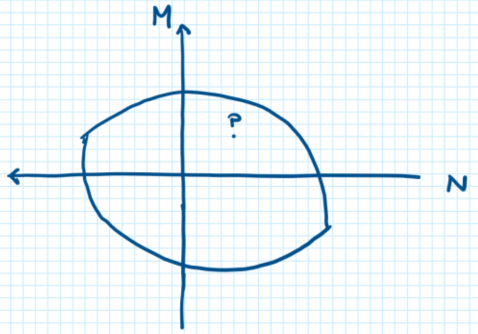
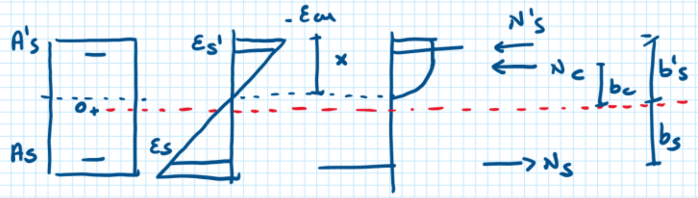
Flessione composta: domini MN



$P(N, M)$

PER COSTRUIRE UN PUNTO DEL DOMINIO: $P(\underset{N}{\overset{\shortparallel}{x}}, \underset{M}{\overset{\shortparallel}{y}})$



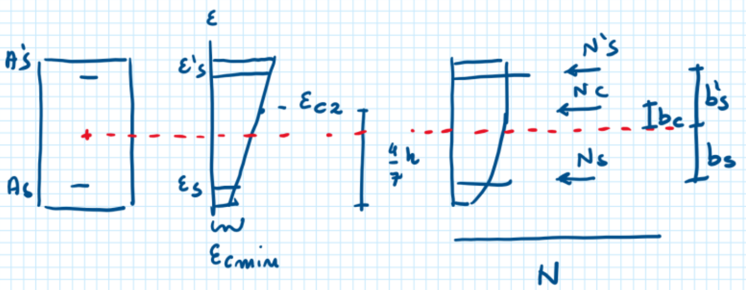
$M_c = N_c\, b_c$

$M'_s = N'_s\, b'_s$

$M_s = N_s\, b_s$

$N_c + N'_s + N_s = N$

$M_c + M'_s + M_s = M$



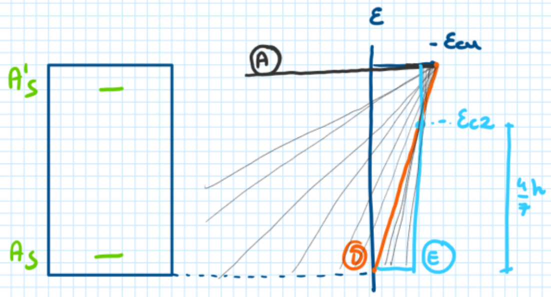
$M_c = N_c\, b_c$

$M'_s = N'_s\, b'_s$

$M_s = N_s\, b_s$

N

M



SEZ. PARZIALIZZATA

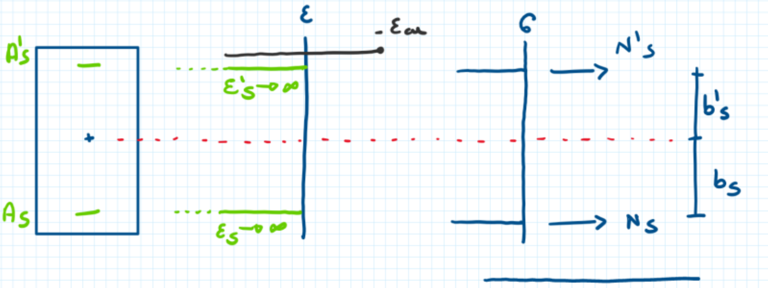
CAMPO (AD) $\begin{cases} \text{(A)} \\ \text{(D)} \end{cases}$

SEZ. TUTTA COMPRESSA

CAMPO (DE) $\begin{cases} \text{(D)} \\ \text{(E)} \end{cases}$

COSTRUIAMO IL DOMINIO M-N PER PUNTI:

DIAGRAMMA A



$$M'_s = -N'_s\left(\frac{h}{2} - c\right)$$
$$M_s = N_s\left(\frac{h}{2} - c\right)$$
$$M_c = 0$$

M

$$\varepsilon'_s = \varepsilon_s \to \infty$$
$$\sigma'_s = \sigma_s = f_{yd}$$
$$N'_s = A'_s f_{yd}$$
$$N_s = A_s f_{yd}$$
$$N_c = 0$$

N

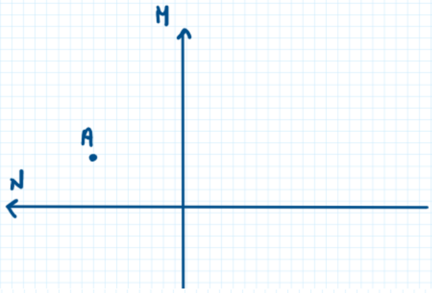
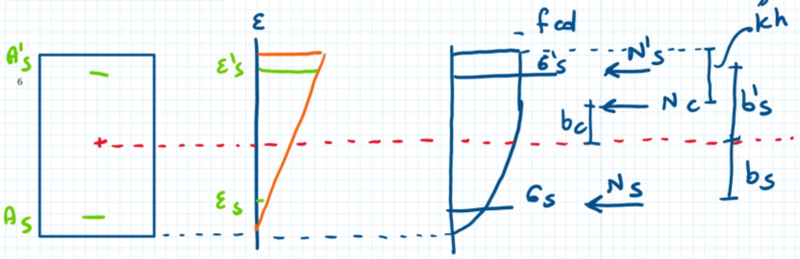


DIAGRAMMA D



$$M'_s = -N'_s\left(\frac{h}{2} - c\right)$$
$$M_s = N_s\left(\frac{h}{2} - c\right)$$
$$M_c = -N_c\left(\frac{h}{2} - kh\right)$$

N

M

$$N_c = -\overset{=0.81}{\beta}\, b h f_{cd}$$

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

$\hookrightarrow \dfrac{\varepsilon'_s}{d} = \dfrac{-\varepsilon_{cu}}{h} \Rightarrow \varepsilon'_s = -\dfrac{d}{h}\varepsilon_{cu}$

$\hookrightarrow \varepsilon'_s \leq -\varepsilon_{yd} \Rightarrow \sigma'_s = -f_{yd}$

$$\sigma'_s = \frac{\varepsilon'_s}{\varepsilon_{yd}} f_{yd}$$

$$N_s = A_s \sigma_s$$

$\hookrightarrow \dfrac{\varepsilon_s}{c} = \dfrac{-\varepsilon_{cu}}{h} \Rightarrow \varepsilon_s = -\dfrac{c}{h}\varepsilon_{cu}$

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

$$\sigma_s = \frac{\varepsilon_s}{\varepsilon_{yd}} f_{yd}$$

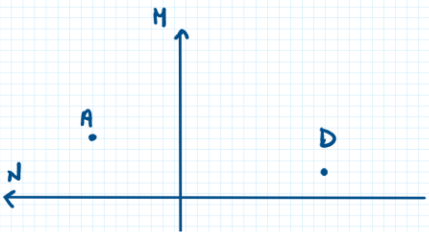
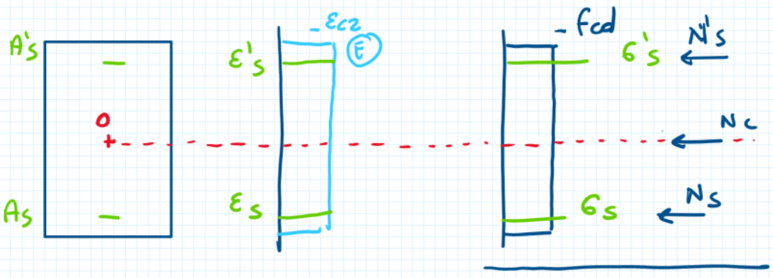


DIAGRAMMA E



$$M'_s = -N'_s\left(\frac{h}{2} - c\right)$$

$$M_s = N_s\left(\frac{h}{2} - c\right)$$

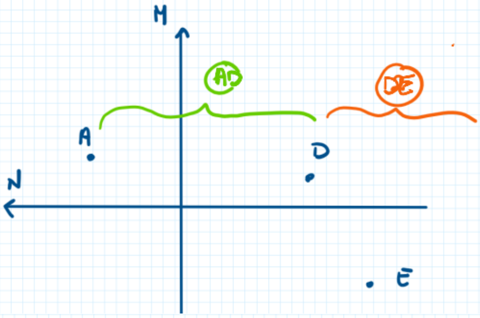
$$M_c = 0$$

M

$$N_c = -\, b h f_{cd}$$

$$N'_s = -A'_s f_{yd}$$

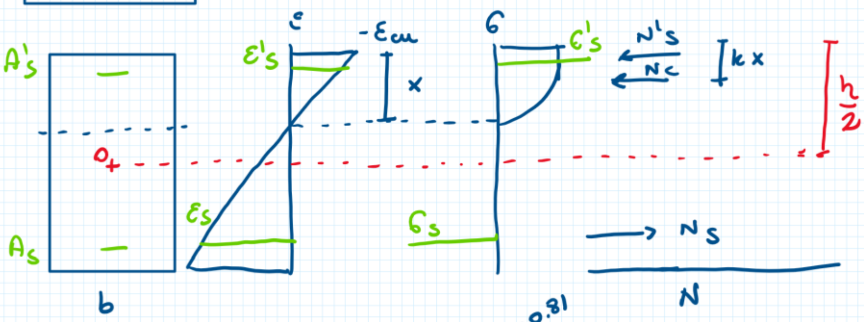
$$N_s = -A_s f_{yd}$$



$\Rightarrow$ 3 PUNTI SONO TROPPO POCHI

DEVO RAFFITTIRE I PUNTI

CAMPO AD



$$M'_s = -N'_s\left(\frac{h}{2} - c\right)$$

$$M_s = N_s\left(\frac{h}{2} - c\right)$$

$$M_c = N_c\left(\frac{h}{2} - kx\right)$$

M

$$N_c = -\overset{=0.81}{\beta}\, b\, x\, f_{cd}$$

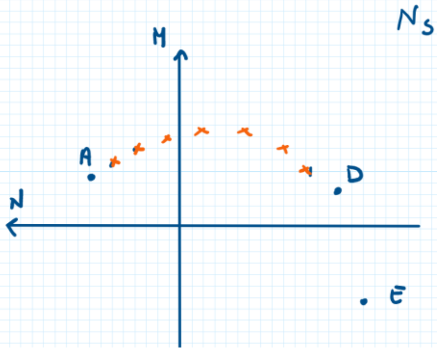
$$k = 0.416$$

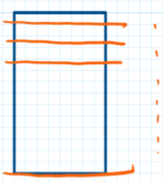
$$N'_s = A'_s \sigma'_s$$

$$\hookrightarrow \varepsilon'_s = -\frac{x-c}{x}\varepsilon_{cu} \Rightarrow \sigma'_s$$

$$N_s = A_s \sigma_s$$

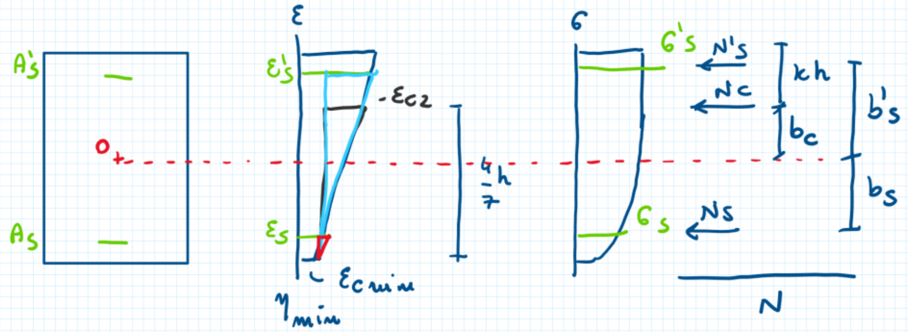
$$\hookrightarrow \varepsilon_s = \frac{d-x}{x}\varepsilon_{cu} \Rightarrow \sigma_s$$





$0 \le x \le h$

CAMPO DE



$$M'_s = -N'_s\left(\frac{h}{2} - c\right)$$

$$M_s = N_s\left(\frac{h}{2} - c\right)$$

$$M_c = -N_c\left(\frac{h}{2} - kh\right)$$

N

M

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

$$\beta = 1 - \frac{4}{21}\left(1 - \eta_{min}\right)^2$$

$$k = \frac{1}{2}\,\frac{1 - \frac{16}{49}\left(1 - \eta_{min}\right)^2}{1 - \frac{4}{21}\left(1 - \eta_{min}\right)^2}$$

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

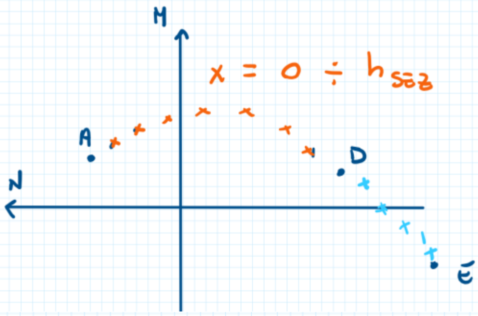
$$\to \varepsilon'_s = -\varepsilon_{c2}\left[\frac{d}{\frac{4}{7}h}\left(1 - \eta_{min}\right) + \eta_{min}\right]$$

$$\to \sigma'_s$$

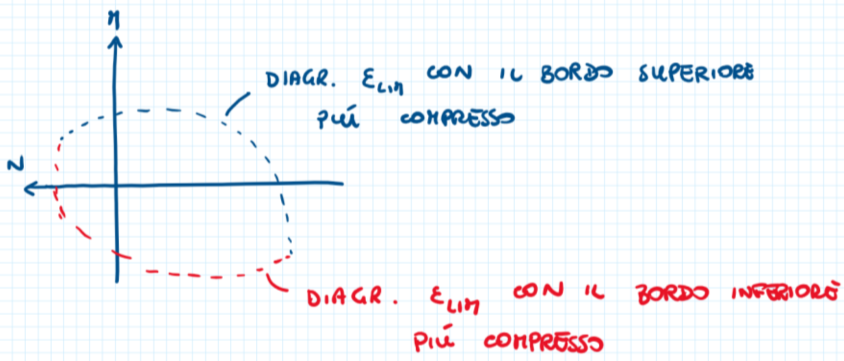
$$N_s = A_s \sigma_s$$

$$\to \varepsilon_s = -\varepsilon_{c2}\left[\frac{c}{\frac{4}{7}h}\left(1 - \eta_{min}\right) + \eta_{min}\right]$$

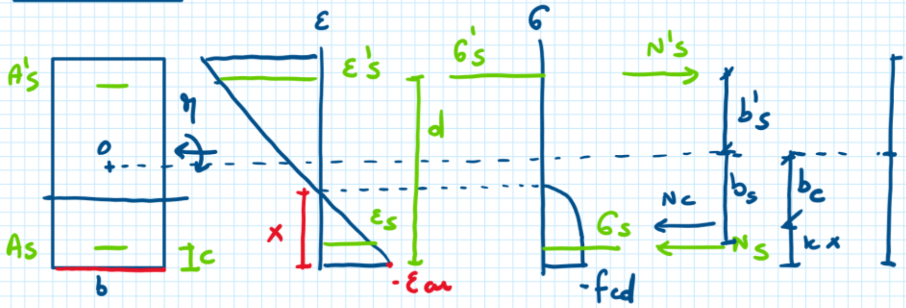
$$\to \sigma_s$$



$\eta_{min} = 0 \div 1$



CAMPO AD



$$M'_s = -N'_s\left(\frac{h}{2}-c\right)$$

$$M_s = N_s\left(\frac{h}{2}-c\right)$$

$$M_c = N_c\left(\frac{h}{2}-kx\right)$$

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

$$M = M'_s + M_s + M_c$$

$$N_c = -\overset{=0.81}{\beta}\, b\, x\, f_{cd}$$

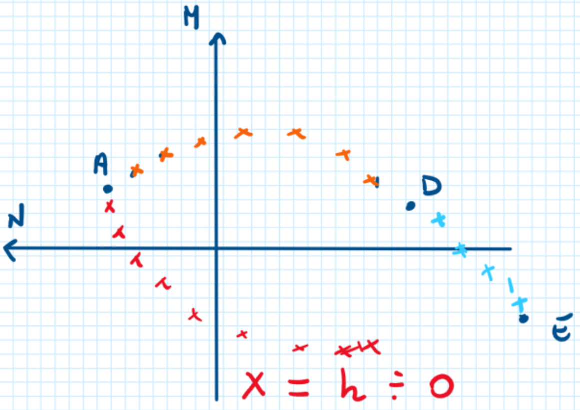
$$k = 0.416$$

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

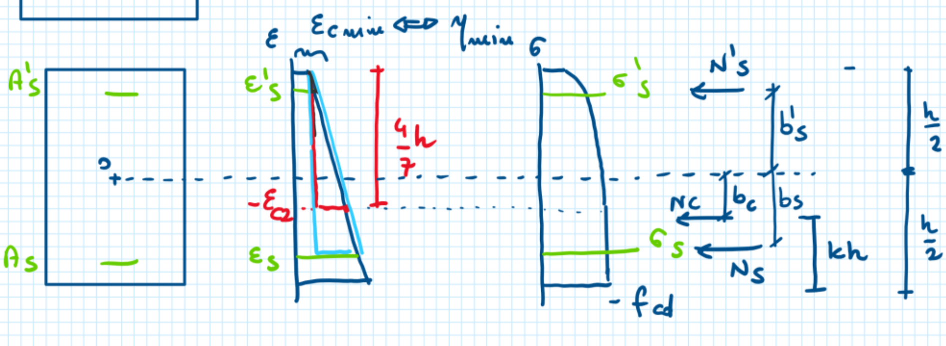
$$\hookrightarrow \frac{\varepsilon'_s}{-(d-x)} = \frac{-\varepsilon_{cu}}{x} \Rightarrow \varepsilon'_s = \frac{d-x}{x}\varepsilon_{cu} \Rightarrow \sigma'_s$$

$$N_s = A_s \sigma_s$$

$$\hookrightarrow \frac{\varepsilon_s}{x-c} = \frac{-\varepsilon_{cu}}{x} \Rightarrow \varepsilon_s = -\frac{x-c}{x}\varepsilon_{cu} \Rightarrow \sigma_s$$



CAMPO DE



$$M'_s = -N'_s\left(\frac{h}{2}-c\right)$$

$$M_s = N_s\left(\frac{h}{2}-c\right)$$

$$M_c = N_c\left(\frac{h}{2}-kh\right)$$

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

$$M_c + M'_s + M_s = M.$$

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

$$\beta = 1 - \frac{4}{21}\left(1 - \eta_{min}\right)^2$$

$$k = \frac{1}{2} \frac{1 - \frac{16}{49}\left(1 - \eta_{min}\right)^2}{1 - \frac{4}{21}\left(1 - \eta_{min}\right)^2}$$

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

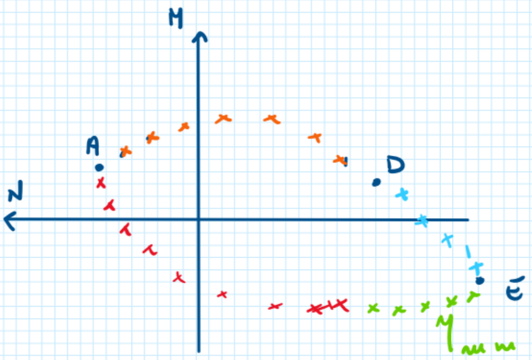
$$\hookrightarrow \frac{\varepsilon'_s - \varepsilon_{c\,min}}{c} = \frac{-\varepsilon_{c2} - \varepsilon_{c\,min}}{\frac{4}{7}h}$$

$$\varepsilon'_s = -\varepsilon_{c2}\left[\frac{c}{\frac{4}{7}h}\left(1 - \eta_{min}\right) + \eta_{min}\right] \Rightarrow \sigma'_s$$

$$N_s = A_s \sigma_s$$

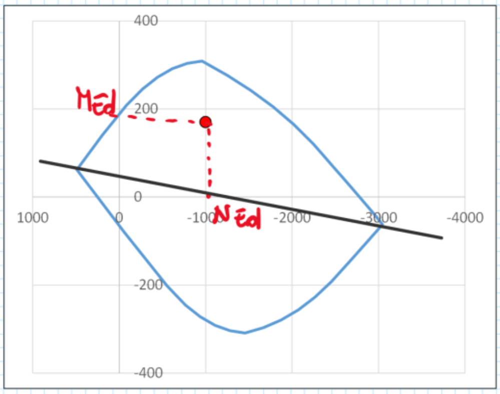
$$\hookrightarrow \frac{\varepsilon_s - \varepsilon_{c\,min}}{d} = \frac{-\varepsilon_{c2} - \varepsilon_{c\,min}}{\frac{4}{7}h}$$

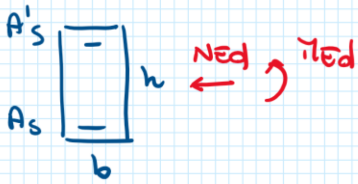
$$\varepsilon_s = -\varepsilon_{c2}\left[\frac{d}{\frac{4}{7}h}\left(1 - \eta_{min}\right) + \eta_{min}\right] \Rightarrow \sigma_s$$



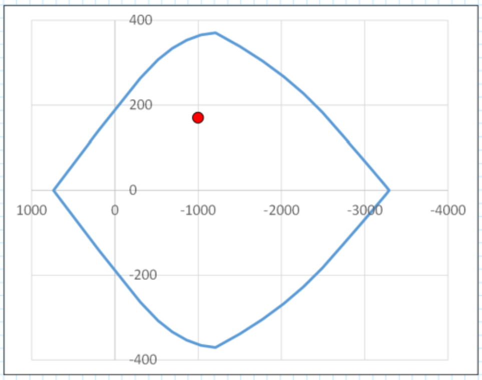
$\eta_{min} = 1.0 \div 0$

IL DOMINIO CHE OTTENGO PER PUNTI :

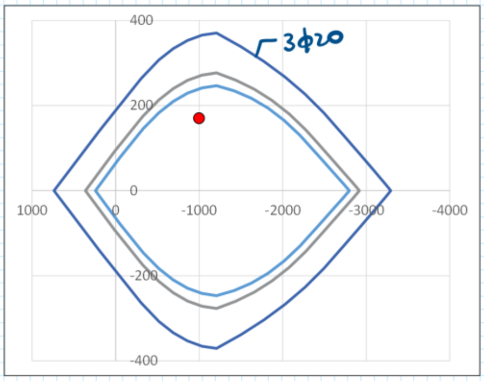




Se $A'_s = A_s$:



EFFETTO DELLE ARMATURE:

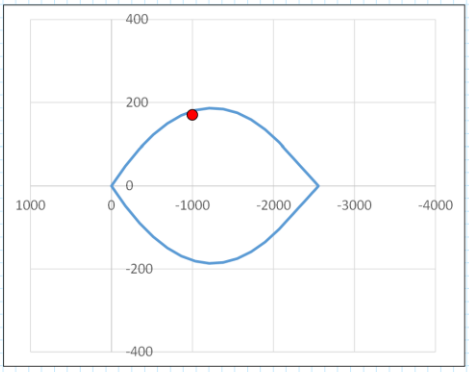


$A_s = A'_s = 2\phi 14$

$A_s = A'_s = 3\phi 14$

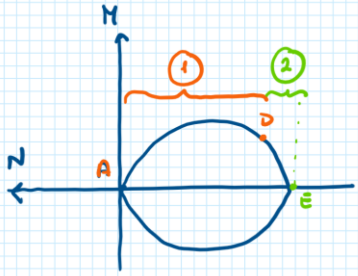
$A_s = A'_s = 3\phi 20$

DOMINIO M-N SOLO CLS :



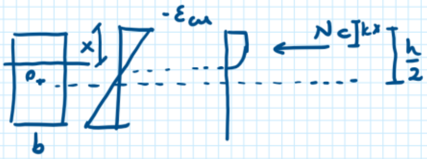
ESPRESSIONI RICAVATE PER SEZIONE RETTANGOLARE CON $A'_s = A_s$

DOMINIO MN SEZ. IN CLS



$$P \begin{cases} N_c = -\overset{=0.81}{\beta}\, b\, x\, f_{cd} & (1) \\ M_c = -N_c\left(\frac{h}{2} - \overset{=0.416}{k}\, x\right) & (2) \end{cases}$$

$P \in (1)$



DA (1) $\longrightarrow$ $x = -\dfrac{N_c}{\beta b f_{cd}}$ (3)

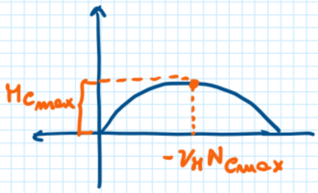
Sostituisco (3) in (2) $\Longrightarrow$ $M_c = -N_c\left(\dfrac{h}{2} + k\dfrac{N_c}{\beta b f_{cd}}\right)$

$\Downarrow$

PARABOLA

$\Downarrow$

VOGLIO TROVARE $M_{c\,max}$



PER TROVARE $M_{c\,max}$: $\dfrac{dM_c}{dN_c} = 0$

$$\frac{d}{dN_c}\left(-\frac{h}{2}N_c - k\frac{N_c^2}{\beta b f_{cd}}\right) = 0$$

$$-\frac{h}{2} - 2N_c\frac{k}{\beta b f_{cd}} = 0$$

$$2N_c\frac{k}{\beta b f_{cd}} = -\frac{h}{2}$$

$$N_c = -\frac{h}{2}\,\frac{\beta b f_{cd}}{2k}$$

$$N_c = -\underbrace{\frac{\overset{0.81}{\beta}}{\underset{0.416}{4k}}}_{0.487 = \nu_M}\;\underbrace{b\, h\, f_{cd}}_{N_{c\,max}} \quad (4)$$

$$N_c = -\nu_M N_{c\,max}$$

PER CONOSCERE x IN CORRISPONDENZA DI $\nu_1 N_{c\,max}$ E $M_{c\,max}$

SOSTITUISCO 4 in 3

$$x = -\frac{N_c}{\beta b f_{cd}} \quad (3)$$

$$x = +\frac{\cancel{\beta}}{4k}\frac{\cancel{b}\, h\, \cancel{f_{cd}}}{\cancel{\beta}\, \cancel{b}\, \cancel{f_{cd}}} = \frac{h}{4k} = 0.60\, h \quad (5)$$

CALCOLO $M_{c\,max}$:

SOSTITUISCO 5 E 4 in 2:

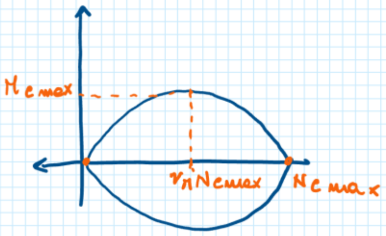
$$M_c = -N_c\left(\frac{h}{2} - kx\right) \quad (2)$$

$$M_{c\,max} = +\frac{\beta}{4k}\, b h f_{cd}\left(\frac{h}{2} - \cancel{k}\,\frac{h}{4\cancel{k}}\right)$$

$$M_{c\,max} = \frac{\beta}{4k}\, b h f_{cd}\, \frac{h}{4}$$

$$M_{c\,max} = \frac{\beta}{16\,k}\, b h^2 f_{cd} = 0.122\, b h^2 f_{cd}$$

EQUAZIONE DELLA PARABOLA CON VERTICE $\left(-\frac{\nu_1 N_{c\,max}}{2}, M_{c\,max}\right)$



$$M_{Rd_c} = M_{c\,max}\left[1 - \left(\frac{N_{Ed} + \nu_1 N_{c\,max}}{\nu_1 N_{c\,max}}\right)\right]$$