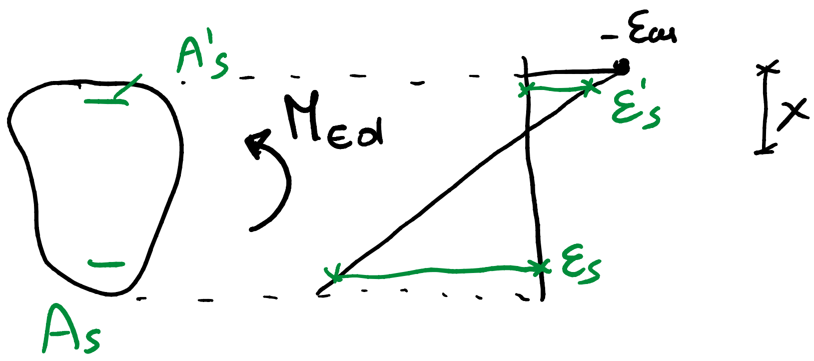
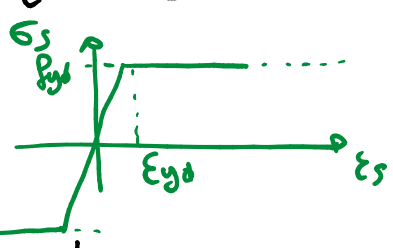
VERIFICA AL III STADIO

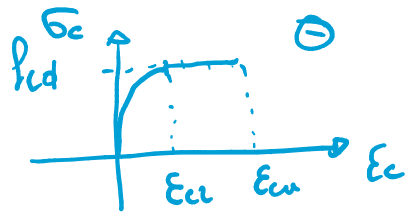
mercoledì 29 aprile 2020 14:00

APPROCCIO GENERALE



1. DEFINIZIONE DI ε LIMITE
2. CALCOLARE σ





3. CALCOLARE N_c, N_s, N'_s
4. TROVIAMO POSIZ. ASSE NEUTRO $N_{TOT} = 0$
   EQ. TRASLAZIONE
5. EQ. ROTAZIONE $M_{Rd} \geq M_{Ed}$

DEFORMAZIONI

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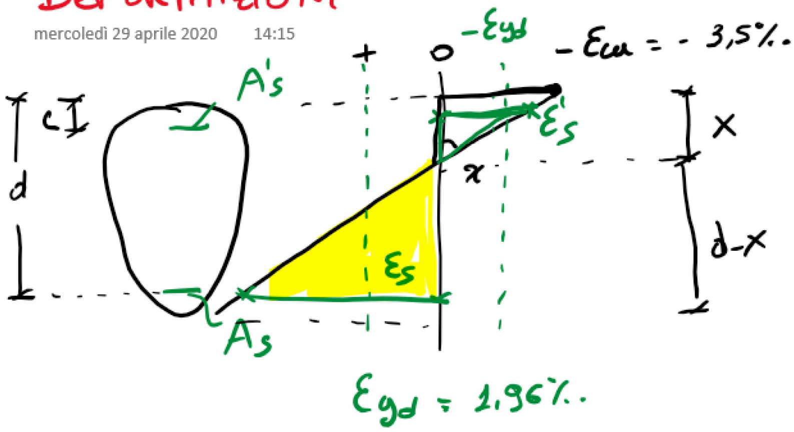
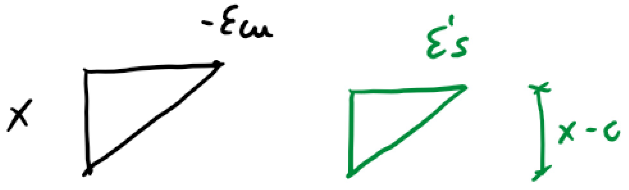
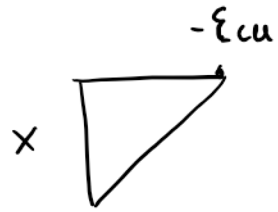


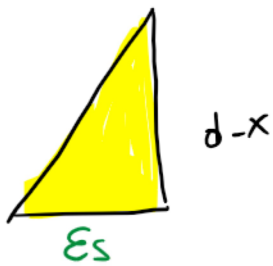




$$\varepsilon_s : (-\varepsilon_{cu}) = (d-x) : (-x)$$

$$\varepsilon'_s : (-\varepsilon_{cu}) = -(x-c) : (-x)$$

$$\boxed{\varepsilon'_s = -\varepsilon_{cu}\,\frac{(x-c)}{x}}$$



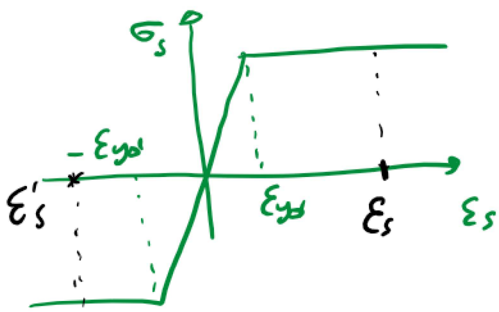
$$\boxed{\varepsilon_s = \varepsilon_{cu}\,\frac{(d-x)}{x}}$$

TENSIONI NELLE ARMATURE

se $-\varepsilon_{yd} \le \varepsilon_s \le \varepsilon_{yd} \rightarrow \sigma_s = E_s \cdot \varepsilon_s$

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

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



TENSIONI NEL CLS

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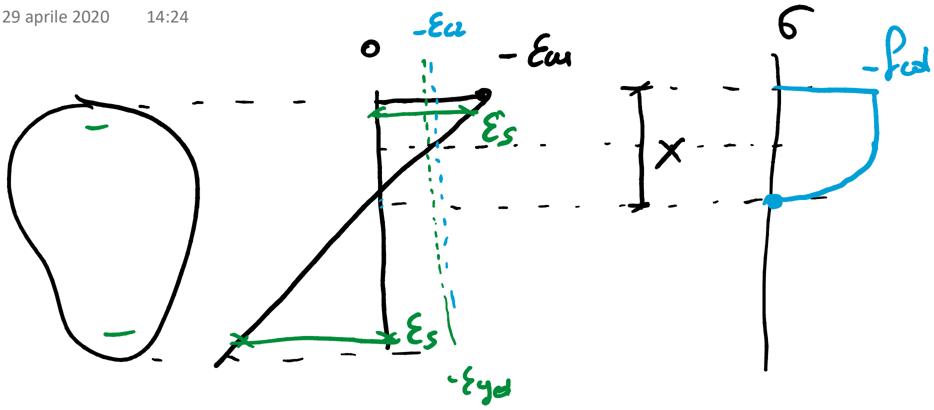
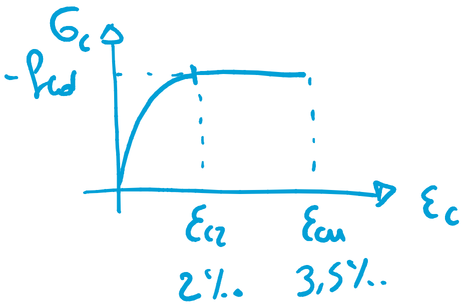
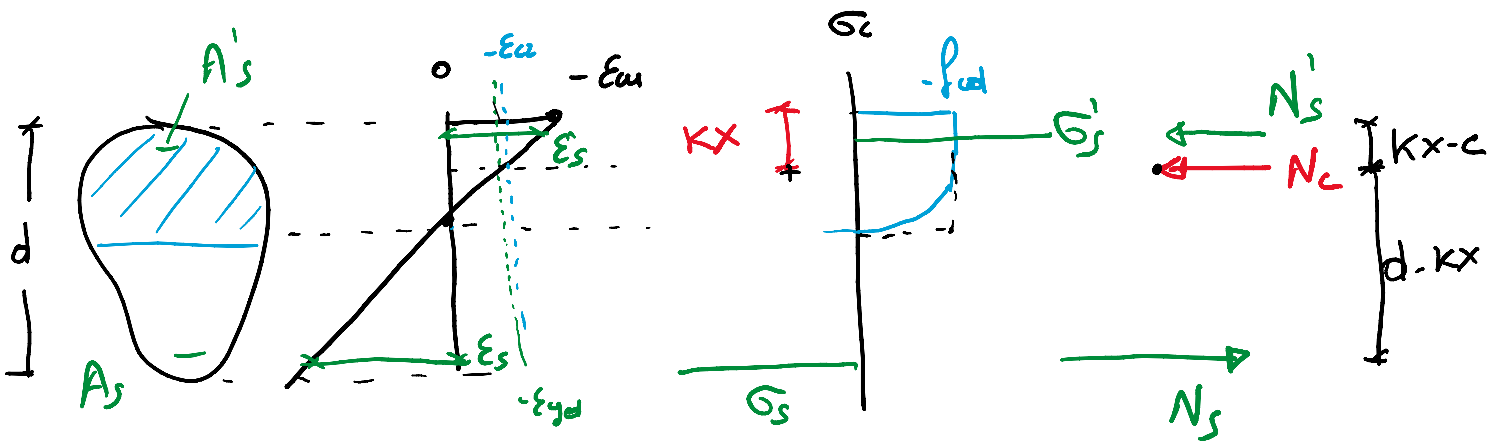




CALCOLO DELLE RISULTANTI



$$N_s = A_s \cdot \sigma_s$$

$$N'_s = A'_s \, \sigma'_s$$

$$N_c = \int \sigma_c \, dA_c = -\beta f_{cd} \cdot A_c$$

β: COEFF. DI RIEMPIMENTO

$$\beta = \frac{\int \sigma_c \, dA_c}{-f_{cd} A_c}$$

K COEFF. DI PROFONDITÀ

DETERMINO LA DISTANZA X DELL'ASSE NEUTRO DAL BORDO COMPRESSO

$$N_{TOT} = 0 \Rightarrow N_c + N'_s + N_s = 0 \rightarrow x$$

CALCOLO DEL MOMENTO RESISTENTE

$$M_{Rd} = N_s (d - kx) - N'_s (kx - c)$$

co

SEZIONE RETTANGOLARE

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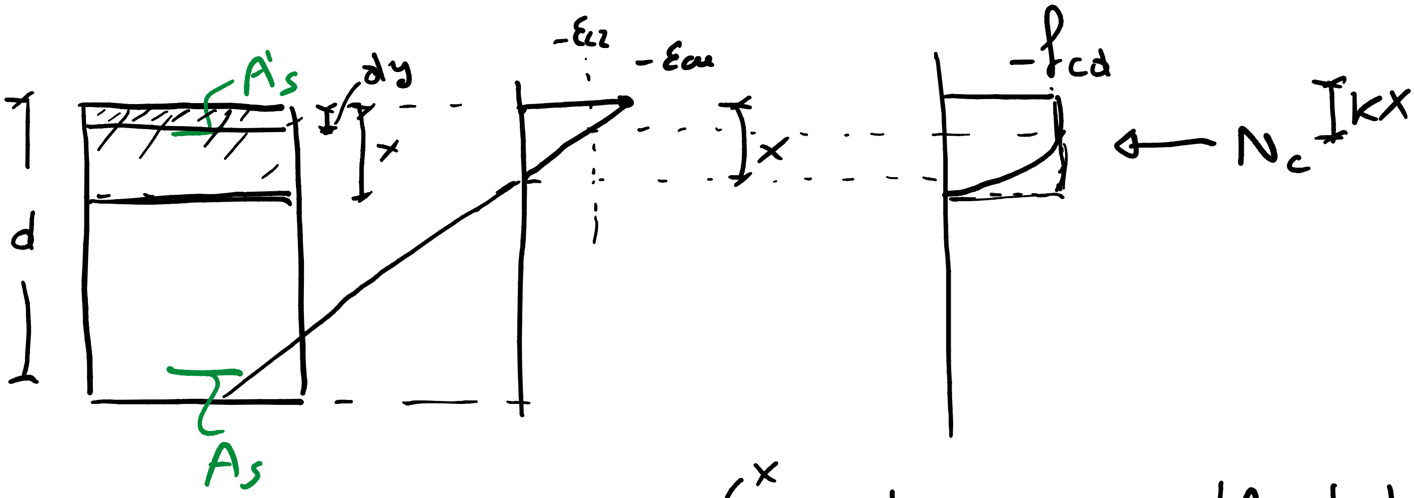

$$N_c = \int_0^x \sigma_c \cdot b\,dy \qquad dA = b\,dy$$

$$\beta = \frac{\int \sigma_c b\,dy}{-f_{cd}\,b x} = 0.81 \qquad N_c = -\underbrace{0.81}_{\beta}\,\underbrace{bx}_{A_c}\,f_{cd}$$

$$k = 0.416$$

SEZIONE A SEMPLICE ARMATURA

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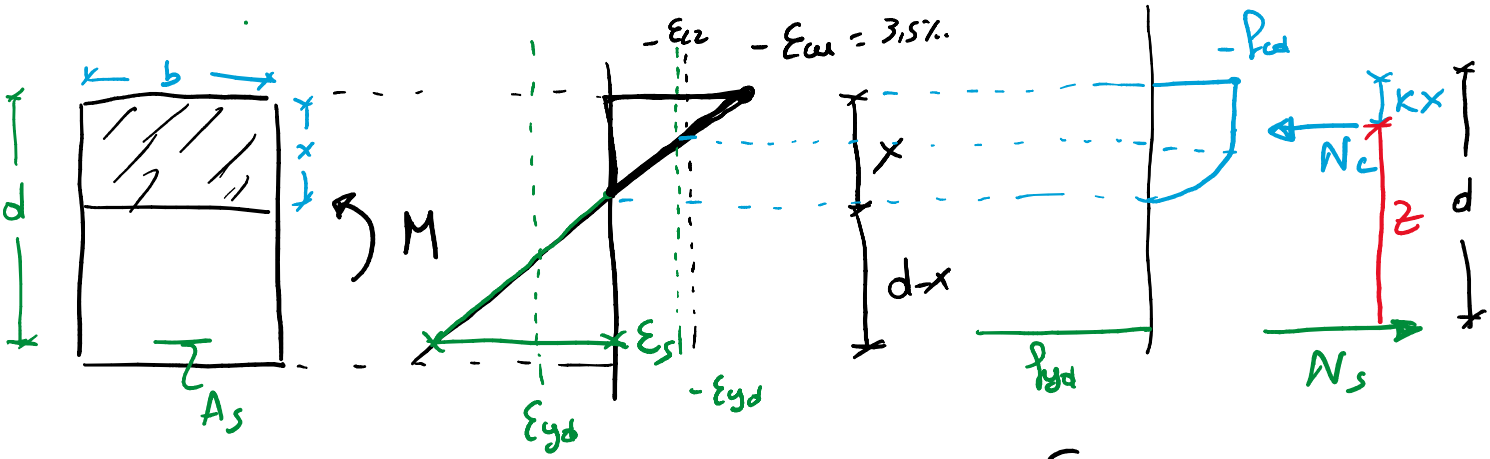
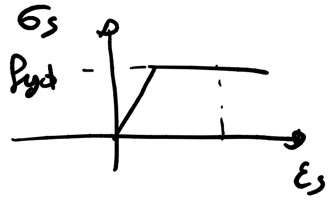
$A'_s = 0$; $A_s \neq 0$



$$\varepsilon_s = \varepsilon_{cu} \frac{(d-x)}{x}$$



PER FLESSIONE SEMPLICE $\varepsilon_s > \varepsilon_{yd}$

$\Rightarrow \sigma_s = f_{yd}$

$$N_s = A_s \cdot f_{yd}$$

$$N_c = -b x f_{cd} \beta$$

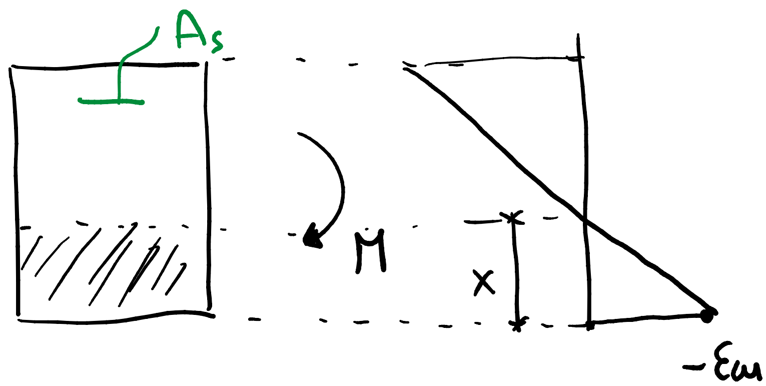
ASSE NEUTRO : $N_c + N_s = 0 \Rightarrow -\beta b x f_{cd} + A_s f_{yd} = 0$

$$x = \frac{A_s f_{yd}}{\beta b f_{cd}}$$

z = BRACCIO DELLA COPPIA INTERNA

$$M_{Rd} = N_s \cdot z = A_s f_{yd} \cdot (d - kx)$$

NEL CASO DI M_{EdCO}



SEZIONE A DOPPIA ARMATURA

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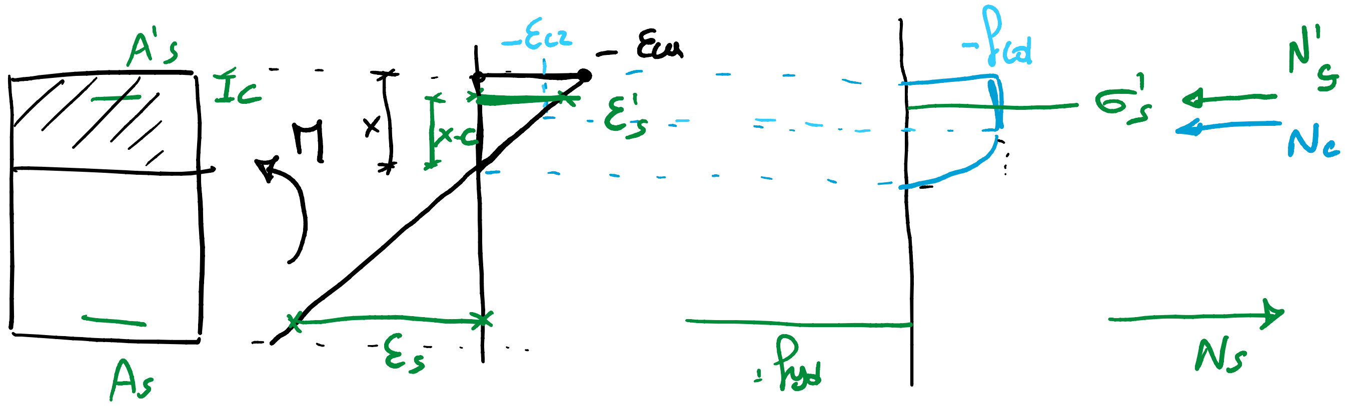
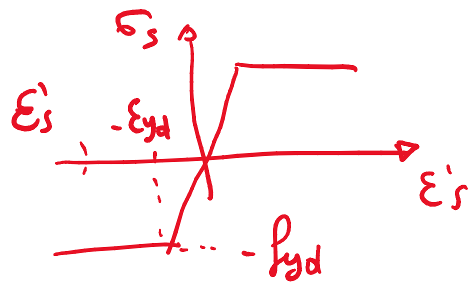


$$\varepsilon'_s : (-\varepsilon_{cu}) = (x-c) : x$$

$$\varepsilon'_s = -\varepsilon_{cu}\frac{(x-c)}{x}$$



1. IPOTIZZO CHE $\varepsilon'_s < -\varepsilon_{yd}$

$$\sigma'_s = -f_{yd}$$

$$N'_s = A'_s \cdot \sigma'_s = -A'_s f_{yd}$$

$$N_c = -\beta b x f_{cd}$$

$$N_s = A_s \cdot f_{yd}$$

EQ. TRASLAZIONE $\rightarrow$ $N_c + N'_s + N_s = 0$

$$-\beta b x f_{cd} - A'_s f_{yd} + A_s f_{yd} = 0 \Rightarrow$$

$$\boxed{x = \frac{A_s f_{yd} - A'_s f_{yd}}{\beta b f_{cd}}}$$

RISULTATO CORRETTO SE $\sigma'_s = -f_{yd}$

VERIFICO SE LE ARMATURE COMPRESSE SONO SNERVATE

CALCOLO $\varepsilon'_s = -\varepsilon_{cu} \frac{(x-c)}{x} \leq -\varepsilon_{yd}$

$$-\varepsilon_{cu} x + \varepsilon_{cu} c \leq -\varepsilon_{yd} \cdot x$$

$$\varepsilon_{cu} x - \varepsilon_{yd} x \geq \varepsilon_{cu} \cdot c$$

$$x \geq \frac{\varepsilon_{cu}}{\varepsilon_{cu} - \varepsilon_{yd}} \cdot c = \frac{3{,}5\text{‰}}{3{,}5\text{‰} - 1{,}96\text{‰}} \cdot c$$

$$\geq \frac{3{,}5}{3{,}5 - 1{,}96} \cdot c = 2{,}27\, c$$

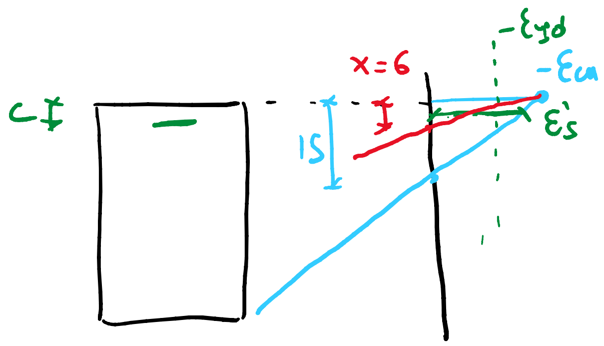
SE $x \geq 2{,}27\,c$ $\rightarrow$ IPOTESI DI PARTENZA CORRETTA $\Rightarrow$ x OK

SE $x < 2{,}27\,c$ $\rightarrow$ IPOTESI DI PARTENZA ERRATA $\rightarrow$ DEVO RICALCOLARE x

ESEMPIO $c = 5\,cm$

SE $x = 15\,cm$ $> 2{,}27 \times 5$

SE $x = 6\,cm$ $< 2{,}27 \times 5$



CASO CON ARMATURA COMPRESSA IN CAMPO ELASTICO

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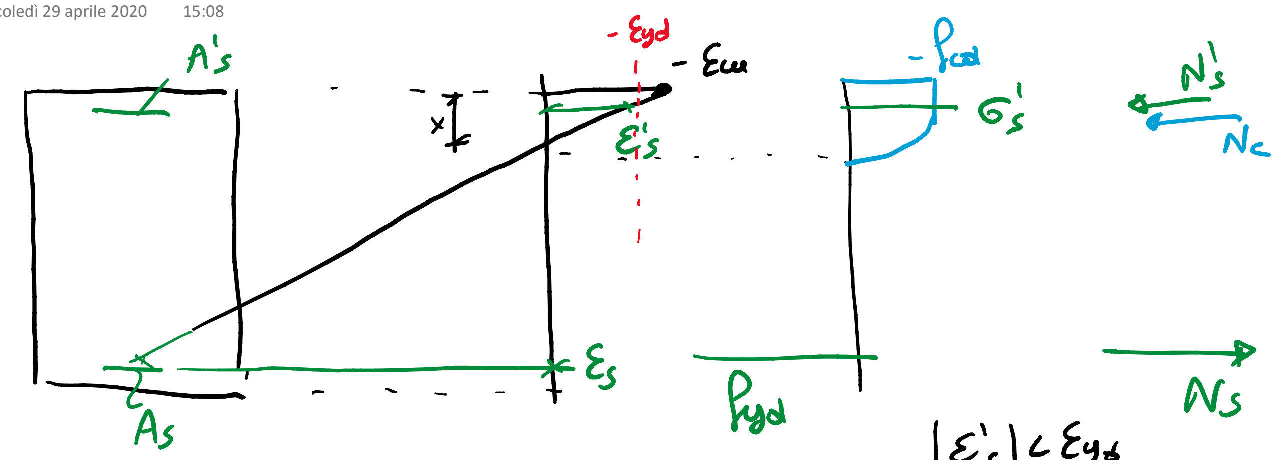
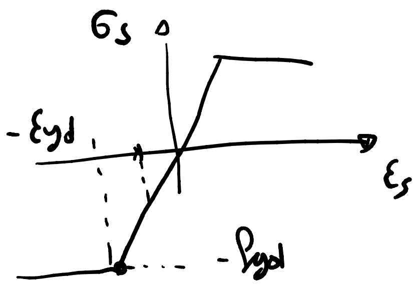


$|\varepsilon'_s| < \varepsilon_{yd}$

$$N_s = A_s f_{yd}$$

$$N_c = -\beta b x f_{cd}$$



$$\sigma'_s = E_s \cdot \varepsilon'_s$$

$$\varepsilon'_s = -\frac{\varepsilon_{cu}(x-c)}{x} \implies$$

$$\sigma'_s = -\frac{\varepsilon_{cu}(x-c)}{x} \cdot \frac{f_{yd}}{\varepsilon_{yd}}$$

$$\sigma_s = E_s \varepsilon_s$$

$$f_{yd} = E_s \cdot \varepsilon_{yd} \rightarrow E_s = \frac{f_{yd}}{\varepsilon_{yd}}$$

$$N'_s = \sigma'_s \cdot A'_s$$

EQ. TRASLAZIONE $\quad N_s + N_c + N'_s = 0$

$$A_s f_{yd} - \beta b x f_{cd} - \frac{\varepsilon_{cu}}{\varepsilon_{yd}} \frac{(x-c)}{x} f_{yd} \cdot A'_s = 0$$

$$-\beta b x^2 f_{cd} + A_s f_{yd}\, x - \frac{\varepsilon_{cu}}{\varepsilon_{yd}} A'_s f_{yd}\, x + \frac{\varepsilon_{cu}}{\varepsilon_{yd}} c A'_s f_{yd} = 0$$

$$u = \frac{A'_s}{A_s} ;$$

$$u_1 = \frac{A'_s}{A_s} \cdot \frac{\varepsilon_{cu}}{\varepsilon_{yd}} = u \cdot \frac{\varepsilon_{cu}}{\varepsilon_{yd}}$$

$$\beta b x^2 f_{cd} - A_s f_{yd}\, x + \underbrace{\frac{\varepsilon_{cu}}{\varepsilon_{yd}} u}_{u_1} A_s f_{yd} \cdot x - \underbrace{\frac{\varepsilon_{cu}}{\varepsilon_{yd}} u}_{u_1} A_s \cdot c f_{yd} = 0$$

$$x^2 - \frac{d A_s f_{yd}}{d \beta b f_{cd}} \left[1 - u_1\right] x - u_1 \frac{A_s f_{yd} \cdot c d}{\beta b f_{cd} d} = 0$$

ω = PERCENTUALE MECCANICA DI ARMATURA TESA $= \dfrac{A_s f_{yd}}{b d f_{cd}}$

$$x^2 - \frac{\omega d}{\beta}(1 - u_1) x - u_1 \frac{\omega d}{\beta} \cdot c = 0$$

$$x = \frac{\omega d}{2\beta}(1 - u_1) \overset{+}{\cancel{\pm}} \sqrt{\frac{\omega^2 d^2}{4\beta^2}(1 - u_1)^2 + u_1 \frac{\omega d}{\beta} c}$$

$$x = \frac{\omega d}{2\beta}(1 - u_1)\left[1 + \sqrt{1 + u_1 \frac{\omega \cancel{d}}{\cancel{\beta}} c \cdot \frac{4\beta^{\cancel{2}}}{\omega^{\cancel{2}} d^{\cancel{2}} (1 - u_1)^2}}\right]$$

$$\boxed{x = \frac{\omega d}{2\beta}(1 - u_1)\left[1 + \sqrt{1 + \frac{4\beta u_1}{\omega (1 - u_1)^2} \cdot \gamma}\right]}$$

DOVE $\gamma = \dfrac{c}{d}$

CALCOLO M_{Rd}

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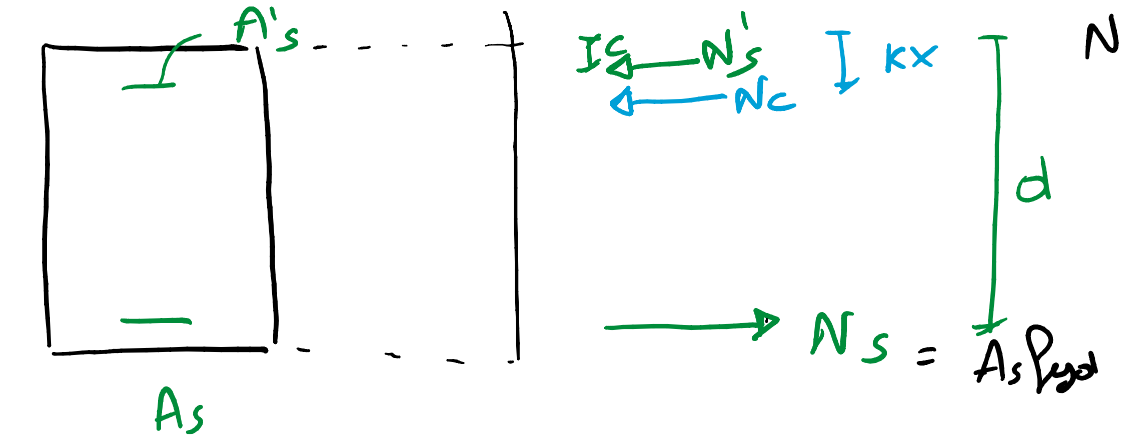

$$N'_s = A'_s \sigma'_s$$
$$\mu A_s \sigma'_s$$

$$M_{Rd} = N_s (d - kx) - N'_s (kx - c)$$

RISPETTO AL PUNTO DI APPLICAZIONE DI N_c
(∀ PUNTO VA BENE)

$$N_s = A_s f_{yd}$$
$$N'_s = A'_s \sigma'_s = \mu A_s \sigma'_s = -\mu A_s s' f_{yd} \quad \text{DOVE} \quad s' = -\frac{\sigma'_s}{f_{yd}}$$

$$M_{Rd} = A_s f_{yd} (d - kx) + \mu A_s \cdot s' f_{yd} (kx - c)$$

DOVE

$$s' = -\frac{\sigma'_s}{f_{yd}} = \frac{\varepsilon'_s}{\varepsilon_{yd}} = \frac{\varepsilon_{cu} (x - c)}{\varepsilon_{yd}\, x} \leq 1$$

$$M_{Rd} = \underbrace{A_s f_{yd} (d - kx)}_{\text{CONTRIBUTO } A_s} \underbrace{\left[1 + \mu s' \frac{(kx - c)}{d - kx}\right]}_{\text{VARIAZIONE DOVUTA A } A'_s}$$

ESEMPIO

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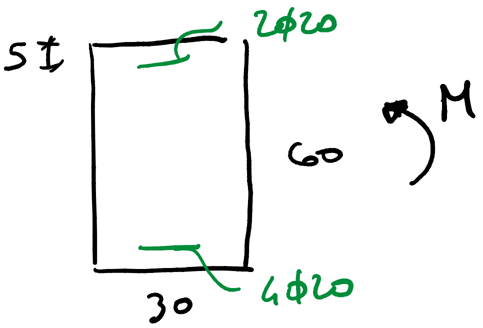


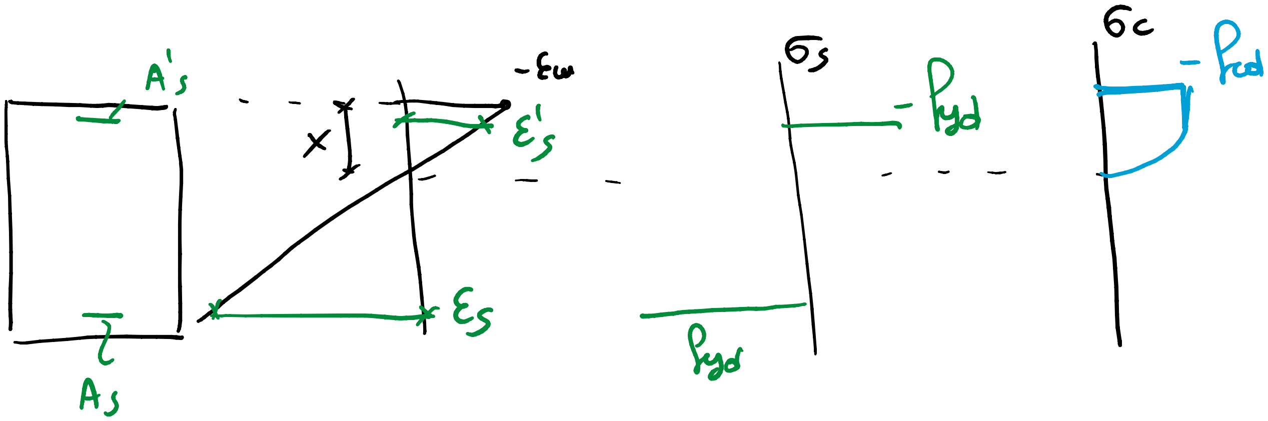
B450C

C25/30

$M_{Rd} = ?$

$A_s = 12.56\ cm^2$

$A'_s = 6.28\ cm^2$



IPOTESI ARMATURE SIANO SNERVATE

$$N_s = 12{,}56\ cm^2 \times 391{,}3\ \frac{N}{mm^2} \times \frac{1}{10} = 491{,}7\ KN$$

$$N'_s = -6{,}28\ cm^2 \times 391{,}3\ \frac{N}{mm^2} \times \frac{1}{10} = 245{,}86\ KN$$

$$N_c = -0.81 \cdot 30\ X \cdot 14.16\ \frac{N}{mm^2} \times \frac{1}{10} = -34{,}4\ X$$

$$N_c + N_s + N'_s = 0 \implies X = \frac{491{,}7 - 245{,}86}{34{,}4} = 7.15\ cm$$

VERIFICO IPOTESI SU ε'_s

$$\varepsilon'_s = -\varepsilon_{cu} \frac{(x-c)}{x} = -\frac{3{,}5}{1000} \cdot \frac{7.14-5}{7{,}14} = -1{,}05‰$$

$$\varepsilon_{yd} = 1{,}96‰ \qquad |\varepsilon'_s| \le \varepsilon_{yd} \implies$$ ARMATURA IN CAMPO ELASTICO

$$\boxed{x = \frac{\omega d}{2\varphi}(1-\mu_1)\left[1+\sqrt{1+\frac{4\varphi\mu_1}{\omega(1-\mu_1)^2}\cdot\gamma}\right]}$$

$$\omega = \frac{A_s \cdot f_{yd}}{b d f_{cd}} = \frac{12{,}56\ \cancel{cm^2} \times 391{,}3\ \cancel{N/mm^2}}{30\ \cancel{cm} \times (60-5)\ \cancel{cm} \times 14{,}16\ \cancel{N/mm^2}} =$$

$$= 0.21$$

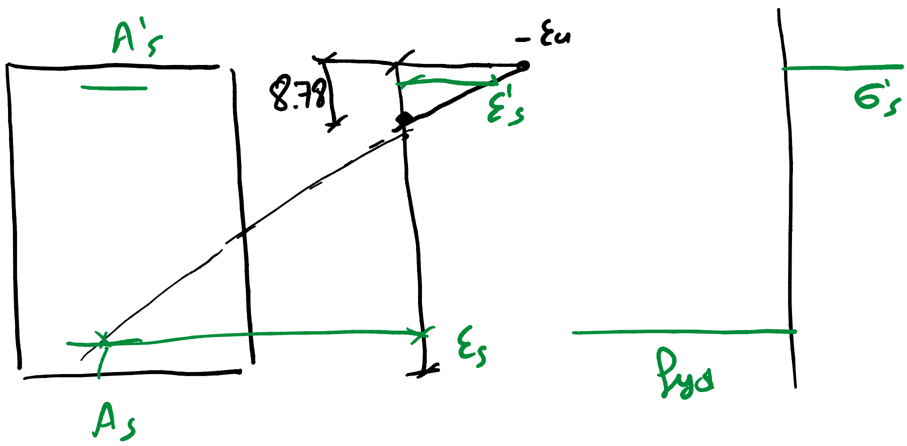
$$\mu = \frac{A'_s}{A_s} = 0.5 \ ; \quad \mu_1 = \frac{A'_s}{A_s} \cdot \frac{\varepsilon_{cu}}{\varepsilon_{yd}} = 0{,}5 \cdot \frac{3{,}5}{\cancel{1000}} \cdot \frac{\cancel{1000}}{1{,}96}$$

$$\mu_1 = 0.89$$

$$\gamma = \frac{c}{d} = \frac{5}{55} = 0{,}09$$

$$x = \frac{0{,}21 \times 55\ cm}{2 \times 0{,}81}(1-0{,}89)\left[1+\sqrt{1+\frac{4 \cdot 0{,}81 \cdot 0{,}89}{0{,}21(1-0{,}89)^2} \cdot 0{,}09}\right]$$

$$= 8{,}78\ cm$$



$$\varepsilon'_s = -\varepsilon_{cu}\frac{(x-c)}{x} = -\frac{3{,}5}{1000} \cdot \frac{8{,}78-5}{8{,}78} = -1{,}5‰$$

$$S' = -\frac{\varepsilon'_s}{\varepsilon_{yd}} = \frac{1{,}5}{1000} \cdot \frac{1000}{1{,}96} = 0.77 \quad < 1 \quad \text{OK}$$

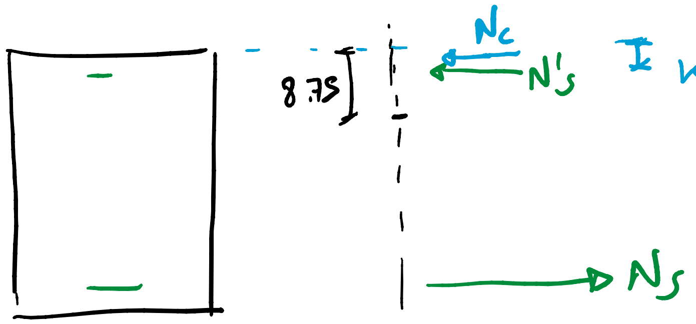
$$\sigma'_s = -S' f_{yd} = -0.77 \times 391{,}3 \text{ MPa} = -301{,}5 \text{ MPa}$$

$$= -1{,}5‰ \times \underbrace{E_s}_{200'000 \text{ MPa}} =$$

$$N_s = 491{,}7 \text{ KN}$$

$$N'_s = -301{,}5 \text{ MPa} \times 6{,}28 \text{ cm}^2 \; \frac{1}{10} = -189{,}4 \text{ KN}$$

$$N_c = -0{,}81 \times 30\text{cm} \times 8{,}78\text{cm} \times 14{,}16 \frac{N}{mm^2} \frac{1}{10} = -302{,}3 \text{ KN}$$



$kx = 0.416 \times x = 0.416 \times 8{,}78 = 3{,}65 \text{ cm}$

$$M_{Rd} = N_s \cdot (d - kx) - N'_s (kx - c)$$

$$= 491{,}7 \text{ KN} \cdot \frac{(55 - 3{,}65)\text{cm}}{100} + 189{,}4 \text{ KN} \cdot \frac{(3{,}65 - 5)_{\text{cm}}}{100}$$

$$= 249{,}9 \text{ KNm}$$

DIAGRAMMI DI TENSIONE ALTERNATIVI

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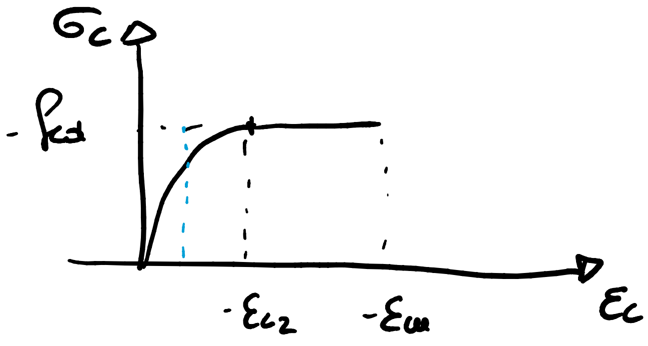
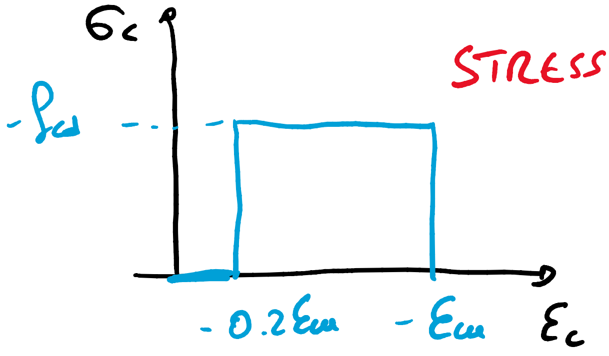
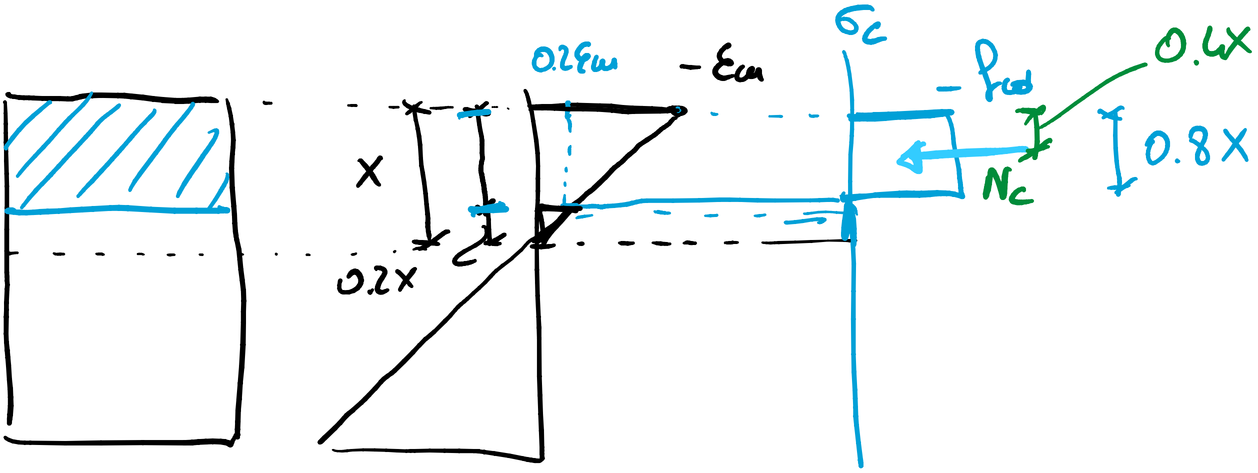


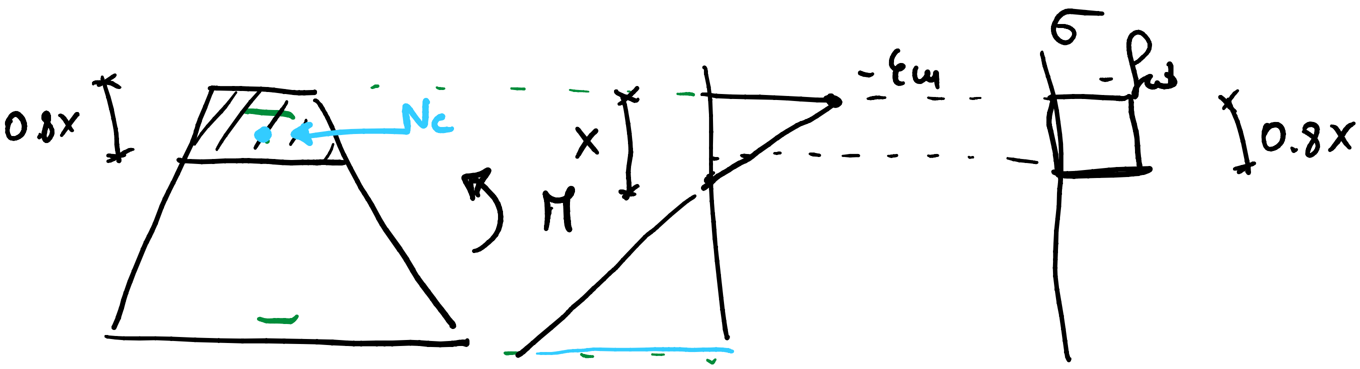




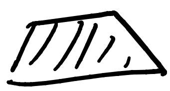
$$\varepsilon_{cu} : x = 0.2\varepsilon_{cu} : \Delta x \rightarrow \Delta x = 0.2x$$

$$N_c = -b \cdot 0.8x \, f_{cd} = -0.8\,b\,x\,f_{cd}$$

SEZIONI DI FORMA ≠ RETTANGOLARE



$$N_c = A_{TRAPEZIO} \cdot (-f_{cd})$$

N_c APPLICATA NEL BARICENTRO DI 

PROGETTO SOLAIO

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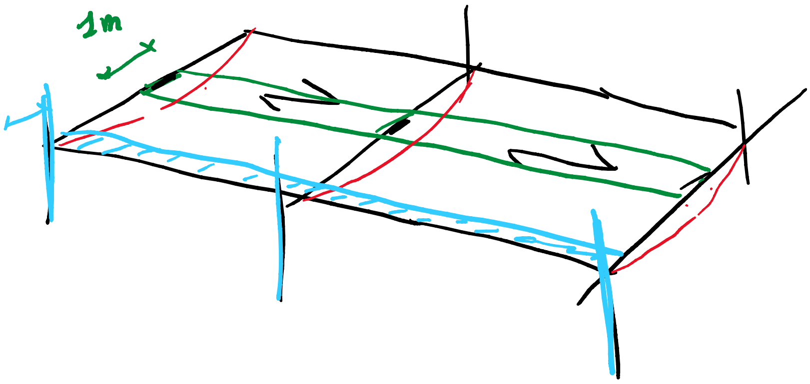
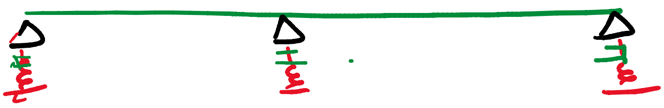
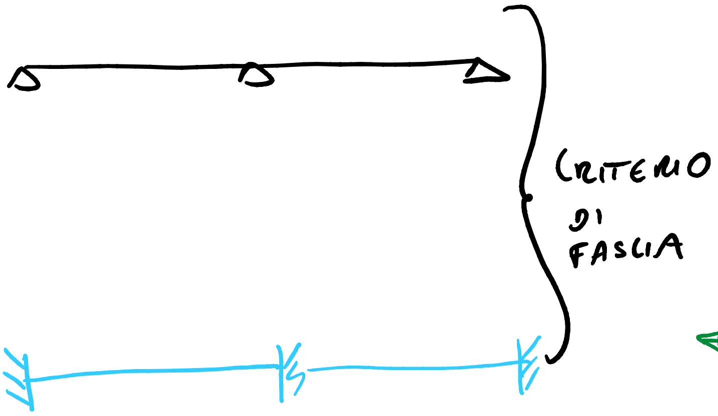


MODELLO DI CALCOLO



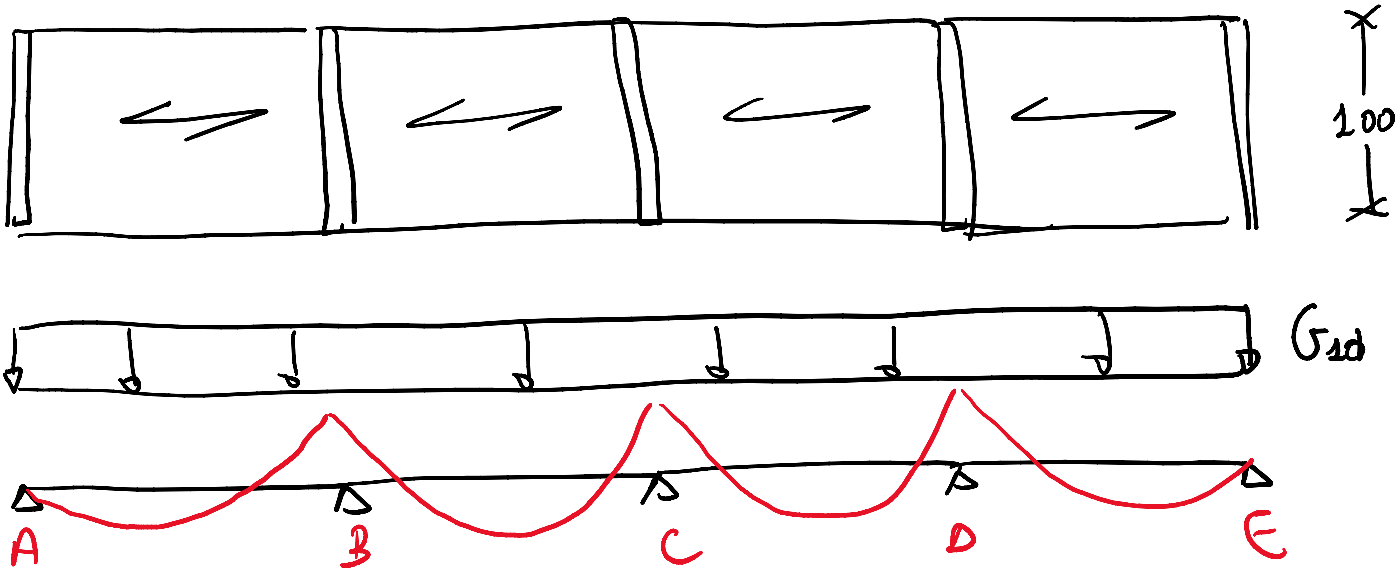
SOLLECITAZIONI AGGIUNTIVE PRODOTTE SOLO DA CEDIMENTI DIFFERENZIALI CHE SONO MODESTI ⇒



← RIGIDEZZA TORSIONALE DELLE TRAVI MODESTA

← SCHEMA LIMITE

DISPOSIZIONE DEI CARICHI



NOTA: $G_{1d} = g_{1d} \times 1m$ IN TUTTE LE CAMPATE

$$\gamma_q \begin{cases} 0 \longrightarrow Q_d = 0 \\ 1.5 \longrightarrow Q_d = 1{,}5\, Q_k \end{cases}$$

$$\gamma_{G2} \begin{cases} 0.8 \longrightarrow G_{2d} = 0.8\, G_{2k} \\ 1.5 \longrightarrow G_{2d} = G_{2k} \times 1{,}5 \end{cases}$$

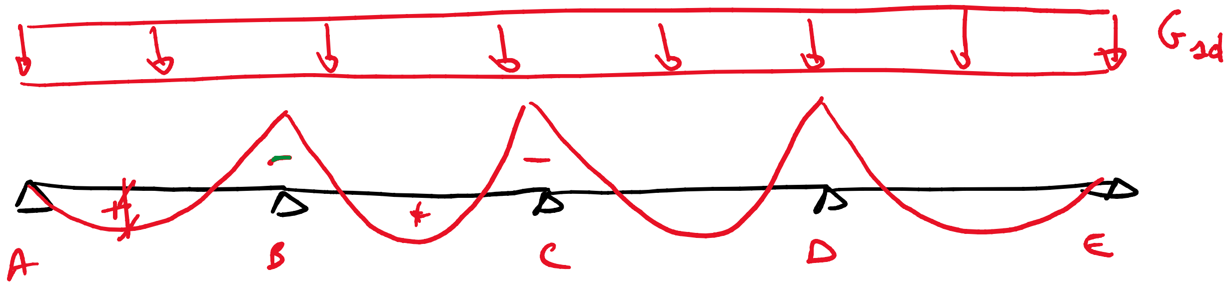
$$G_{d\,max} = G_{1d} + 1{,}5\, G_{2k}$$

$$G_{d\,min} = G_{1d} + 0{,}8\, G_{2k}$$

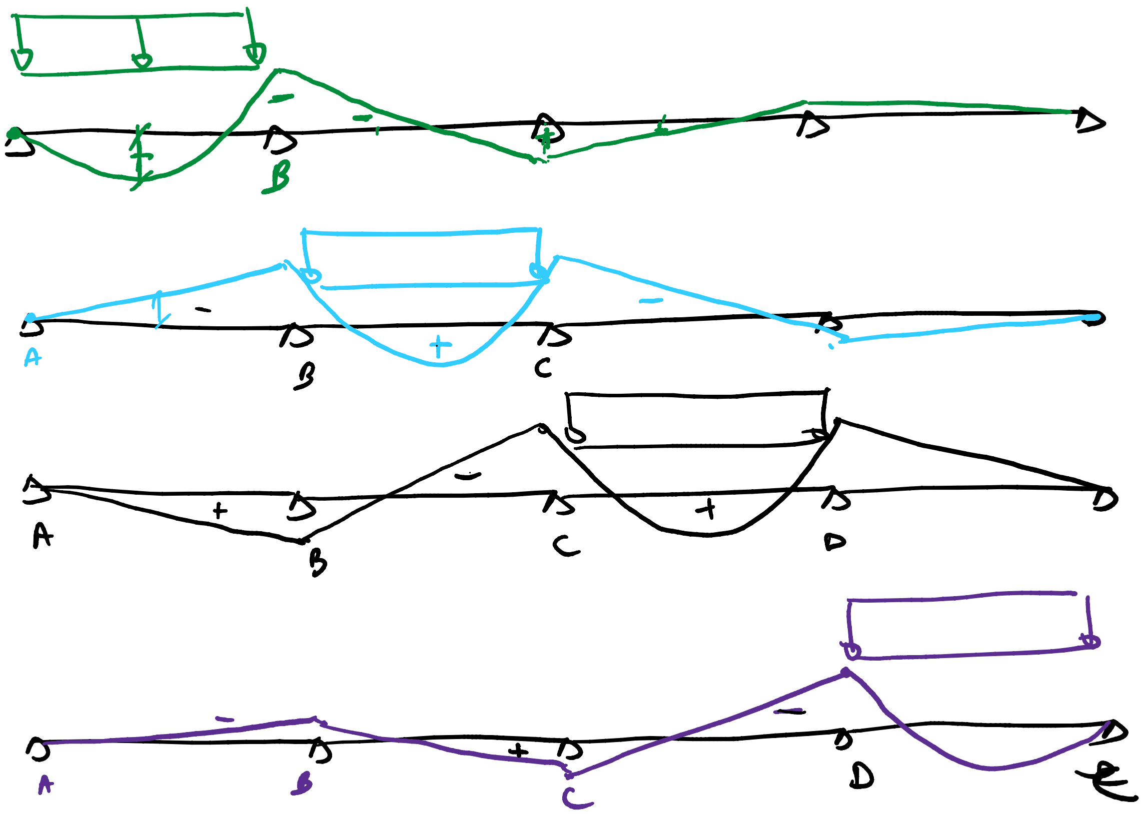
DOVE DISPORRE $\left.\begin{matrix} G_{d\,max} + Q_d \\ G_{d\,min} \end{matrix}\right\} \Rightarrow$ MASSIMIZZARE M_{ed}

EFFETTO DEI CARICHI PERMANENTI

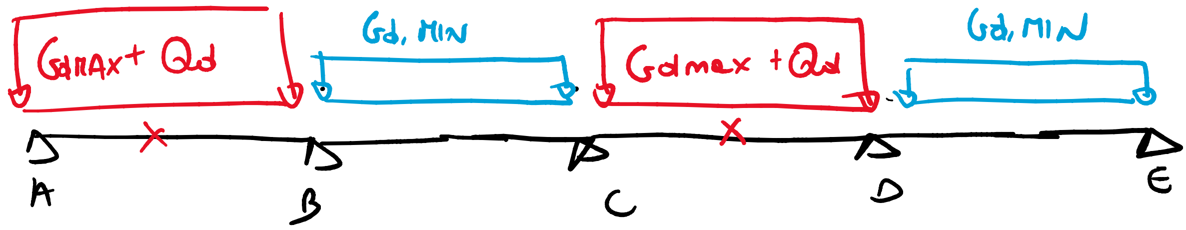
mercoledì 29 aprile 2020 16:33



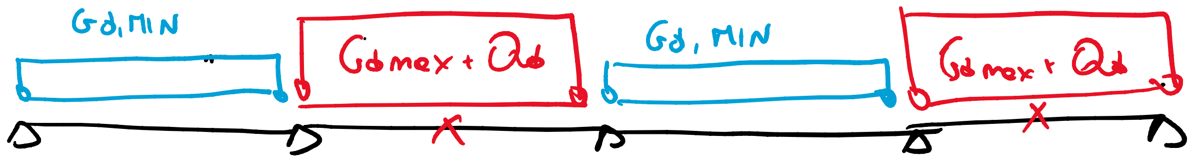
EFFETTO DEI CARICHI SULLE SINGOLE CAMPATE



MOMEMENTO MAX CAMPATE AB, CD (DISPARI)

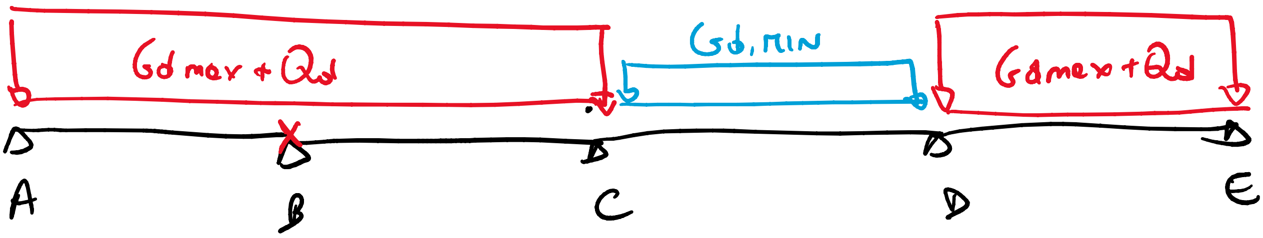


MOMENTO MAX CAMPATE PARI (BC, DE...)

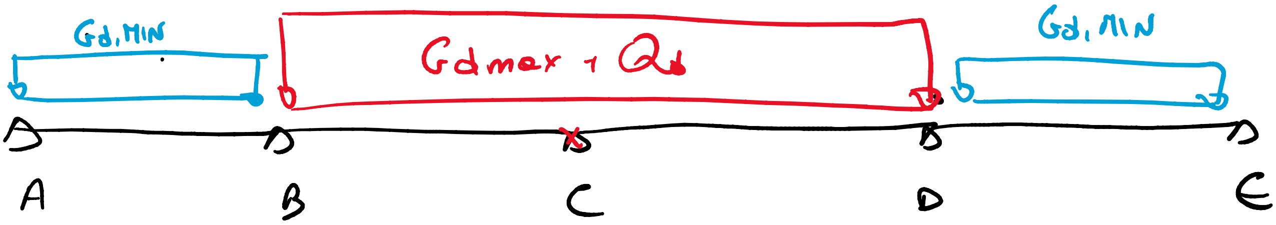


SI PARLA DI "COMBINAZIONI DI CARICO A SCACCHIERA"

MOMEMENO MASSIMO IN B



MOMENTO MASSIMO IN C



MOMENTO MASSIMO IN D.