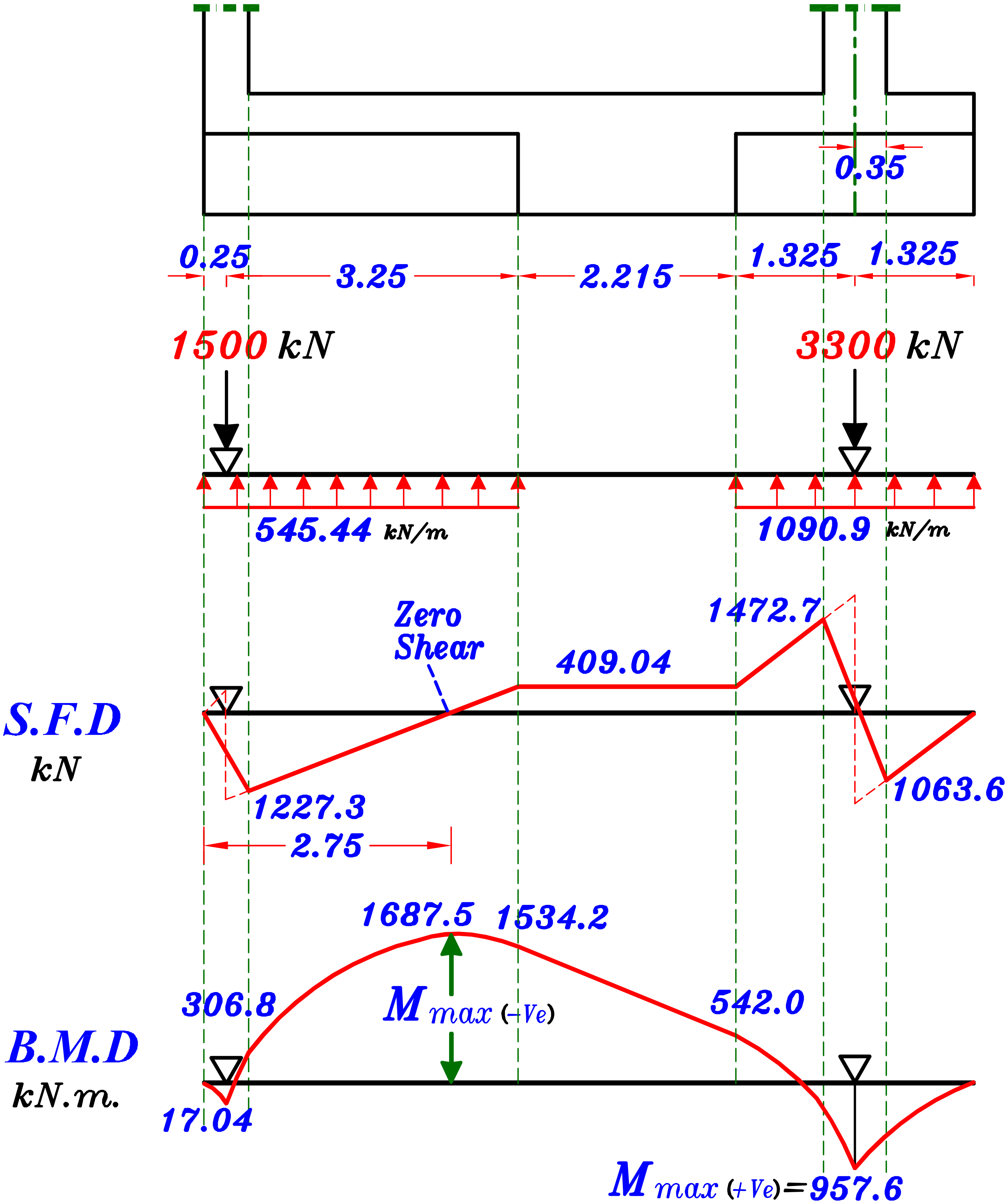
$$w_1 = \frac{1.5 * 1272.7}{3.50} = 545.44 \quad (kN/m)$$

$$w_2 = \frac{R_2 \, (U.L.)}{L_{2\,R.C.}}$$

$$w_2 = \frac{1.5 * 1927.3}{2.65} = 1090.9 \quad (kN/m)$$



Drawing B.M.D. & S.F.D. For the Beam.



Point of Zero Shear (X_o) $= \dfrac{1500}{545.44} = 2.75$ m

Take $b \nless C_1$ or C_2 Take $b = 0.7\ m$

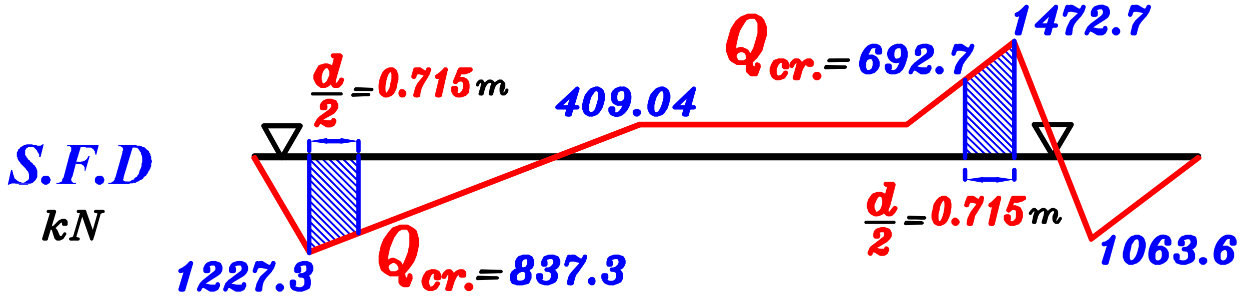
$\because d = C_1 \sqrt{\frac{M_{max}}{F_{cu} * b}}$ Choose $C_1 = 4.5$

$\therefore d = 4.5 \sqrt{\frac{1687.5 * 10^6}{25 * 700}} = 1397\ mm$

$t_{R.C.} = d + 70\ mm = 1397 + 70 = 1467\ mm$

$t_{R.C.} = 1500\ mm$ $d = 1430\ mm$

4 – Check Shear For Strap Beam. as beams.



$Q_{cr.} = Q_{max.} - w\left(\frac{d}{2}\right) = 1472.7 - 1090.9\left(\frac{1.43}{2}\right) = 692.7\ kN$

$Q_{cr.} = Q_{max.} - w\left(\frac{d}{2}\right) = 1227.3 - 545.44\left(\frac{1.43}{2}\right) = 837.3\ kN$

– Actual Shear Stress.

$q_{act.} = \frac{Q_{cr.}}{b * d} = \frac{837.3 * 10^3}{700 * 1430} = 0.836\ kN/m^2$

– Allowable shear stress.

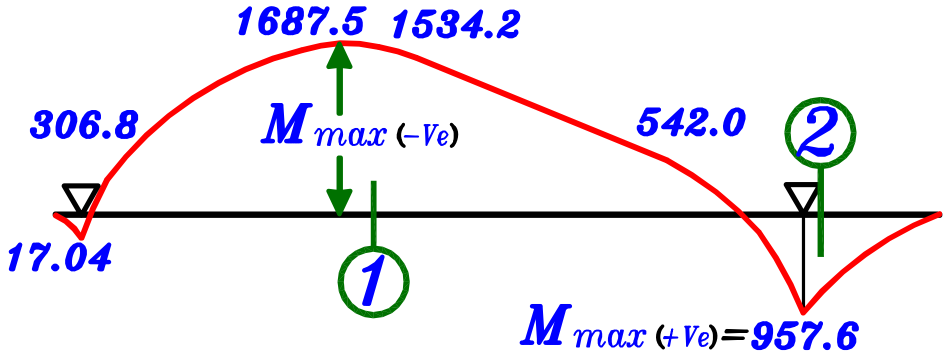
– $q_{cu} = 0.24 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.24 \sqrt{\frac{25}{1.5}} = 0.98\ N\backslash mm^2$

– $q_{max.} = 0.7 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.7 \sqrt{\frac{25}{1.5}} = 2.85\ N\backslash mm^2$

$\therefore q_{act.} < q_{cu.} \longrightarrow$ use min. stirrups

Use Stirrups $5 \phi 10 \backslash m$ 6 branches

5 – Reinforcement of Strap Beam.



Sec. ① $M_{max\,(-Ve)} = 1687.5$ kN.m.

$$1430 = C_1 \sqrt{\frac{1687.5 * 10^6}{25 * 700}} \longrightarrow C_1 = 4.60 \longrightarrow J = 0.818$$

$$A_s = \frac{M}{J\,F_y\,d} = \frac{1687.5 * 10^6}{0.818 * 360 * 1430} = 4007.3\ mm^2$$

Check $A_{s_{min.}} = \frac{1.1}{F_y}\,b\,d = \frac{1.1}{360}(700)(1430) = 3058.6\ mm^2$

$\therefore A_s > A_{s_{min.}}$ $\quad \therefore A_s = 4007.3\ mm^2$ $\quad$ **11 ϕ 22**

Sec. ② $M_{max\,(+Ve)} = 957.6$ kN.m.

$$1430 = C_1 \sqrt{\frac{957.6 * 10^6}{25 * 700}} \longrightarrow C_1 = 6.11 \longrightarrow J = 0.826$$

$$A_s = \frac{M}{J\,F_y\,d} = \frac{957.6 * 10^6}{0.826 * 360 * 1430} = 2252\ mm^2$$

Check $A_{s_{min.}} = \frac{1.1}{F_y}\,b\,d = \frac{1.1}{360}(700)(1430) = 3058.6\ mm^2$

$\therefore A_s < A_{s_{min.}}$ $\quad \therefore$ Take $A_s = A_{s_{min.}}$

$A_{s_{min.}} = \frac{1.1}{F_y}\,b\,d = \frac{1.1}{360}(700)(1430) = 3058.6$

$1.3\,A_{s\,req.} = (1.3)(2252) = 2927.6$

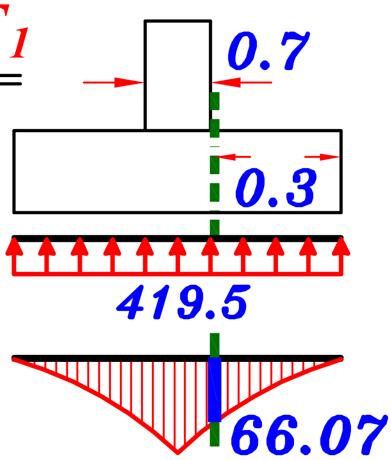
→ 2927.6

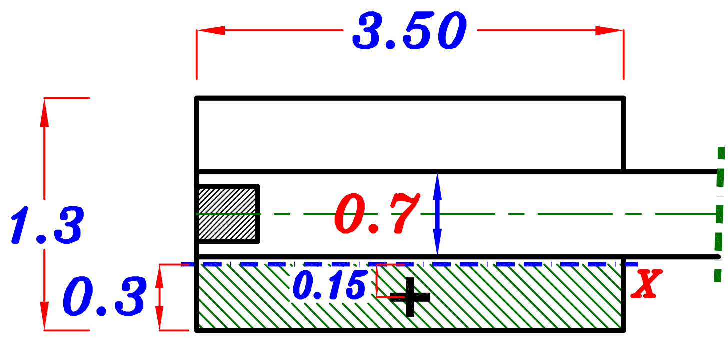
st. 360/520 $\quad \frac{0.15}{100}\,b\,d = \frac{0.15}{100}(700)(1430) = 1501.5$

→ $2927.6\ mm^2$ $\quad$ **8 ϕ 22**

6 – Design of Footings. as a strip Footing.

Footing. F_1



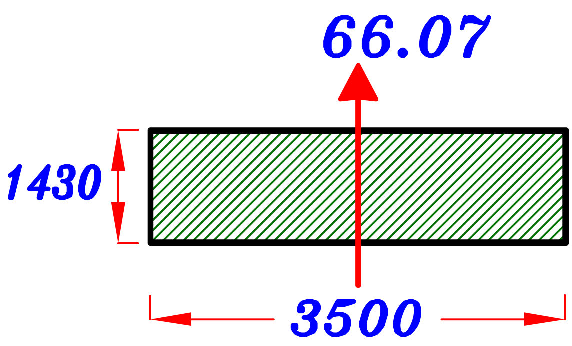


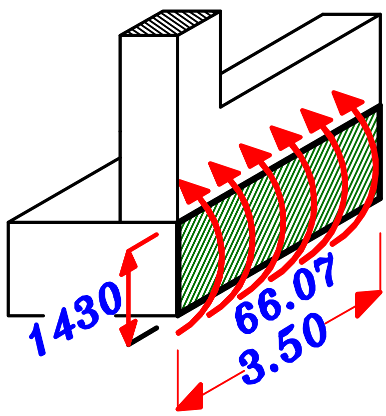
– Actual Normal stress on R.C. Footing (U.L.)

$$F_{1act.} = \frac{R_{1U.L.}}{B_{1R.C.} * L_{1R.C.}} = \frac{1909.05}{3.5 * 1.3} = 419.5 \ kN/m^2$$

– moment = Force * Distance

$$M_{1act.} = 419.5 * 0.3 * 3.5 * 0.15 = 66.07 \ kN/m$$





$\because \ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$ Choose $C_1 = 5.0$

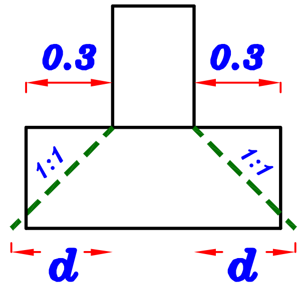
$$\therefore \ d = 5.0 \sqrt{\frac{66.07 * 10^6}{25 * 3500}} = 137.4 \ mm < 330 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 330 + 70 = 400 \ mm$$

$t_{R.C.} = 400 \ mm$ $d = 330 \ mm$

Check Shear.

No shear on the Footing.



Reinforcement of the Footing.

$$J = 0.826$$

$$A_s = \frac{M_{1act.}}{J\, F_y\, d} = \frac{66.07 * 10^6}{0.826 * 360 * 330} = 673.3 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{673.3}{3.50} = 192.3 \ mm^2/m'$$

Check $A_{s\,min}$

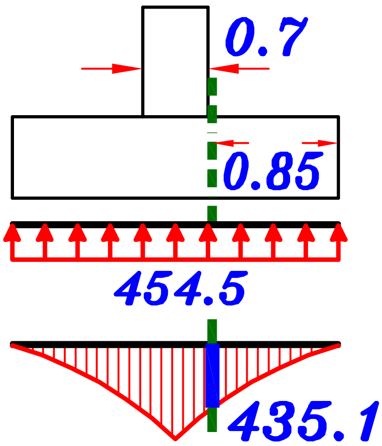
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 330 = 495 \\ 5 \phi 12/m' = 565 \end{array} \right\} 565\, mm^2$$

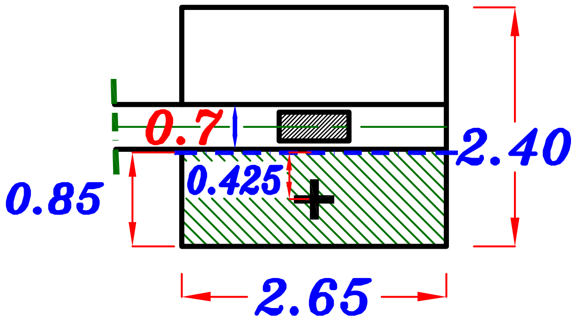
$$\therefore \ A_s < A_{s\,min} \longrightarrow$$

$$A_s = 565 \quad mm^2$$

$$\boxed{5 \phi 12/m'}$$

Footing. F_2





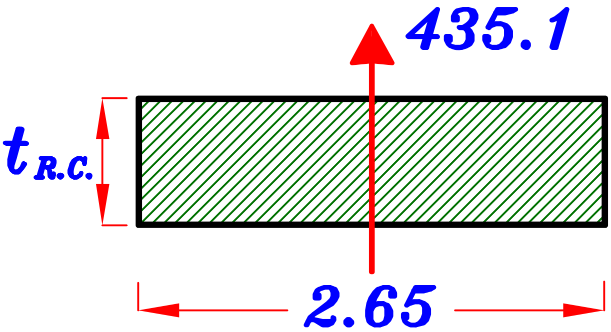
Footing. F_2

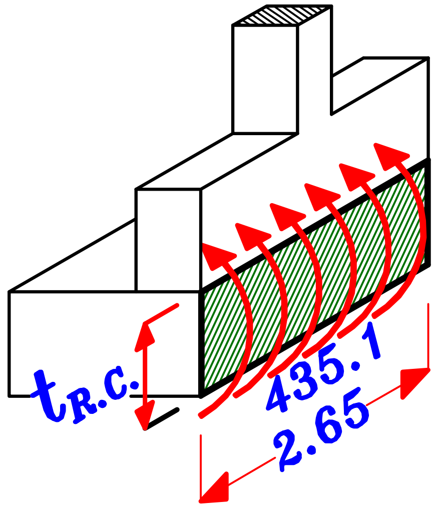
– Actual Normal stress on R.C. Footing (U.L.)

$$F_{2act.} = \frac{R_{2U.L.}}{B_{2R.C.} * L_{2R.C.}} = \frac{2890.95}{2.65 * 2.4} = 454.5 \ kN/m^2$$

– moment = Force * Distance

$$M_{2act.} = 454.5 * 0.85 * 2.65 * 0.425 = 435.1 \ kN/m$$





$$\because \ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

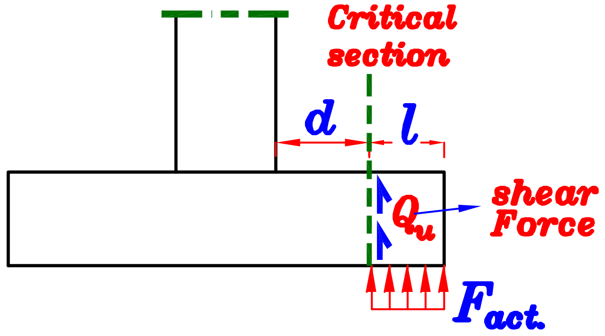
Choose $C_1 = 5.0$

$$\therefore \ d = 5.0 \sqrt{\frac{435.1 * 10^6}{25 * 2650}} = 405.2 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 405.2 + 70 = 475.2 \ mm$$

$t_{R.C.} = 500 \ mm$ | $d = 430 \ mm$

3 – Check Shear.



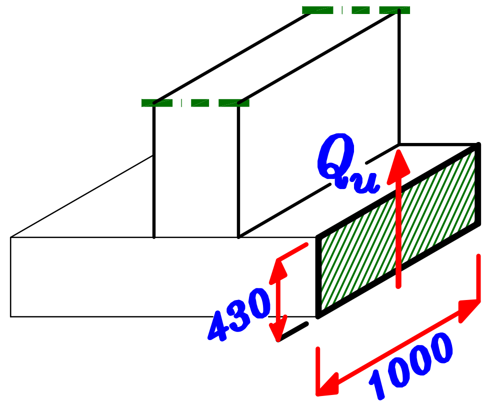
∗ Critical section For Shear.

$$l = z - d$$

$$l = 0.85 - 0.43 = 0.42\ m$$

∗ Actual shear Force. (Q_u)

$$Q_u = F_{act.} * l * 1.0\ m = 454.5 * 0.42 * 1.0 = 190.9\ kN$$



∗ Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{190.9 * 10^3}{1000 * 430} = 0.44\ N/mm^2$$

∗ Allowable shear stress. (q_{su})

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

$$q_u < q_{su}$$ ⟶ Safe shear stresses

No need to increase dimensions.

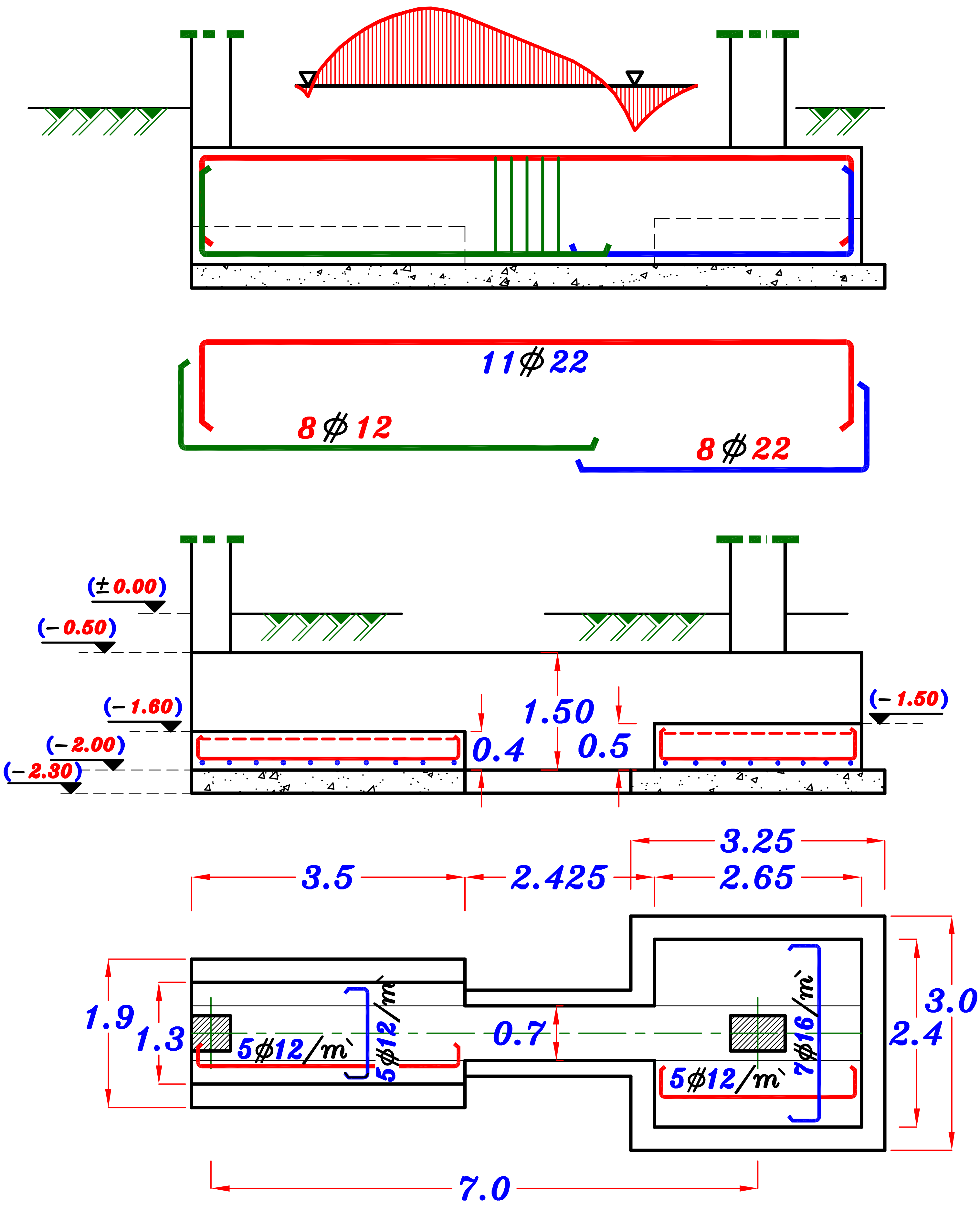
Reinforcement of the Footing.

$$A_s = \frac{M_{2act.}}{J\ F_y\ d} = \frac{435.1 * 10^6}{0.826 * 360 * 430} = 3402.8\ mm^2$$

$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{3402.8}{2.65} = 1284\ mm^2/m'$$

7 ϕ 16 / m'

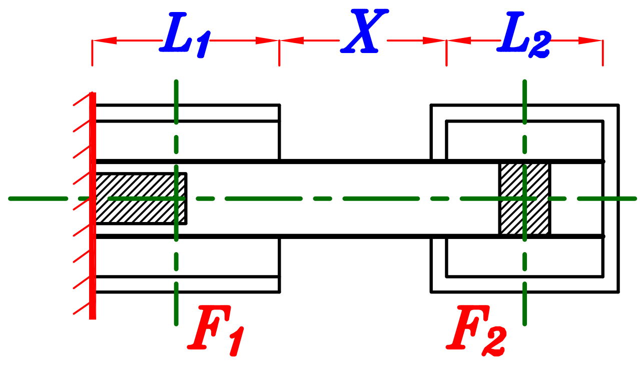
7 – Details of Reinforcement.



2 - Combined Footing For column near an existing (property line)

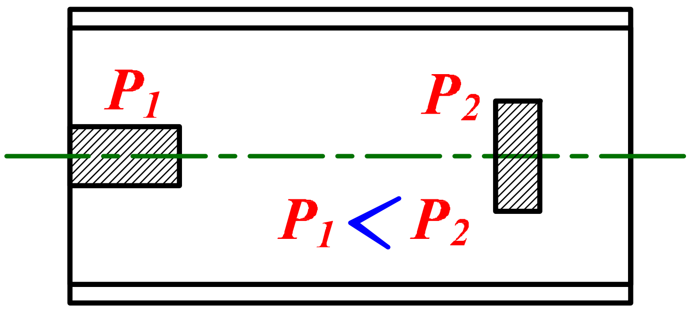
اذا لم ينفع حل ال Strap Beam

عندما تكون IF $X < \frac{L_1}{2}$ & $\frac{L_2}{2}$

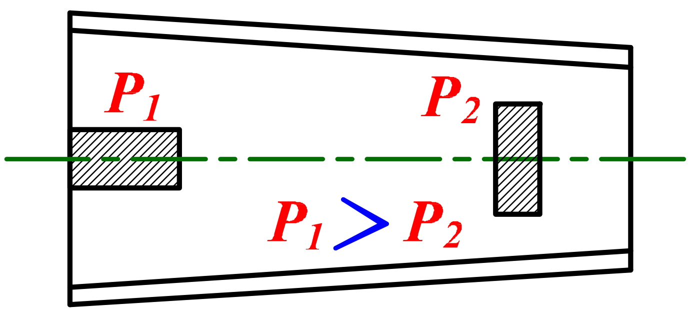


يتم عمل قاعده مشتركه و يكون شكلها كالاتى :

a- IF $P_1 < P_2$ use **Rectangular** combined Footing.

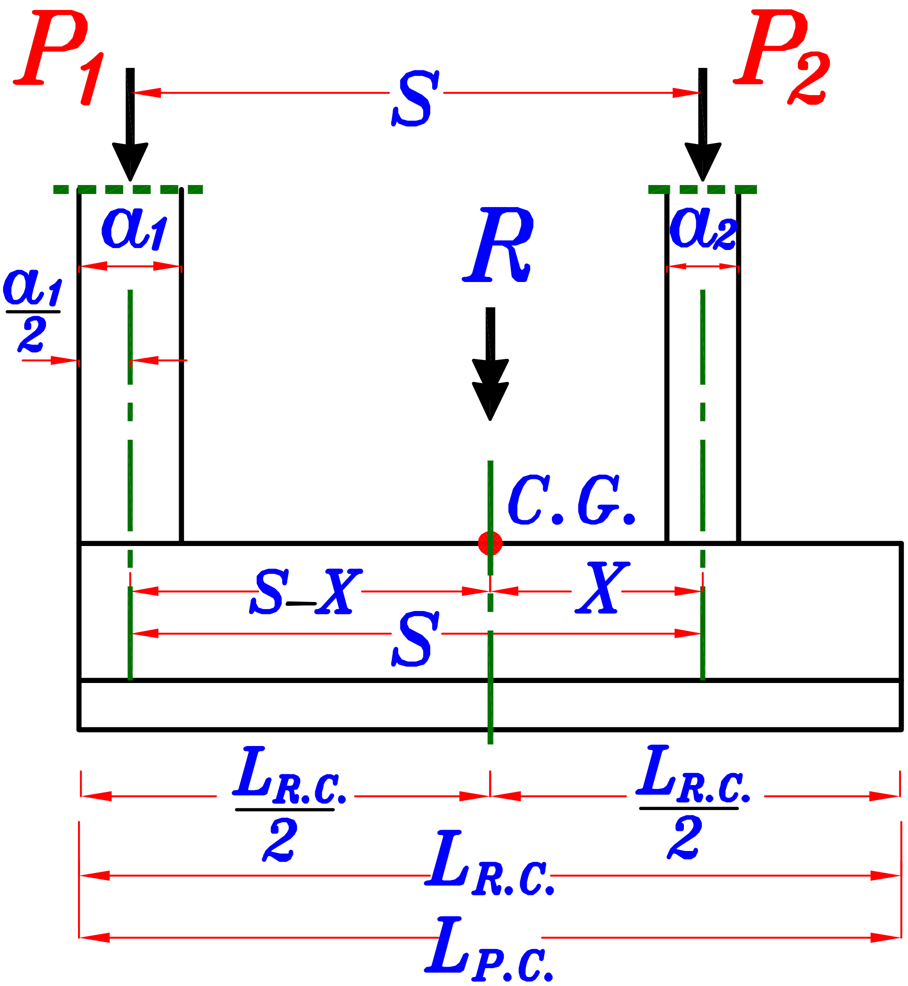


b- IF $P_1 > P_2$ use **Trapezoidal** combined Footing.



α Rectangular Combined Footing. $P_1 < P_2$

قاعده مشتركه مستطيله بجوار حد الجار .



$$R = P_1 + P_2$$

يتم حساب قيمه محصله الاحمال R

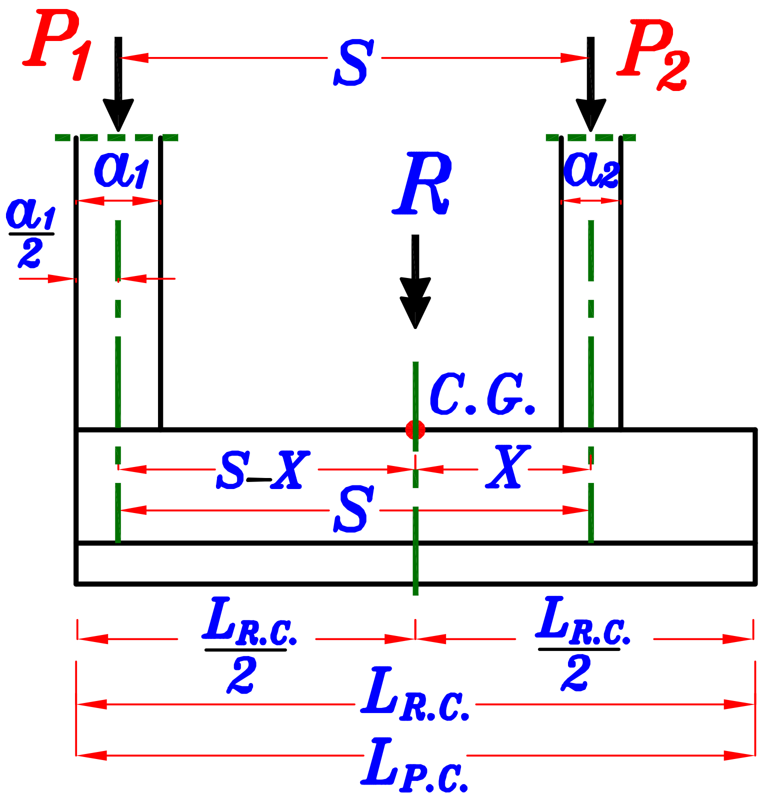
يتم تحديد مكان محصله الاحمال X

$$R * X = P_1 * S \longrightarrow X = \frac{P_1}{R} * S$$

1– Calculate the Footing area. (Width & Length of R.C. Footing.)

$$\frac{L_{R.C.}}{2} = (S-X) + \frac{a_1}{2}$$

$\longrightarrow$ $L_{R.C.} = \checkmark$



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

و ذلك لانه غير مسموح ببروز ال P.C. عن ال R.C. من جهه الجار و بالتالى غير مسموح بالبروز من الجهه الاخرى حتى يظل $C.G._R$ at $C.G._{P.C.}$ at $C.G._{R.C.}$

Calculate the width of the Footing. B

IF $t_{P.C.} \geq 20\ cm$ get $B_{P.C.}$ From

$$A_{P.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = B_{P.C.} * L_{P.C.} \longrightarrow B_{P.C.} = \checkmark$$

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

IF $t_{P.C.} < 20\ cm$ get $B_{R.C.}$ From

$$A_{R.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = B_{R.C.} * L_{R.C.} \longrightarrow B_{R.C.} = \checkmark$$

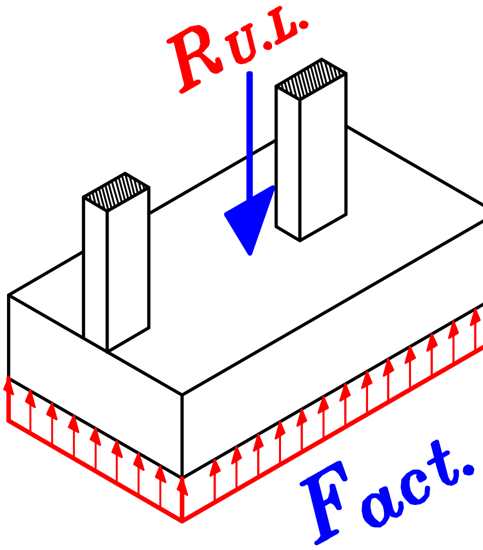
$$B_{P.C.} = B_{R.C.} + 2\ t_{P.C.}$$

2– Design the critical sections For moment. (Depth of R.C. Footing.)

$P_{1\,U.L.} = 1.5 * P_{1w}$, $P_{2\,U.L.} = 1.5 * P_{2w}$, $R_{U.L.} = 1.5 * R_w$

– **Actual Normal stress on R.C. Footing (U.L.)**

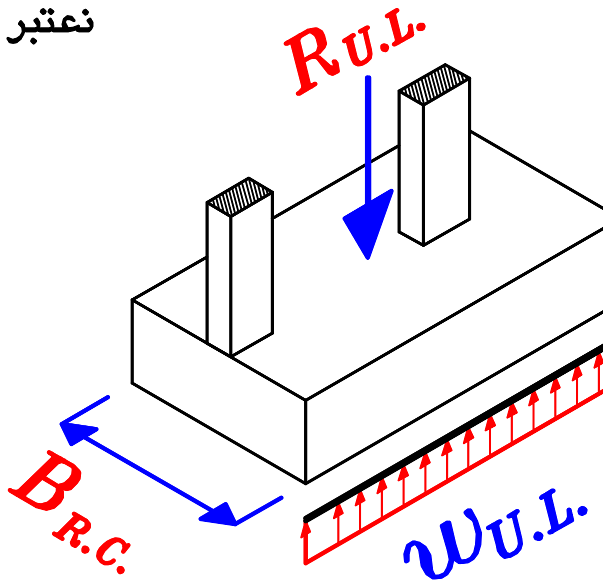
$$F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}} \quad (kN/m^2)$$



– **Actual Uniform Load on R.C. Footing (U.L.) as a beam.**

$B_{R.C.}$ نعتبر أن القاعده عباره عن كمره بعرض

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m')$$



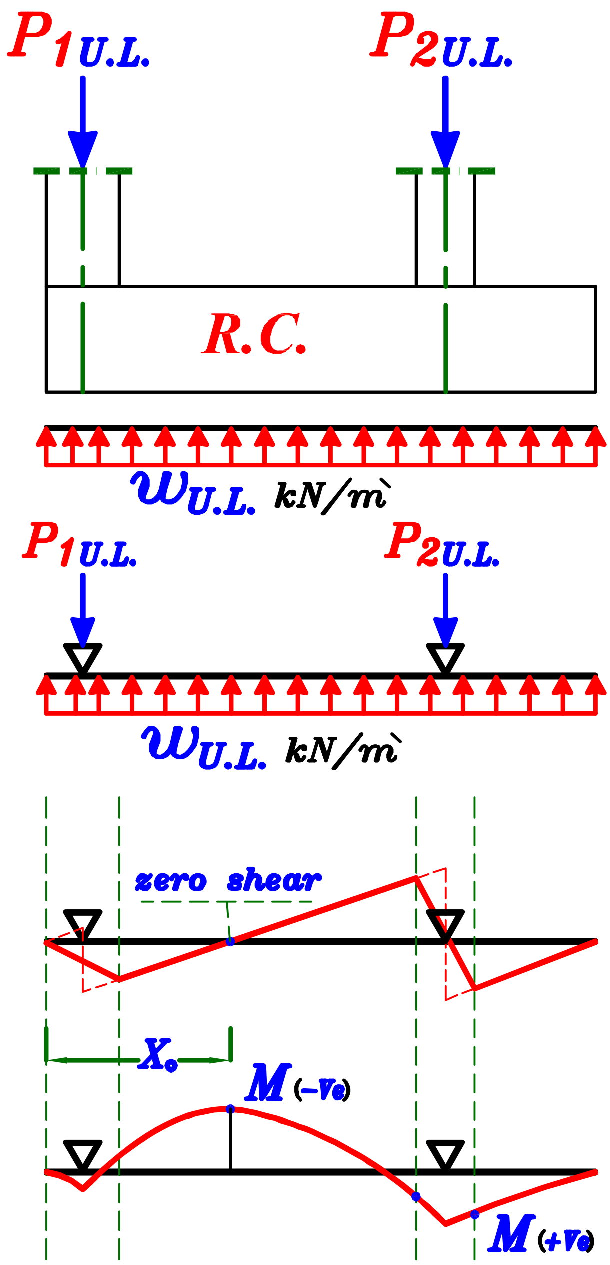
Drawing U.L. B.M.D. & S.F.D. on the all R.C. Footing.

Longitudinal direction.

نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$

يتم رسم B.M.D. , S.F.D. للقاعده كلها كأنها كمره بعرض $B_{R.C.}$

و يتم حساب قيم B.M. , S.F. على وش الاعمده .



S.F.D

B.M.D

لتحديد أكبر moment فى منتصف القاعده $M_{(-Ve)}$

يتم تحديد مكان نقطه zero shear أى حساب المسافه X_o

$P_{1\,U.L.} = w_{U.L.} * X_o$ → $X_o = \checkmark$ → $M_{(-Ve)} = \checkmark$

$M_{max.}$ is the bigger moment of $M_{(+Ve)}$ & $M_{(-Ve)}$

$$d\ (mm) = C_1 \sqrt{\frac{M_{max}\ (kN.m) * 10^6}{F_{cu}\ (N/mm^2) * B_{R.C.}\ (mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$ Get $d = \checkmark\checkmark$ (mm)

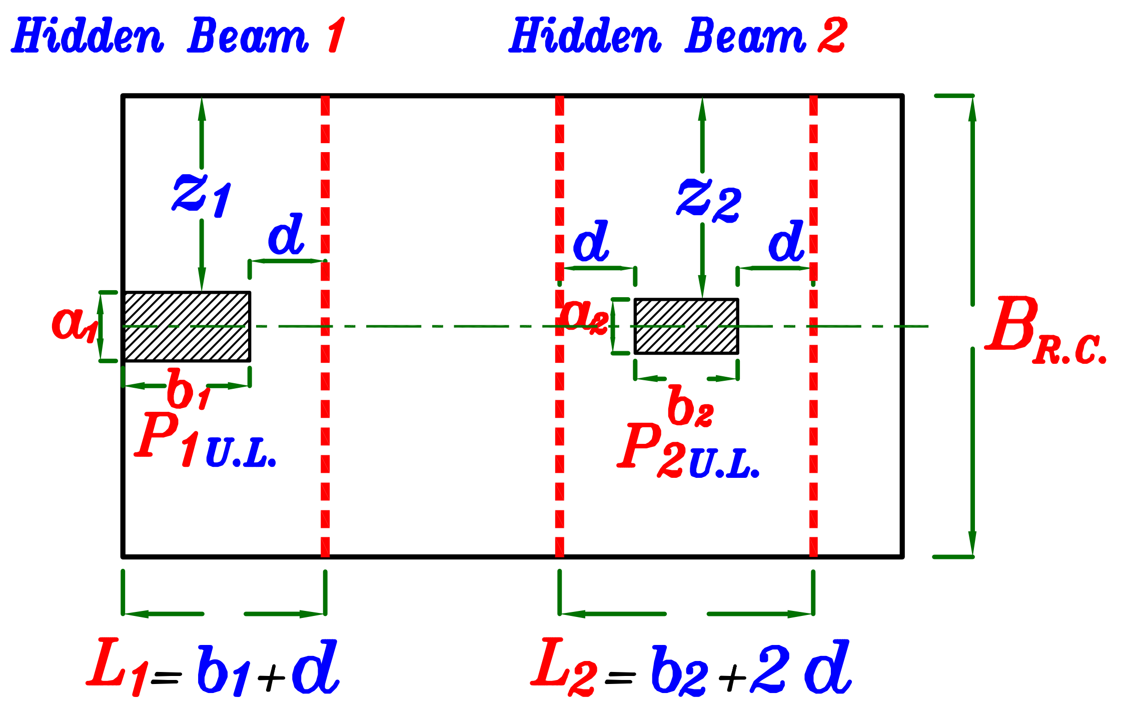
$$t_{R.C.} = d + cover\ (70\ mm)$$

Check depth in Transverse direction. Short direction.

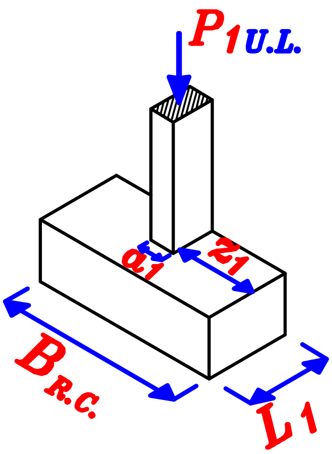
As a Hidden Beam.

نعتبر القاعده أسفل كل عمود كأنها كمره مدفونه **(Hidden Beam)**

أبعادها أسفل العمود $L * B_{R.C.}$



Hidden Beam 1

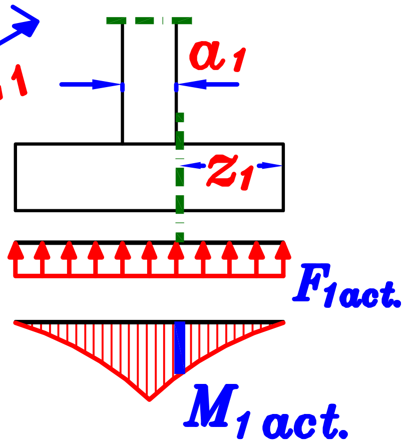


$$F_{1act.} = \frac{P_{1U.L.}}{B_{R.C.} * L_1} \quad (kN/m^2)$$

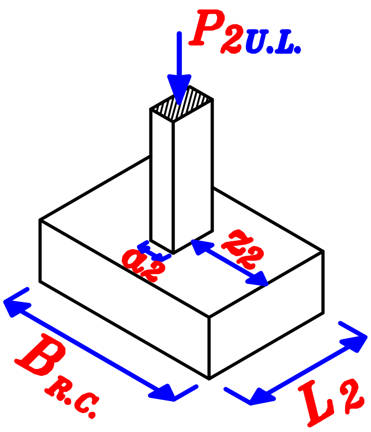
$$z_1 = \frac{B_{R.C.} - a_1}{2} \quad (m)$$

$$M_{1act.} = (F_{1act.} * z_1 * 1.0m)\ \frac{z_1}{2}$$

$(kN.m/1.0m)$



Hidden Beam 2

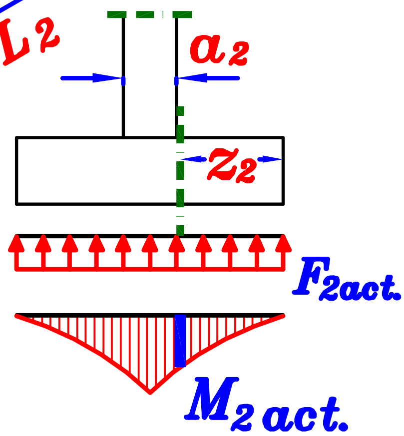


$$F_{2act.} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} \quad (kN/m^2)$$

$$z_2 = \frac{B_{R.C.} - a_2}{2} \quad (m)$$

$$M_{2act.} = (F_{2act.} * z_2 * 1.0m)\ \frac{z_2}{2}$$

$(kN.m/1.0m)$



Choose M_{bigger} The bigger value of $M_{1act.}$ & $M_{2act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{Get} C_1$$

Then Check on $C_1 \not< 3.0$

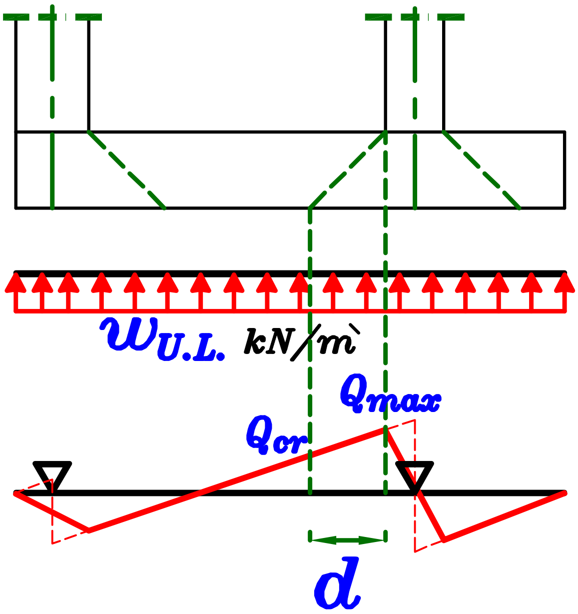
IF $C_1 < 3.0 \longrightarrow$ Increase d

and Recheck the transverse direction.

3 – Check Shear. at long direction

Critical section For Shear.

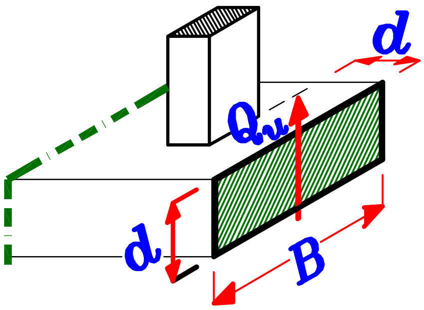
$Q_{max.}$ على بعد d من وش العمود اللى عنده



$$Q_{cr.} = Q_{max.} - w_{U.L.} * d$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}\ (kN) * 10^3}{B\ (mm) * d\ (mm)} \quad (N/mm^2)$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

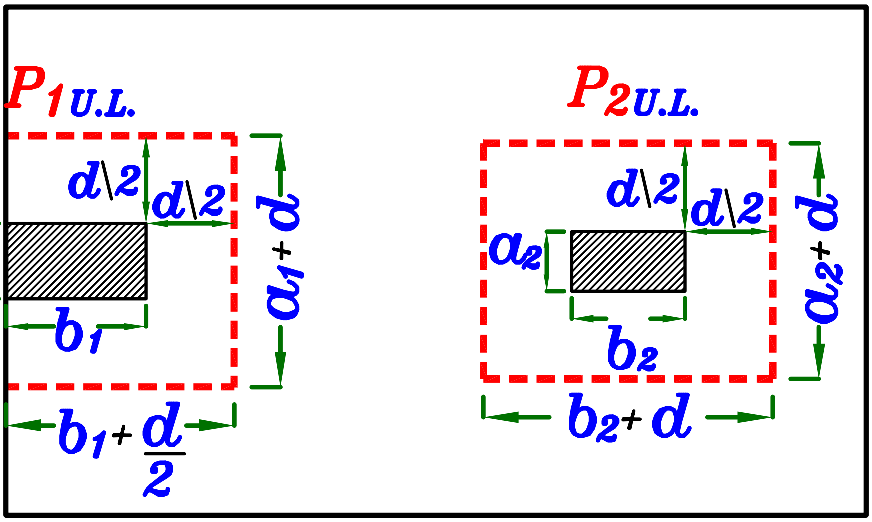
* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leq q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

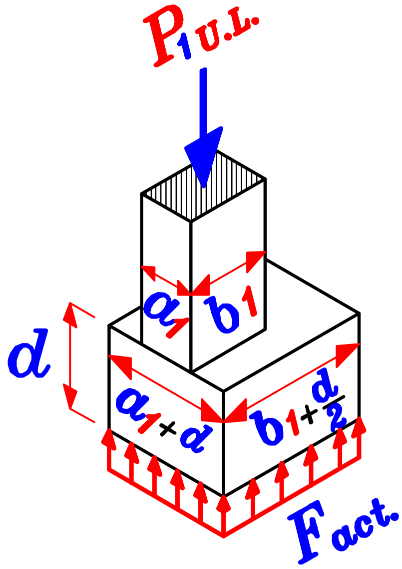
* IF $q_u > q_{su}$ ⟶ UnSafe shear stresses
We have to increase dimensions.

4 – Check Punching Shear. القص الثاقب .



Column 1

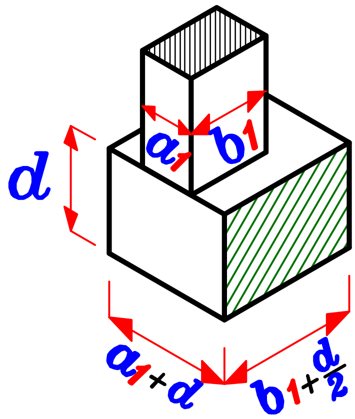
* Calculate Punching Force. (Q_{1p})



$$Q_{1p} = P_{1\,U.L.} - (F_{act.})\left[(a_1+d)(b_1+\frac{d}{2})\right]$$

(kN)

* Calculate Punching shear area. (A_{1p})



المحيط العمق

$$A_{1p} = \left[(a_1+d) + 2\,(b_1+\frac{d}{2})\right] * d$$

(mm^2)

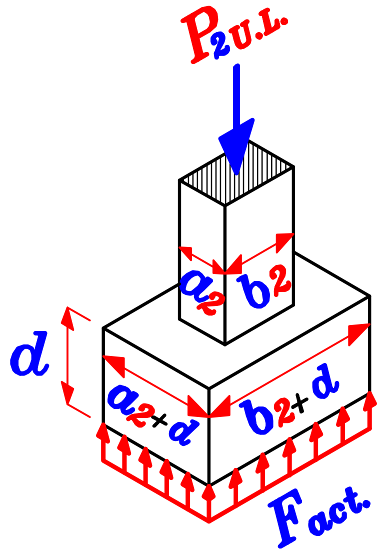
* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{Q_{1p}\ (kN) * 10^3}{\left[(a_1+d)+2\,(b_1+\frac{d}{2})\right] * d\ (mm^2)}$$

(N/mm^2)

Column 2

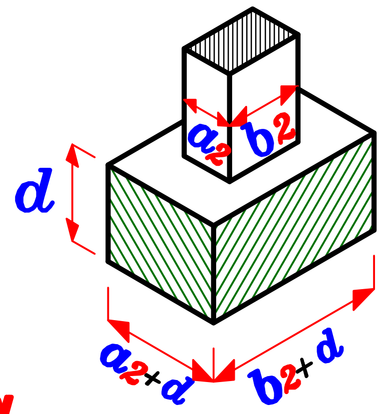
* Calculate Punching Force. (Q_{2p})



$$Q_{2p} = P_{2\,U.L.} - (F_{act.})\left[(a_2+d)(b_2+d)\right]$$

(kN)

* Calculate Punching shear area. (A_{2p})



المحيط العمق

$$A_{2p} = \left[2(a_2+d) + 2(b_2+d)\right] * d$$

(mm^2)

* Calculate Actual Punching shear stress. q_{2pu}

$$q_{2pu} = \frac{Q_{2p}\ (kN) * 10^3}{\left[2(a_2+d)+2(b_2+d)\right] * d\ (mm^2)}$$

(N/mm^2)

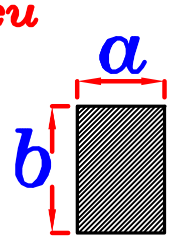
Choose q_{pumax} the bigger value of q_{1pu} & q_{2pu}

---

* Calculate allowable Punching shear stress. q_{pcu}

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\delta_c}}$$

(N/mm^2)



IF $\left(0.5 + \frac{a}{b}\right) \leq 1.0$ Take → $q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\delta_c}}$ (N/mm^2)

* Compare between

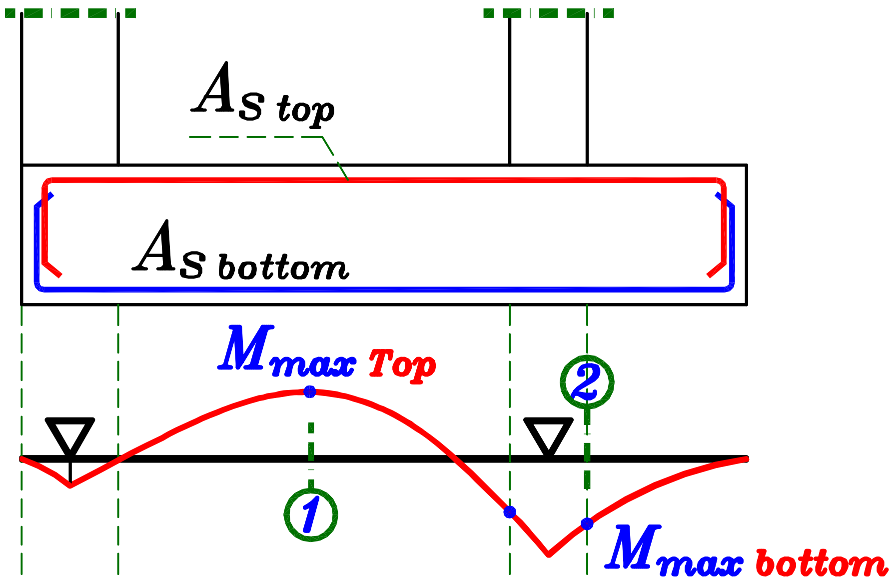
Actual punching shear stress ($q_{pu_{max}}$) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu_{max}} \leqslant q_{pcu}$ → Safe punching shear. No need to increase dimensions.

* IF $q_{pu_{max}} > q_{pcu}$ → UnSafe punching shear. We have to increase dimensions.

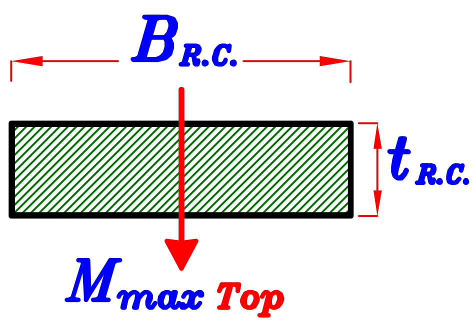
5- Reinforcement of the Footing.

Longitudinal direction.



B.M.D

Sec. ①



From $d = C_1 \sqrt{\dfrac{M_{max\ Top}}{F_{cu} * B_{R.C.}}}$ $\xrightarrow{Get}$ $C_1 \longrightarrow J$

Get $$A_{s\,top} = \frac{M_{max\ Top}}{J\ F_y\ d} \quad (mm^2)$$

Check $A_{s\,min}$

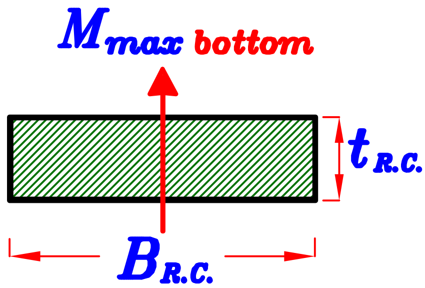
$$A_{s\,min}\ (mm^2/m) = \begin{Bmatrix} 1.5\,d\ (mm) \\ 5\phi 12/m' \end{Bmatrix} \text{ الأكبر}$$

IF $A_{s\,top} \geqslant A_{s\,min} \longrightarrow o.k.$

IF $A_{s\,top} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

Sec. ②

From $$d = C_1 \sqrt{\frac{M_{max\ bottom}}{F_{cu} * B_{R.C.}}}$$



$\xrightarrow{Get} C_1 \longrightarrow J$

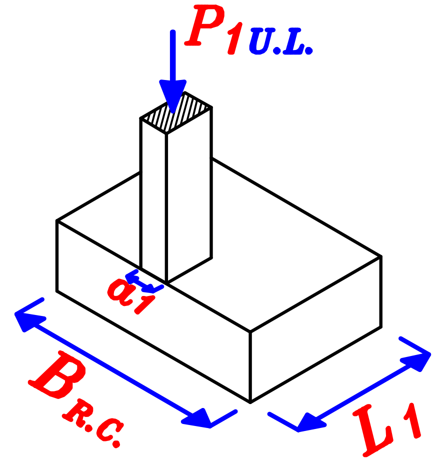
Get $$A_{s\,bottom} = \frac{M_{max\ bottom}}{J\ F_y\ d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{Bmatrix} 1.5\,d\ (mm) \\ 5\phi 12/m' \end{Bmatrix} \text{ الأكبر}$$

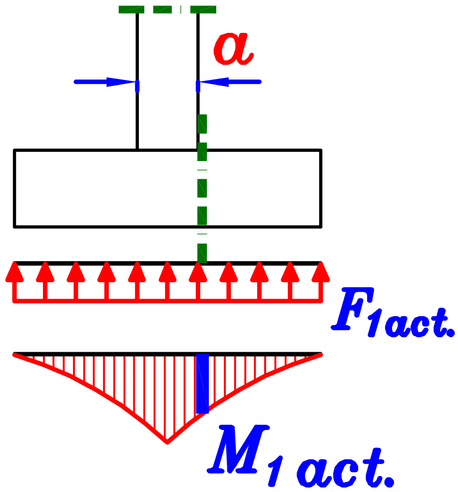
Transverse direction. Short direction.

Hidden Beam 1



From $d = C_1 \sqrt{\dfrac{M_{1act.}}{F_{cu} * 1000}}$

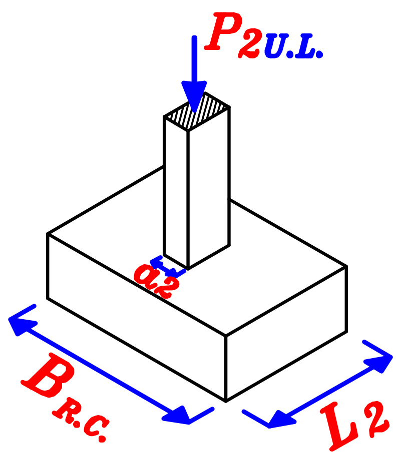
$\xrightarrow{Get} C_1 \longrightarrow J$



Get $$A_{s1} = \frac{M_{1act.}}{J\ F_y\ d} \quad (mm^2/m')$$

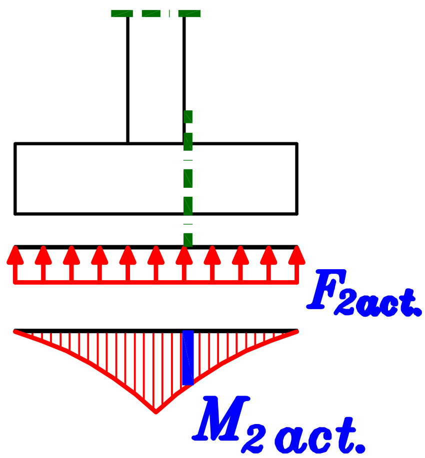
Check $A_{s_{min}}$

Hidden Beam 2



From $d = C_1 \sqrt{\dfrac{M_{2act.}}{F_{cu} * 1000}}$

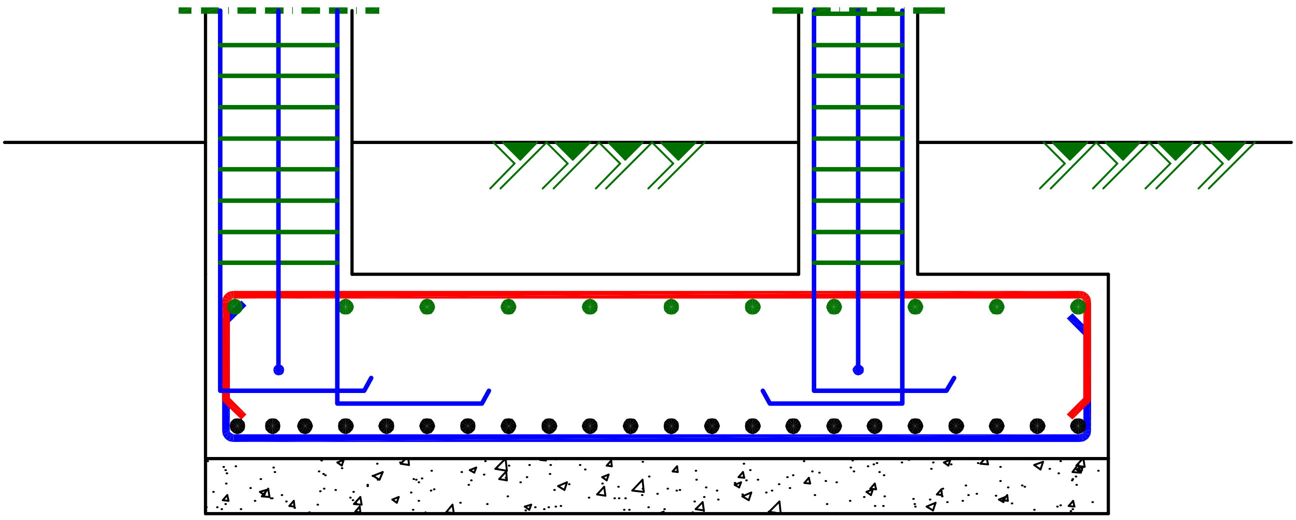
$\xrightarrow{Get} C_1 \longrightarrow J$



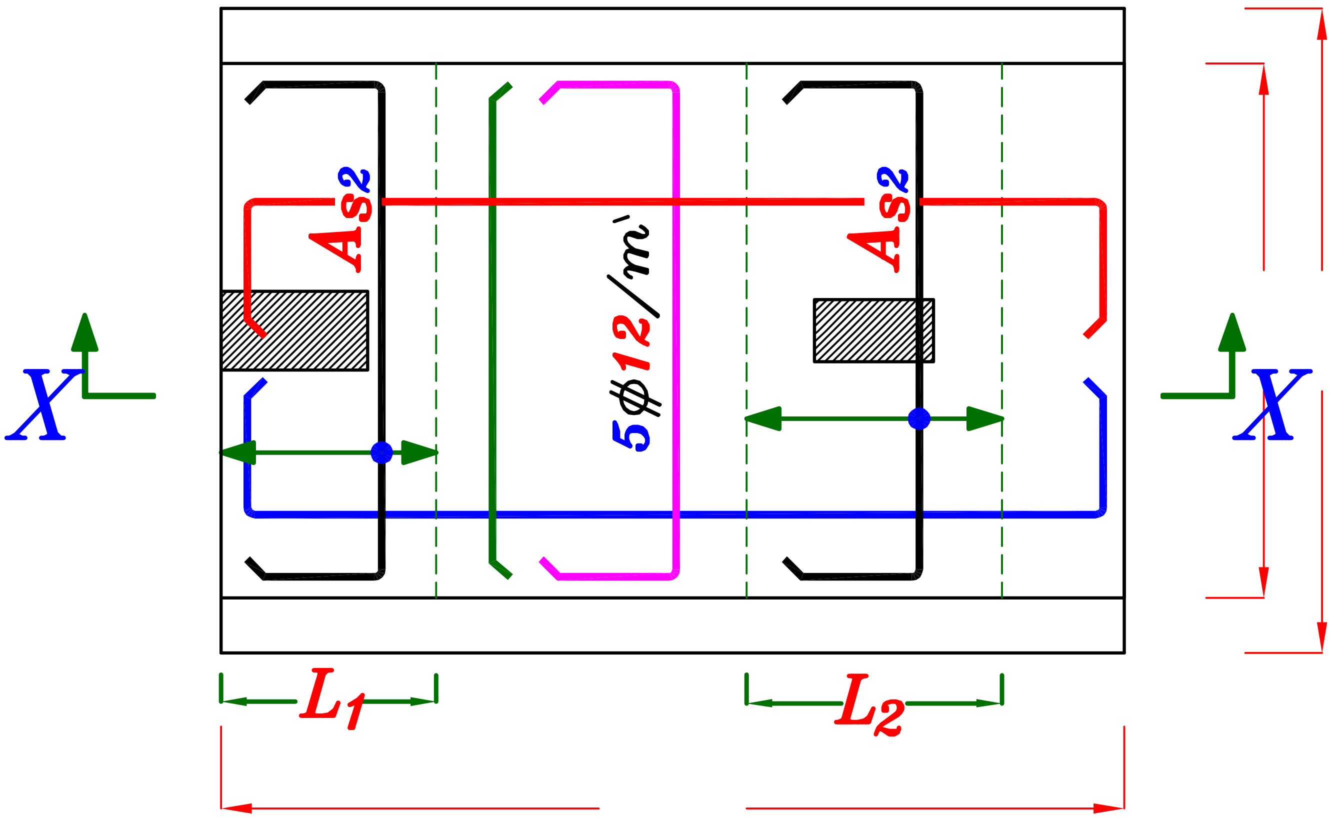
Get $$A_{s2} = \frac{M_{2act.}}{J\ F_y\ d} \quad (mm^2/m')$$

Check $A_{s_{min}}$

6 – Details of Reinforcement.



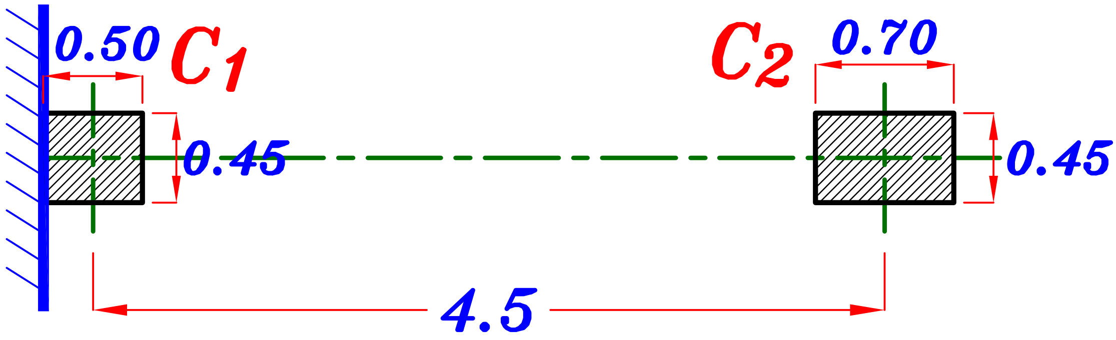
Sec X–X



Plan

Example.

It is required to design Footings to support a proterty line column C_1 (45 * 50) cm. and carrying working load 1000 kN and interior column C_2 (45 * 70) cm. and carrying working load 2200 kN the spacing between the C.L. of the two columns is 4.5 m as shown



and the allowable net bearing capacity in the Footing site is 200 kN/m^2. (F_{cu} = 25 N/mm^2, F_y = 360 N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given:

Column C_1 dimensions (450 * 500) mm

P_1 (working) = 1000 kN $\quad$ P_1 (U.L.) = 1000 * 1.5 = 1500 kN

Column C_2 dimensions (450 * 700) mm

P_2 (working) = 2200 kN $\quad$ P_2 (U.L.) = 2200 * 1.5 = 3300 kN

$R_{(working)} = P_1 + P_2 = 3200$ kN

$R_{(U.L.)} = 1.5 * 3200 = 4800$ kN

Bearing capacity of the soil = $q_{all} = 200$ kN/m^2

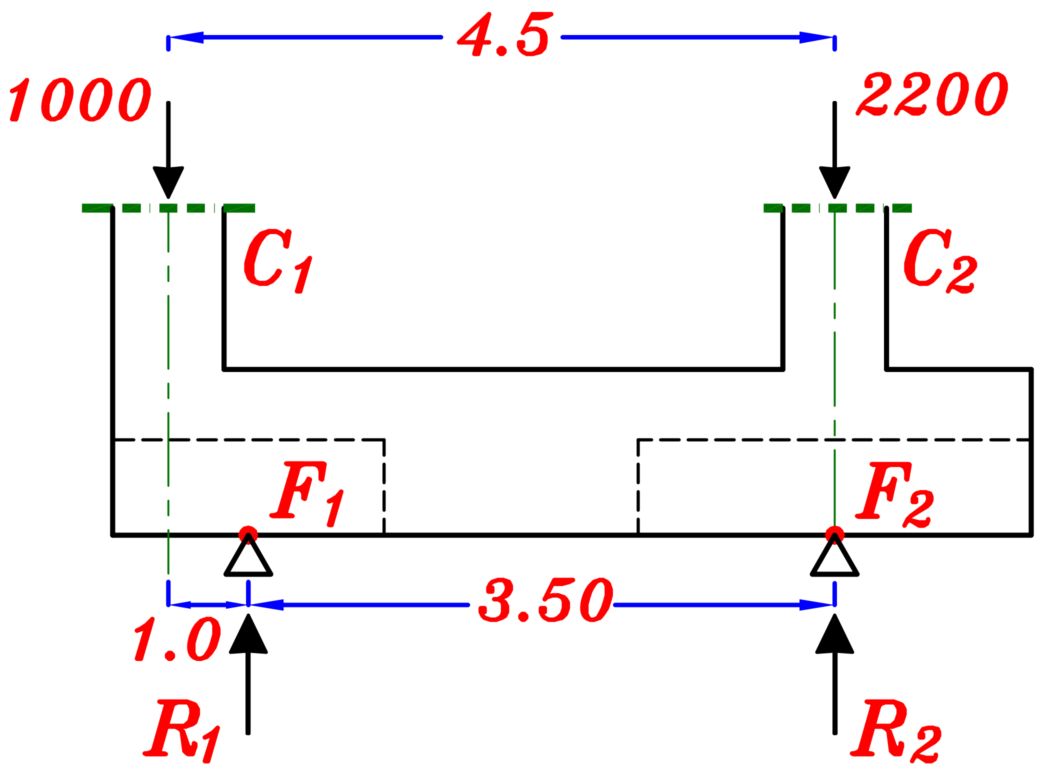
$F_{cu} = 25$ N/mm^2 $\quad$ $F_y = 360$ N/mm^2

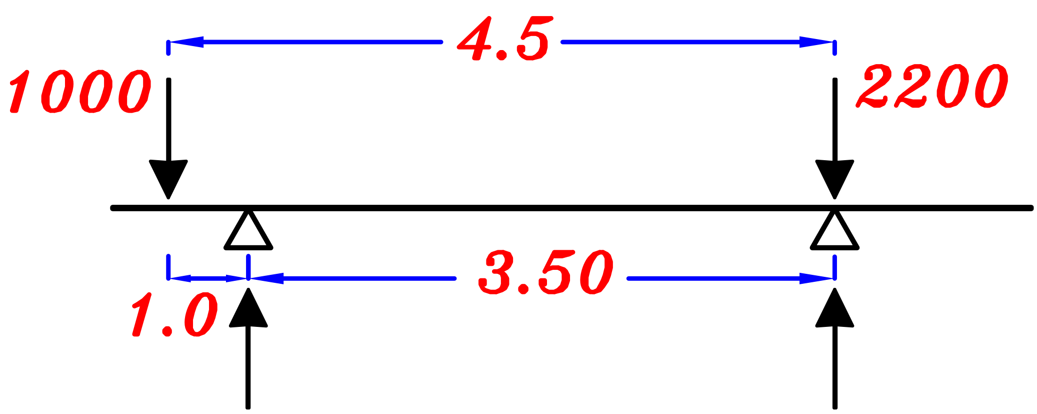
For property line use
Strap Beam or Combined Footing.

Start with Strap Beam.

1- *Calculate the Footing area.* (*Width & Length of R.C. Footings.*)

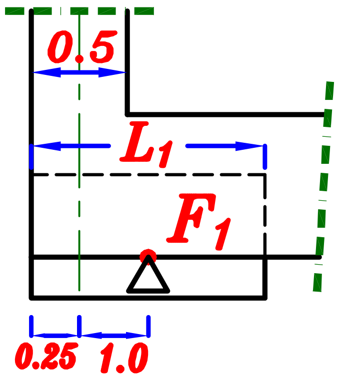
Take $e = 0.1 + 0.2\,(S) = 0.1 + 0.2\,(4.5) = 1.0\ m$





$R_1 = 1285.7\ kN$ $R_2 = 1914.3\ kN$

Footing F_1



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

$$L_{1\,P.C.} = 2\left(e + \frac{C_1}{2}\right) = 2\,(1.0 + 0.25) = 2.50\ m$$

get $B_{1\,P.C.}$ From $A_{P.C.} = \dfrac{R_1}{q_{all}} = A_{P.C.} = B_{1P.C.} * L_{1P.C.}$

$$A_{P.C.} = \frac{1285.7}{200} = B_{1P.C.} * 2.50 \longrightarrow B_{1P.C.} = 2.57\ m$$

$B_{1P.C.} = 2.60\ m$	$L_{1P.C.} = 2.50\ m$
$B_{1R.C.} = 2.0\ m$	$L_{1R.C.} = 2.50\ m$

Footing F_2

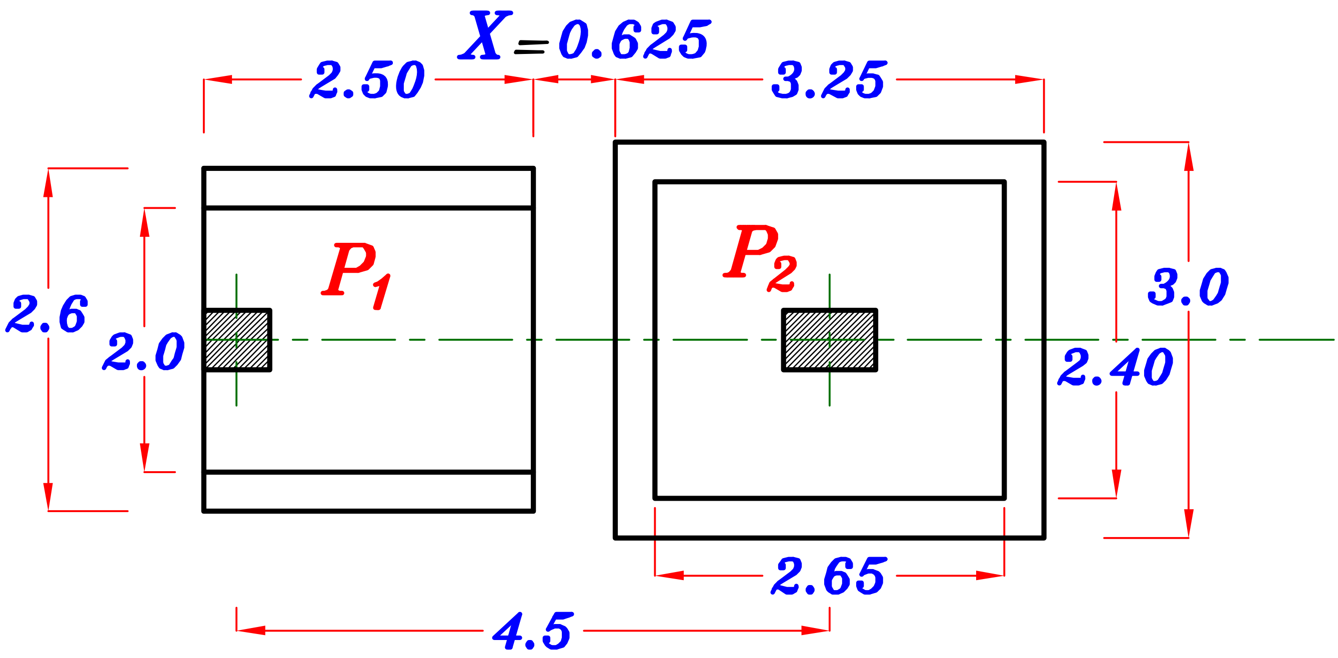
$$L_{2P.C.} - B_{2P.C.} = b - a = 0.70 - 0.45 = 0.25\ m$$

$$L_{2P.C.} = B_{2P.C.} + 0.25\ m \quad \text{------} (1)$$

$$A_{2P.C.} = \frac{R_2}{q_{all}} = \frac{1914.3\ (kN)}{200\ (kN/m^2)} = 9.57\ m^2$$

$$A_{2P.C.} = B_{2P.C.} * L_{2P.C.} = 9.57\ m^2 \quad \text{-----} (2)$$

$B_{2P.C.} = 3.0\ m$	$L_{2P.C.} = 3.25\ m$
$B_{2R.C.} = 2.40\ m$	$L_{2R.C.} = 2.65\ m$

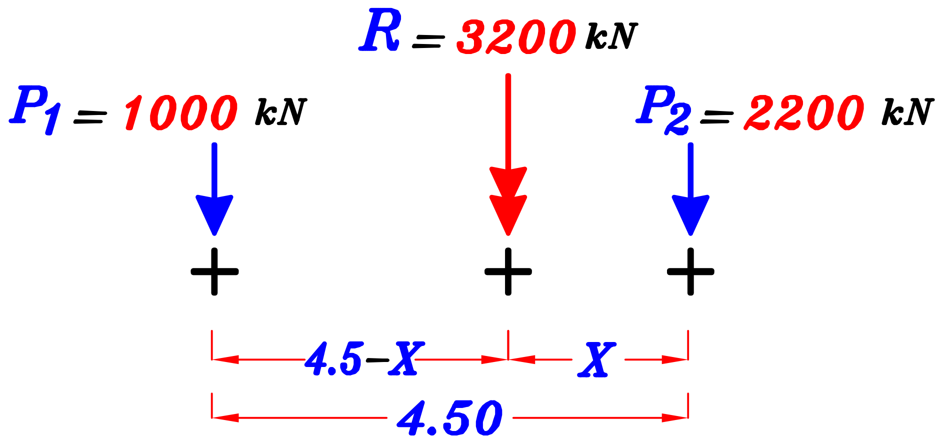


$X = 0.625\ m \quad \therefore \quad X < \frac{L_1}{2} \text{ or } \frac{L_2}{2}$

$\because \quad P_1 < P_2$

$\therefore$ **use Rectangular Combined Footing**

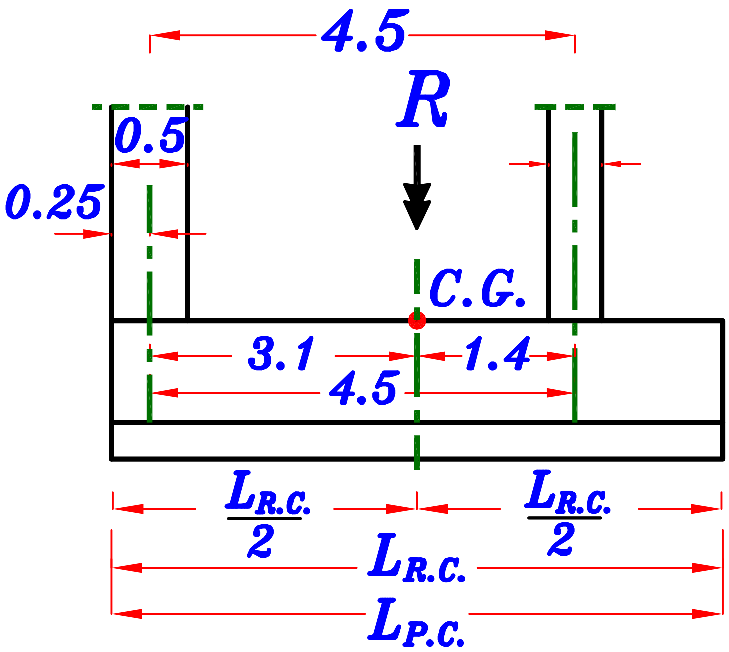
1– Calculate the Footing area. (Width & Length of R.C. Footing.)



$$X = \frac{P_1}{R} * S = \frac{1000}{3200} * 4.5 = 1.40 \ m$$

$$R = P_1 + P_2 = 1000 + 2200 = 3200 \ kN$$

$$L_{R.C.} = 2(3.1 + 0.25) = 6.70 \ m$$



$$L_{R.C.} = 6.70 \ m$$

$$L_{P.C.} = 6.70 \ m$$

Calculate the width of the Footing. B

$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{3200}{200} = 16.0 \ m^2 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 6.70$$

$B_{P.C.} = 2.39 \ m$

$B_{P.C.} = 2.40 \ m$

$B_{R.C.} = 1.80 \ m$

2- Design the critical sections For moment. (Depth of R.C. Footing.)

$P_{1U.L.} = 1.5 * 1000 = 1500$ kN

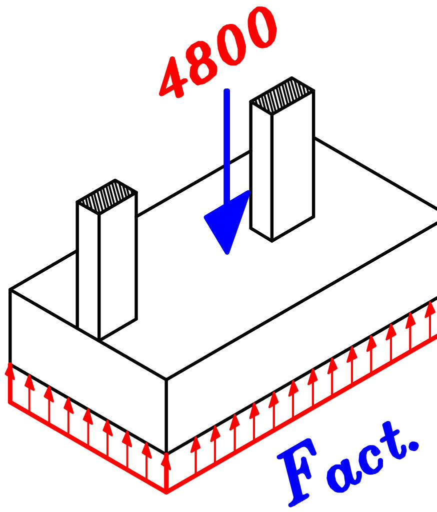
$P_{2U.L.} = 1.5 * 2200 = 3300$ kN

$R_{U.L.} = 1.5 * 3200 = 4800$ kN

- Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}}$$

$$F_{act.} = \frac{4800}{1.8 * 6.7} = 398.0 \ kN/m^2$$

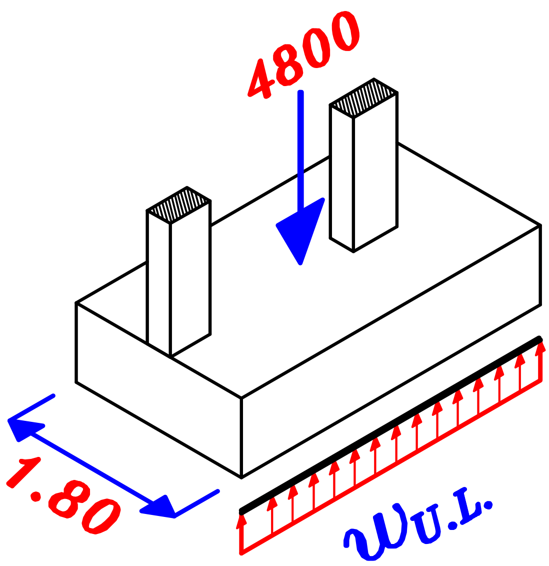


$$\boxed{F_{act.} = 398.0} \ kN/m^2$$

- Actual Uniform Load on R.C. Footing (U.L.) as a beam.

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m')$$

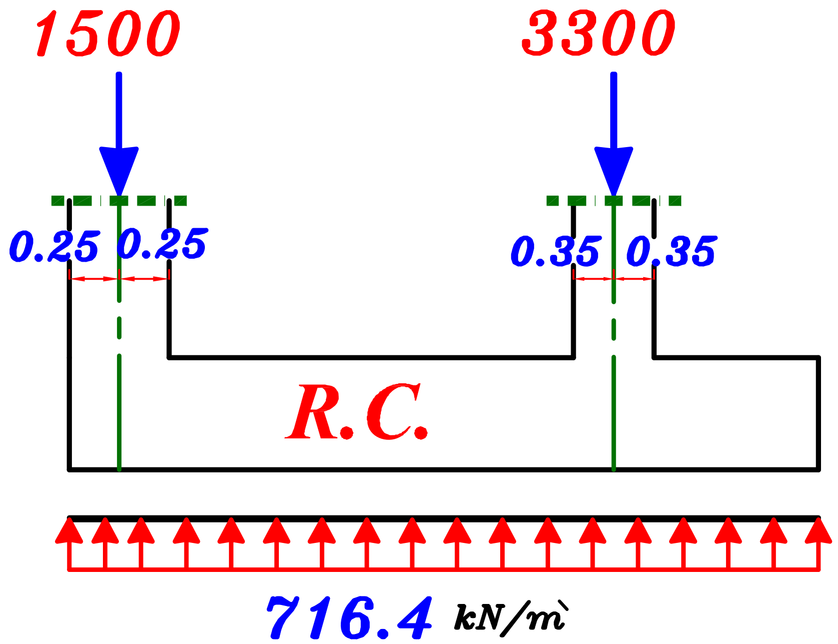
$$w_{U.L.} = \frac{4800}{6.7} = 716.4 \ kN/m'$$

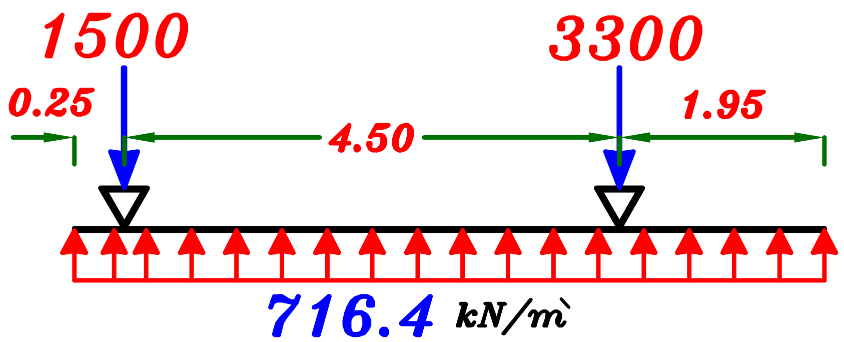


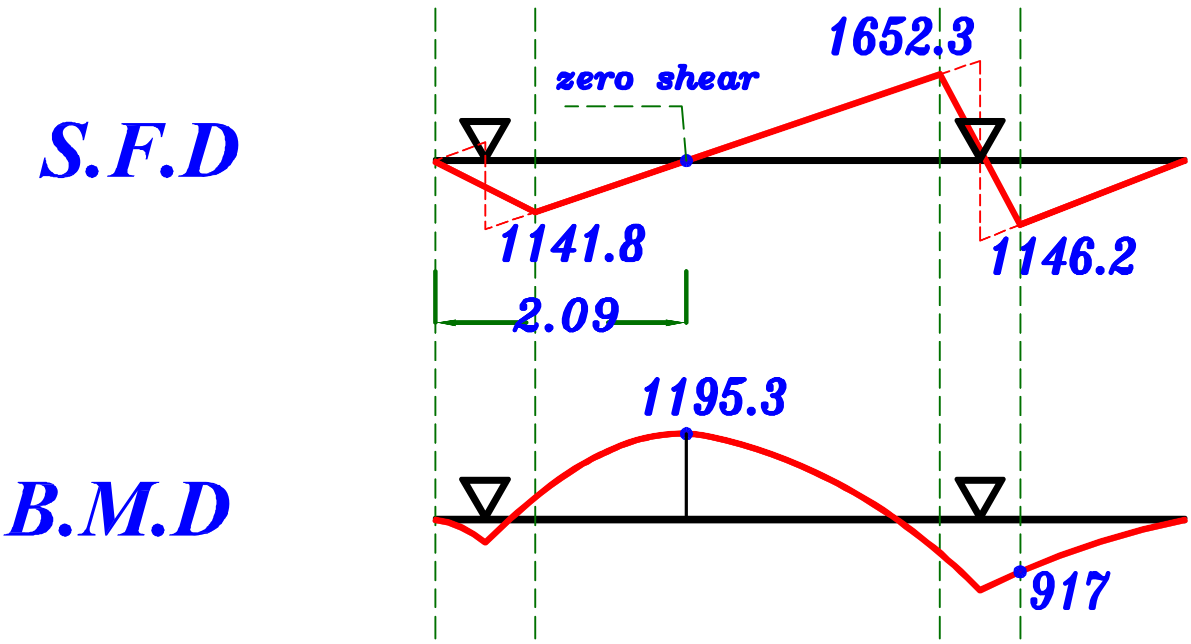
$$\boxed{w_{U.L.} = 716.4} \ kN/m'$$

Drawing U.L. B.M.D. & S.F.D. on the all R.C. Footing.

Longitudinal direction.







$$\because\ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

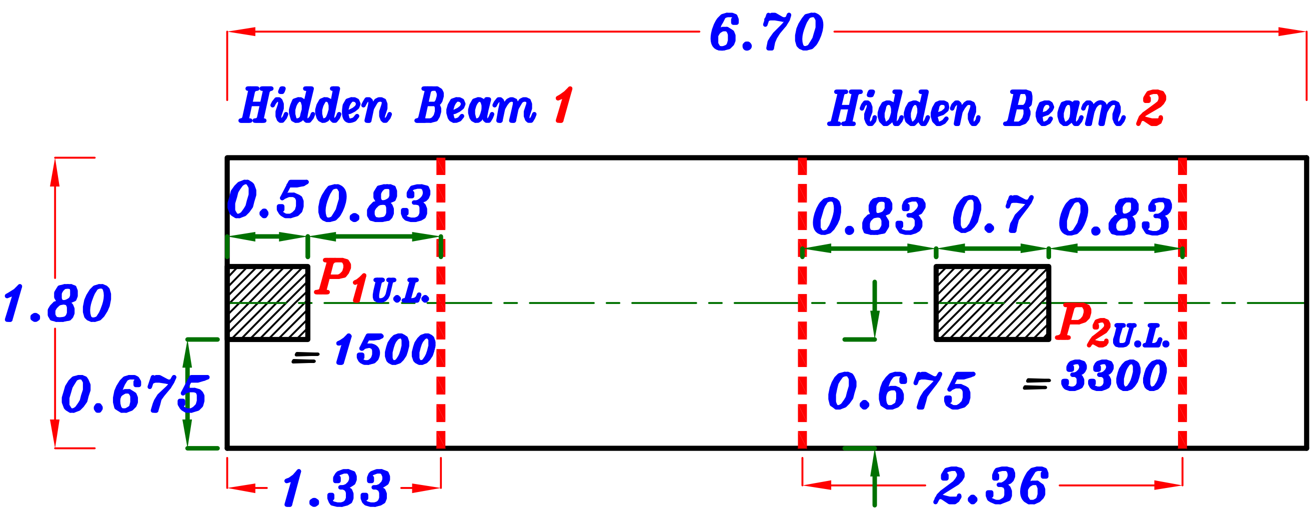
$$\therefore\ d = 5.0 \sqrt{\frac{1195.3 * 10^6}{25 * 1800}} = 814.9\ mm$$

$$t_{R.C.} = d + 70\ mm = 814.9 + 70 = 884.9\ mm$$

$t_{R.C.} = 900\ mm$ **$d = 830\ mm$**

Check depth in Transverse direction.

As a Hidden Beam.



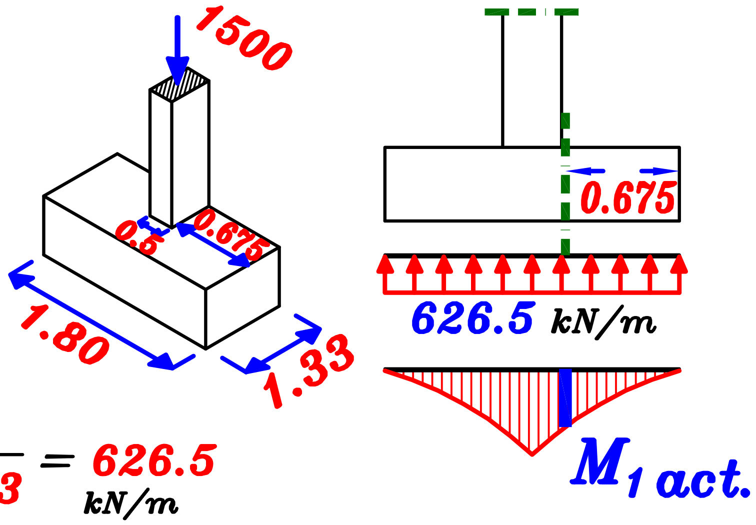
$L_1 = 0.5 + 0.83$

$L_1 = 1.33\ m$

$L_2 = 0.7 + 2 * 0.83$

$L_2 = 2.36\ m$

Hidden Beam 1

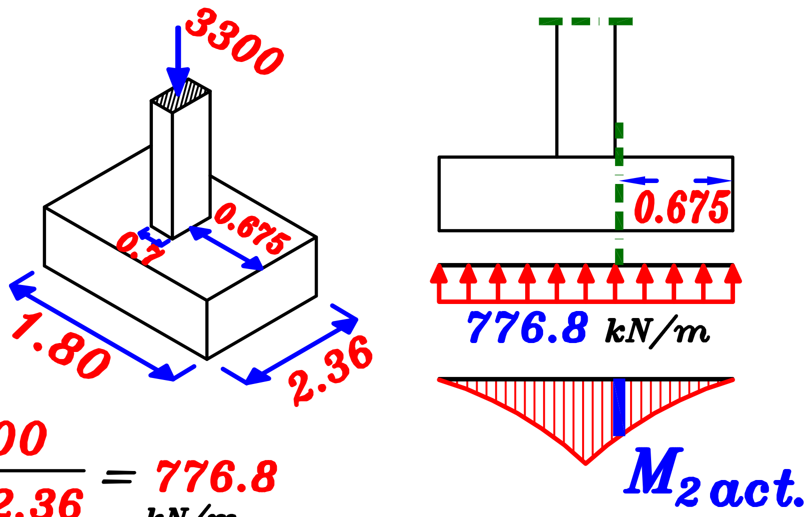


$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} = \frac{1500}{1.8 * 1.33} = 626.5 \text{ kN/m}$$

$$M_{1act.} = (626.5 * 0.675 * 1.0\,m)\,\frac{0.675}{2}$$

$$M_{1act.} = 142.7 \text{ kN.m/m}$$

Hidden Beam 2



$$F_{2act.} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} = \frac{3300}{1.8 * 2.36} = 776.8 \text{ kN/m}$$

$$M_{2act.} = (776.8 * 0.675 * 1.0\,m)\,\frac{0.675}{2}$$

$$M_{2act.} = 176.9 \text{ kN.m/m}$$

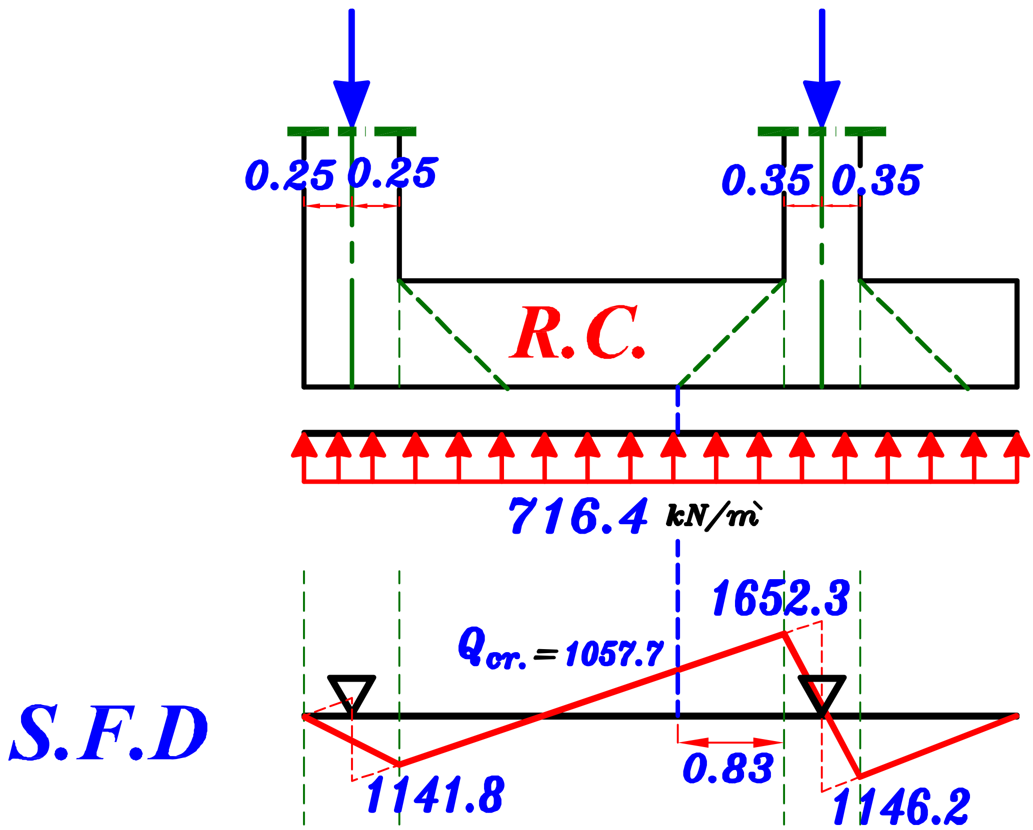
M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$M_{bigger} = 176.9 \text{ kN.m/m}$$

$$830 = C_1 \sqrt{\frac{176.9 * 10^6}{25 * 1000}} \longrightarrow C_1 = 9.86 > 3.0 \therefore ok.$$

3 – Check Shear. at long direction

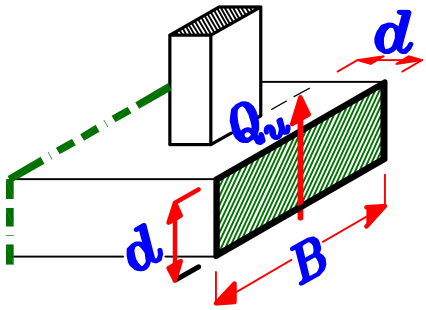
Critical section For Shear.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * d = 1652.3 - 716.4 * 0.83 = 1057.7 \text{ kN}$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}}{B * d} = \frac{1057.7 * 10^3}{1800 * 830} = 0.707 \text{ kN/m}^2$$



* Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\delta_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

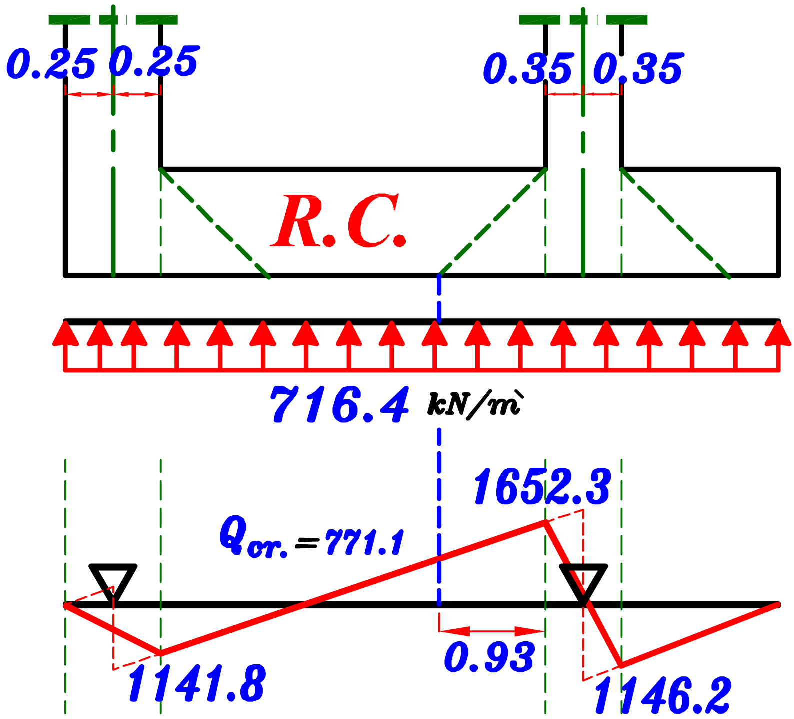
$q_u > q_{su}$ ⟶ UnSafe shear stresses

We have to increase Depth

Increase the depth of the Footing.

يتم زياده *depth* القاعده ١٠ سم ثم يتم عمل **Check Shear**

Take $t_{R.C.} = 1000\ mm$ $\quad$ $d = 930\ mm$

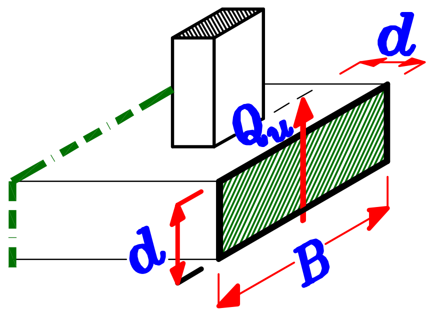


S.F.D

$$Q_{cr.} = Q_{max.} - w_{U.L.} * d = 1652.3 - 716.4 * 0.93 = 986.05\ kN$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}}{1000 * d} = \frac{986.05 * 10^3}{1800 * 930} = 0.59\ kN/m^2$$

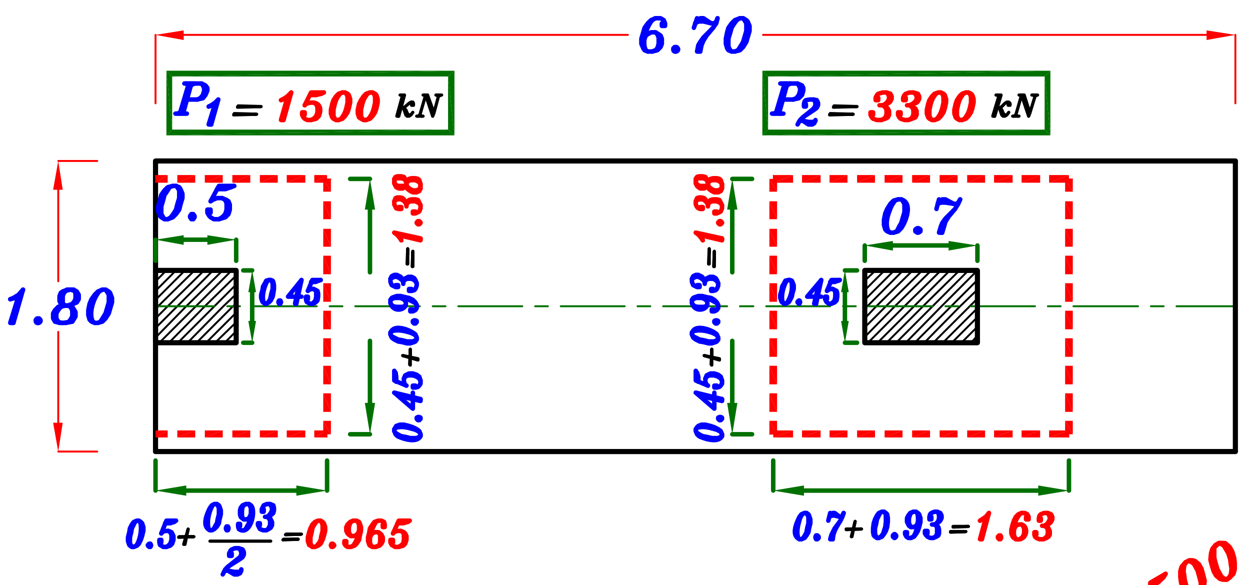


* Allowable shear stress. (q_{su})

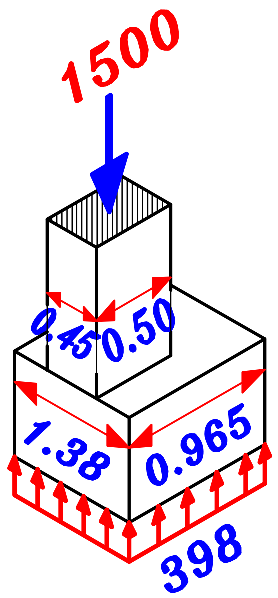
$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\delta_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653\ N/mm^2$$

$q_u < q_{su}$ $\longrightarrow$ Safe shear stresses

4 – Check Punching Shear. القص الثاقب .



Column 1

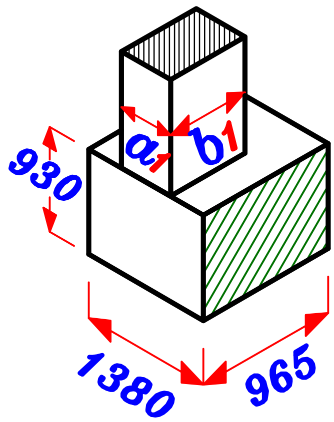


* *Calculate Punching Force.* (Q_{1p})

$$Q_{1p} = 1500 - 398\ (0.965 * 1.38) = 967\ kN$$

$$A_{1p} = \left[2\,(965) + (1380)\right] * 930$$

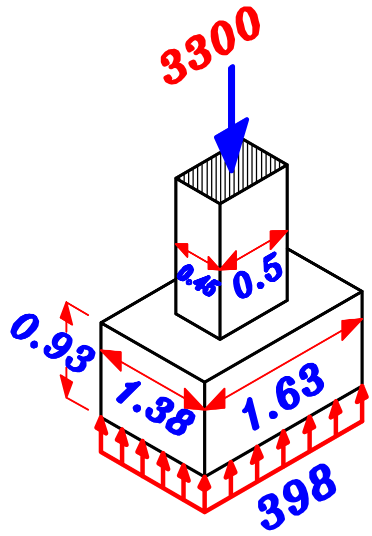
$$= 3078300\ mm^2$$



* *Calculate Actual Punching shear stress.* q_{1pu}

$$q_{1pu} = \frac{967.0 * 10^3}{3078300} = 0.314\ N/mm^2$$

Column 2



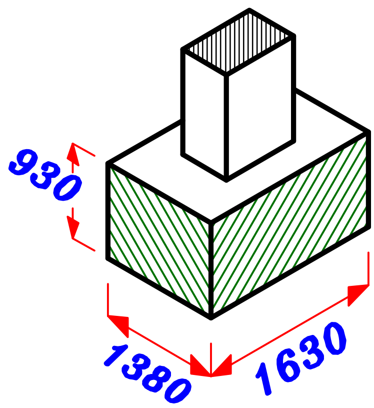
* *Calculate Punching Force.* (Q_{2p})

$$Q_{2p} = 3300 - 398\,(1.63 * 1.38)$$

$$= 2404.7 \text{ kN}$$

$$A_{2p} = [2(1380) + 2(1630)] * 930$$

$$= 5598600 \text{ mm}^2$$



* *Calculate Actual Punching shear stress.* q_{1pu}

$$q_{2pu} = \frac{2404.7 * 10^3}{5598600} = 0.423 \text{ N/mm}^2$$

$q_{pu\,max}$ the bigger q_{1pu} & q_{2pu} $= 0.429$ N/mm^2

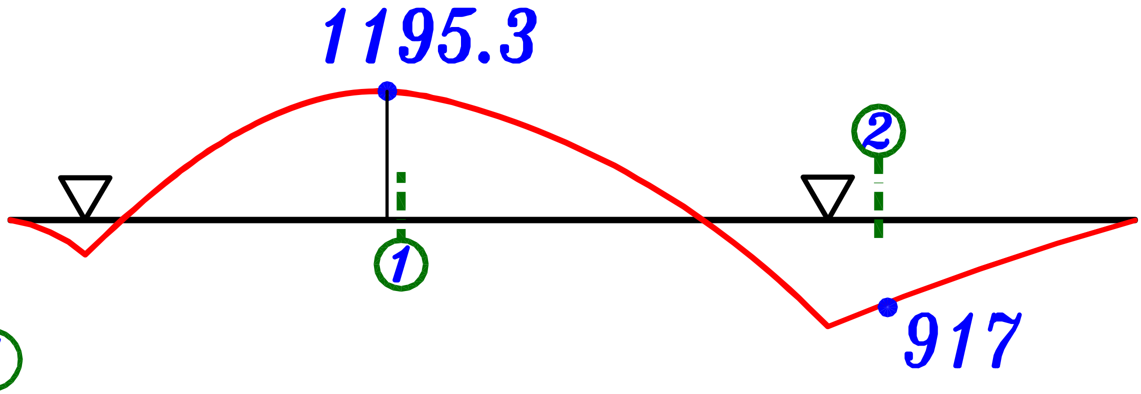
* *Calculate allowable Punching shear stress.* q_{pcu}

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} =$$

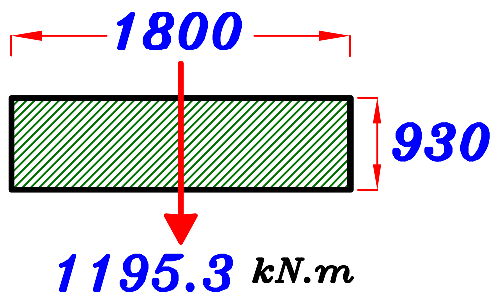
$$q_{pcu} = 0.316\left(0.5 + \frac{0.45}{0.70}\right)\sqrt{\frac{25}{1.5}} = 1.47 \text{ N/mm}^2$$

$q_{pu} \leqslant q_{pcu}$ ⟶ **Safe punching shear.** *No need to increase dimensions.*

5- Reinforcement of the Footing.



Sec. ①



$$930 = C_1 \sqrt{\frac{1195.3 * 10^6}{25 * 1800}}$$

$$\rightarrow C_1 = 5.70 \rightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\, F_y\, d} = \frac{1195.3 * 10^6}{0.826 * 360 * 930} = 4322.2\ mm^2$$

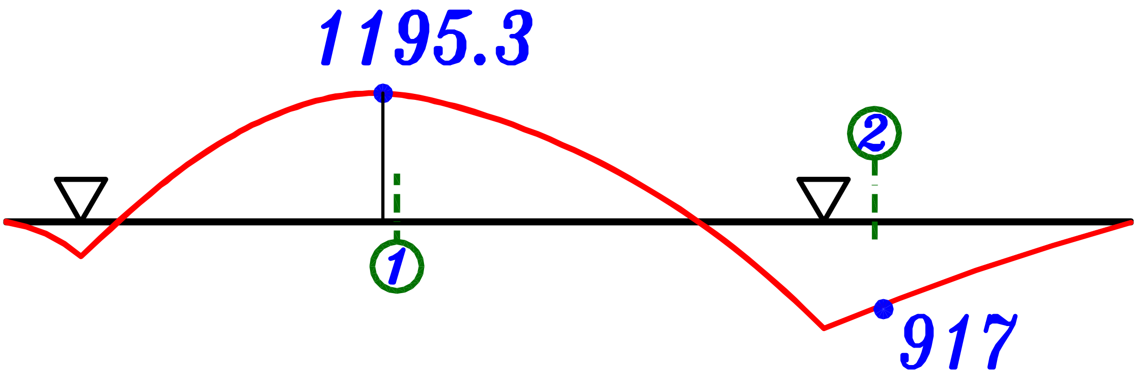
$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{4322.2}{1.80} = 2401.2\ mm^2/m'$$

Check $A_{s\,min}$

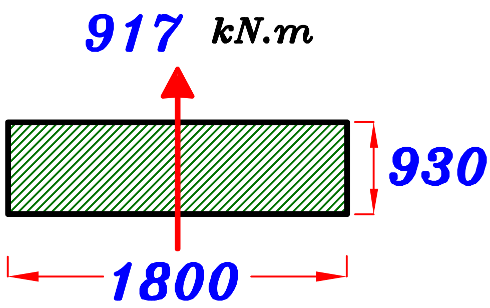
$$A_{s\,min} = \begin{cases} 1.5\, d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{cases} 1395\ mm^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow \text{Take } A_s = 2401.2\ mm^2$$

$$7 \phi 22/m'$$



Sec. ③



$$930 = C_1 \sqrt{\frac{917 * 10^6}{25 * 1800}}$$

$$\longrightarrow C_1 = 6.51 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\ F_y\ d} = \frac{917 * 10^6}{0.826 * 360 * 930} = 3315.9\ mm^2$$

$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{3315.9}{1.80} = 1842.1\ mm^2/m'$$

Check $A_{s_{min}}$

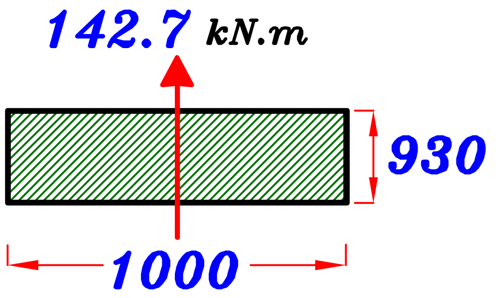
$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1395\ mm^2$$

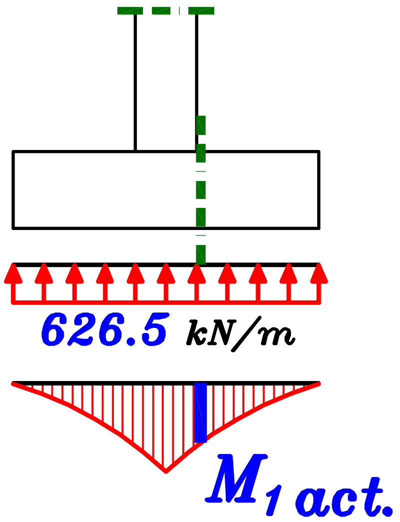
$$\therefore A_s > A_{s_{min}} \longrightarrow \text{Take } A_s = 1842.1\ mm^2$$

$5 \phi 22/m'$

Hidden Beam 1

$$M_{1act.} = 142.7 \ kN.m/m$$





$$930 = C_1 \sqrt{\frac{142.7 * 10^6}{25 * 1000}} \longrightarrow C_1 = 12.3 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \ F_y \ d} = \frac{142.7 * 10^6}{0.826 * 360 * 930} = 516.0 \quad mm^2/m'$$

Check $A_{s_{min}}$

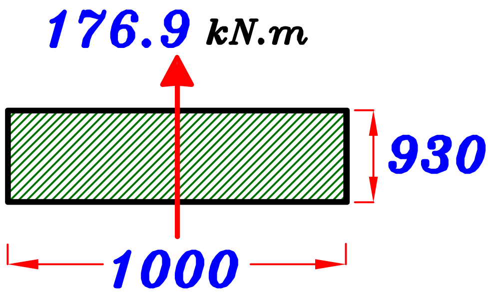
$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1395 \ mm^2$$

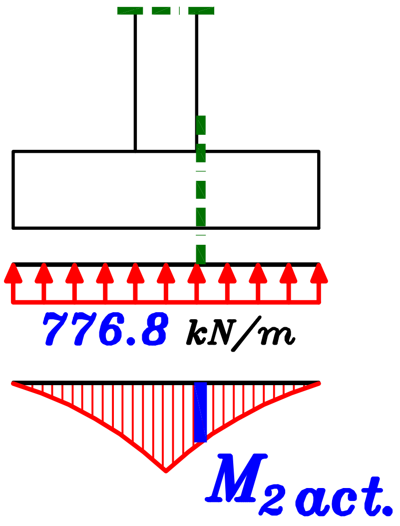
$$\therefore A_s < A_{s_{min}} \longrightarrow Take \ A_s = 1395 \ mm^2$$

$$6 \phi 18/m'$$

Hidden Beam 2

$$M_{2act.} = 176.9 \ kN.m/m$$





$$930 = C_1 \sqrt{\frac{176.9 * 10^6}{25 * 1000}} \longrightarrow C_1 = 11.0 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \ F_y \ d} = \frac{176.9 * 10^6}{0.826 * 360 * 930} = 639.6 \ mm^2/m'$$

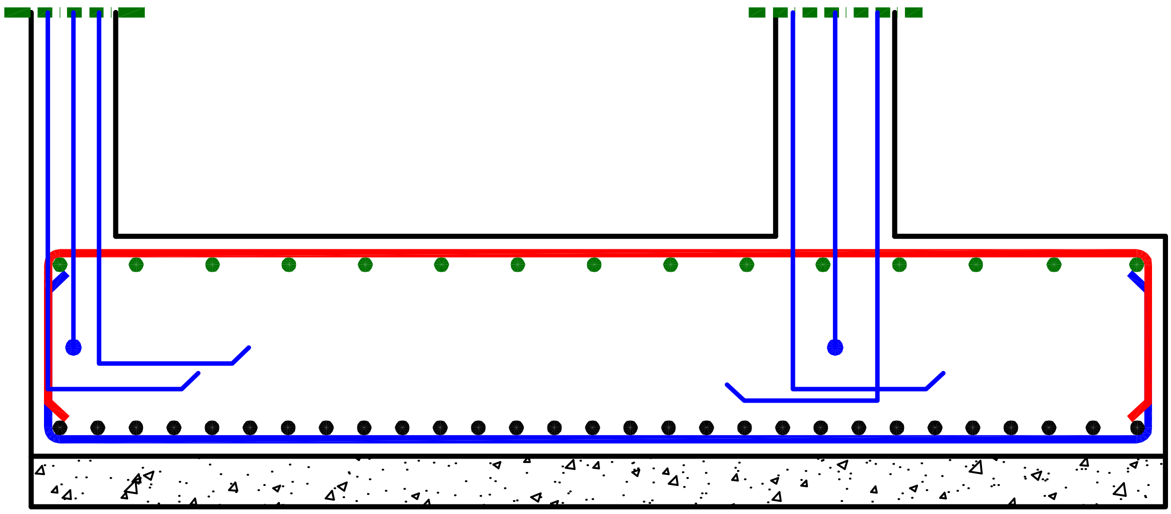
Check $A_{s_{min}}$

$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5 \, d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1395 \ mm^2$$

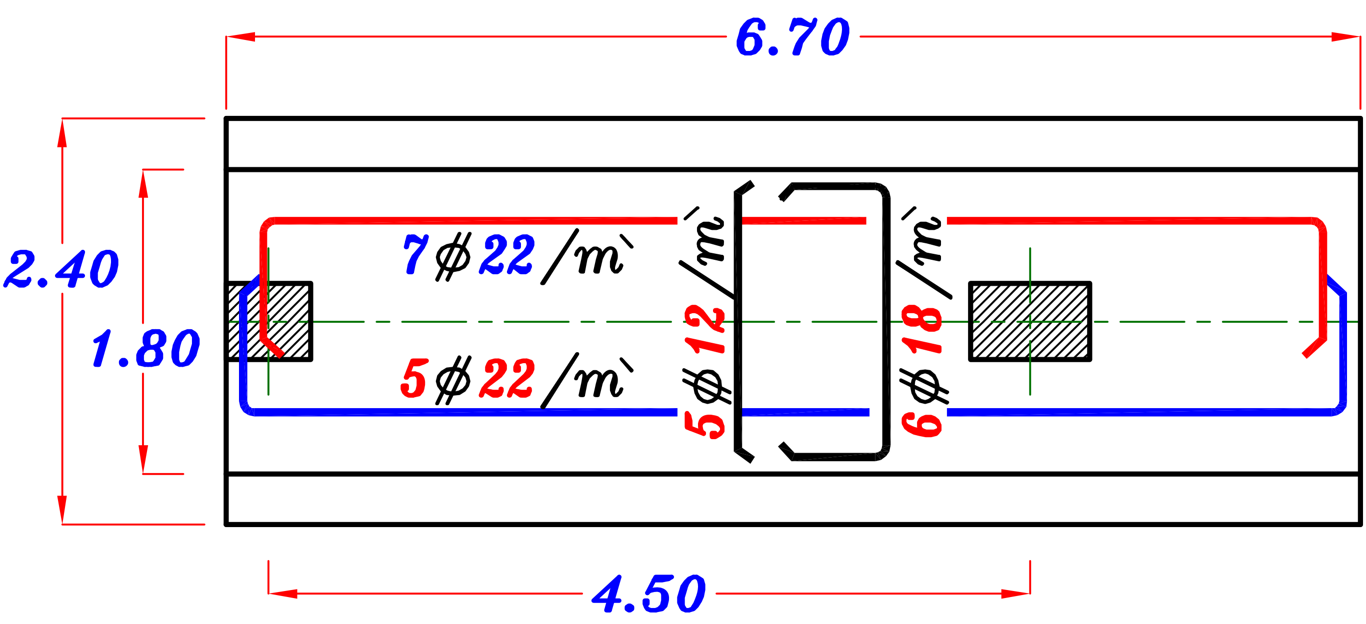
$$\therefore A_s < A_{s_{min}} \longrightarrow Take \ A_s = 1845 \ mm^2$$

$6 \phi 18/m'$

6- Details of Reinforcement.



Sec X-X

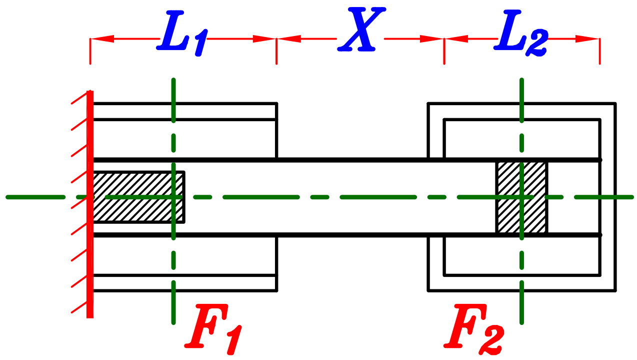


Plan

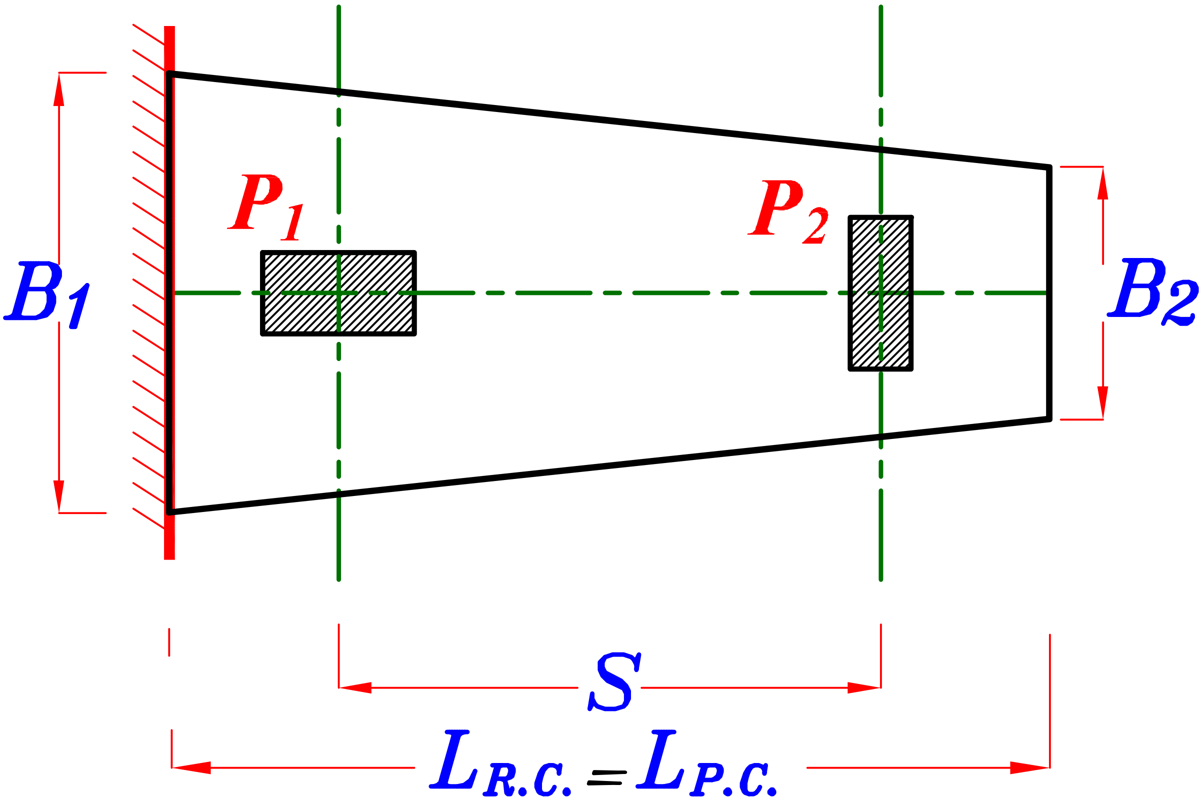
b Trapezoidal Combined Footing. $P_1 > P_2$ حاله نادره .

اذا لم ينفع حل ال **Strap Beam**

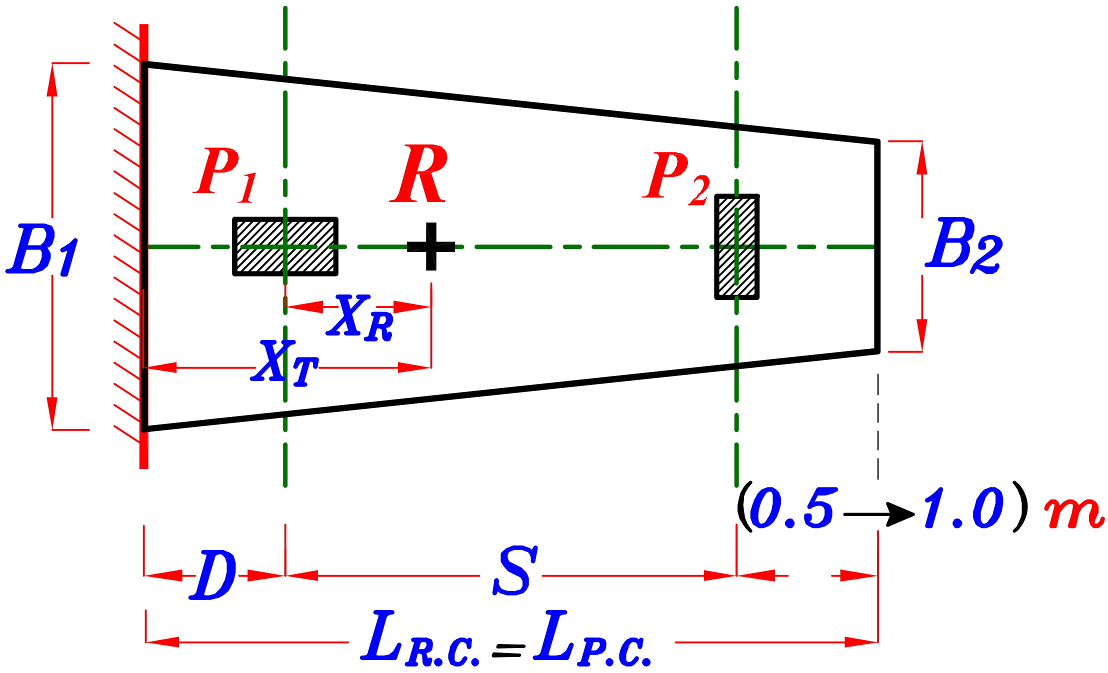
IF $X < \frac{L_1}{2}$ & $\frac{L_2}{2}$ عندما تكون



IF $P_1 > P_2$ use **Trapezoidal** combined Footing.



1– Calculate the Footing area. (Width & Length of R.C. Footing.)



يتم تحديد طول القاعده $L_{R.C.} = L_{P.C.} = D + S + (0.5 \rightarrow 1.0)m$

حيث D هى المسافه من منتصف عمود الجار الى حد الجار .

و S هى المسافه بين منتصف العمودين .

يتم حساب قيمه محصله الاحمال R

$$R = P_1 + P_2$$

يتم تحديد بعد محصله الاحمال X_R عن منتصف عمود الجار .

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

يتم تحديد بعد محصله الاحمال X_T عن حد الجار .

$$X_T = X_R + D$$

Calculate the width of the Footing. B

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

$$A_{P.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = L_{P.C.}\left(\frac{B_{1\,P.C.} + B_{2\,P.C.}}{2}\right) \quad \text{------} (1)$$

$$X_T = \frac{L_{P.C.}}{3}\left(\frac{B_{1\,P.C.} + 2\,B_{2\,P.C.}}{B_{1\,P.C.} + B_{2\,P.C.}}\right) \quad \text{------} (2)$$ مكان محصله شبه المنحرف

From (1), (2) $\longrightarrow$ $B_{1\,P.C.} = \checkmark$ & $B_{2\,P.C.} = \checkmark$

$$B_{1\,R.C.} = B_{1\,P.C.} - 2\,t_{P.C.} \qquad B_{2\,R.C.} = B_{2\,P.C.} - 2\,t_{P.C.}$$

IF $t_{P.C.} < 20\ cm$

$$A_{R.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = L_{R.C.}\left(\frac{B_{1\,R.C.} + B_{2\,R.C.}}{2}\right) \quad \text{------} (1)$$

$$X_T = \frac{L_{R.C.}}{3}\left(\frac{B_{1\,R.C.} + 2\,B_{2\,R.C.}}{B_{1\,R.C.} + B_{2\,R.C.}}\right) \quad \text{------} (2)$$

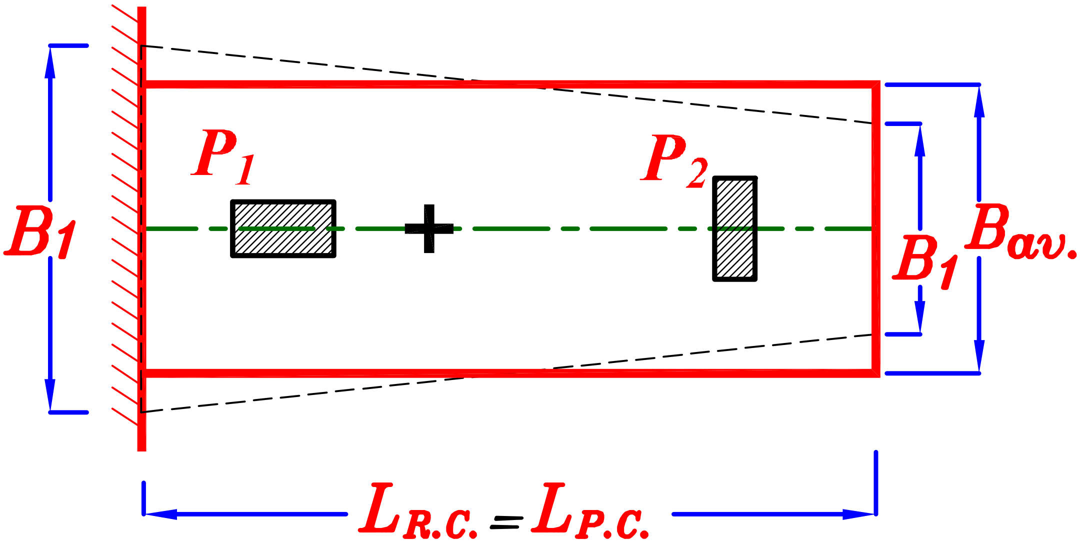
From (1), (2) $\longrightarrow$ $B_{1\,R.C.} = \checkmark$ & $B_{2\,R.C.} = \checkmark$

$$B_{1\,P.C.} = B_{1\,R.C.} + 2\,t_{P.C.} \qquad B_{2\,P.C.} = B_{2\,R.C.} + 2\,t_{P.C.}$$

Calculate the average width of the Footing.

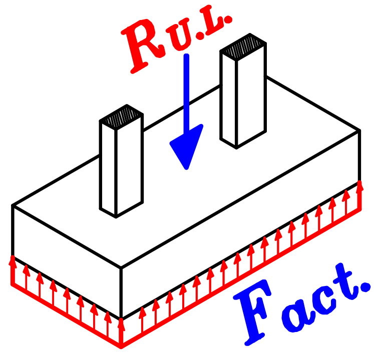
نعتبر أن القاعده الشبه منحرف عباره عن مستطيل أبعاده $(B_{av.R.C.} * L_{R.C.})$

$$B_{av.R.C.} = \frac{B_{1\,R.C.} + B_{2\,R.C.}}{2}$$



- Actual Normal stress on R.C. Footing (U.L.)

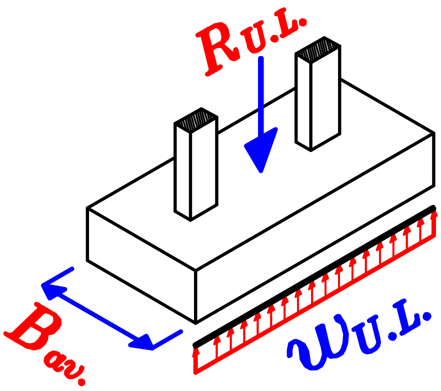
$$F_{act.} = \frac{R_{U.L.}}{B_{av.\,R.C.} * L_{R.C.}} \quad (kN/m^2)$$



- Actual Uniform Load on R.C. Footing (U.L.) as a beam.

نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m')$$



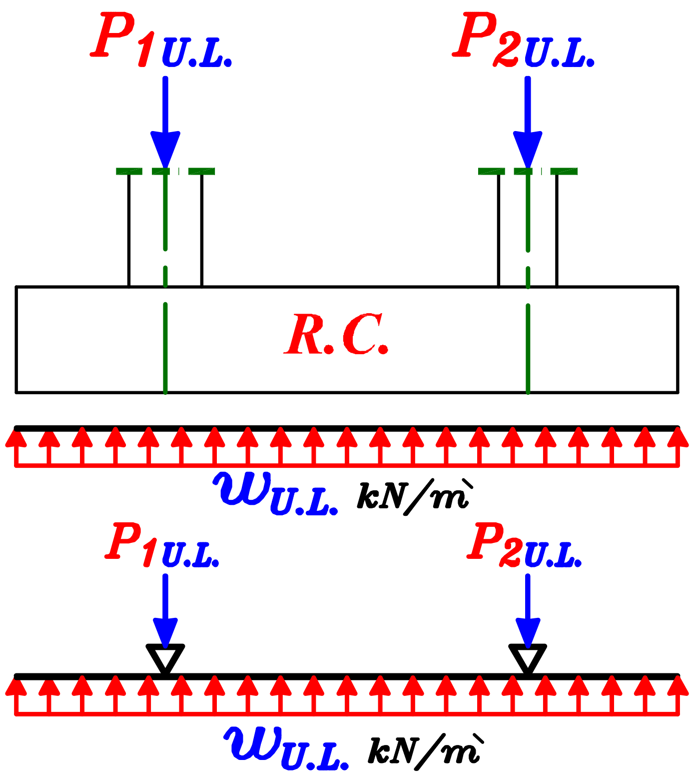
Drawing U.L. B.M.D. & S.F.D. on the all R.C. Footing.

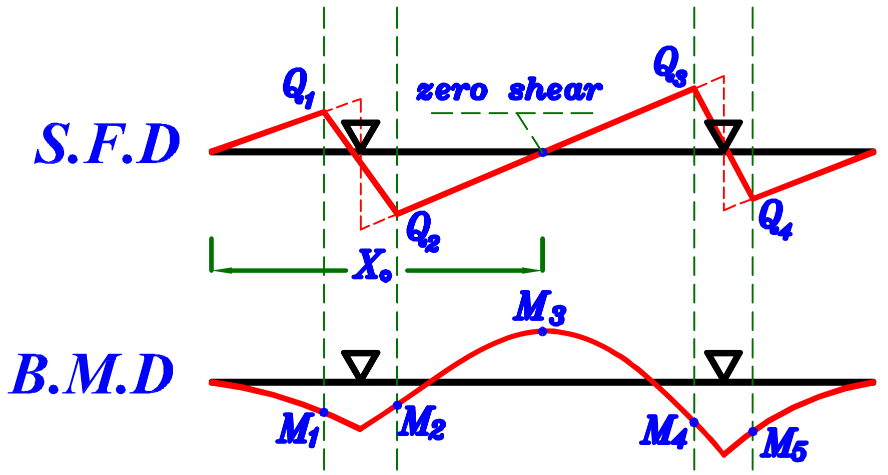
Longitudinal direction.

نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$

يتم رسم B.M.D. , S.F.D. للقاعده كلها كأنها كمره بعرض $B_{R.C.}$

و يتم حساب قيم B.M. , S.F. على وش الاعمده .





لتحديد أكبر moment فى منتصف القاعده M_3

يتم تحديد مكان نقطه zero shear أى حساب المسافه X_o

$P_{1\,U.L.} = w_{U.L.} * X_o$ → $X_o = \checkmark$ → $M_3 = \checkmark$

$M_{max.}$ is the bigger moment of M_1, M_2, M_3, M_4 & M_5

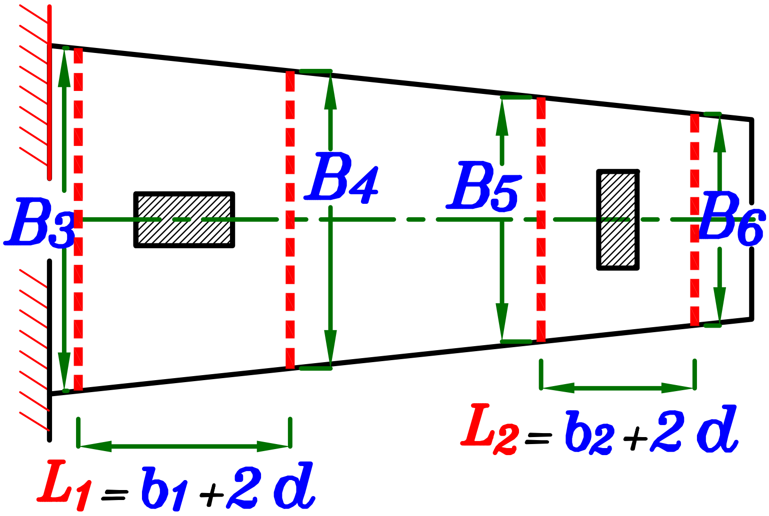
$$d\ (mm) = C_1 \sqrt{\frac{M_{max}\ (kN.m) * 10^6}{F_{cu}\ (N/mm^2) * B_{av.R.C.}\ (mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$ Get $d = ✓✓$ (mm)

$$t_{R.C.} = d + cover\ (70\ mm)$$

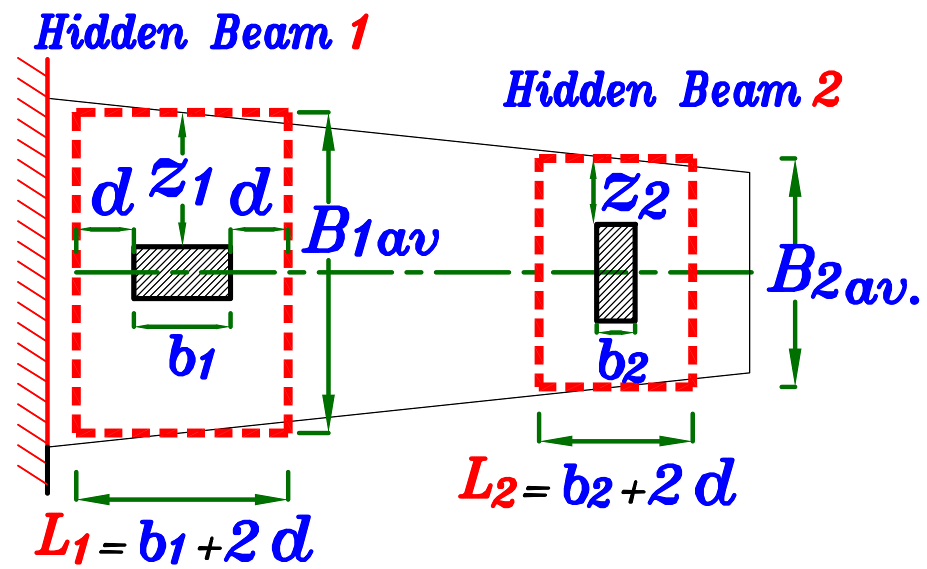
Check depth in Transverse direction. Short direction.

As a Hidden Beam.



$$B_{1av.} = \frac{B_3 + B_4}{2}$$

$$B_{2av.} = \frac{B_5 + B_6}{2}$$



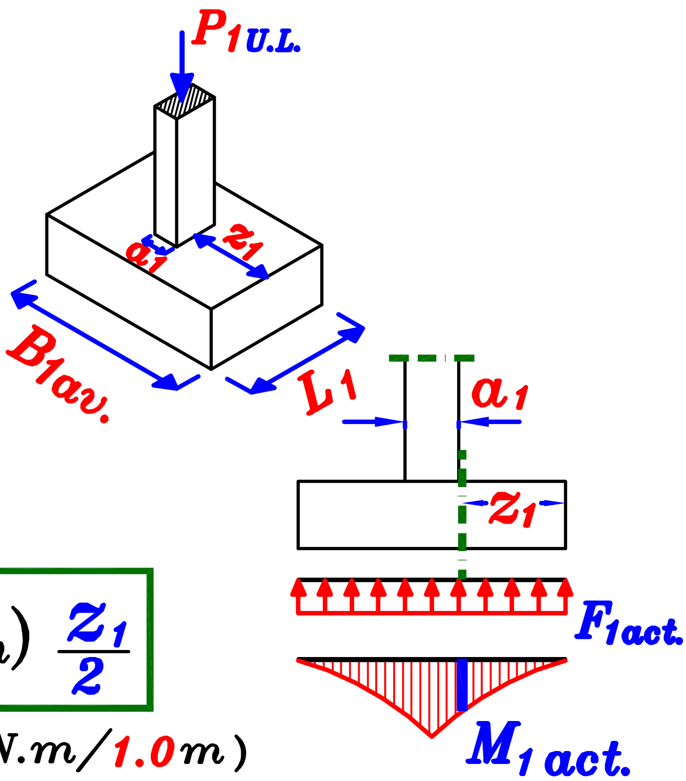
Hidden Beam 1

$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{1av} * L_1} \quad (kN/m^2)$$

$$Z_1 = \frac{B_{1av} - a_1}{2} \quad (m)$$

$$M_{1act.} = (F_{1act.} * Z_1 * 1.0m)\ \frac{Z_1}{2}$$

$(kN.m/1.0m)$



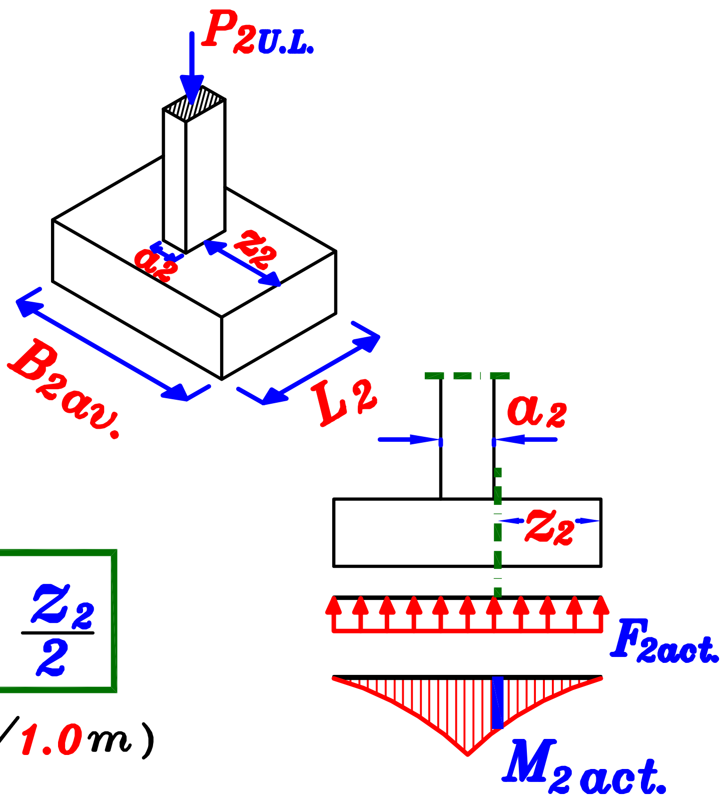
Hidden Beam 2

$$F_{2act.} = \frac{P_{2\,U.L.}}{B_{2av} * L_2} \quad (kN/m^2)$$

$$Z_2 = \frac{B_{2av} - a_2}{2} \quad (m)$$

$$M_{2act.} = (F_{2act.} * Z_2 * 1.0m)\ \frac{Z_2}{2}$$

$(kN.m/1.0m)$



Choose M_{bigger} The bigger value of $M_{1act.}$ & $M_{2act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{Get} C_1$$

Then Check on $C_1 \not< 3.0$

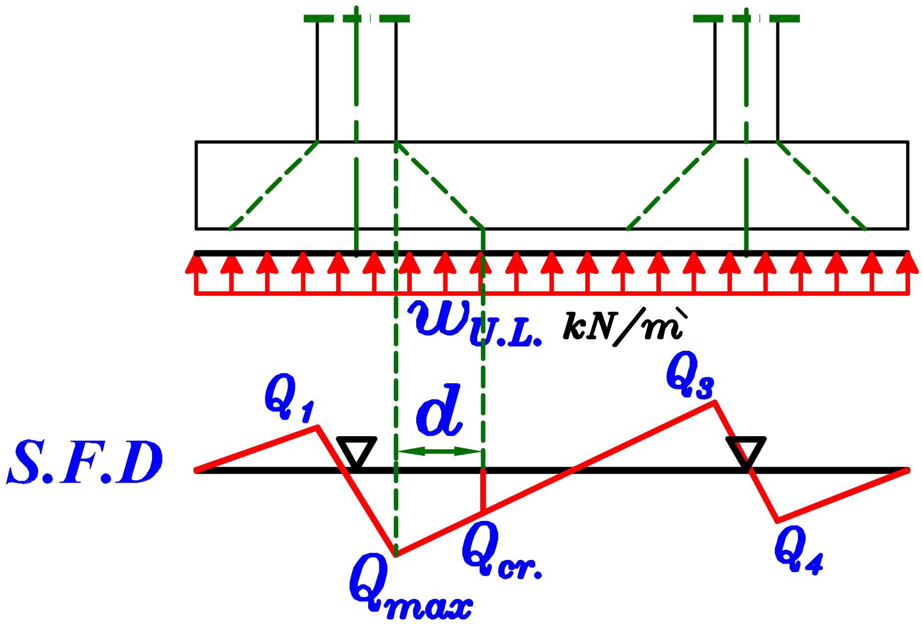
IF $C_1 < 3.0$ ⟶ Increase d

and Recheck the transverse direction.

3 – Check Shear. *at long direction*

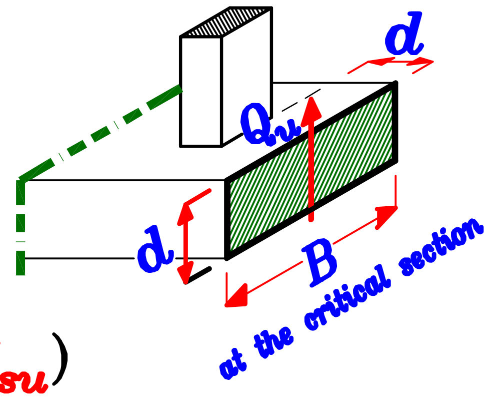
Critical section For Shear.

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



$$Q_{cr.} = Q_{max.} - w_{U.L.} * d$$

* *Calculate Actual shear stress.* (q_u)



$$q_u = \frac{Q_{cr.}\,(kN) * 10^3}{B\,(mm) * d\,(mm)} \quad (N/mm^2)$$

* *Calculate Allowable shear stress.* (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\delta_c}} \quad (N/mm^2)$$

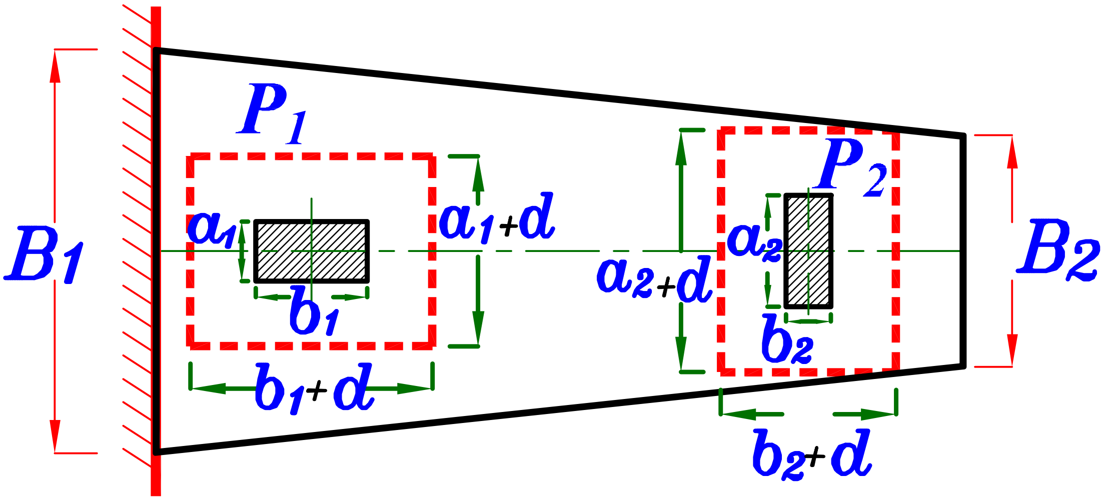
* *Compare between*

Actual shear stress (q_u) & *Allowable shear stress* (q_{su})

* IF $q_u \leqslant q_{su}$ ⟶ **Safe shear stresses**
No need to increase dimensions.

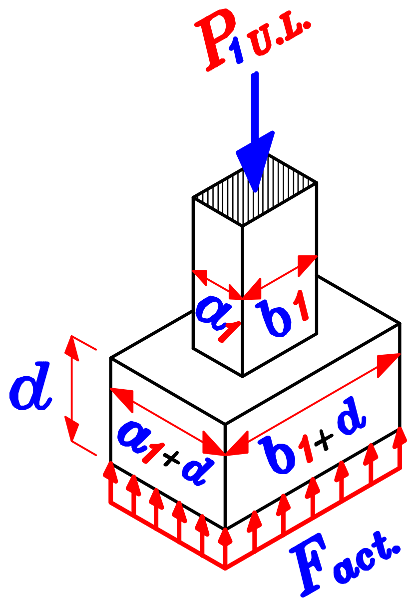
* IF $q_u > q_{su}$ ⟶ **UnSafe shear stresses**
We have to increase dimensions.

4 – Check Punching Shear. القص الثاقب .



Column 1

* **Calculate Punching Force.** (Q_{1p})



$$Q_{1p} = P_{1\,U.L.} - (F_{act.})\left[(a_1+d)(b_1+d)\right]$$

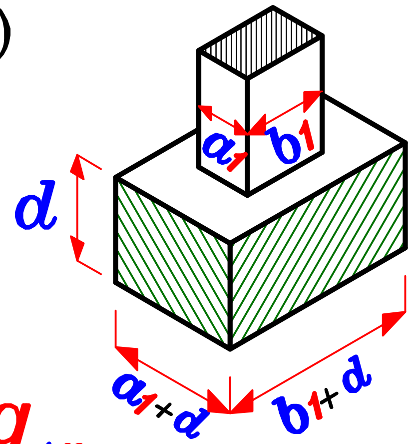
(kN)

* **Calculate Punching shear area.** (A_{1p})

المحيط العمق

$$A_{1p} = \left[2(a_1+d) + 2(b_1+d)\right] * d$$

(mm^2)



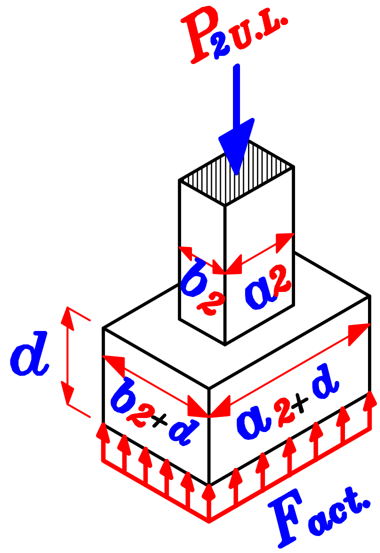
* **Calculate Actual Punching shear stress.** q_{1pu}

$$q_{1pu} = \frac{Q_{1p}\ (kN) * 10^3}{\left[2(a_1+d) + 2(b_1+d)\right] * d\ (mm^2)}$$

(N/mm^2)

Column 2

* **Calculate Punching Force.** (Q_{2p})



$$Q_{2p} = P_{2\,U.L.} - (F_{act.})\left[(a_2+d)(b_2+d)\right]$$

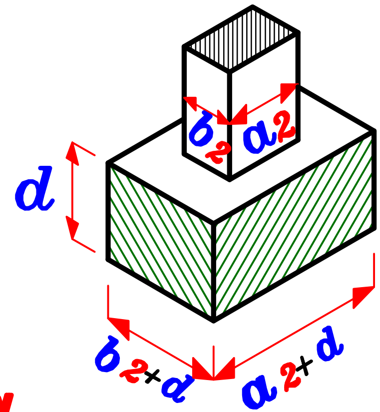
(kN)

* **Calculate Punching shear area.** (A_{2p})

المحيط العمق

$$A_{2p} = \left[2(a_2+d)+2(b_2+d)\right] * d$$

(mm^2)



* **Calculate Actual Punching shear stress.** q_{2pu}

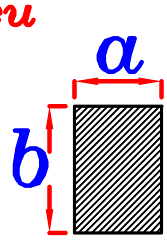
$$q_{2pu} = \frac{Q_{2p}\ (kN) * 10^3}{\left[2(a_2+d)+2(b_2+d)\right] * d\ \ (mm^2)} \quad (N/mm^2)$$

Choose q_{pumax} **the bigger value of** q_{1pu} & q_{2pu}

---

* **Calculate allowable Punching shear stress.** q_{pcu}

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



IF $\left(0.5+\frac{a}{b}\right) \leqslant 1.0$ **Take** → $q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}}$ (N/mm^2)

* Compare between

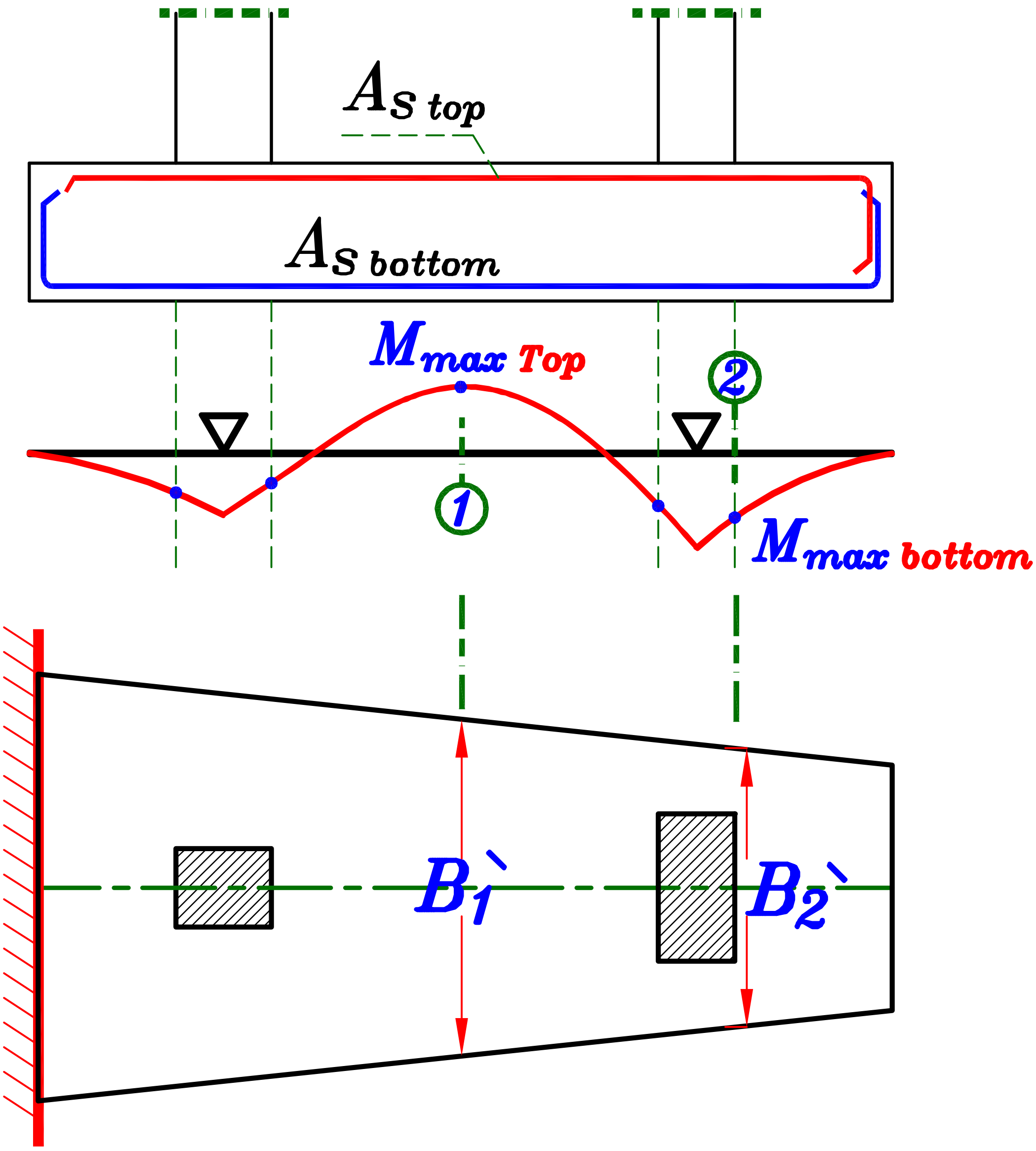
Actual punching shear stress (q_{pumax}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pumax} \leqslant q_{pcu}$ ⟶ Safe punching shear.
No need to increase dimensions.

* IF $q_{pumax} > q_{pcu}$ ⟶ UnSafe punching shear.
We have to increase dimensions.

5- Reinforcement of the Footing.

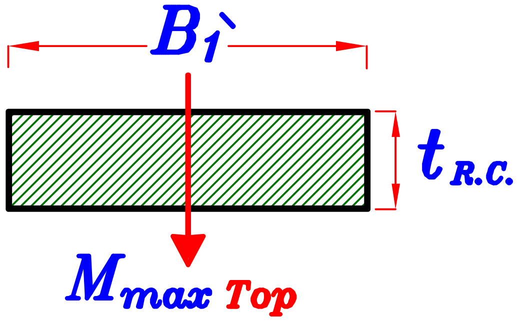
Longitudinal direction.



Sec. ①

From $d = C_1 \sqrt{\dfrac{M_{max\ Top}}{F_{cu} * B_1`}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



Get $\boxed{As_{top} = \dfrac{M_{max\ Top}}{J\ F_y\ d}}$ (mm^2)

Check As_{min} $\boxed{As_{min}\ (mm^2/m) = \begin{cases} 1.5\ d\ (mm) \\ 5 \phi 12 / m` \end{cases}}$ الأكبر

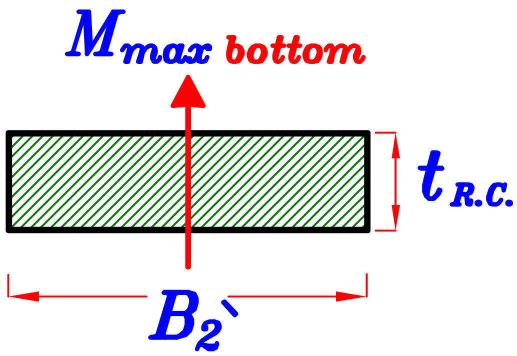
IF $As_{top} \geqslant As_{min} \longrightarrow$ o.k.

IF $As_{top} < As_{min} \longrightarrow$ Take $As = As_{min}$

Sec. ②

From $d = C_1 \sqrt{\dfrac{M_{max\ bottom}}{F_{cu} * B_2`}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



Get $\boxed{As_{bott} = \dfrac{M_{max\ bottom}}{J\ F_y\ d}}$ (mm^2)

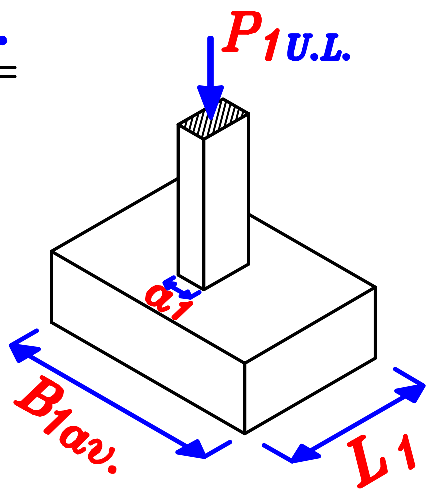
Check As_{min} $\boxed{As_{min}\ (mm^2/m) = \begin{cases} 1.5\ d\ (mm) \\ 5 \phi 12 / m` \end{cases}}$ الأكبر

IF $As_{bott} \geqslant As_{min} \longrightarrow$ o.k.

IF $As_{bott} < As_{min} \longrightarrow$ Take $As = As_{min}$

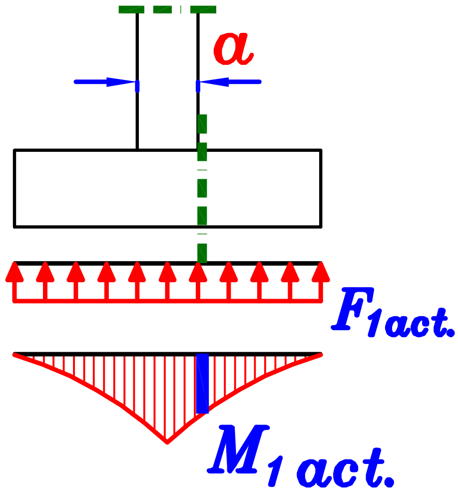
Transverse direction. Short direction.

Hidden Beam 1



From $d = C_1 \sqrt{\dfrac{M_{1act.}}{F_{cu} * 1000}}$

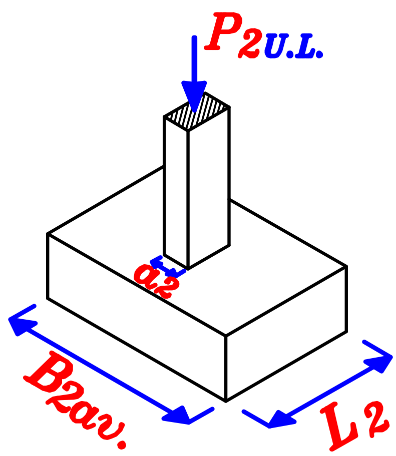
$\xrightarrow{Get} C_1 \longrightarrow J$



Get $$A_{s1} = \frac{M_{1act.}}{J\ F_y\ d} \quad (mm^2/m`)$$

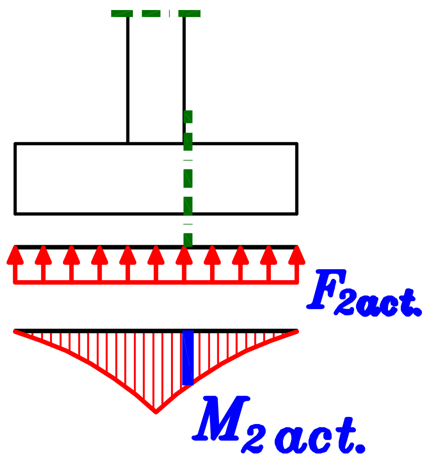
Check $A_{s\,min}$

Hidden Beam 2



From $d = C_1 \sqrt{\dfrac{M_{2act.}}{F_{cu} * 1000}}$

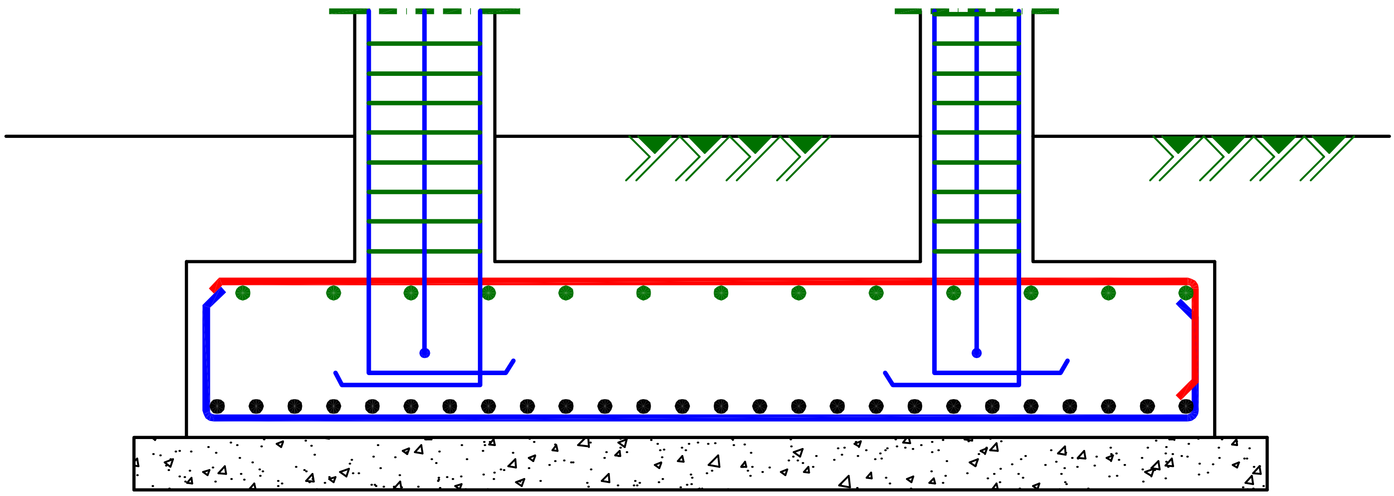
$\xrightarrow{Get} C_1 \longrightarrow J$



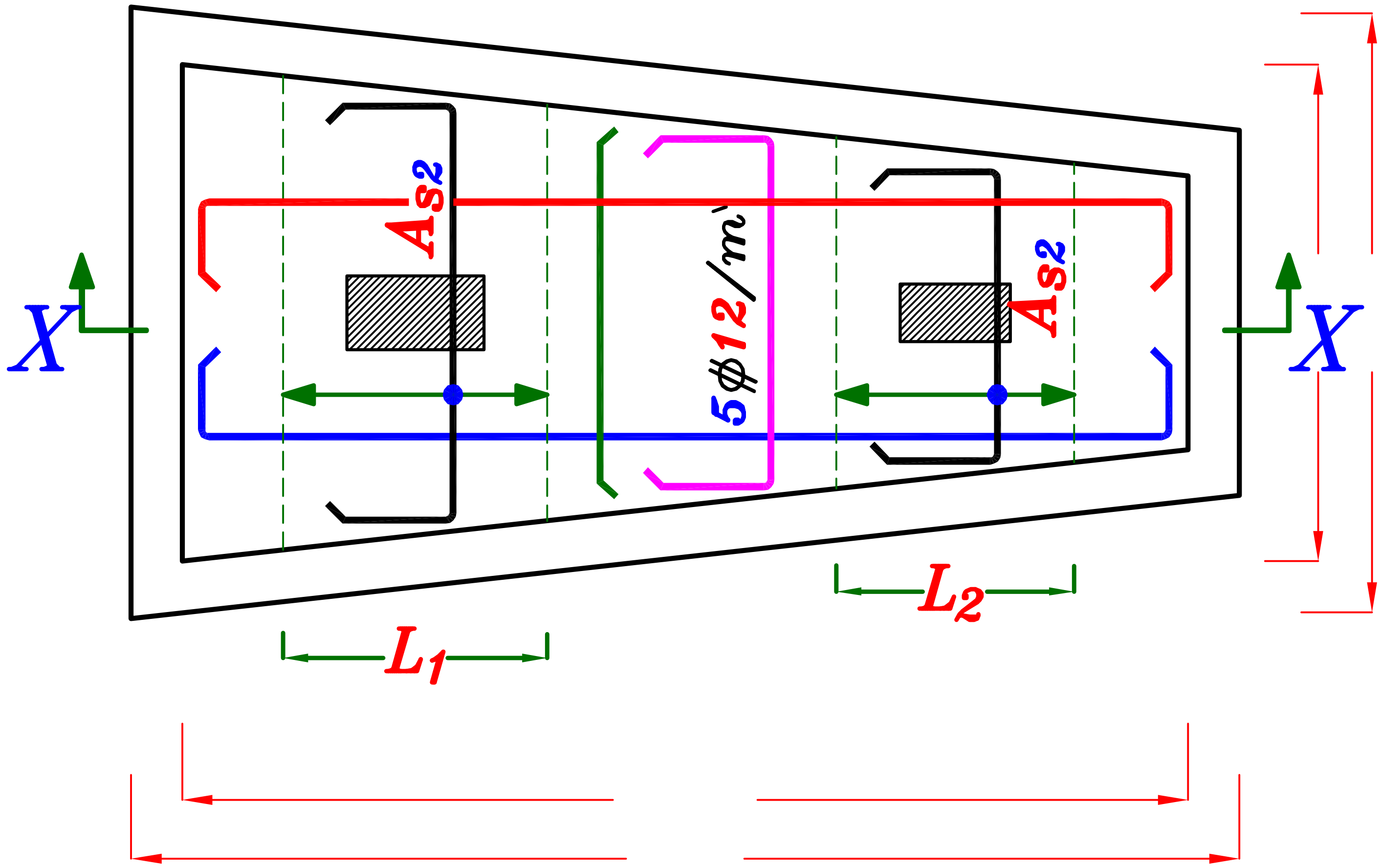
Get $$A_{s2} = \frac{M_{2act.}}{J\ F_y\ d} \quad (mm^2/m`)$$

Check $A_{s\,min}$

6 – Details of Reinforcement.



Sec X–X



Plan