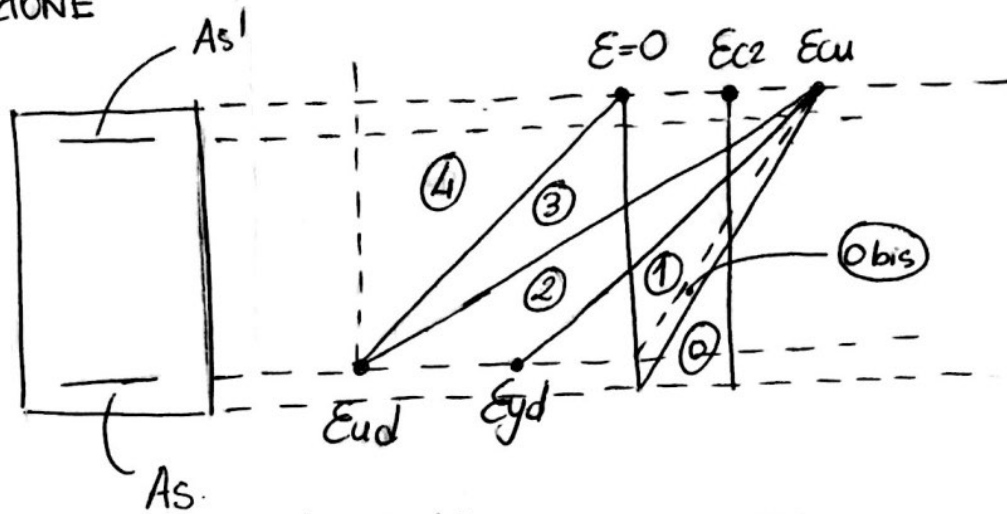
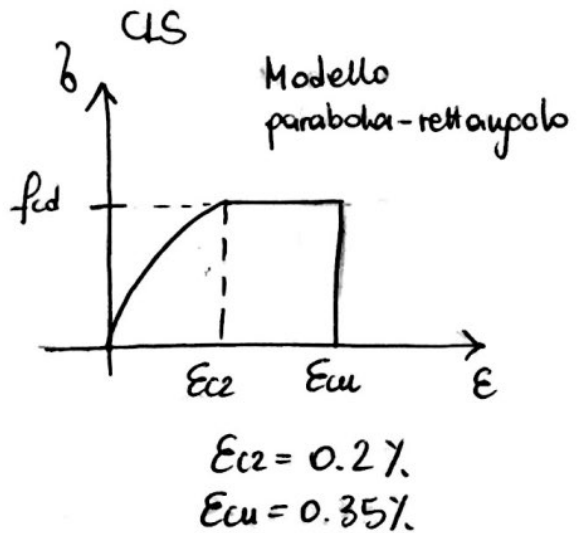
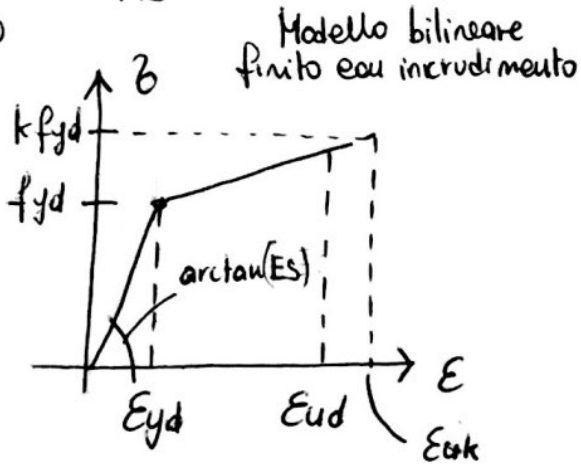


PRESSO FLESSIONE ELEMENTI C.A.

INTRODUZIONE



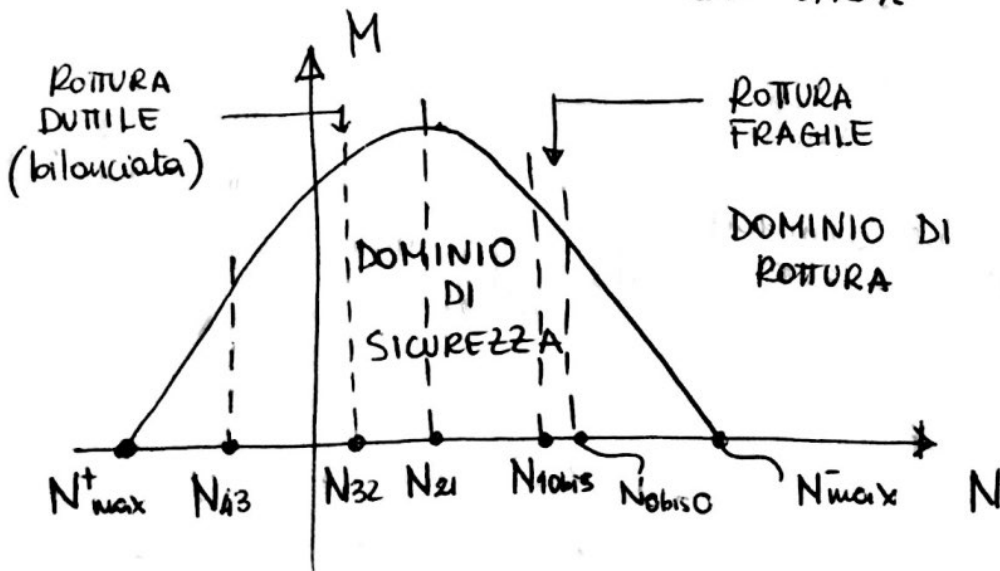
ACCIAIO

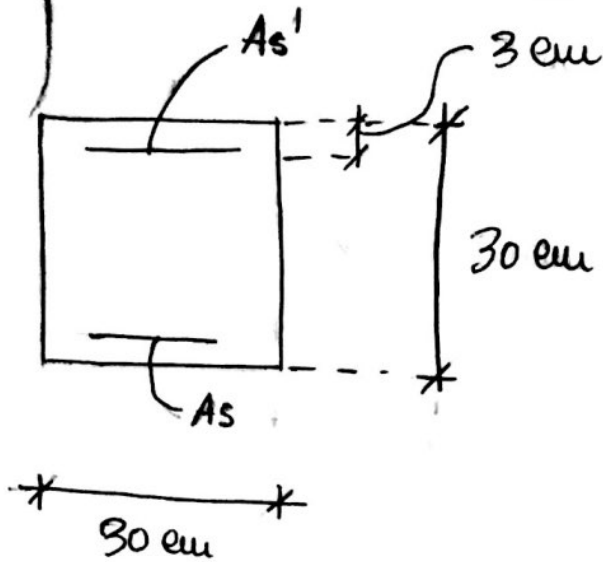


B450C

$$E_{yd} = \frac{f_{yd}}{E_s} = 1.96 \times 10^{-3}$$

$$E_{ud} = 0.9 E_{uk} \rightarrow \text{B450C: } E_{uk} = 7.5\% \\ E_{ud} = 6.75\%$$





$$As' = As = 4\phi 20$$

$$N_{Ed} = -357,5 \text{ kN}$$

$$M_{Ed} = 117,2 \text{ kNm}$$

$$(C15) f_{ck} = 30 \text{ MPa}$$

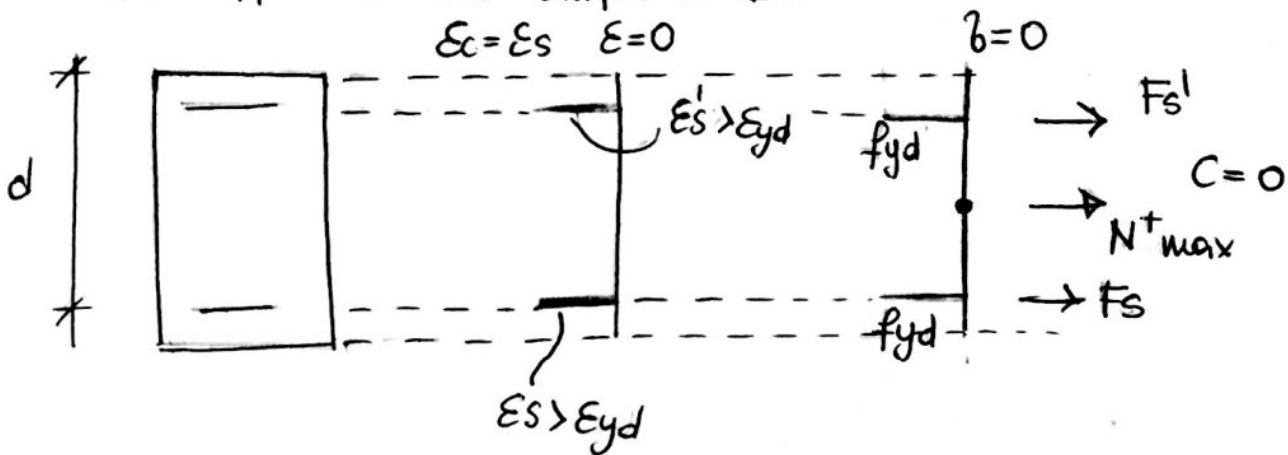
$$f_{yk} = 450 \text{ MPa}$$

$$f_{cd} = \frac{0,85 f_{ck}}{1,5} = 17 \text{ MPa}$$

+ COSTRUZIONE DEL DOMINIO RESISTENTE M-N

REGIONE 4 → sez. uniform. TESA

$$\epsilon_c = \epsilon_s \quad \epsilon = 0$$



• Asse neutro $y_c = -\infty$

$$\epsilon_s' = \epsilon_s = \epsilon_{ud} \rightarrow \delta_s' = \delta_s = f_{yd}$$

$$N_{max}^+ = As' f_{yd} + As f_{yd} = A_{stot} f_{yd}$$

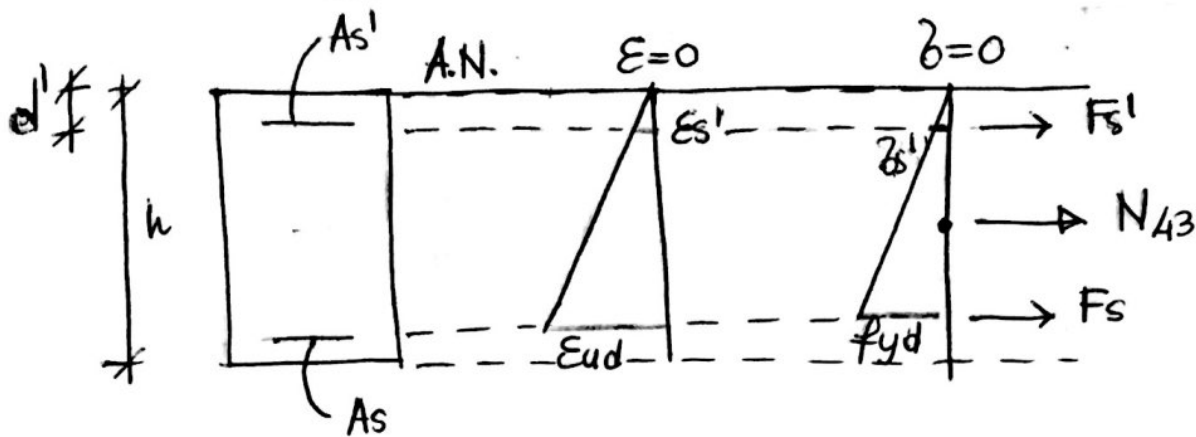
$$A (1\phi 20) = 3,14 \text{ cm}^2 \rightarrow (4+4)\phi 20 = 25,12 \text{ cm}^2$$

$$N_{max}^+ = 12,56 \text{ cm}^2 \cdot 39,13 \frac{\text{kN}}{\text{cm}^2} + 12,56 \cdot 39,13 = \frac{982,94 \text{ kN}}{\text{TRAZIONE}}$$

(Pdo centro della sez.)

$$M_{max}^+ = As f_{yd} \left(d - \frac{h}{2} \right) - As' f_{yd} \left(\frac{h}{2} - d' \right) = 0$$

REGIONE 3 → determino N₄₃: N₄₃



• $y_c = 0$

• $\frac{\epsilon_{s'}}{d'} = \frac{\epsilon_{ud}}{d} \rightarrow \epsilon_{s'} = \epsilon_{ud} \frac{d'}{d} \rightarrow \sigma_{s'} = \sigma_{s'}(\epsilon_{s'})$

$\epsilon_{s'} = 0,00675 \cdot \frac{3}{27} = 7,5 \cdot 10^{-4} < 1,96 \cdot 10^{-3} = \epsilon_{yd}$

$\sigma_{s'} = \underbrace{7,5 \cdot 10^{-4}}_{\epsilon_{s'}} \cdot \underbrace{20'000 \frac{kN}{cm^2}}_{E_s} = 15 \frac{kN}{cm^2}$

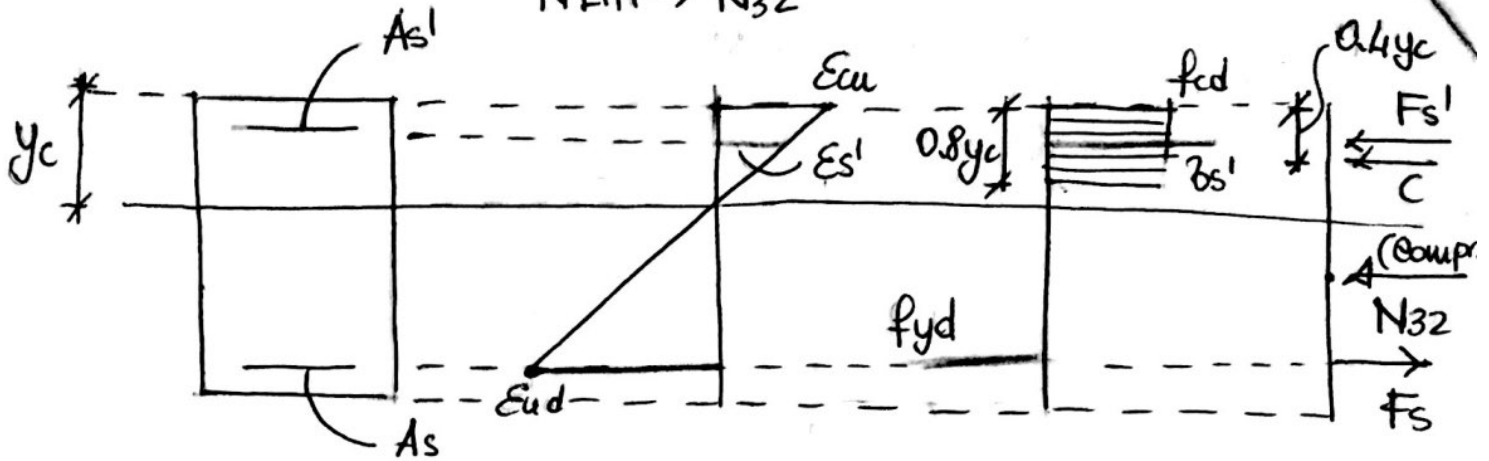
$E_s = \epsilon_{ud} \rightarrow \sigma_s = f_{yd} \rightarrow \left\{ \begin{array}{l} \text{ARMATURA INF.: SNERVATA} \\ \text{ARMATURA SUP.: NON SNERVATA} \end{array} \right.$

$N_{43} = A_s f_{yd} + A_{s'} \sigma_{s'} = 12,56 \times 39,13 + 12,56 \times 15 = \underline{679,9 \text{ kN}}$
TRAZIONE

$M_{43} = A_s f_{yd} \left(d - \frac{h}{2}\right) - A_{s'} \sigma_{s'} \left(\frac{h}{2} - d'\right) =$
 $= 12,56 \cdot 39,13 (27 - 3) - 12,56 \cdot 15 (15 - 3) = \underline{59 \text{ kNm}}$

REGIONE 2 → sez. parzializzata
 NLIM → N32

PAG. 4



• calcolo di $y_c \rightarrow \frac{\epsilon_{cu}}{y_c} = \frac{\epsilon_{cu} + \epsilon_{ud}}{d}$

$$y_c = \frac{\epsilon_{cu} \cdot d}{\epsilon_{cu} + \epsilon_{ud}} = \frac{0,0035 \cdot 27}{0,0035 + 0,00675} = 9,22 \text{ cm}$$

• $\epsilon_s = \epsilon_{ud} \rightarrow \delta_s = f_{yd}$

$$\frac{\epsilon_s'}{y_c - d'} = \frac{\epsilon_{cu}}{y_c} \rightarrow \epsilon_s' = \epsilon_{cu} \frac{(y_c - d')}{y_c} = 0,0035 \cdot \frac{(9,22 - 3)}{9,22} = 2,36 \cdot 10^{-3} > 1,96 \cdot 10^{-3}$$

$\epsilon_s' = \epsilon_{ud} \rightarrow \delta_s' = f_{yd}$

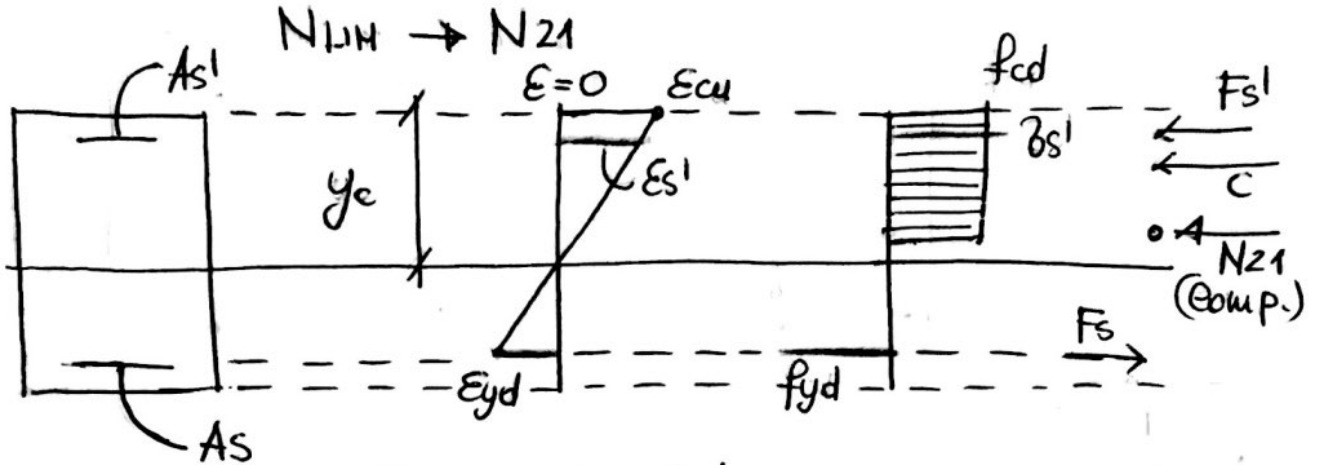
$$N_{32} = -0,8 y_c b \cdot f_{cd} - A_s' f_{yd} + A_s f_{yd} = -0,8 \cdot 9,22 \cdot 30 \cdot 17 = -376,18 \text{ kN}$$

COMPRESSIONE

(Polo centro della sez.)

$$M_{32} = 0,8 \cdot y_c b f_{cd} \left(\frac{h}{2} - 0,4 y_c \right) + A_s f_{yd} \left(d - \frac{h}{2} \right) + A_s' f_{yd} \left(\frac{h}{2} - d' \right) = 160,41 \text{ kNm}$$

- ~~REAZIONE~~ REAZIONE 1: sez. parzializzata (rottura bilanciata)



- calcoliamo $y_c \rightarrow \frac{E_{cu}}{y_c} = \frac{E_{cu} + E_{yd}}{d}$

$$y_c = \frac{E_{cu} \cdot d}{E_{cu} + E_{yd}} = \frac{0,0035 \cdot 27}{0,0035 + 0,00196} = 17,3 \text{ cm}$$

- $E_s = E_{yd} \rightarrow \beta_s = f_{yd}$

- Determino $\epsilon_s', \beta_s' \rightarrow \frac{\epsilon_s'}{y_c - d'} = \frac{E_{cu}}{y_c} \rightarrow \epsilon_s' = E_{cu} \frac{(y_c - d')}{y_c}$
 $= 2,893 \cdot 10^{-3} > 1,96 \cdot 10^{-3}$

- $\beta_s' = f_{yd}$

$$N_{21} = -0,8 y_c b f_{cd} - A_s' f_{yd} + A_s f_{yd} = -0,8 \cdot 17,3 \cdot 30 \cdot 1,7 = -705,84 \text{ kN}$$

COMPRESSIONE

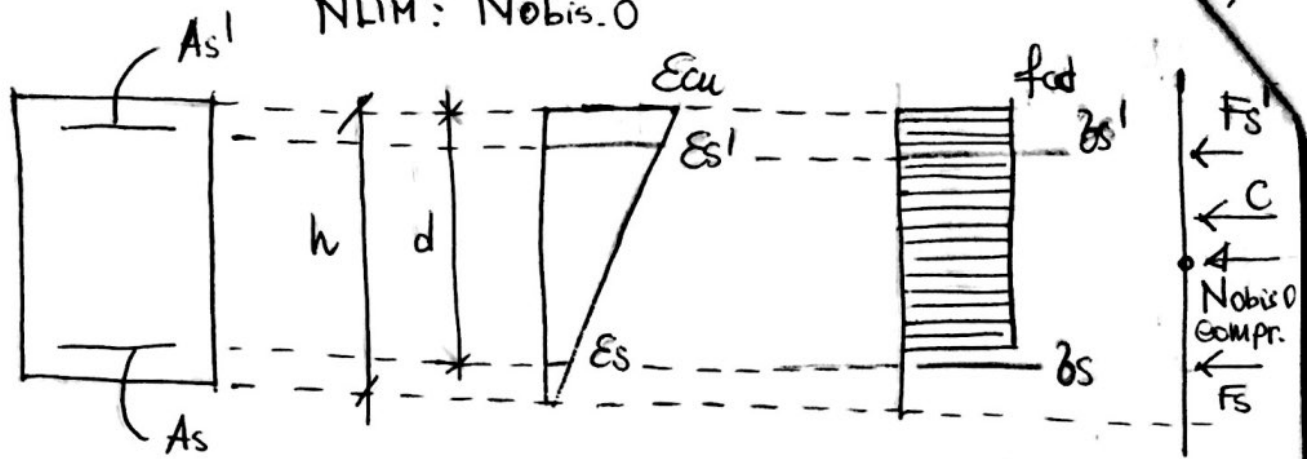
(Polo centro della sez.)

$$M_{21} = 0,8 y_c b f_{cd} \left(\frac{h}{2} - 0,4 y_c \right) + A_s' f_{yd} \left(\frac{h}{2} - d' \right) + A_s f_{yd} \left(d - \frac{h}{2} \right) = 174,9 \text{ kNm}$$

• REGIONE Obis : sez. interamente COMPRESSA

PAG.6

NLIM: Nobis.0



• $y_c = h$

• Determino $\epsilon_{s'}$: $\frac{\epsilon_{s'}}{h-d'} = \frac{\epsilon_{cu}}{h} \rightarrow \epsilon_{s'} = \frac{\epsilon_{cu}(h-d')}{h} = 3,15 \cdot 10^{-3} > 1,96 \cdot 10^{-3}$

$\sigma_{s'} = f_{yd}$

• Determino ϵ_s : $\frac{\epsilon_s}{(h-d)} = \frac{\epsilon_{cu}}{h} \rightarrow \epsilon_s = \epsilon_{cu} \frac{(h-d)}{h} = 3,5 \cdot 10^{-4} < 1,96 \cdot 10^{-3}$

$\sigma_s = \epsilon_s \cdot E_s = 3,5 \cdot 10^{-4} \cdot 20000 \frac{kN}{cm^2} = 7 \frac{kN}{cm^2}$

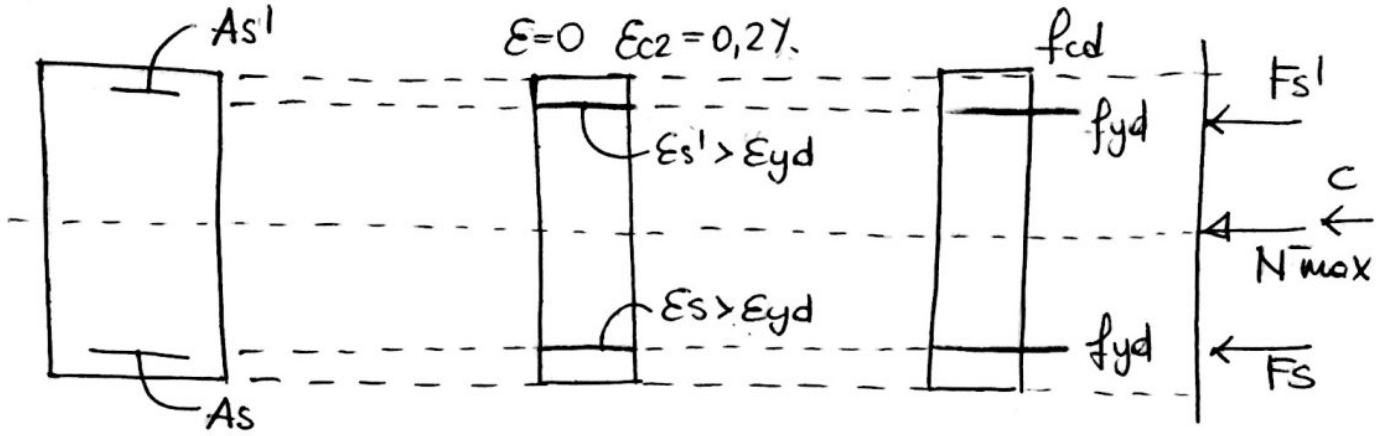
$N_{obis.0} = -0,8 h b f_{cd} - A_{s'} f_{yd} - A_s \sigma_s =$

$= -0,8 \cdot 30 \cdot 30 \cdot 1,7 - 12,56 \cdot 39,13 - 12,56 \cdot 7 = \underline{\underline{-1803 \text{ kN}}}$
 COMPRESSIONE

(Polo centro della sez.)

$M_{obis.0} = 0,8 h b f_{cd} \left(\frac{h}{2} - 0,4h\right) + A_{s'} f_{yd} \left(\frac{h}{2} - d'\right) - A_s \sigma_s \left(d - \frac{h}{2}\right) = 60,6 \text{ kNm}$

REGIONE 0 : NUH : N_{max}^-

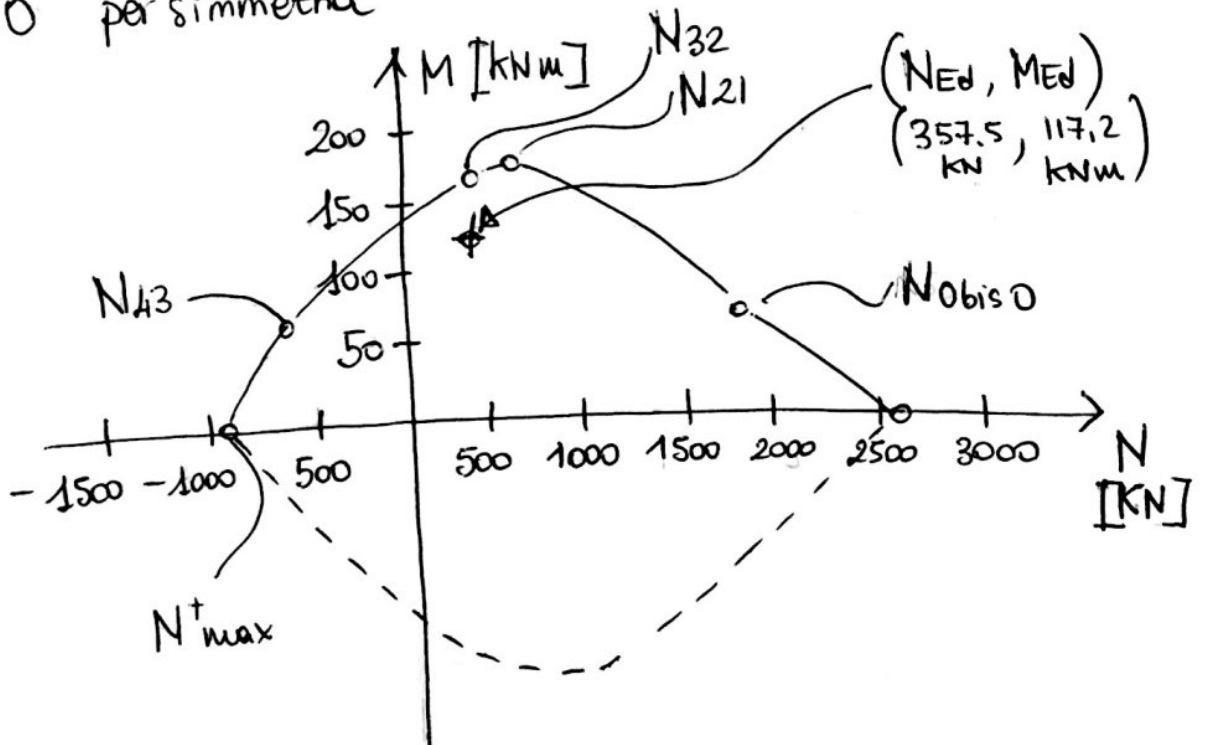


$y_c = +\infty$

$\epsilon_{s'} = \epsilon_s = \epsilon_{c2} = 0,27 > \epsilon_{yd} \rightarrow \sigma_s = \sigma_{s'} = f_{yd}$

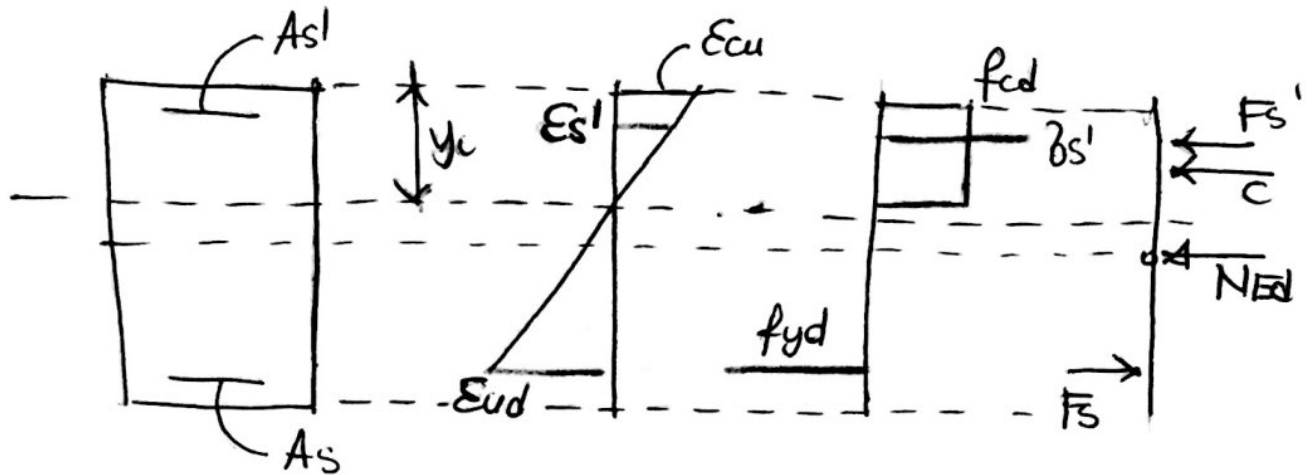
$N_{max}^- = -bh f_{cd} - A_s f_{yd} - A_{s'} f_{yd} =$
 $= -30 \cdot 30 \cdot 1,7 - 2 \cdot 12,56 \cdot 39,13 = \underline{-2512,2 \text{ kN}} \text{ COMPRESSIONE}$

$M_{max}^- = 0$ per simmetria



$\rightarrow N_{43} < N_{Ed} < N_{32} \rightarrow \text{REGIONE 3}$

Calcolo il MOMENTO RESISTENTE ULTIMO della sezione:



EQ. TRASL.

$$N_{Ed} = C + F_{s'} - F_s$$

$$C = 0,8 y_c b f_{cd}$$

$$F_s = A_s f_{yd}$$

$$F_{s'} = A_s \sigma_{s'} (\epsilon_{s'}) \rightarrow \frac{\epsilon_{s'}}{y_c - d'} = \frac{\epsilon_{ud}}{d - y_c} \rightarrow \epsilon_{s'} = \frac{\epsilon_{ud}(y_c - d')}{(d - y_c)}$$

Ipotesi $\epsilon_{s'} > \epsilon_{yd} \rightarrow \sigma_{s'} = f_{yd}$

$$N_{Ed} + C + F_{s'} - F_s = 0$$

$$-357,5 - 0,8 \cdot y_c \cdot 30 \cdot 1,7 - 12,56 \cdot 39,13 + 12,56 \cdot 39,13 = 0$$

$$y_c = \frac{357,5}{0,8 \times 1,7 \times 30} = 8,76 \text{ cm}$$

$$\epsilon_{s'} = 0,00675 \cdot \frac{(8,76 - 3)}{(27 - 8,76)} = 2,13 \times 10^{-3} > 1,96 \times 10^{-3}$$

→ ARM. SUP. SNERVATA

$$M_{Rd} = 0,8 b y_c f_{cd} \left(\frac{h}{2} - 0,4 y_c \right) + A_s' f_{yd} \left(\frac{h}{2} - d' \right) - A_s f_{yd} \left(d - \frac{h}{2} \right) =$$

$$= 158,95 \text{ kNm} > M_{Ed} = 117,2 \text{ kNm}$$