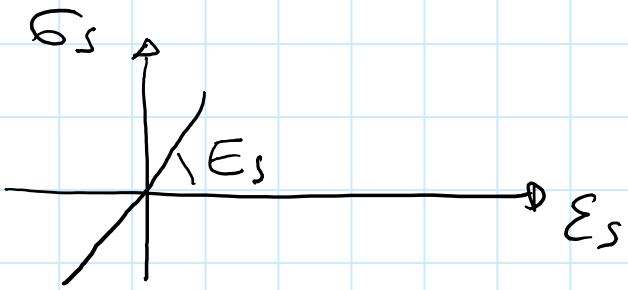
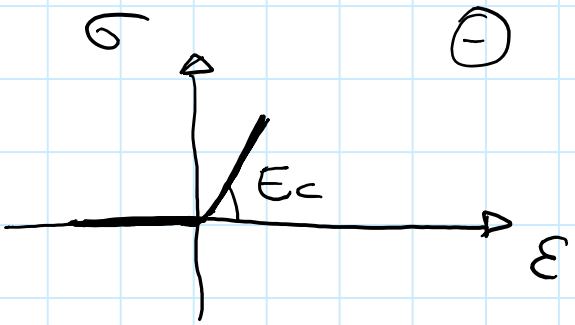
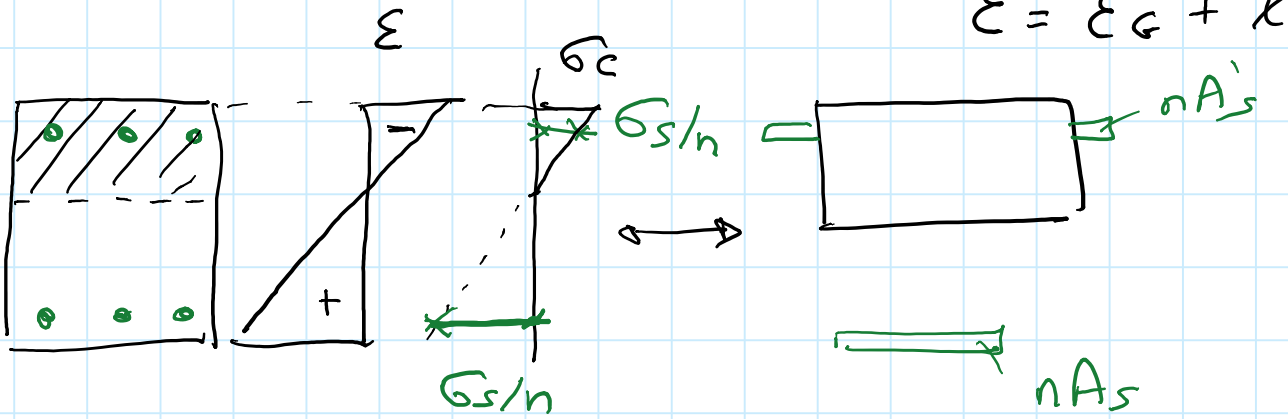
II STADIO





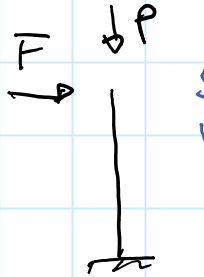
$$\varepsilon = \varepsilon_G + \chi_x X + \chi_y Y$$



SEZIONE REAGENTE OMOGENEIZZATA

$$\sigma_c = E_c \varepsilon$$

PASSO PRELIMINARE: TROVARE POSIZIONE ASSE NEUTRO

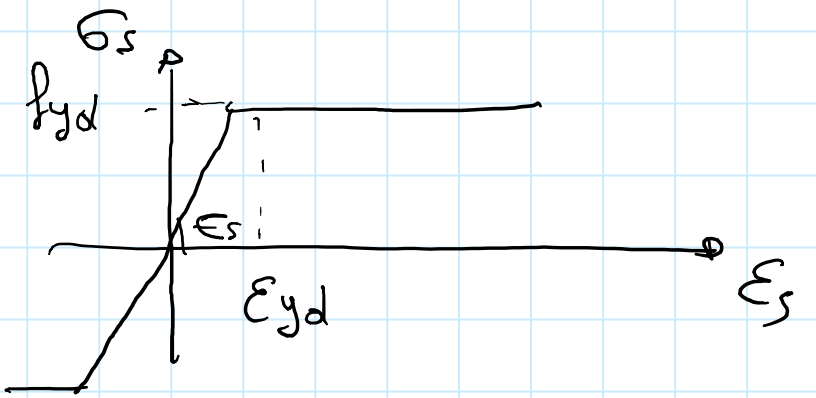


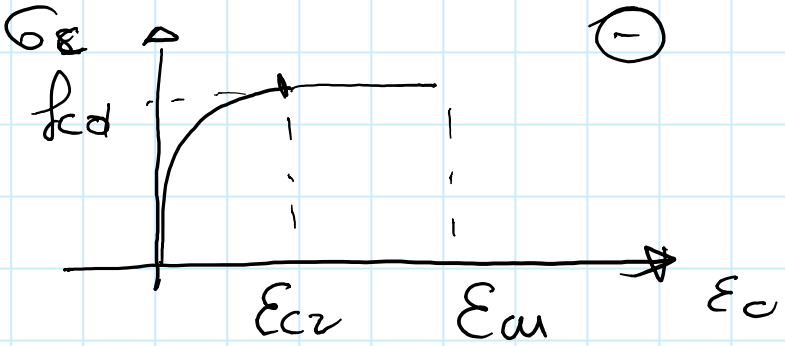
SEZIONE VARIABILE IN ALTEZZA

$$\sigma_c = \frac{N}{A} + \frac{M_x}{I_x} y - \frac{M_y}{I_y} x$$

$$\sigma_s = n \sigma_c$$

III STADIO





CALCOLO M_{Rd}, N_{Rd} CONFRONTO CON M_{Ed}, N_{Ed}

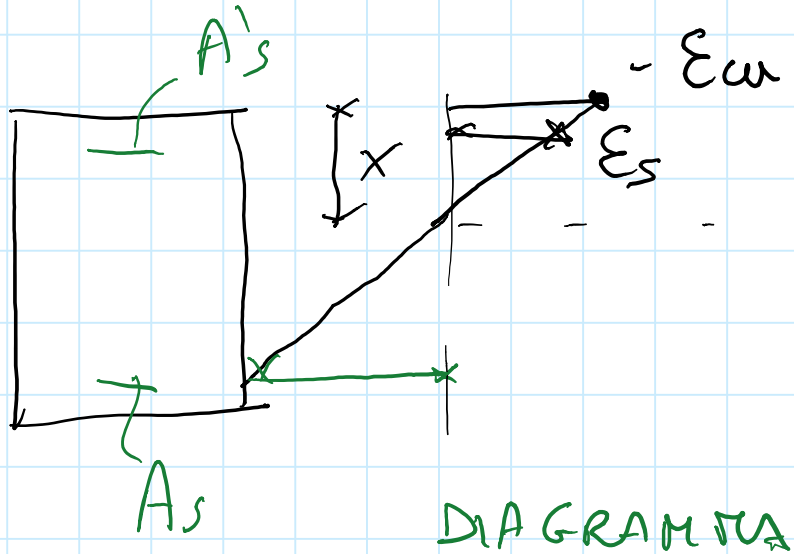
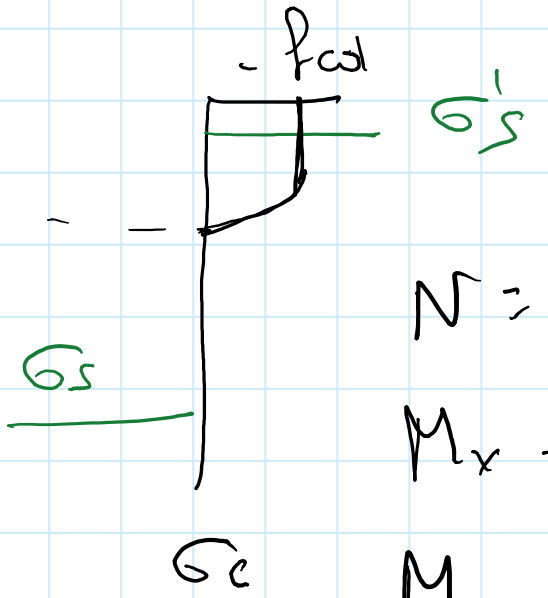


DIAGRAMMA ε LIMITE



$$N = \int \sigma \, dA$$

$$M_x = \int \sigma \, y \, dA$$

$$M_y = -\int \sigma \, x \, dA$$

VERIFICHE SLU → III STADIO

VERIFICHE DI CAPACITÀ PORTANTE

VERIFICHE SLE
- DEFORMABILITÀ
- FESSURAZIONE (a)
- TENSIONI DI ESERCIZIO (b)

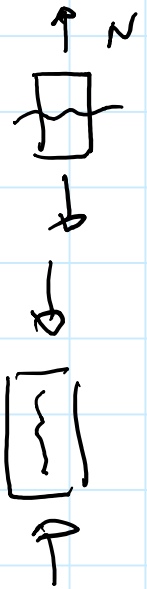
(a) $\sigma_t(N) \leq f_{ctk}$

$\sigma_t(M) \leq f_{cfk}$

(b) $\sigma_c \leq 0.6 f_{ck}$

$\sigma_s \leq 0.8 f_{yk}$

$\sigma_c \leq 0.45 f_{ck}$ (LIMITARE DEF. VISCOSE)



I STADIO

II STADIO

COMBINAZIONE RARA

$G_k + Q_{k1} + \sum \psi_0 Q_{ki}$

COMB. QUASI PERM.

$G_k + \psi_2 Q_k$

SFORZO NORMALE

I STADIO

CONSERVAZIONE SEZ. PIANE

$$\varepsilon = \varepsilon_G + \chi_x X + \chi_y y$$

PERFETTA ADERENZA

$$\varepsilon_s = \varepsilon_c$$

$$\sigma_c = E_c \varepsilon \qquad \sigma_s = E_s \varepsilon \qquad \longrightarrow \qquad \sigma_s = n \sigma_c \qquad n = \frac{E_s}{E_c}$$

$$\varepsilon_G = \frac{N}{E_c A_{ci}} \; ; \qquad \chi_y = \frac{M_x}{E_c I_x} \; ; \qquad \chi_x = -\frac{M_y}{E_c I_y}$$

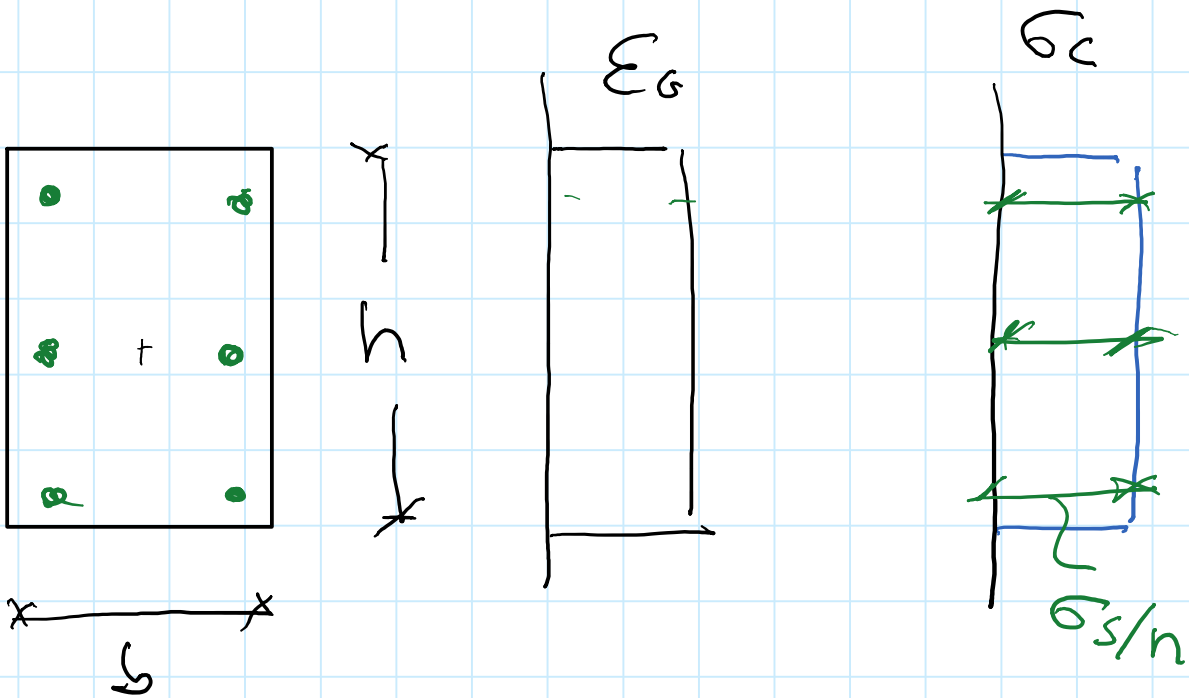
$N \neq 0$

$M_x = 0 \quad \Rightarrow \quad \varepsilon = \varepsilon_G$

$M_y = 0$

SEZIONE OMOGENEIZZATA

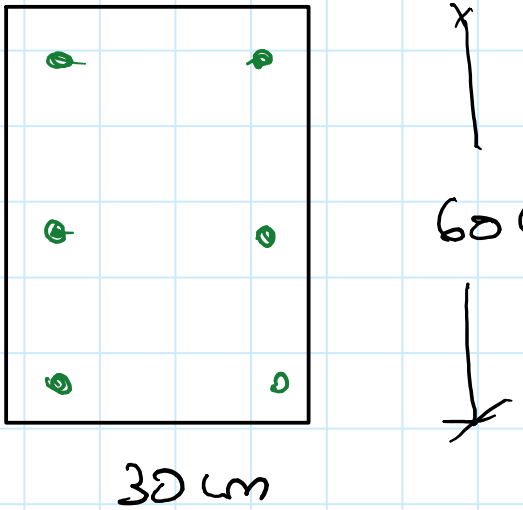
N CENTRATO, I STADIO



$$\sigma_c = \frac{N}{A_{ci}} \qquad \text{DOVE} \qquad A_{ci} = bh + A_{staf}\, n$$

$$\sigma_s = n\,\sigma_c$$

ESEMPIO



DATI

$6\phi 14$

C30/37

B450C

$N = 250\ kN$

$A_{ci} = 30 \times 60 + 6.09 \times 6 \times 1.54 = 1853\ cm^2$

$A\ \phi 14 = \pi \cdot \frac{1,4^2}{4} = 1.54\ cm^2$

$$\sigma_c^{(+)} = \frac{250\ kN}{1853\ cm^2} \cdot \frac{10^3}{10^2} = 1.35\ MPa$$

$f_{ctk} = 0.7\, f_{ctm}$

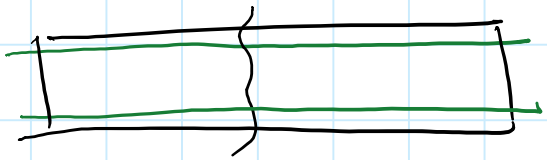
$f_{ctm} = 0.3 \sqrt[3]{f_{ck}^2} = 0.3 \sqrt[3]{30^2} = 2.90\ MPa$

$f_{ctk} = 0.7 \times 2.90 = 2.03\ MPa > \sigma_c^{(+)}$ → NON FESSURATA

SFORZO NORMALE DI FESSURAZIONE

$$\sigma_c = f_{ctk} \Rightarrow$$

$$N = f_{ctk} A_{ci} = 2.03 \frac{N}{mm^2} \times \frac{1853}{10} cm^2 \simeq 376 \, kN$$



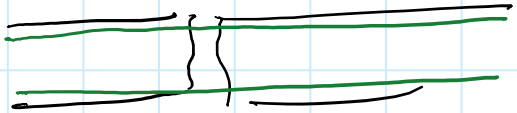
$\rightarrow N$

$$\sigma_s = n f_{ctk} = 6.08 \times 2.03 \frac{N}{mm^2}$$

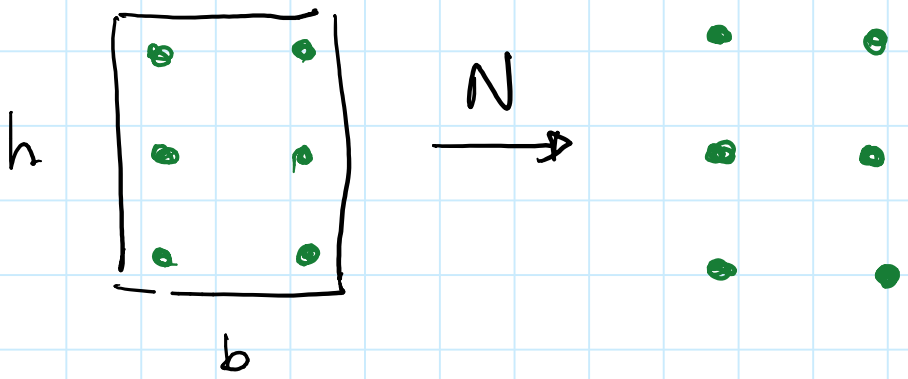
$$= 12.36 \, N/mm^2$$

ARMATURE POCO SOLLECITATE PRIMA DELLA FESSURAZIONE

DOPO LA FESSURAZIONE?



II STADIO, N > 0



SEZIONE REAGENTE DATA SOLO DALLE ARMATURE

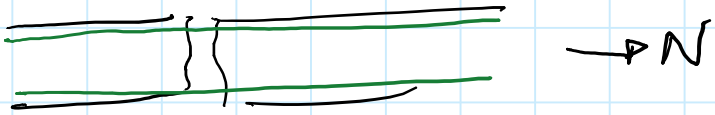
$$\sigma_c = 0$$

$$\sigma_s = \frac{N}{A_{s\,tot}}$$

DA ESEMPIO PRECEDENTE ⟹ DATI: $A_{s\,tot} = 6\phi 14$, $N = 376\ kN$

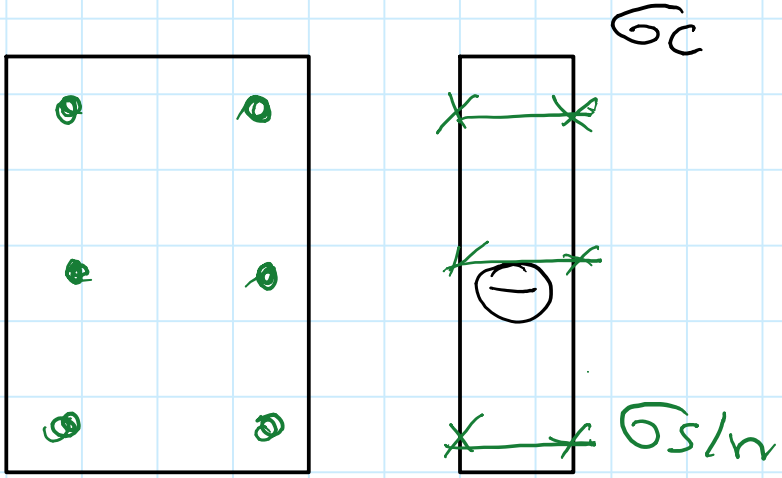
$$A_{stot} = 6 \times 1{,}54\ cm^2 = 9{,}24\ cm^2$$

$$\sigma_s = \frac{N}{A_{stot}} = \frac{376\ kN}{9{,}24\ cm^2} \times 10 = 407\ N/mm^2$$



ARMATURA QUASI SNERVATA → ARMATURA PRESENTE NON BEN PROPORZIONATA

II STADIO, N < 0



SEZIONE INTERAMENTE COMPRESSA →

VERIFICA SIMILE A QUELLA DEL 1° STADIO

$$\sigma_c = N / A_{ci}$$

$$\sigma_s = n \sigma_c$$

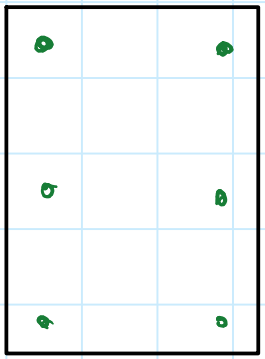
$$A_{ci} = bh + 15\, A_{stot}$$

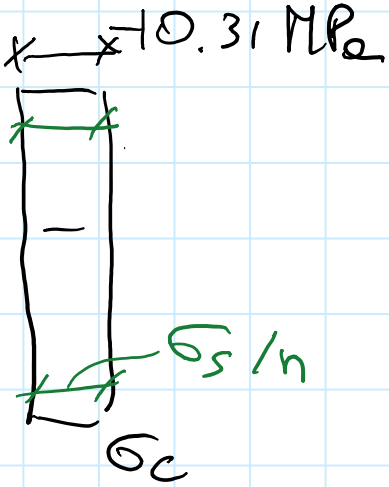
CARICHI LUNGA DURATA

$$A_{ci} = bh + \frac{E_s}{E_c} A_{s,tot}$$

CARICHI DI BREVE DURATA

ESEMPIO





DATI

6 ϕ 14 B450C

C30/37

- COMB. RARA
- CARICHI LUNGA DURATA

$N = -2000$ kN

$$A_{ci} = 30 \times 60 + 15 \cdot 6 \cdot 1{,}54\ cm^2 = 1939\ cm^2$$

$$\sigma_c = \frac{N}{A_{ci}} = \frac{2000\ kN}{1939\ cm^2} \times 10 = 10{,}31\ MPa$$

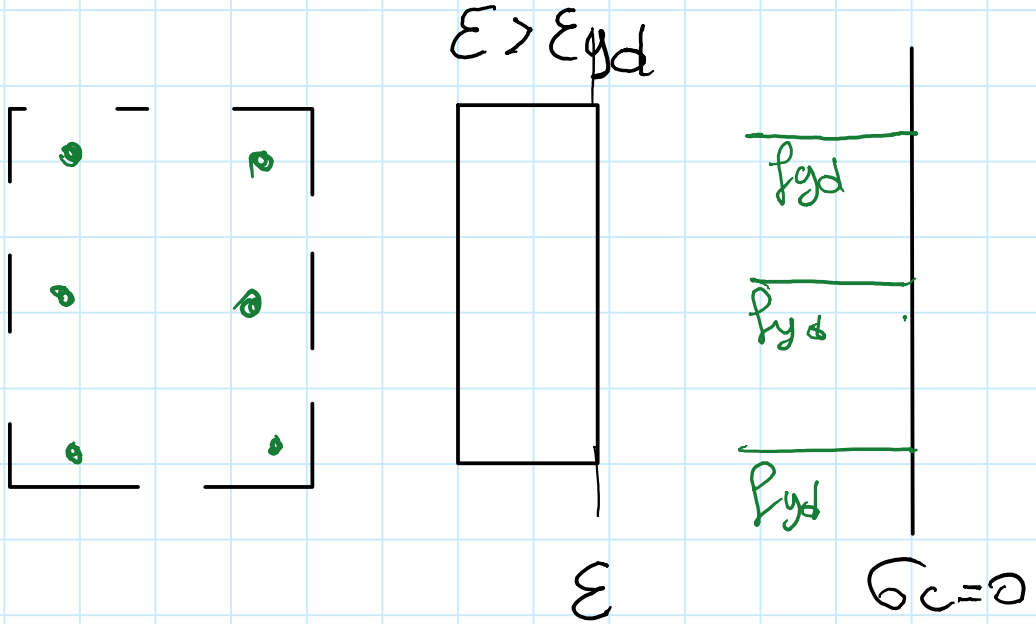
$$0.6\, f_{ck} = 0{,}6 \times 30 = 18\ MPa \Rightarrow \sigma_c \leq 0.6\, f_{ck}$$

$$\sigma_s = 15 \times \sigma_c = 15 \times 10{,}31 = 154\ N/mm^2$$

$$0.8\, f_{yk} = 0{,}8 \times 450 = 360\ N/mm^2 \rightarrow \sigma_s \leq 0.8\, f_{yk}$$

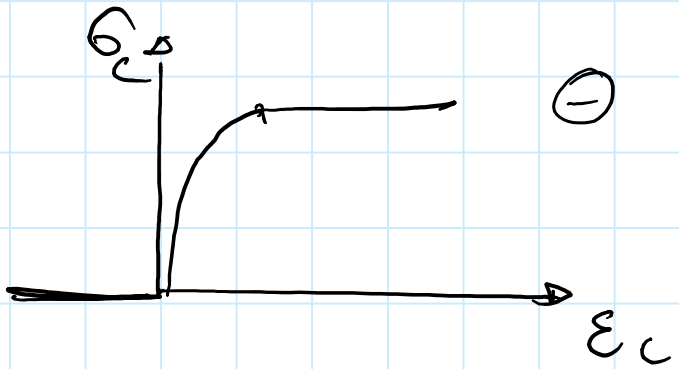
NON CONDIZIONANTE

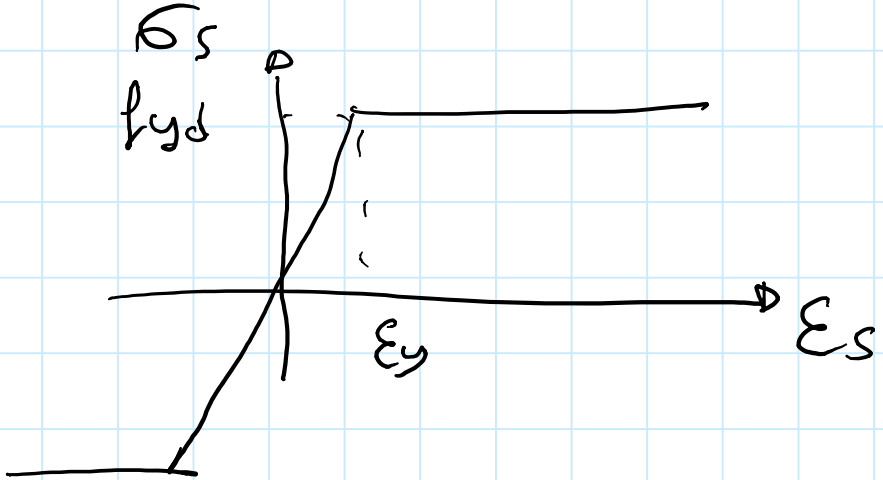
III) STADIO , $N > 0$



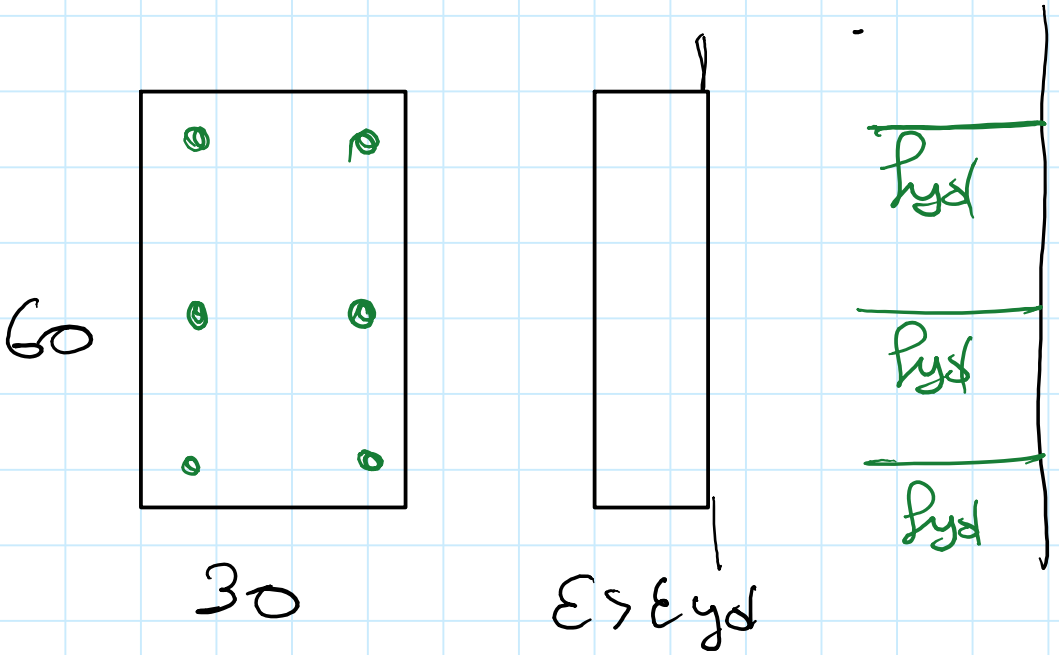
$$N_{Rd} = A_{s,tot}\, f_{yd}$$

$$N_{Rd} \geq N_{Ed}$$





ESEMPIO



DATI

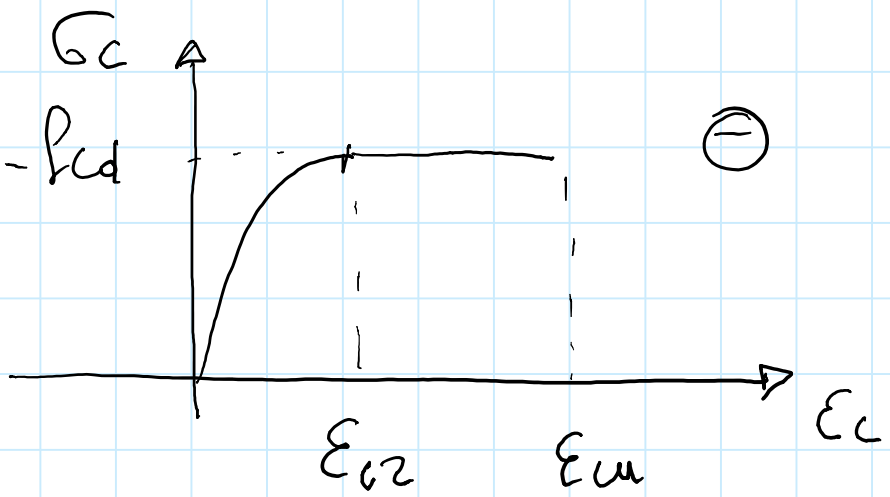
6 ϕ14

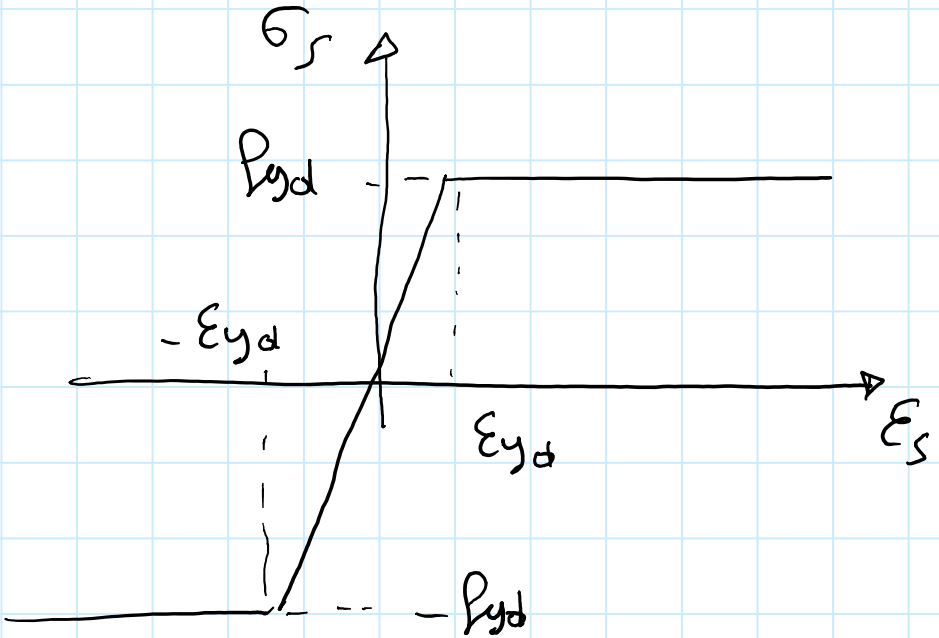
B450C

C30/37

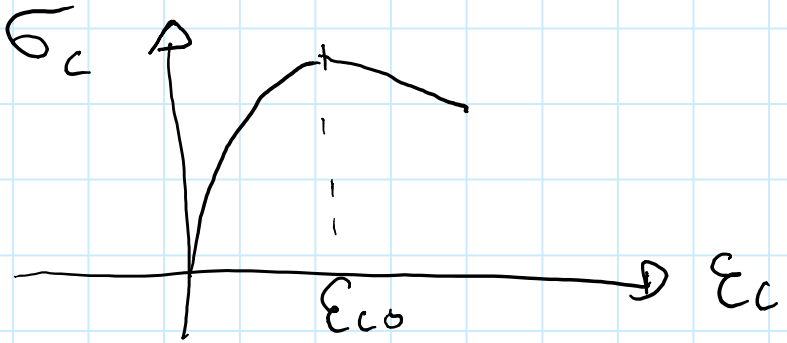
$$N_{Rd}^{\oplus} = \underbrace{6 \times 1{,}54\,cm^2}_{A_{s,tot}} \times \frac{\overbrace{450}^{f_{yd}}\ N/mm^2}{1.15} \cdot \frac{1}{10} = 361{,}6\ kN$$

III STADIO , $N < 0$





ASSUMO DIAGRAMMA ε LIMITE
PER SEZ. INTERAMENTE COMPRESSA $\varepsilon_{LIM} = \varepsilon_{c2}$

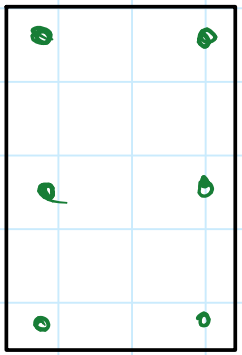


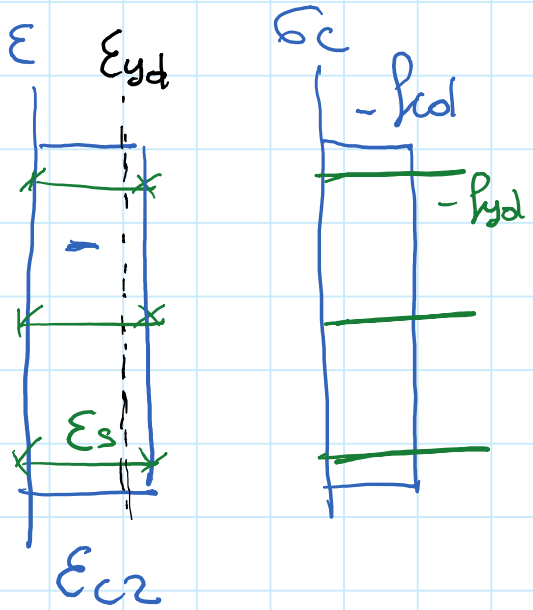
IN REALTÀ DOPO
ε_{c2} HO SOFTENING

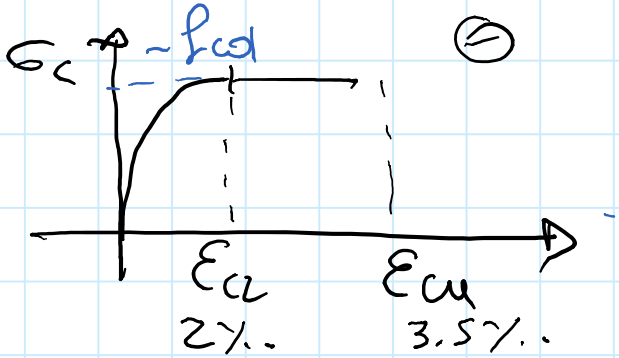
III STADIO

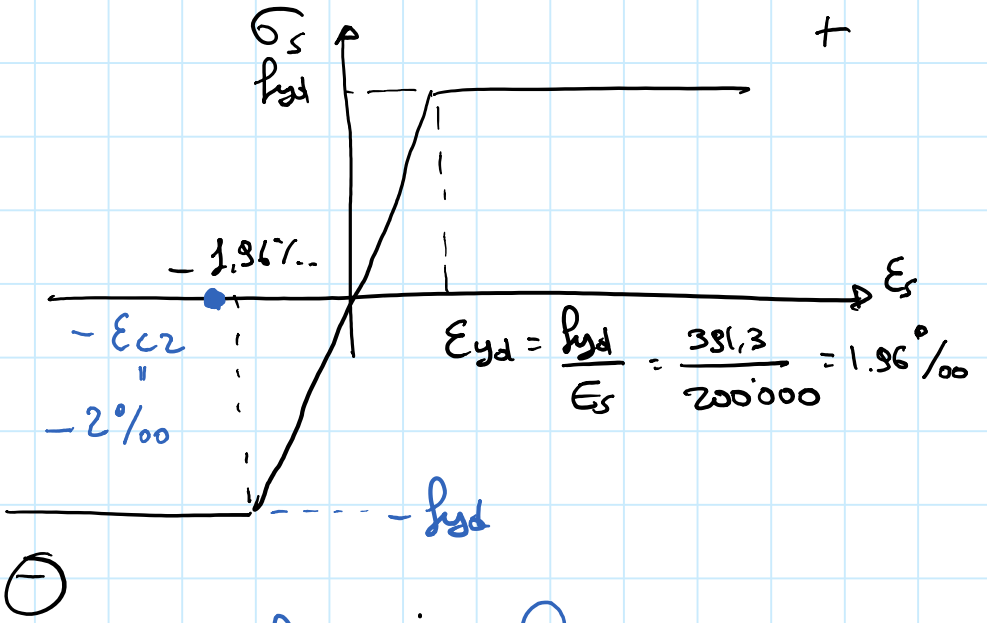
$$N_{Rd}^{\ominus} \geq N_{Ed}$$

$N < 0$









$\ominus$

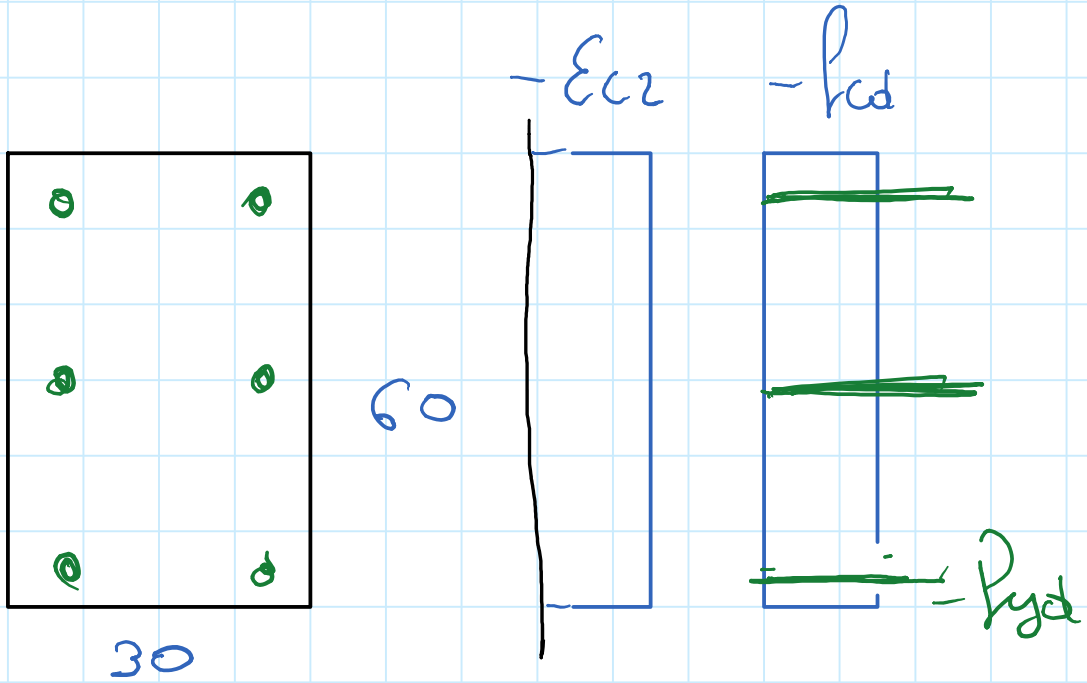
$$\varepsilon_s \geq \varepsilon_{yd} \rightarrow \sigma_s = f_{yd}$$

$$\varepsilon_s \leq -\varepsilon_{yd} \rightarrow \sigma_s = -f_{yd}$$

$$-\varepsilon_{yd} < \varepsilon_s < \varepsilon_{yd} \rightarrow \sigma_s = E_s \varepsilon_s$$

$$N_{Rd} = \int \sigma \, dA = -A_c f_{cd} - A_{stot} f_{yd}$$

ESEMPIO



DATI

$6\phi 14$, B450C

C30/37

$N_{Rd}^{\ominus} = ?$

$$N_{Rd}^{\ominus} = \underbrace{30 \times 60}_{A_c}\ cm^2 \times 17 \frac{N}{mm^2} \cdot \frac{1}{10} + 6 \times 1.54\ cm^2 \times \frac{391.3}{10} \frac{N}{mm^2}$$

$$= 3421.6\ KN \quad (\text{DI COMPRESSIONE})$$