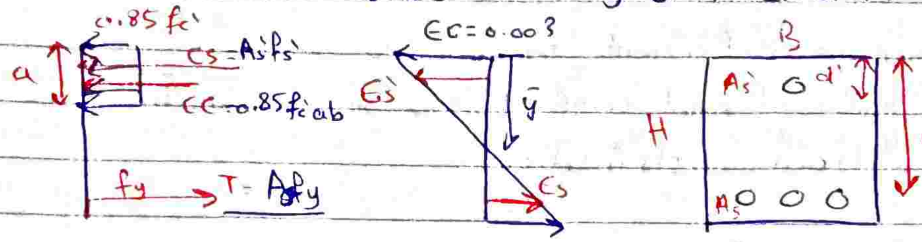
⟶ نعملها لما تكون الحمولة عالية، وما بنقدر نغير أبعاد الخرسانة

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 → calculat ϵ_s' then by Hooks low → $f_s' = E \epsilon_s'$

$T = A_s f_y$
- → couple Cs → ϕM_{n1}
- → couple Cc → ϕM_{n2}

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

Nominal strength:

- → Cs coupled with part of T
  - $\epsilon_s' > \epsilon_y$ ← من تشابه المثلثات → compression steel yields → $C_s = A_s' f_s'$
    - → $\phi M_{n1} = \phi A_s' f_y (d - d')$
    - → $\phi M_{n2} = \phi (A_s f_y - A_s' f_s')(d - a/2) = \phi (A_s - A_s') f_y (d - a/2)$
  - $\epsilon_s' < \epsilon_y$ → من تشابه المثلثات → compression steel doesn't yields → $C_s = A_s f_s'$
    - → $\phi M_{n1} = \phi f_s' A_s' (d - d')$
    - → $\phi M_{n2} = \phi (A_s f_s - A_s' f_s')(d - a/2)$
- → Cc coupled with rest of T

- We have to calculat a then find $\bar{y}$ to determin if the section yield or no

- find [a] By section Equilibrium.

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

- 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

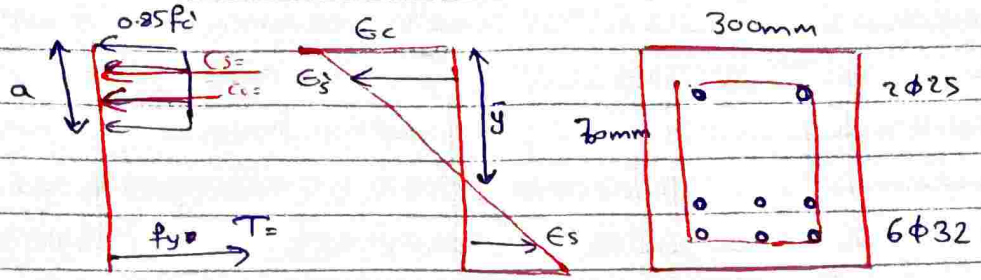
$$\rightarrow \frac{\epsilon_c}{\bar{y}} = \frac{\epsilon_s}{d-\bar{y}} \rightarrow \epsilon_s = \quad > 0.004$$

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

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

• $\rho = \frac{4914}{300\times602} = \frac{A_s}{bd} = 0.027$

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

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

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

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

$a = 183.24$

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

$\epsilon_s' = 2.18\times10^{-3} > 2\times10^{-3}$ yield

$\epsilon_s = 4.88\times10^{-3} > 0.004$ → ACI ✓

< 0.005 → ϕ = ?

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

$\phi = 0.89$

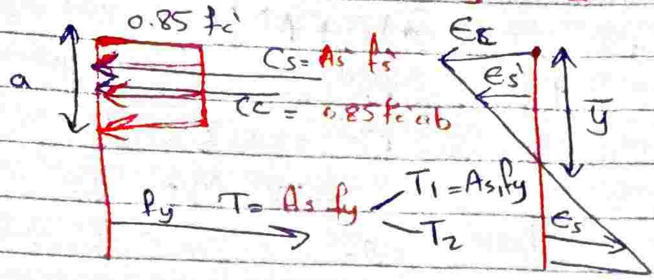
$\phi M_n = \phi M_{n1} + \phi M_{n2}$

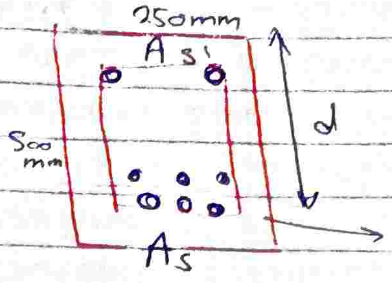
$= \phi A_s' f_y (d-d') + \phi (A_s - A_s') f_y (d - a/2)$ ← $0.85 f_c' ab$

$= 206.5 + 742.89 = 949.5$ kN.m

• Design ↓

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





ببدأ بعرض
إنه في 2layers
لأنه اكونة على
وأقطار الكرتيه ستكون صغيرة

• Singly Rc → $R = \frac{M_u}{\phi b d^2}$ → $R = 7.4\,MPa$ → 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 Reinforcment < 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 → $\phi M_{n_1} = \phi R d^2 b$

$\phi = 0.9$

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

$= 249.4\,kN.m$

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

• $A_{s_1} = \rho b d = 1889\,mm^2$

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

• $C_c = T_1$ → $A_{s_1} f_y = 0.85 f_c' a b$ → $a = 133.34\,mm^2$

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

→ $\epsilon_s' = 0.00185$

→ $f_c' = 370\,MPa$

→ $40.6 = 0.9 A_s' (370)(417.5 - 60)$ → $A_s' = 341\,mm^2$ ← We need add steel on T-side

• $T_2 = C_s$ → $A_{s_2} f_y = A_s' f_s'$ → $A_{s_2} = A_s' \left(\frac{f_s'}{f_y}\right)$ → قوطا صارنا الـ yield الكومبرشن مساية ، لرفي

$A_{s_1} = A_{s_2}$ ← yield

• $A_{s_2} = 300\,mm^2$

• $A_s' = 341\,mm^2$, $A_s = 1889\,mm^2 + 300\,mm^2 = 2189\,mm^2$

• 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 ⇒

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

$S = 25 mm$

$3\phi12 \rightarrow S = 57 mm$

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

• معظم بزبطوا بس الأفضل إنه تكون قطر البارات أكبر (فرصة بالبيم).

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

• أفضل نقلل عدد الطبقات.

$A_s = 2189 mm^2$

$2\phi19$, $1\phi16$ → بزبط نستخدمهم بس لازم أعيد الميزانية لإنه عدد البارات كتاج لعدد طبقات أكثر

كل ما ليست (d) ← بكون أكثر.

← d → بأثر مقدار العزم فاما يقل بقل العزم كالأساس

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

$d_{exact} = 415.5 mm$

$d'_{exact} = 58 mm$

• 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): $f_s' = 380 \rightarrow a = 138.5 mm \rightarrow \bar{y} = 162.9 mm$

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

وبنستغني بإكمال الإتيريشن ← acceptable

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

> 0.004 ✓ OK Doubly Reinforcement

$\phi = 0.87$ ← ع القانون

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

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

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

$T_1 = C_c$

$T_2 = C_s$

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

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

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

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