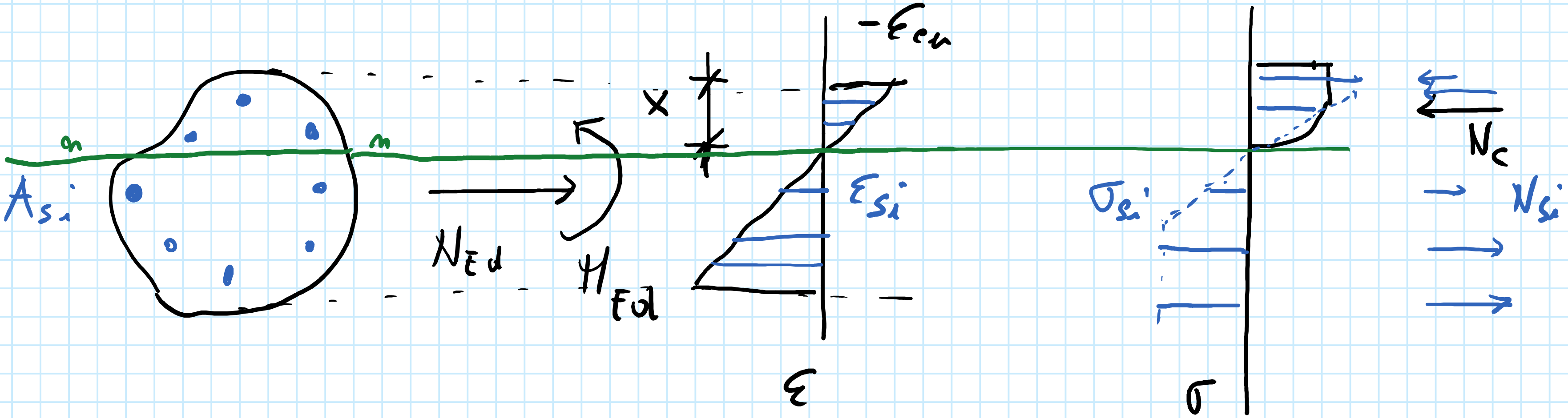
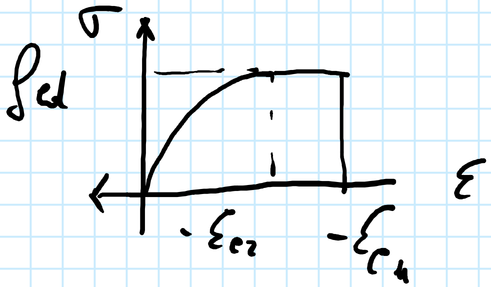
Flessione composta di sezione generica nel III stadio

Caso delle sezioni parzializzate

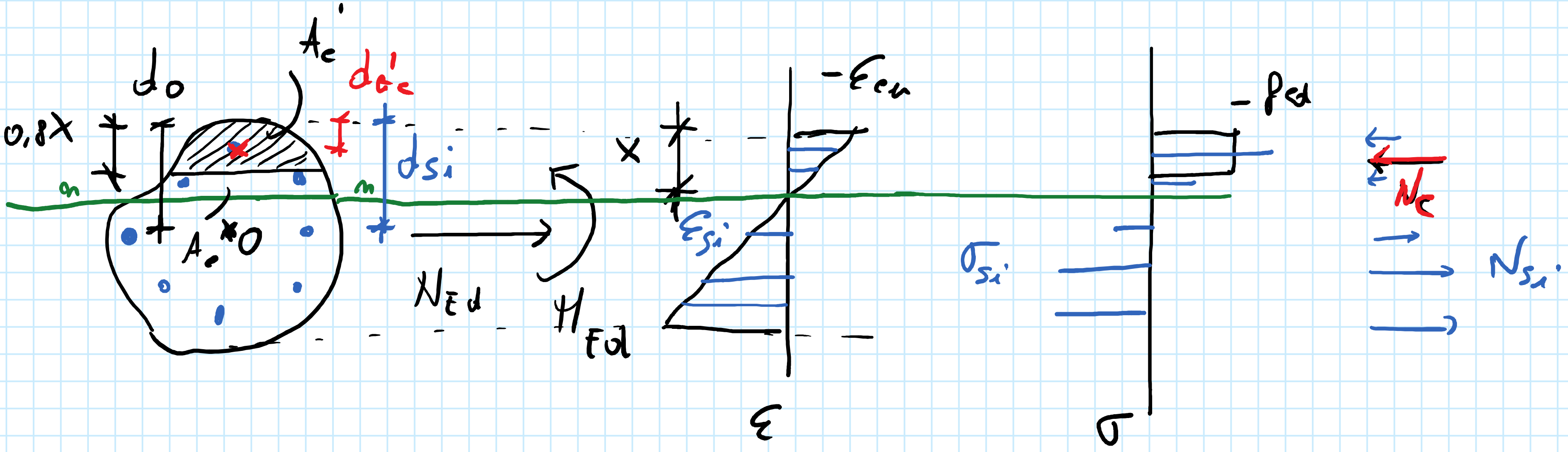


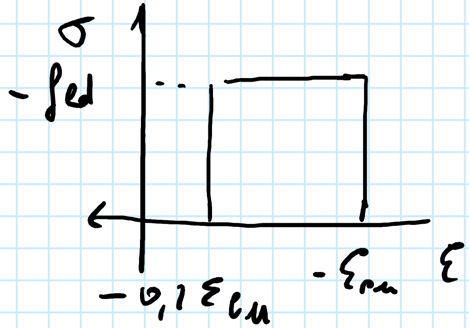
$$M_{Ed} \leq M_{Rd}(N_{Ed})$$

Legame parabola - rettangolo



$$N_c = \int_{A_c} \sigma_c \, dA$$

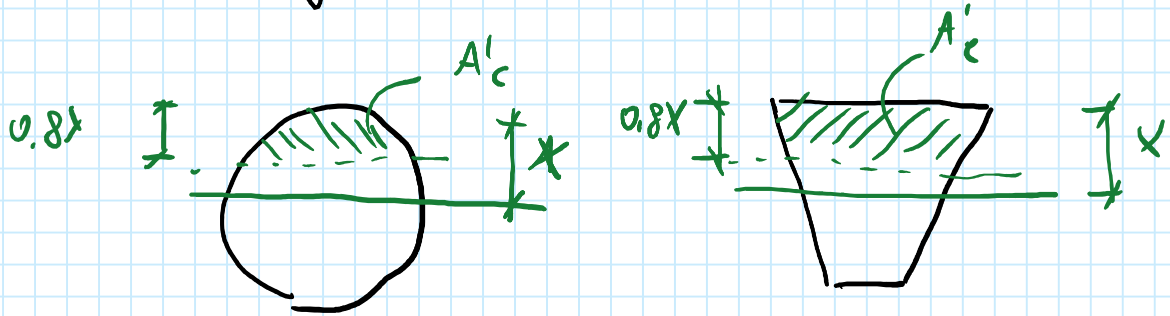




$$N_c = \int_{A_c} \sigma_c \, dA = \int_{A_c'} \sigma_c \, dA + \cancel{\int_{A_c''} \sigma_c \, dA} \rightarrow 0$$

$$= -A_c' f_{cd}$$

Se uso lo stress-block tutto diventa più semplice



$$-\frac{\varepsilon_{cu}}{x} = \frac{\varepsilon_{si}}{d_{si} - x} \Rightarrow \varepsilon_{si} = -\frac{d_{si} - x}{x}\,\varepsilon_{cu}$$

$$\varepsilon_{si} < -\varepsilon_{yd} \qquad \sigma_{si} = -f_{yd}$$

$$-\varepsilon_{yd} \leq \varepsilon_{si} \leq \varepsilon_{yd} \qquad \sigma_{si} = \frac{\varepsilon_{si}}{\varepsilon_{yd}}\,f_{yd}$$

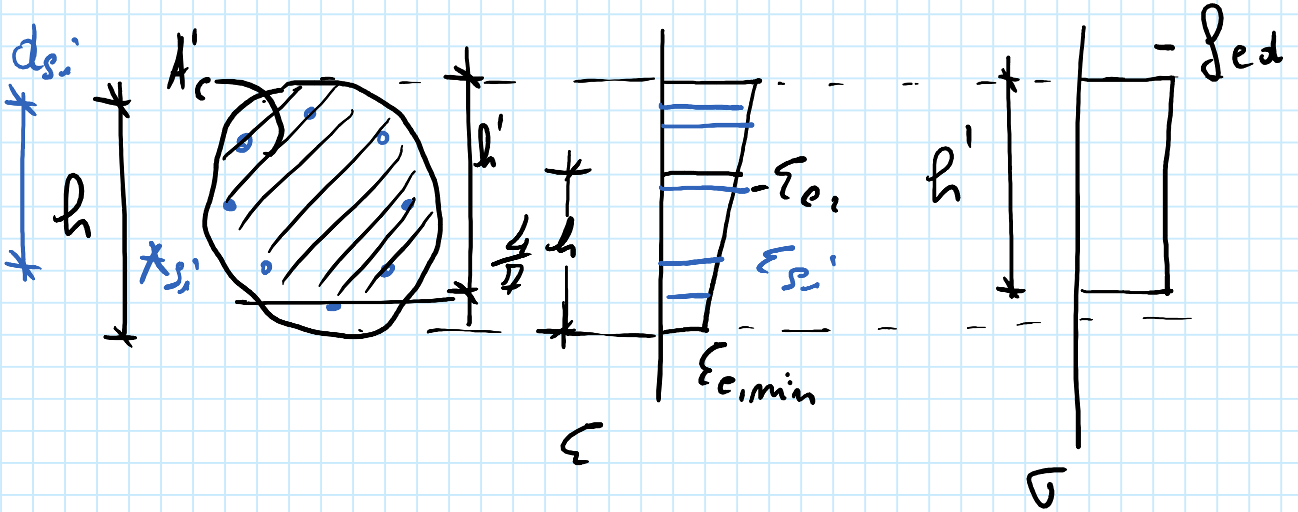
$$\varepsilon_{si} > \varepsilon_{yd} \qquad \sigma_{si} = f_{yd}$$

$$N_{si} = A_s\,\sigma_{si}$$

$$N_c + \sum N_{si} = N_{Ed} \Rightarrow x$$

Calcolo del momento resistente

$$M_{Rd}(N_{Ed}) = -N_c\,(d_0 - d_{G'c}) - \sum N_{si}\,(d_0 - d_{si})$$



Caso della sezione interamente compressa

$$h' = \left[1 - 0{,}2\,(1-\eta_{min})^2\right] h \qquad \eta_{min} = -\frac{\varepsilon_{c,min}}{\varepsilon_{c2}}$$

$$N_c = -A'_c \, f_{cd}$$

$$\varepsilon_{si} = -\left[\frac{h - d_{si}}{4/7\, h}\,(1-\eta_{min}) + \eta_{min}\right]\varepsilon_{c2} \Rightarrow \sigma_{si} \Rightarrow N_{si} = A_{si}\,\sigma_{si}$$

$$N_c + \sum N_{si} = N_{Ed} \Rightarrow \eta_{min}$$

Calcolo del momento resistente

$$M_{Rd} = -N_c\,(d_0 - d_{G'_c}) - \sum N_{si}\,(d_0 - d_{si})$$

$$\overset{!}{=} N_c\,(d_{G'_i} - d_0) + \sum N_{si}\,(d_{si} - d_0)$$

Costruzione dei domini di resistenza allo SLU

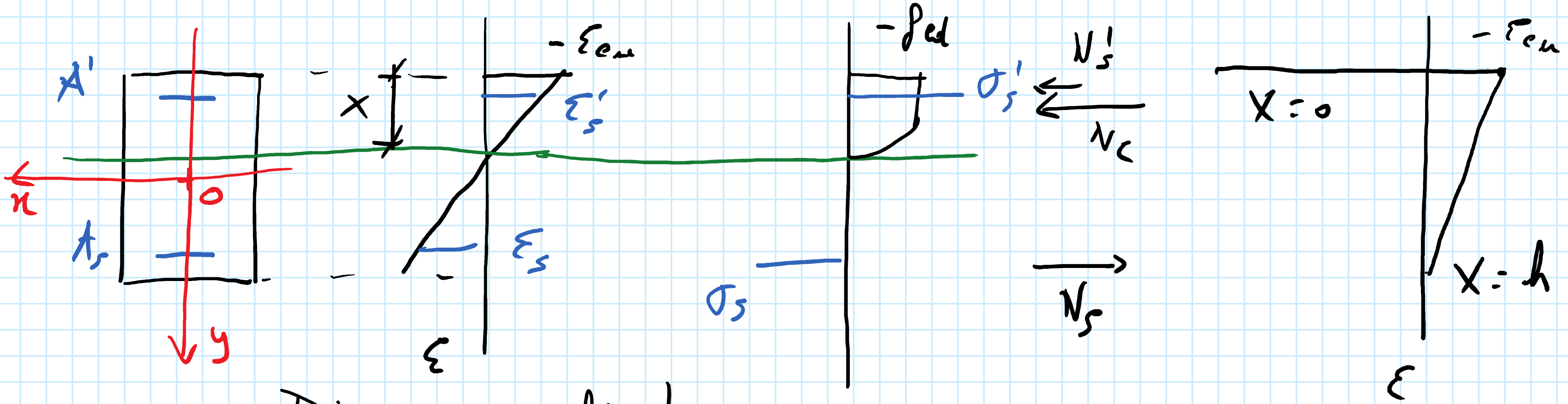


Diagramma limite
di deformazione

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

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

$$\Downarrow$$

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

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

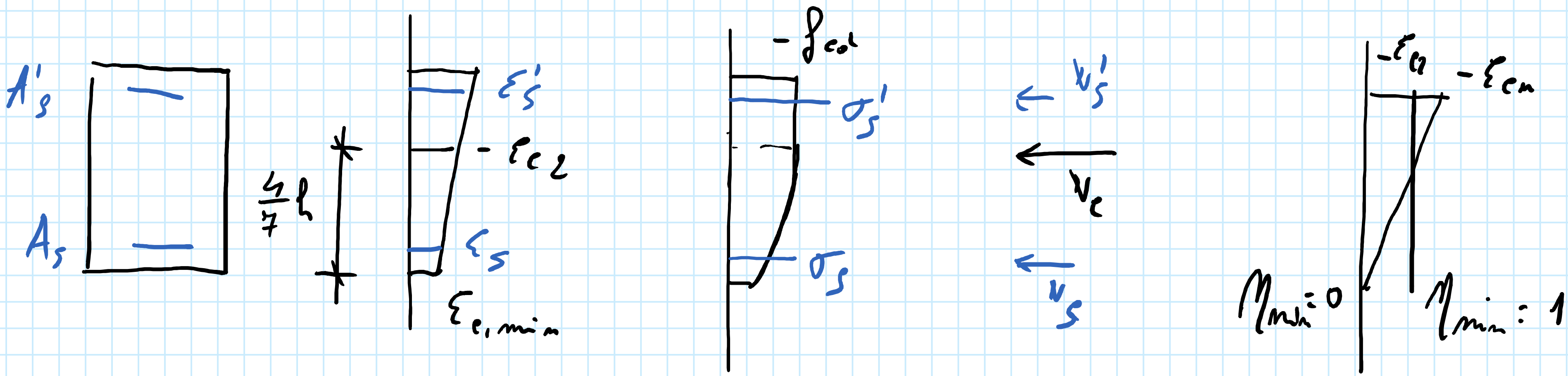
$$N_s = A_s \, \sigma_s$$

$$\Downarrow$$

$$N = N_c + N'_s + N_s$$

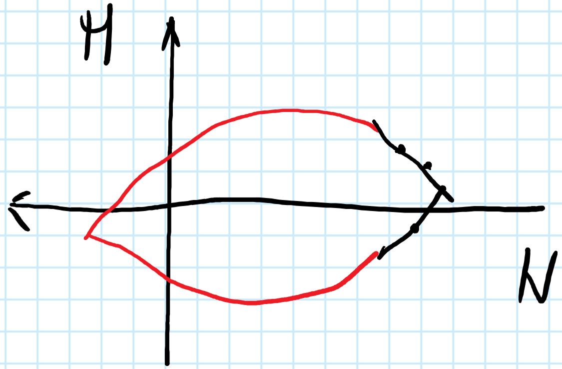
$$M = -N_c \left(\frac{h}{2} - k x\right) + \left(A_s \sigma_s - A'_s \sigma'_s\right)\left(\frac{h}{2} - c\right)$$

$$\Longrightarrow$$



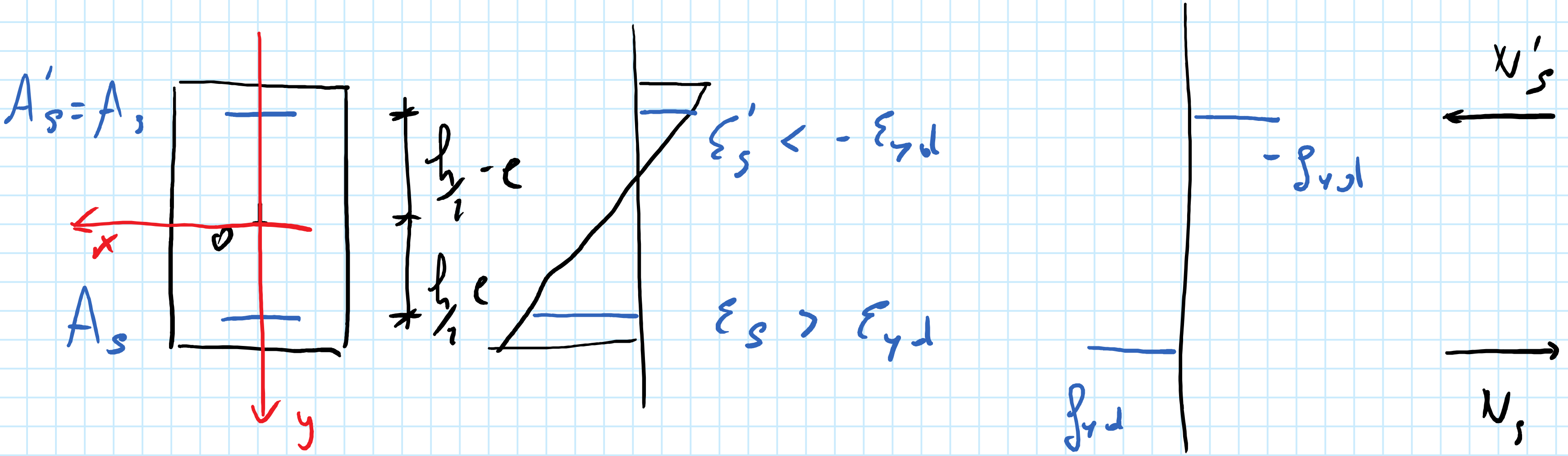
$$N = \int \sigma \, dA = N_c + N'_s + N_s$$

$$M = \int \sigma y \, dA = -N_c \left(\frac{h}{2} - \kappa h \right) + \left(A_s \sigma_s - A'_s \sigma'_s \right) \left(\frac{h}{2} - c \right)$$



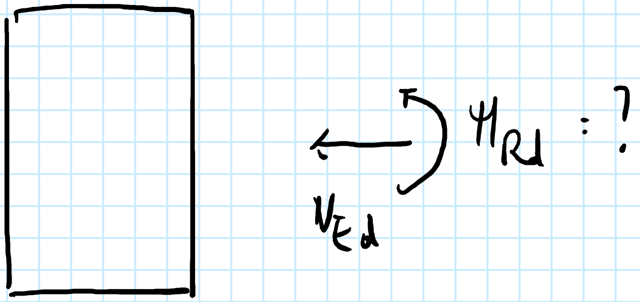
Sezione rettangolare con armatura simmetrica

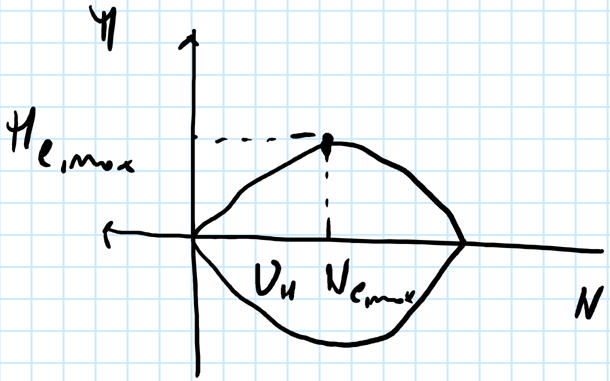
Rappresentazione analitica del dominio di resistenza



$$+A'_s f_{yd}\left(\frac{h}{2} - e\right) + A_s f_{yd}\left(\frac{h}{2} - e\right) = \underbrace{2 A_s f_{yd}\left(\frac{h}{2} - e\right)}_{M_{s,max}}$$

$$N_{s,max} = 2 A_s f_{yd}$$





$$N_{c,max} = A_c f_{cd} = b\,h\,f_{cd}$$

$$\nu_M \simeq 0{,}48$$

$$M_{c,max} \simeq 0{,}12\, b\, h^2 f_{cd}$$

Rappresentazione a "tre tratti"

1. $$M_{Rd}(N_{Ed}) = M_{s,max}\left(1 - \frac{N_{Ed}}{N_{s,max}}\right) \qquad 0 \le N_{Ed} \le N_{s,max}$$

2. $$M_{Rd}(N_{Ed}) = M_{e,max}\left[1 - \left(\frac{N_{Ed} + \nu_M N_{e,max}}{\nu_M N_{e,max}}\right)^2\right] + M_{s,max}$$

$$-\nu_M N_{e,max} \le N_{Ed} < 0$$

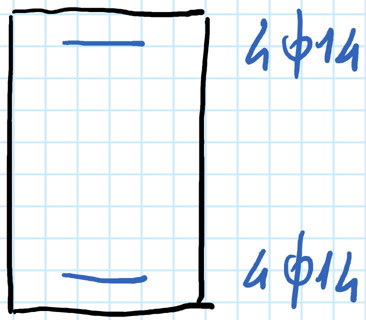
3. $$M_{Rd}(N_{Ed}) = (M_{e,max} + M_{s,max})\left[1 - \left|\frac{N_{Ed} + \nu_M N_{e,max}}{(1-\nu_M) N_{e,max} + N_{s,max}}\right|^m\right]$$

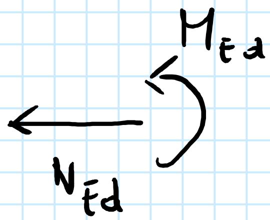
$$m = 1 + \left[\frac{\nu_M N_{e,max}}{(1-\nu_M) N_{e,max} + N_{s,max}}\right]^2 , \qquad N_{Ed} \le -\nu_M N_{e,max}$$

Rappresentazione ad "un tratto"

$$M_{Rd}(N_{Ed}) = (M_{e,max} + M_{s,max})\left[1 - \left|\frac{N_{Ed} + \nu_M N_{e,max}}{\nu_M N_{e,max} + N_{s,max}}\right|^{m}\right]$$

$$m = 1 + \frac{\nu_M N_{e,max}}{\nu_M N_{e,max} + N_{s,max}}$$





C30/37

B450C

$N_{Ed} = -1000 \text{ kN}$

$M_{Ed} = 380 \text{ kNm}$

$$N_{c,max} = b\,h\,f_{cd} = 30 \times 60 \times \frac{17}{10} = 3060 \text{ kN}$$

$$M_{c,max} = 0{,}12\, b\, h^2 f_{cd} = 0{,}12 \times 30 \times 60^2 \times 17 \,\frac{1}{10^3} = 220{,}3 \text{ kNm}$$

$$N_{s,max} = 2 A_s f_{yd} = 2 \times 6{,}16 \times \frac{391{,}3}{10} = 482{,}1 \text{ kN}$$

$$M_{s,max} = 2 A_s \left(\frac{h}{2} - c\right) f_{yd} = 2 \times 6{,}16 \times (30-4) \times \frac{391{,}3}{10^3} = 125{,}4 \text{ kN}$$

Verifica - Dominio a tre tratti

$$N_{Ed} = -1000 > -\nu_M N_{e,max} = -0{,}48 \times 3060 = -1468 \text{ kN}$$

$$2.\ M_{Rd}(N_{Ed}) = M_{e,max}\left[1-\left(\frac{N_{Ed}+\nu_M N_{e,max}}{\nu_M N_{e,max}}\right)^2\right] + M_{s,max}$$

$$-\nu_M N_{e,max} \le N_{Ed} < 0$$

$$M_{Rd}(N_{Ed}) = \underbrace{220{,}3 \times \left[1-\left(\frac{-1000+1468}{1468}\right)^2\right]}_{197{,}9} + 125{,}4$$

$$= 197{,}9 + 125{,}4 = 323{,}5 \text{ kNm}$$

NO

Verifica - Dominio ad un tratto

$$M_{Rd}(N_{Ed}) = (M_{e,max} + M_{s,max})\left[1 - \left|\frac{N_{Ed} + \nu_M N_{e,max}}{\nu_M N_{e,max} + N_{s,max}}\right|^m\right]$$

$$m = 1 + \frac{\nu_M N_{e,max}}{\nu_M N_{e,max} + N_{s,max}}$$

NO

$$M_{Rd}(N_{Ed}) = (220,3 + 125,4)\left[1 - \left|\frac{-1000 + 1468}{1468 + 481,8}\right|^{1,75}\right] = 335,4 \text{ kNm}$$

$$m = 1 + \frac{1468}{1468 + 481,8} = 1,75$$

Progetto - Dominio a tre tratti:

$M_{Ed} = 380\ KNm > M_{Rd}(N_{Ed}) = 323,5\ KNm$

l'armatura non basta

Considero l'equazione n. 2

$$\underbrace{M_{Rd}(N_{Ed}) = M_{e,max}\left[1 - \left(\frac{N_{Ed} + \nu_H N_{e,max}}{\nu_H N_{e,max}}\right)^2\right]}_{\text{Momento portato dalle azioni in calcestruzzo}} + M_{s,max}$$

Momento portato dalle azioni in calcestruzzo

L'armatura da portare

$$M_{s,max} = M_{Ed} - M_{c,max}\left[1 - \left(\frac{N_{Ed} + \nu_H N_{c,max}}{\nu_H N_{c,max}}\right)^2\right]$$

$$= 380 - \underbrace{220{,}3 \times \left[1 - \left(\frac{-1000 + 1468}{1468}\right)^2\right]}_{197{,}9} = 182{,}1 \text{ KNm}$$

ma $M_{s,max} = 2 A_s f_{yd}\left(\frac{h}{2} - c\right) \Rightarrow A_s = \dfrac{M_{s,max}}{2\left(\frac{h}{2} - c\right) f_{yd}}$

$$A_s = \frac{182{,}1}{2 \times (30-4) \times 391{,}3} \times 10^3 = 8{,}95 \text{ cm}^2 \quad 3\phi 20 \text{ per letto}$$