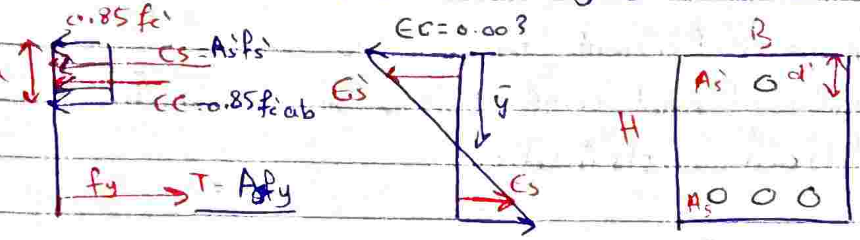
نلجأ لما تكون الخرسانة عالية وما نقدر ⟵
نغير أبعاد الخرسانة

• Doubly Reinforced Beams: $\Rightarrow \rho > \rho_{max}$

- If ρ exceeds the maximum allowed, we Increase [d, B] → if there is No limit on the Dimensions.
- If theres a limit ⟹ Use Doubly Reinforcement.



- To know the stress in the steel in the compression side → calculate ϵ_s' then by Hooks low → $f_s' = E\epsilon_s'$

$T = A_s f_y$ → couple Cs, couple Cc $\left(\phi M_{n1} + \phi M_{n2}\right) = \phi M_n$

مشابه بالمثلثات ← $\epsilon_s' > \epsilon_y$

Nominal strength

→ Cs coupled with part of T → compression steel yields → $C_s = A_s' f_s'$

$\rightarrow \phi M_{n1} = \phi A_s' f_y (d - d')$

$\rightarrow \phi M_{n2} = \phi (A_s f_y - A_s' f_s')(d - a/2)$

$= \phi (A_s - A_s') f_y (d - a/2)$

$\epsilon_s' < \epsilon_y$ ← من تشابه المثلثات

→ compression steel doesn't yields → $C_s = A_s f_s'$

$\rightarrow \phi M_{n1} = \phi f_s' A_s' (d - d')$

$\rightarrow \phi M_{n2} = \phi (A_s f_s - A_s' f_s')(d - a/2)$

→ Cc coupled with rest of T

- We have to calculat a then find ȳ to determin if the section yield or no
- find [a] By section Equilibrium.

$$A_s' f_s' + 0.85 f_c' a B = A_s f_y \quad (1)$$

- Assume $f_s' = f_y$ → yield
- Find a . make sure if the section yield.
- If No yield must change $f_s' = E\epsilon_s'$ and Check If the section is yield.

• or look to TAble 3.2:-

If $d'/d > 0.13 \rightarrow$ No yield

• Tension Reinforcment limits:

- Minimum reinforcment remains the same.
- we calculat and compare the steel strain from the strain distribution

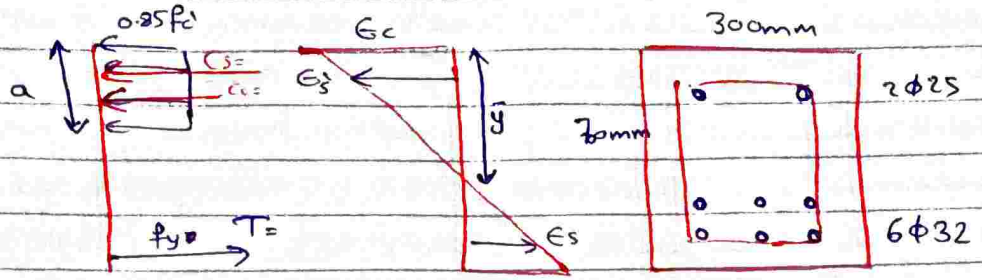
$$\rightarrow \frac{\epsilon_c}{\bar{y}} = \frac{\epsilon_s}{d-\bar{y}} \rightarrow \epsilon_s = \quad > 0.004$$

$$\rightarrow \frac{\epsilon_c}{\bar{y}} = \frac{\epsilon_s'}{\bar{y}-d'} \rightarrow \epsilon_s' = \begin{cases} > 0.0021 \\ < 0.0021 \end{cases}$$

double

$$\rightarrow \bar{\rho}_{0.004} = \rho_{0.004} + \rho' \frac{f_s'}{f_y}$$

• Example: f_y=420 Mpa, f_c=35Mpa, Moment Capacity?



→ d' = 40+10+12.5 = 62.5 mm

→ d = H − 40 − 10 − 32 − 32/2 = 602 mm

• $\rho = \frac{4914}{300 \times 602} = \frac{A_s}{bd} = 0.027$

• ρ_{max} from table = 0.0243 ← $\rho > \rho_{max}$ → Doubly Reinforcement

• d'/d = 62.5/602 = 0.104 < 0.13 → yield

• T = C ⇒ $A_s f_y = f_y A_s' + 0.85 f_c' ab$

$4914 \times 420 = 420 \times 1020 + 0.85(a)(35)(200)$

$a = 183.24$

$\bar{y} = \frac{a}{B_1}$ → from table $= 183.24/0.8 = 229.05$ mm

$\epsilon_s' = 2.18 \times 10^{-3} > 2 \times 10^{-3}$ yield

$\epsilon_s = 4.88 \times 10^{-3} > 0.004$ → ACI ✓

< 0.005 → ϕ = ?

$\phi = 0.65 + (\epsilon_s - 0.002)\left(\frac{250}{3}\right)$

$\phi = 0.89$

$\phi M_n = \phi M_{n1} + \phi M_{n2}$

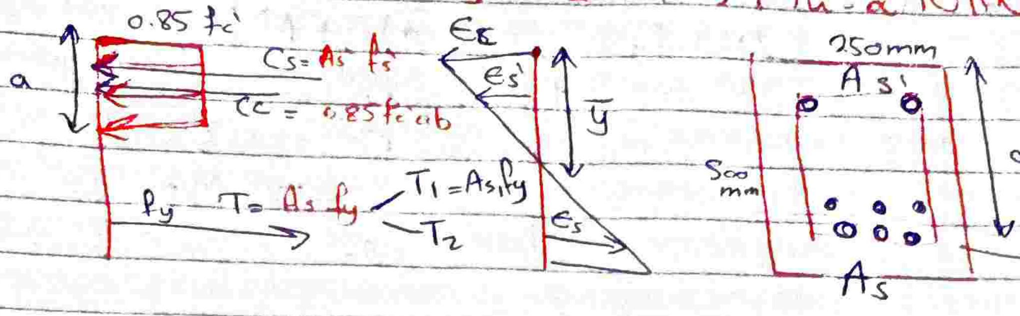
$= \phi A_s' f_y (d - d') + \phi (A_s - A_s') f_y (d - a/2)$

↳ $0.85 f_c' ab$

$= 206.5 + 742.89 = 949.5$ kN.m

• Design ↓

• Example: $f_y = 420$ MPa , $f_c' = 28$ MPa , $M_u = 290$ kN.m



يبدأ بعرض إنه في 2layers لأنه الكونت على والعدد الكبير سكون صغيرة

• Singly R_c → $R = \frac{M_u}{\phi b d^2}$ → $R = 7.4$ MPa → doesn't exist In Table

flexural resistance

• $d = 500 - 40 - 10 - 20 - \frac{25}{2} = 417.5$ mm

• which mean that we need to make a Doubley Reinforcement < T, C > steel

• $d' = 40 + 10 + \frac{20}{2} = 60$ mm

• $d'/d = 0.14 > 0.13$ → No yield ⇒ $f_s' \neq f_y$

• $\rho = \rho_{0.005} = 0.181$ → Singley → $\phi M_{n_1} = \phi R d^2 b$

$\phi = 0.9$

$\phi M_{n_1} = 0.9 * 6.36 \times 417.5 \times 250$

$= 249.4$ kN.m

• $\phi M_{n_2} = 290 - 249.4 = 40.6$ kN.m → $S_C - S_T$ (steel (Tension - Compression))

• $A_{s_1} = \rho b d = 1889$ mm²

• $\phi M_{n_2} = \phi A_s' f_s' (d - d')$

• $C_c = T_1$ → $A_{s_1} f_y = 0.85 f_c' a b$ → $a = 133.34$ mm²

→ $\beta_1 = 0.85$ → $\bar{y} = 156.9$ mm

→ $\epsilon_s' = 0.00185$

→ $f_c' = 370$ MPa

→ $40.6 = 0.9 A_s' (370)(417.5 - 60)$ → $A_s' = 341$ mm² ← We need add steel on T-side

• $T_2 = C_s$ → $A_{s_2} f_y = A_s' f_s'$ → $A_{s_2} = A_s' \left(\frac{f_s'}{f_y}\right)$ → في حال وصلنا للكومبرشن سا يلد yield

$A_{s_1} = A_{s_2}$ ← yield لو في

• $A_{s_2} = 300$ mm²

• $A_s' = 341$ mm² , $A_s = 1889$ mm² $+ 300$ mm² $= 2189$ mm²

• check d : $T = C$

$2189 \times f_y = 0.85\, f_c'\, ab + A_s' f_s'$

$a = 133.34 \rightarrow \epsilon_s' = 0.00185$

$\bar{y} = 156.4\,mm \rightarrow \epsilon_s = 0.005$

$f_s' = 370\, MPa$

$\phi = 0.9$

$A_s' = 341\, mm^2 \rightarrow$

• possible choice $\Rightarrow$

$5\phi10 \rightarrow$ $B = 2(40) + 2(10) + n d_b + (n-1) S$

$S = 25\,mm$

$3\phi12 \rightarrow$ $S = 57\,mm$

$A_s' = 398\,mm^2 \leftarrow 2\phi16 \rightarrow$ $S = 118\,mm$ ✓

• كلهم بزبطوا بس الأفضل إنه تكون قطر للبارات أكبر (فرصة بالبيم).

• بتفضل إنه فرق القطر ل As ، As' تكون صغير.

• أفضل نقلل عدد الطبقات.

كل ما ليست (d) بتكون أكبر.

بأثر مقدار العزم d ⟵ فكلما بقل بتقل العزم كالباسي.

$A_s = 2189\, mm^2$

$8\phi19$

$11\phi16$

بزبط نستخدمهم بس لازم أعيد الميزانية لإنه عدد البارات كثير بتحتاج لعدد طبقات أكثر.

$A_s = 2322\,mm^2 \leftarrow 6\phi22$ ✓

d exact $= 415.5\, mm$

d' exact $= 58\,mm$

• نعمل تشييك عليهم.

itr (1):

$T = C \rightarrow A_s f_y = 0.85\, f_c'\, ab + A_s' f_s' \rightarrow f_s' = 360\, MPa$

$\rightarrow a = 139.15\,mm$, $\bar{y} = 163.7\,mm$

$\rightarrow \epsilon_s' = 1.9 \times 10^{-3} \rightarrow f_s' = 380\, MPa$

itr (2): $f_s' = 380 \rightarrow a = 138.5\,mm \rightarrow \bar{y} = 162.9\,mm$

$\rightarrow \epsilon_s' = 1.93 \times 10^{-3} \rightarrow f_s' = 386\, MPa$

acceptable ⟵ وبستغنى عن إكمال الإترشنة

$\epsilon_s = 0.00965 < 0.005$, $\phi = ?$

> 0.004 ✓ OK Doubly Reinforcement

$\phi = 0.87$ ⟵ ع القانون

$A_s' = 398\ mm^2$, $A_s = 2322\ mm^2$

$a = 138.5$, $f_s' = 386\ MPa$

$d = 415.5$, $d' = 58\ mm$

$T_1 = C_c$

$T_2 = C_s$

- $\phi M_{n_1}\ (C_{concrete}, T_{steel}) = \phi\ A_{s_1} f_y (d - a/2)$
  - $T_{s_1} = C_c \rightarrow$
    - $0.85 f_c' ab$
    - $A_s f_y - A_s' f_s'$

$\phi M_{n_1} = 248.2\ kN.m$

- $\phi M_{n_2} = \phi\ A_s' f_s' (d - d') = 47.7\ kN.m$

$\rightarrow \boxed{\phi M_n = 296\ kN.m} > M_u$ ✓