spread Footing Design

• وظيفة القواعد نقل أحمال المنشأ للأرض.

* Type of footing
  - → single col → isolated or spread Footing: mat, pile, wall
  - → two col. or more → compined Footing: Rect, trapizoid, Strap

← إذا أعطاني LL & DL → $W = 1.2DL + 1.6LL$

← إذا أعطى في سؤال حمل الكلي بدون ما يفصل بضرب ب $1.5W$.

← $\phi = 0.9$

⇒ $a = A_s f_y / 0.85 f'_c b$

⇒ $A_s / bd = \rho$

⇒ $\rho_{max} = 0.75 \rho_b$

⇒ $\rho_{min} = 200 / f_y$ ⇒ $\frac{0.25\sqrt{f'_c}}{f_y} \geq \left(\frac{1.4}{f_y}\right)$ → نختار القيمة الأكبر هي تكون ρ_{min}

⇒ $M_u = 0.9 A_s f_y \left[d - \frac{a}{2}\right]$

* shear:- كل الشير تحملها الكونكريت يعني (Strip ?)

Rigidity ~~Rdg~~ لأنه لما نلغي (strip) بتزيد d وبالتالي بتحصل قاسية أكثر

$V_u = \phi V_n$
$V_n = V_c + V_s$

- V_u: Ultimate Shear
- V_c: shear strength provide by concrete
- V_s: " " " " Shear Reinforcement (حالياً لا نتعامل بالقواعد)

Type of shear :

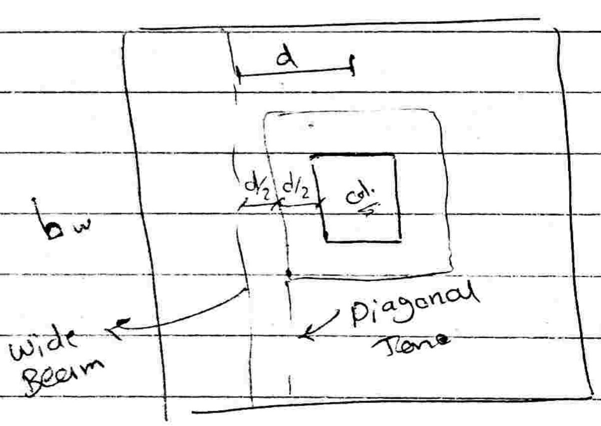
① wide Beam : one way shear

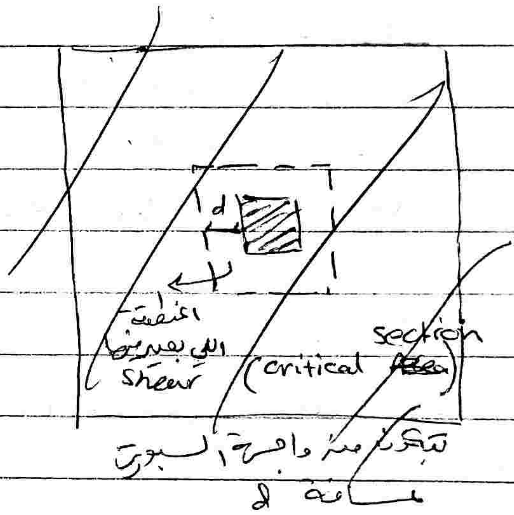
punching → ② Diagonal tension : tow way sheear ⟵ ضغط

depth of footing → بتكون أدى أمنا لشير (لما نوضع)

- one way → $V_u = \frac{\phi}{6} \cdot \sqrt{f_c'} \, b_w d$
- two way → $V_u = \frac{\phi}{3} \sqrt{f_c'} \, b_w d$

] $\phi = 0.75$
بنفرض d
من ال two cases
ونستخدم الأكبر





● Tension bar:- → ld (req)

※ Development length:- (ld) ≥ 12" (300 mm)

- $0.02\, A_b f_y/\sqrt{f'_c}$ (mm)
- $0.06\, d_b f_y$ (mm) → MPa

الأكبر فيهم هي التي نستخدمها

d_b max 35 mm

معظم الحديد أقل منه 35 لأنه يصير التعامل معه صعب

← إذا كان الحديد علوي بنضرب ld بـ 1.4

● Compression bar:-

$l_d = 0.24\, f_y d_b/\sqrt{f'_c}$, or $0.044\, f_y d_b$, or 200 mm ≪ الأكبر منهم

● cover = 7.5 cm : لأن القاعدة بتصير معرضة للتربة الي بتتأثر بالماء والأملاح والخ...

※ Example:-

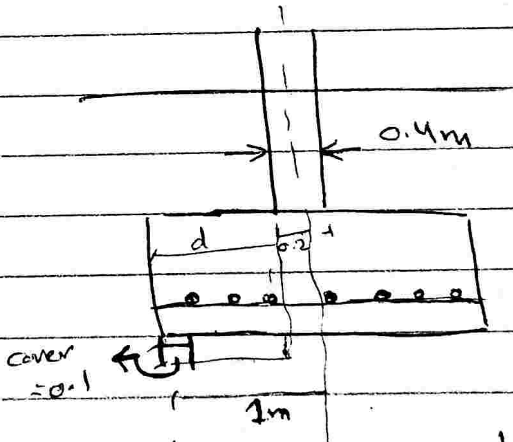
→ ld req = 500 mm (calculated)

→ ld awal (furnish) = ← الموجودة

= 1 - 0.2 - 0.1 = 0.7

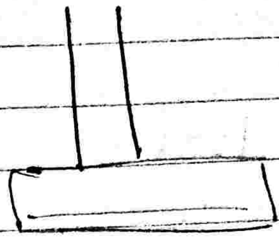
700 mm > 500 ✓✓

في حال طلع أقل مثلاً 300 mm الفرق 200 mm بعمل هوك بال 200 mm



● ld furnished: المسافة من واجهة السيرة لقبل الكفر.

* Example



l_d av = 1500 mm

l_d r = 500 mm

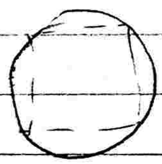
- معناه عند زيادة عن المطلوب بمقدار معين ما بكون نشيله ؟!

لإنه بشتغل بأحد الحركات Main Reinforcement

ما بكرها الثاني بشتغل Development length.

ولا من أسلحة من الحركة الثانية بنعكس على كل واحد منهم، عشان هيك ما بزبط نقصه.

- لحساب ال (critical section) لازم يحسب بعد ال face of support
(الموشح)

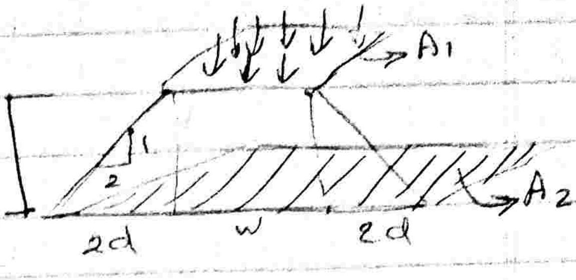


- إذا كان عندنا الكولوم دائري بنحول لمربع مساوي إله

※ Bearing on concrete:-

$q_{brg} \leq 0.85 f_c' A_1$

لـ بتحكم فيه بانتقال الترصيص بطريقة آمنة للأرض بدون كسر القاعدة



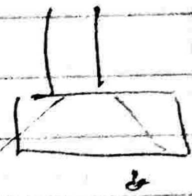
- $f_{c\,actual} \leq 0.85(\phi) f_c' \sqrt{\frac{A_2}{A_1}}$ (ϕ = 0.7)

$f_{c\,allow}$ لـ

A_2 → المساحة الجديدة اللي شتركها بمساحة d depth of the footing

A_1 → (الطول × العرض) للعمود

⇒ $\sqrt{\frac{A_2}{A_1}} \leq 2$



في هاي الحالة ما بتحمل الكونكريت

بحيث $\sqrt{\frac{A_2}{A_1}} = 1$

- $f_{c\,act} = \frac{D+L}{A_{col}}$

- $\sqrt{\frac{A_2}{A_1}} \leq 2$

we have two Cases:-

[1] $f_{c\,actual} < f_{c\,allow}$

min dowels = $0.005\, A_{col}$

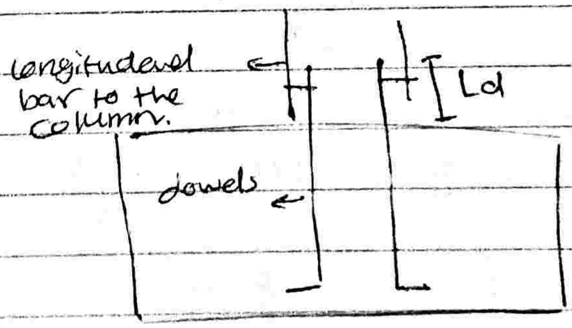
ع الأقل لازم يكونوا 4 أسياخ.

diam(dow) < diam(column)

مش لازم تزيد بمقدار 3.8mm لحتى يطل يصير انتقال صحيح للوزن

- dowels: الأشاير (أساسات التشريك) — هي الحديد اللي بطلع من القاعدة لحتى يربطها مع العمود

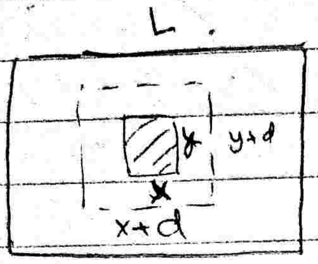
ينقل الوزن بطريقة آمنة



[2] $f_{c\,actual} > f_{c\,allow}$

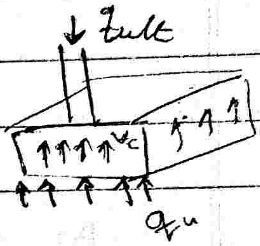
dowels = Δ(actual − allowable) stress × A_{col} / f_y > $A_{s\,dowel} = 0.005\, A_{col}$

- Spread - Footing Design:-



. ultiment Bearing Capacity :

← لإيجاد ال depth of foundation نعتمد ع "punching shear"



⇒ $\Sigma F_y = 0$

$$P_u \doteq B L q_u = 2(x+d) V_c d + 2(y+d) V_c d + (x+d)(y+d) q_u$$

q_u ← لـ : . $\frac{P_{ult}}{area}$: ultimite soil pressure

وهي متغيرة (يعني تتغير حسب الحمل اللي عليها).

• q_{ult}: ثابتة ولها علاقة بنوع التربة

(propertity of the soil)

* rearrange the Equ.

. For Rectangular Col:- x, y column dimension

$$(BL - xy) q_u = d^2 (4V_c + q_u) + d (2V_c + q_u)(x + y)$$

(Diagonal) قيمة ال shear stress ← $\frac{\phi}{3}\sqrt{f_c'}$

. For squre Col. = . x = y

$$(BL - x^2) \frac{q_u}{4} = d^2 \left(V_c + \frac{q_u}{4}\right) + d x \left(V_c + \frac{q_u}{2}\right)$$

. For round Col. of diameter = 2r

$$(BL - A_{col}) \frac{q_u}{\pi} = d^2 \left(V_c + \frac{q_u}{4}\right) + 2dr \left(V_c + \frac{q_u}{2}\right)$$

بنستخدمها لإيجاد d

* General procedure of Design isolated Footing:-

Known / col. dimension and reinforc., col. loads (L, D), f_c', $q_{allowable}$

1- $P_u = 1.2D + 1.6L$

2- Determine B & L $\Rightarrow$ $A = \dfrac{D + L + (W)}{q_a}$ $\Rightarrow$ (Assume) $\simeq 8\%\ (D+L)$

<< 5cm بنقرب الأبعاد لأقرب >> — q_a ← serviec load

(ما برجع نستخدمه مرة ثانية ؟)

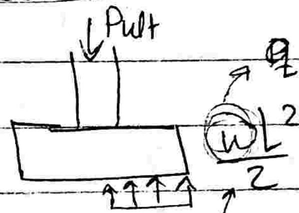
3- Find $q_u = \dfrac{P_u}{BL}$

4- Determine V_c for diagonal tension $\frac{\phi}{3}\sqrt{f_c'}\, b_o d$

5- determine d by previous Eq.

6- compute the rein. flexural steel, Ld In each direction at critical section.

ليش بس بنستخدم ال service load هان؟ لأن F.S لل q_a ما بعطينا ... عـ مقطع بناياها



7- compute col. bearing stress and select the appropriate Dowels.

8- complete design drawing showing all detalis (& scale).

*Design of Square Footing:

col
DL = 900 KN
LL = 1600 KN
48x48 cm

Footing
$f_c' = 20$ MPa
$f_y = 400$ MPa
$q_{all} = 170 KN/m^2$

⇒ w footing = 8% of column load
= 0.08 (900 + 1600) = 200 KN

⇒ service load = 200 + 900 + 1600 = 2700 KN

⇒ $P_{ult} = 1.2 \times 900 + 1.6 \times 1600 = 3640$ KN

⇒ $A = \frac{D.L + LL}{q_{all}} = \frac{2700}{170} = 15.88 \, m^2$

B = 3.98 ≃ 4m

⇒ $q_u = \frac{P_u}{BL} = \frac{3640}{4 \times 4} = 227.5 \, kN/m^2$

⇒ For diagonal Tension
$V_c = \frac{0.75}{3} \sqrt{20} \times 1000 = 1118 \, kN/m^2$

⇒ calculate d:-

$(BL - x^2) \frac{q_{ult}}{4} = d^2 \left(V_c + \frac{q_{ult}}{4}\right) + dx \left(V_c + \frac{q_{ult}}{2}\right)$

$(4^2 - 0.48^2) \frac{227.5}{4} = d^2 \left(1118 + \frac{227.5}{4}\right) + d(0.48)\left(1118 + \frac{227.5}{2}\right)$

d = 0.657 ≃ 0.7 m → Check Wide Beam ال ع ... ناقص داي اعلى

⇒ w = 4x4x24 x 0.7 = 268.8

⇒ $M_u = \frac{wL^2}{2}$, $L = \frac{4 - 0.48}{2} = 1.76$

$= \frac{227.5 \times 1.76^2}{2} = 352.4$ kN.m

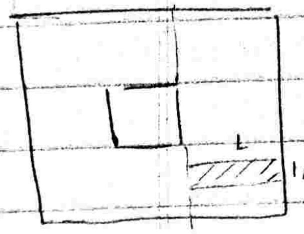
⇒ $M_u = \phi A_s f_y (d - \frac{a}{2})$ ⇒ $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s (400)}{(0.85)(20)(1)}$

$= 23.53 A_s$ — (1)

↳ $352.4 = (0.75)(A_s)(400)(0.7 - \frac{a}{2})$

solve The Equation → $A_s = 1.43 \times 10^{-3} \, m^2/m$

* check $\rho_{min} = \frac{1.4}{f_y} = \frac{1.4}{400} = 0.0035$



(strip اعتبار)

$\Rightarrow As = \frac{1.4}{400}(100 \times 70) = 24.5\ cm^2$

$\Rightarrow As\ Total = 24.5 \times 4 = 98\ cm^2$

* Using 25 mm bars $As_{bar} = 4.91\ cm^2$

* bars $= \frac{98}{4.91} = 19.95 \simeq 20$ bar , Use cover 10 cm

$\Rightarrow$ spacing $= \frac{400-20}{19} = 20\ cm$ center/cente both way

$\Rightarrow$ check development length : (requierd)

$$ld = \begin{cases} 300 \\ 0.02\,(491) \times 400/\sqrt{20} = 878.3\,mm \leftarrow \text{control} \\ 0.06\,(25)\,(400) = 600 \end{cases}$$

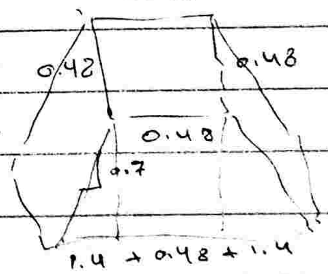
(→ Area bar ×100 (mm²); d → mm)

so required $ld = 878.3\,mm \simeq 88\ cm$

$\Rightarrow$ ld furnished (available) $= \left(\frac{400-48}{2}\right) - 10 = 166\ cm$

$\Rightarrow$ ld fur > Ld req ✓✓

$\Rightarrow$ Check bearing :



• $f_{c\,act} = \frac{900+1600}{0.48^2} = \frac{D+L}{A_{col}} = 10850\ kN/m^2$

$\sqrt{\frac{A_2}{A_1}} = \sqrt{\frac{(2.8+0.48)^2}{0.48^2}} > 2$

Use 2

• $f_{c\,all} = 0.85\,(0.75)\,(20)_{\times 1000} \times (2)$

$= 23800\ kN/m^2$

$f_{c\,all} > f_{c\,act}$. $\Rightarrow$ Use min $As = 0.005\ A_{gcol}$

$= 0.005\,(48 \times 48)$

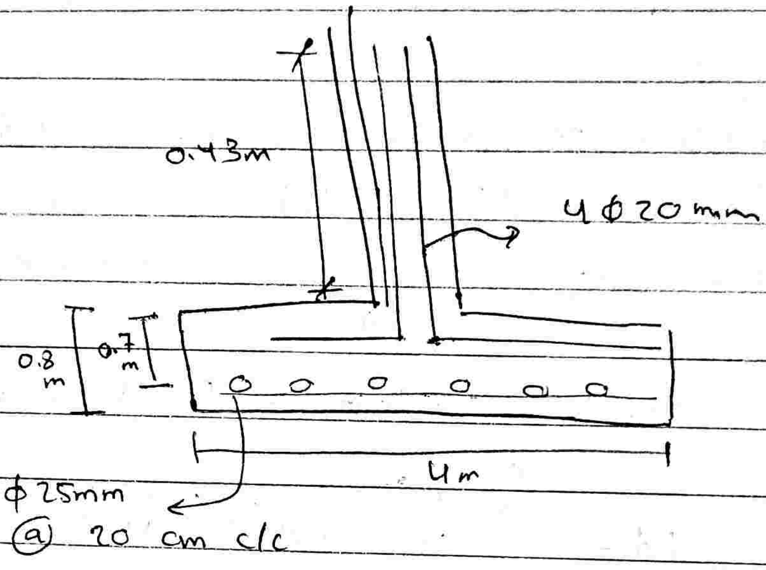
$= 11.52\ cm^2$

Use four dowels

ϕ 20 mm

⇒ l_d for dowels = max $\begin{cases} = 200 \\ = 0.24(400)\dfrac{(20)}{\sqrt{20}} = 429\ mm \checkmark \text{ control} \\ = 0.044(400)(20) = 352\ mm \end{cases}$

⇒ l_d = 429 ≈ 43 cm



* For rectangular Footing :-

col.	Footing
DL = 800 kN	$f_c' = 20$ MPa
LL = 800 kN	$f_y = 400$ MPa
45×45	$q_a = 250$ kN/m^2
25 mm bars	width of the footing limited to 2m

⇒ assum $W_{footing}$ = 8% load = $0.08 \times (800+800) = 128$ kN

⇒ Total service load = $800 + 800 + 128 = 1728$

⇒ Area = $\frac{1728}{250} = 6.91$ m^2 ⇒ $A = 2L = 6.91$

$L = 3.46 \simeq 3.5$ m

⇒ P_{ult} = $1.2 \times 800 + 1.6 \times 800 = 2240$ kN

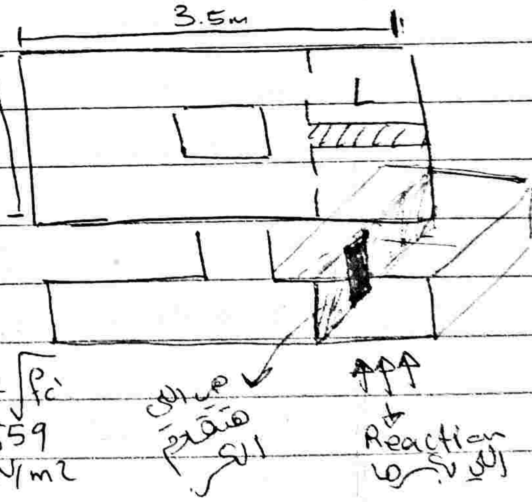
⇒ $q_{ult} = \frac{2240}{2 \times 3.5} = 320$ kN/m^2

⇒ diagonal Tension :- $V_c = \frac{\phi}{3}\sqrt{f_c'} = 1118$ kN/m^2

* calculat d :-

$$(2 \times 3.5 - 0.45^2)\left(\frac{320}{4}\right) = d^2\left(1118 + \frac{320}{4}\right) + d(0.45)\left(1118 + \frac{320}{2}\right)$$

solve the Equation → $d = 0.48$ m use ≃ 0.5 m



⇒ $L = \frac{3.5 - 0.45}{2} - 0.5 = 1.025$ m

⇐ نتأكد إذا d بتكفي أو لأ.

L vs q_{ult}

⇒ $V = (1.025)(1)(320) = 328$ kN

$V_{c\,act} = \frac{328}{(1)(0.5)} = 656$ kN/m^2 , $V_{c\,all} = \frac{\phi}{6}\sqrt{f_c'} = 559$ kN/m^2

$V_{c\,act} > V_{c\,all}$ XX not ok

⇒ $558 = \frac{328}{(1)d}$ ⇒ $d = 0.59$ m ≃ use 0.6 m

⇒ moment In long direction :-

$L = \frac{3.5 - 0.45}{2} = 1.525\,m$

⇒ $M_u = \frac{wL^2}{2} = \frac{320\,(1.525)^2}{2} = 372.1$ KN.m

$a = \frac{A_s f_y}{0.85 f'_c b}$

$M_u = \phi A_s f_y \left[d - \frac{a}{2} \right]$

$372.1 = 0.9 A_s \left[400 \times 1000\right] \left[0.6 - \frac{23.53}{2} A_s\right]$

Solve the Equation ⇒ $A_s = 1.79 \times 10^{-3}\ m^3$

$\rho_{min} = \frac{1.4}{400} = 3.5 \times 10^{-3}$

$\rho = \frac{1.79 \times 10^{-3}}{(1) \times (0.6)} = 0.002983 < \rho_{min}$

use ρ_{min} 0.0035 , $A_s = \rho bd = 0.0035 \times 100 \times 60 = 21$

$\# bars = \frac{A_s}{A_b} = 4.27 \times 2 = 8$ [illegible]

⇒ $A_s = \rho bd = 0.0035 \times 100 \times (60) = 21$ ←

$A_s = 35.8\ cm^2$ [illegible]

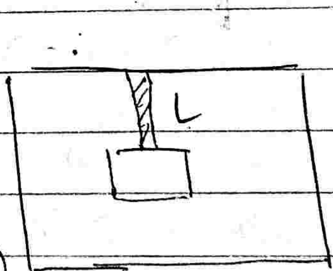
using $\phi 25$ ⇒ $\# bar = \frac{35.8}{4.91} \approx 7.2 \simeq 8$ bars

use cover 18cm

⇒ spacing = $\frac{200 - 18 \times 2}{7} = 23.4 \simeq 25$ cm c/c

⇒ moment In short direction :-

$L = \frac{2 - 0.45}{2} = 0.775$



$M_u = \frac{320}{2} (0.775)^2 = 96.1$ KN.m

$96.1 = 0.9 A_s (400 \times 1000) \left(0.6 - \frac{23.53}{2} A_s\right)$

solve it

$A_s = 4.69 \times 10^{-4} \longrightarrow \rho = \frac{A_s}{bd} = \frac{4.69 \times 10^{-4}}{(1)(0.6)} = < \rho_{min}$

use ⇒ $\rho = 0.0035$

$$\Rightarrow A_s = \frac{1.4}{400}(1)(0.6)(35) = 7.35\times10^{-3}\ m^2$$

(In short direction)

⇓

- If we have rectangular footing + squre col
- or Rectangular footing with moment

⇓

$$\% = \frac{2}{\left(\frac{L}{B}+1\right)} \times 100$$ of steel In short band of width B = 2m

$$\% = \frac{2}{\left(\frac{3.5}{2}+1\right)}\times 100 = 72.7\ \% \longrightarrow A_s = 7.35\times10^{-3}\times 72.7\% = 53.4\ cm^2$$

⇒ using 25 mm bars $\#\ bar = \frac{53.4}{4.91} = 11\ bar$

$$spacing = \frac{200}{10} = 20\ cm\ c/c$$

⇒ Remaining steel $= 73.5 - 53.4 = 20.1\ cm^2$

$$\#bars = \frac{20.1}{4.91} = 4\ bars$$

$$spacing = \frac{0.75 - 0.15}{2} = \frac{0.60}{2}$$

$= 0.3$

$= 30cm$

(cover)