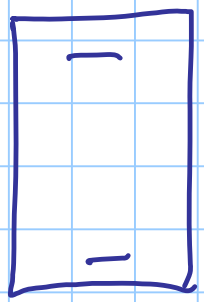
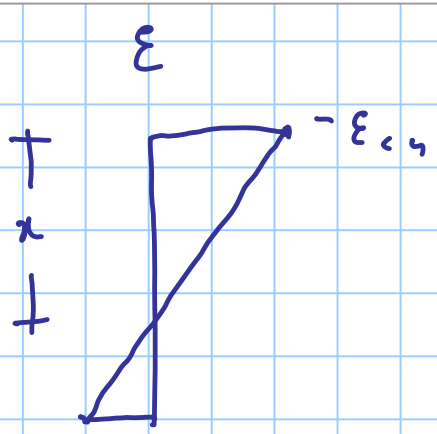
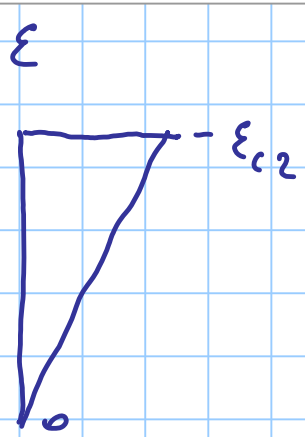
FLESSIONE COMPOSTA – SLU

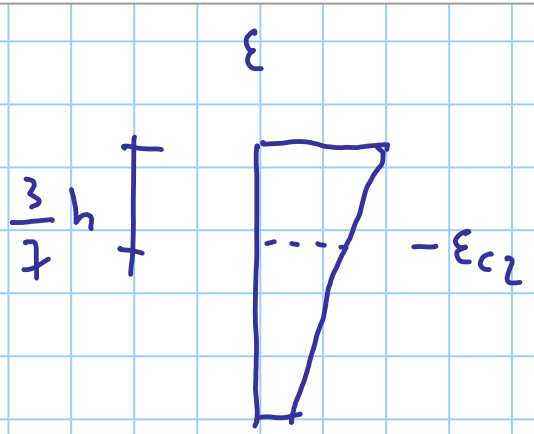
Titolo nota 29/11/2016





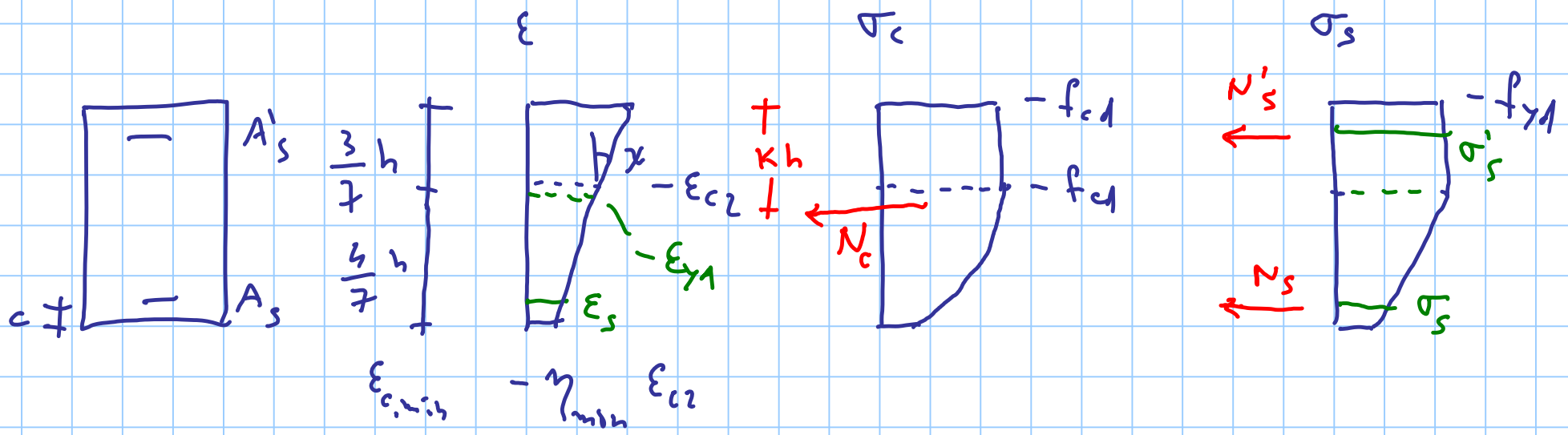


$x = h$; $\eta_{min} = 0$



$\varepsilon_{c,min}$ $-\eta_{min}$ ε_{c2}

M_{Ed} N_{Ed}



$$N = \int \sigma \, dA = N_{Ed}$$

$$N = N_s + N'_s + N_c = N_{Ed}$$

$$N_s = A_s \, \sigma_s \qquad N'_s = A'_s \, \sigma'_s$$

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

$\beta = 0.810$ per $\eta_{min} = 0$

$\beta = 1$ per $\eta_{min} = 1$

$$\varepsilon_s = -\varepsilon_{c2} + \chi\left(\frac{4}{7}h - c\right)$$

$$\chi = \frac{-\eta_{min}\,\varepsilon_{c2} + \varepsilon_{c2}}{\frac{4}{7}h}$$

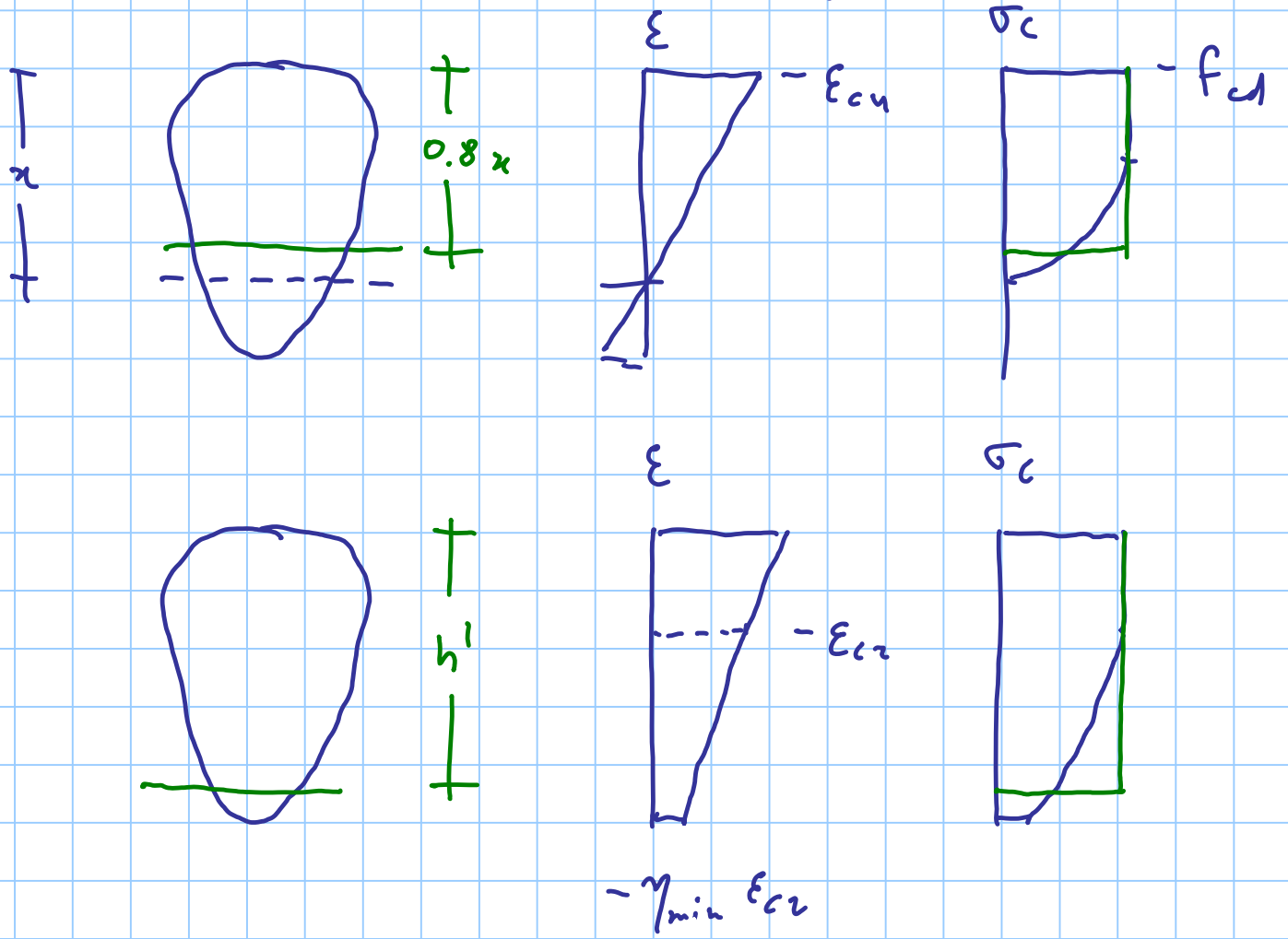
$$\varepsilon_s = -\left[\frac{c}{4/7\,h}(1-\eta_{min}) + \eta_{min}\right]\varepsilon_{c2}$$

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

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

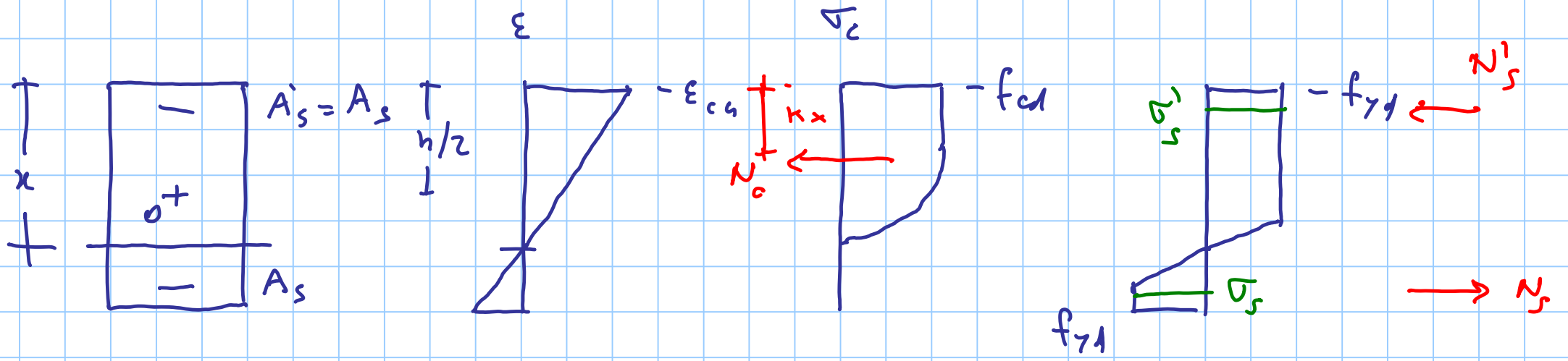
$$k = \frac{1}{2}\,\frac{1 - 16/49\,(1-\eta_{min})^2}{1 - 4/21\,(1-\eta_{min})^2}$$

per sezioni non rettangolari



$$h' = \left[1 - 0.2\left(1 - \eta_{min}\right)^2\right] h$$

SEZIONE RETTANGOLARE con $A_s = A'_s$



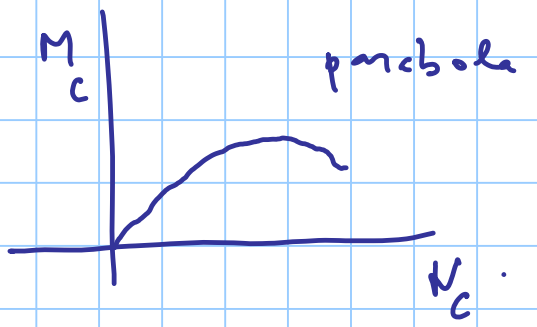
CONTRIBUTO CLS

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

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

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

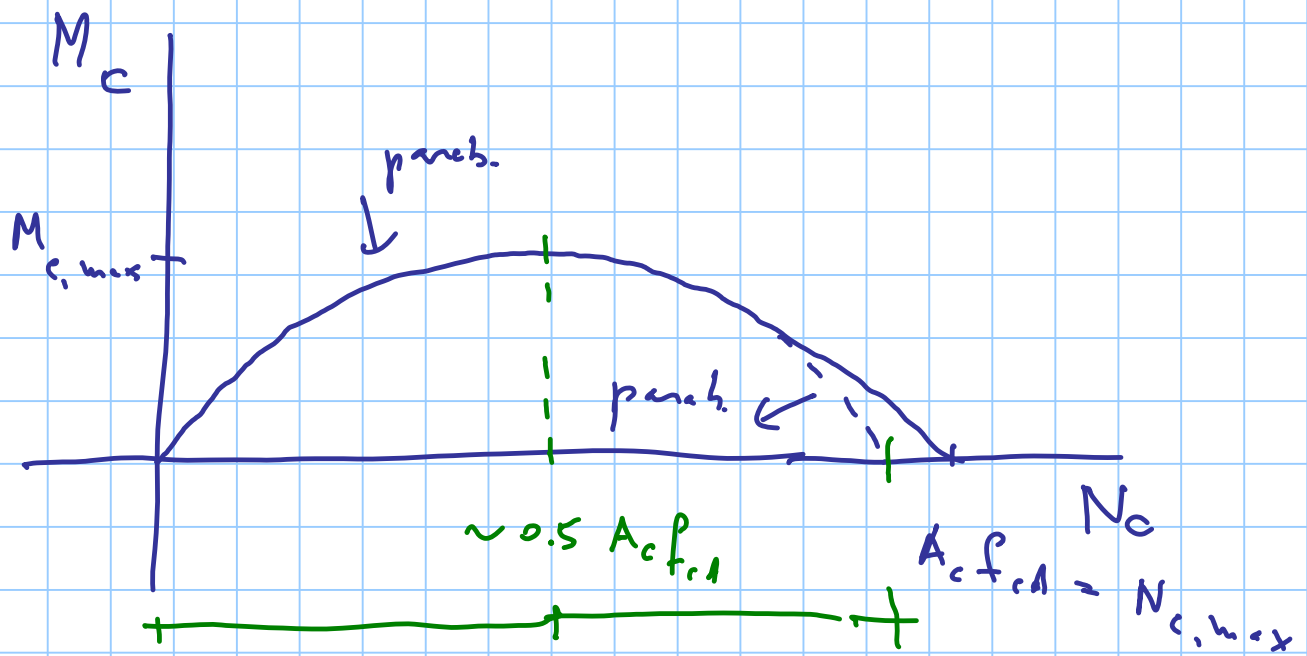
$$M_c = -N_c\left(\frac{h}{2} + k\,\frac{N_c}{\beta\, b\, f_{cd}}\right)$$



se la sezione è tutta compressa

è ancora $$M_c = - N_c \left(\frac{h}{2} + k \frac{N_c}{\beta b f_{cd}} \right)$$

ma β e k non sono costanti:



$$M_c = -N_c \left(\frac{h}{2} + k \frac{N_c}{\beta b f_{cd}} \right)$$

max se $\dfrac{dM_c}{dN_c} = 0$

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

$$N_c = -\frac{h}{4} \frac{\beta b f_{cd}}{k} = -\frac{\beta}{4k} A_c f_{cd} = -\nu_m A_c f_{cd}$$

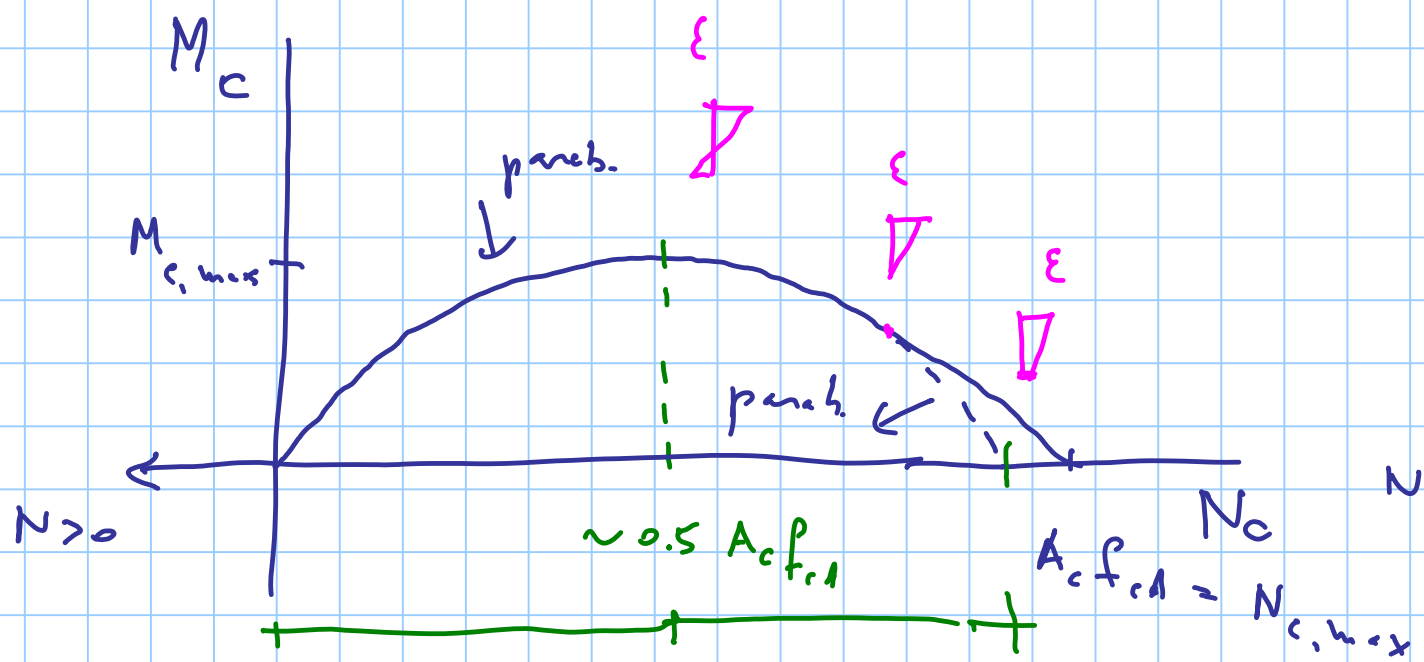
$$\nu_m = \frac{\beta}{4k} = \frac{0.810}{4 \times 0.416} = 0.486 \simeq 0.5$$

$$M_{c,max} = M_c\left(N = \nu_m A_c f_{cd}\right) =$$

$$= +\nu_m A_c f_{cd}\left(\frac{h}{2} + k\,\frac{-\nu_m A_c f_{cd}}{\beta b f_{cd}}\right) =$$

$$= \nu_m A_c f_{cd}\, h\left[\frac{1}{2} - k\,\frac{\nu_m \cancel{A_c f_{cd}}}{\beta \cancel{b h} \cancel{f_{cd}}}\right] =$$

$$= A_c f_{cd}\, h\, \underbrace{\nu_m\left[\frac{1}{2} - k\,\frac{\nu_m}{\beta}\right]}_{0.1216}$$



$$N_{c,max} = A_c f_{cd}$$

$N < 0$ compression

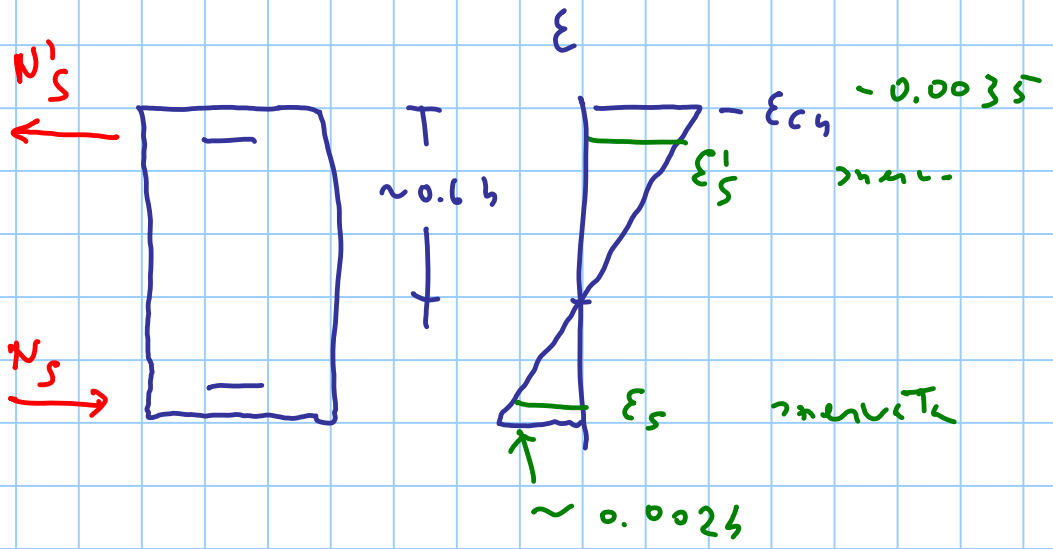
$$M_{Rd} = M_{c,max}\left[1 - \left(\frac{N_{Rd} + \nu_m N_{c,max}}{\nu_m N_{c,max}}\right)^2\right]$$

max per $N = -\nu_m N_{c,max}$

si ha $M_{c,max}$ quando

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

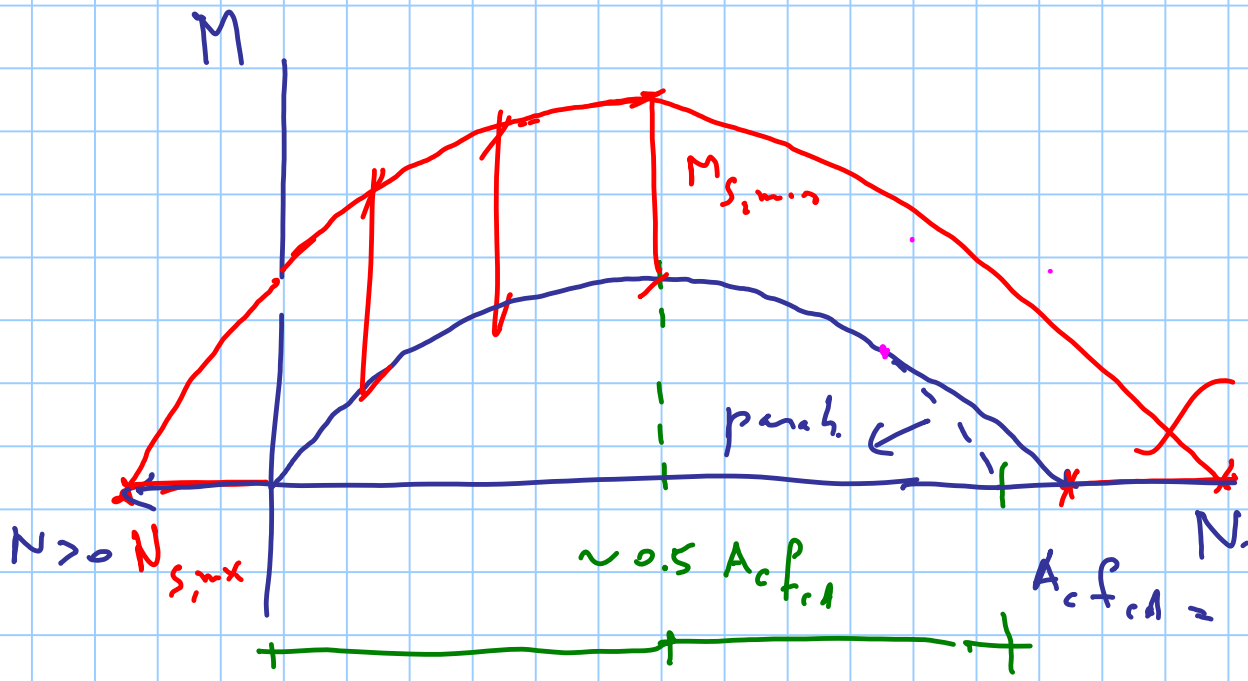
cioè per $x = \dfrac{\nu_m \cancel{b} h \cancel{f_{cd}}}{\beta \cancel{b} \cancel{f_{cd}}} = \dfrac{\nu_m}{\beta} h \simeq 0.6\, h$



se $\dfrac{c}{h}$ è piccolo

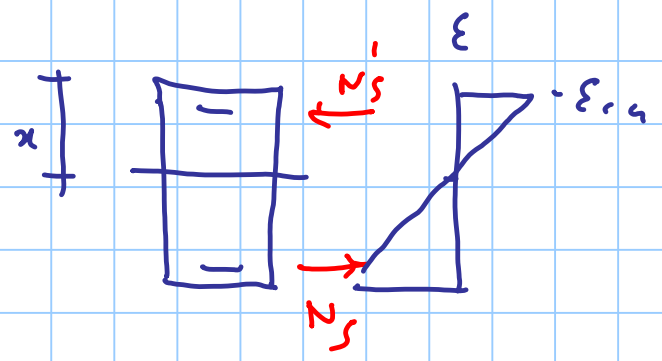
A_s e A'_s sono snervate

$N_s = N'_s = A_s f_{yd}$ compr. e traz.

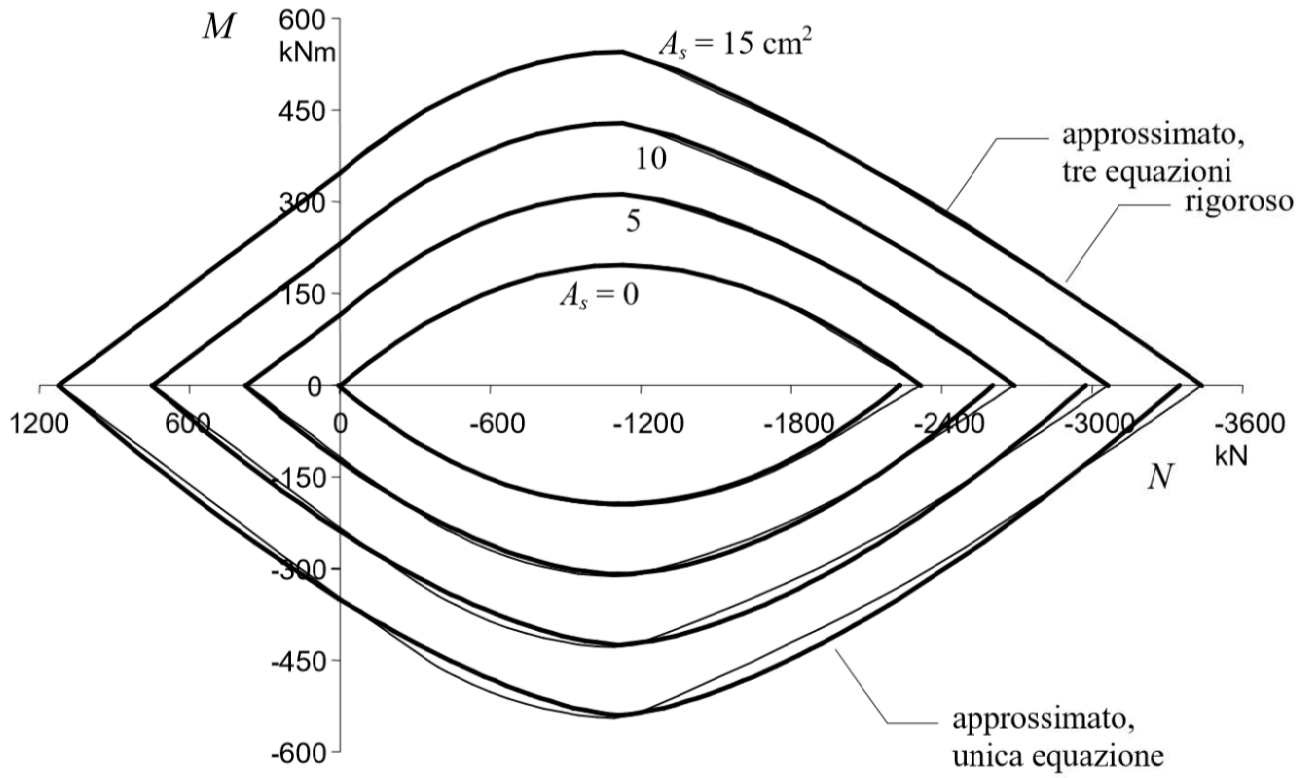


$$M_{s,max} = A_s f_{yd} (h - 2c)$$

$$N_{s,max} \geq 2 A_s f_{yd} = A_{s,tot} f_{yd}$$

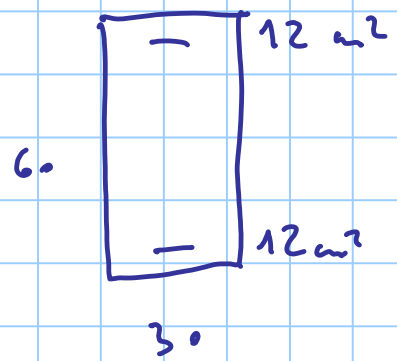


$x \leq 0.6\, h$


M
600
kNm
450
300
150
0
-150
-300
-450
-600
1200
600
0
-600
-1200
-1800
-2400
-3000
-3600
kN
N
$A_s = 15$ cm^2
10
5
$A_s = 0$
approssimato,
tre equazioni
rigoroso
approssimato,
unica equazione

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

$$m = 1 + \frac{\nu_m N_{c,max}}{\nu_m N_{c,max} + N_{s,max}} \simeq 1 + \frac{1}{1 + 2 N_{s,max}/N_{c,max}}$$



$N_{Ed} = -1300$ kN

$M_{Ed} = 180$ kNm

M_{Rd}

C25/30

B450C

$c = 4$ cm

$$N_{c,max} = b h f_{cd} = 30 \times 60 \times 16.17 \times 10^{-1} = 2551 \text{ kN}$$

$$M_{c,max} \simeq 0.12\, b h^2 f_{cd} = 0.12 \times 60 \times 10^{-2} \times 2551 =$$

$$= 0.12\, h\, N_{c,max} = 183.6 \text{ kNm}$$

$$N_{s,max} = 2 A_s f_{yd} = 24 \times 391.3 \times 10^{-1} = 939 \text{ kN}$$

$$M_{s,max} = A_s f_{yd} (h - 2c) = \frac{939}{2} \times 0.52 = 244.2 \text{ kNm}$$

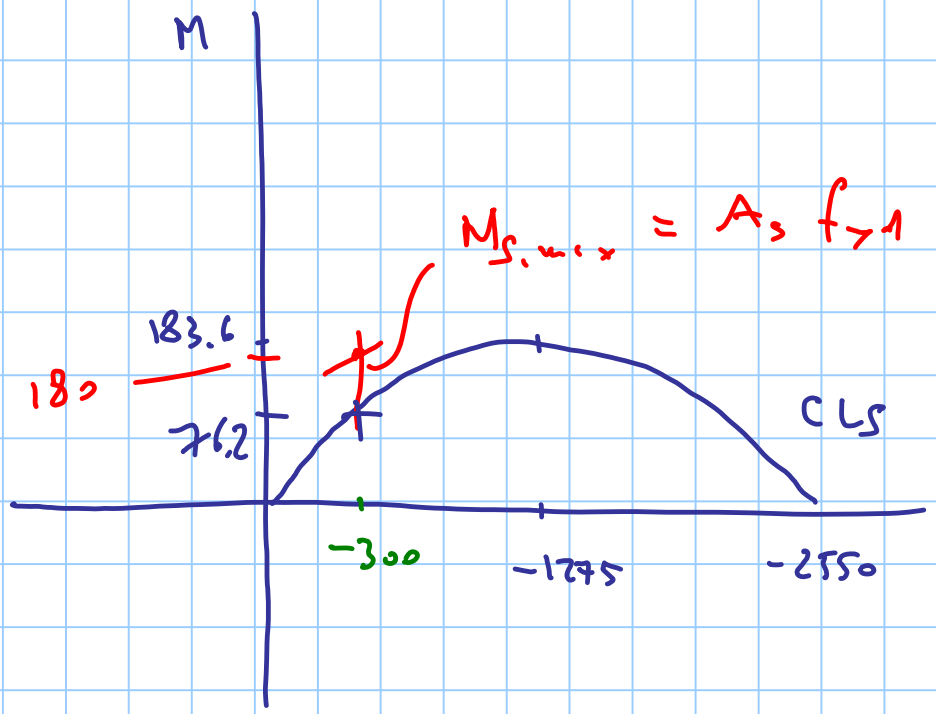
$$m = 1 + \frac{1}{1 + 2\, N_{s,max}/N_{c,max}} = 1 + \frac{1}{1 + 2 \times 939/2551} = 1.576$$

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

$$= \underbrace{\left(183.6 + 244.2\right)}_{427.8}\underbrace{\left[1 - \left|\frac{-1300 + 0.5 \times 2551}{0.5 \times 2551 + 939}\right|^{1.576}\right]}_{0.959} = 427.5 \text{ kNm}$$

$$N_{Ed} = -300 \text{ KN}$$

$$M_{Rd} = \underbrace{(183.6 + 244.2)}_{427.8} \underbrace{\left[1 - \left|\frac{-300 + 0.5 \times 255'}{0.5 \times 255' + 939}\right|^{1.576}\right]}_{0.725} = 310.3 \text{ KN}_m$$



$M_{s,max} = A_s f_{yd} (h-2c)$

$$A_s = \frac{\Delta M}{(h-2c) f_{yd}} = \frac{103.8 \times 10}{0.52 \times 391.3} = 5,1 \ cm^2$$

sob CLS

$$M_{Rd} = M_{c,max} \left[1 - \left(\frac{N + \nu_n N_{c,max}}{\nu_n N_{c,max}} \right)^2 \right]$$

-300

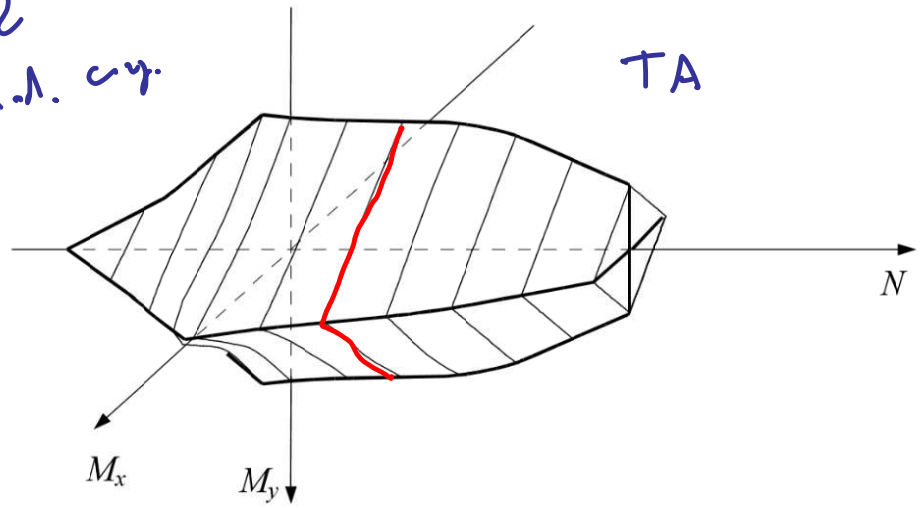
$$= 183.6 \left[1 - \left(\frac{-300 + 1275}{1275} \right)^2 \right] = 76.2 \ kN_m$$

$\Delta M = 180 - 76.2 = 103.8 \ kN_m$

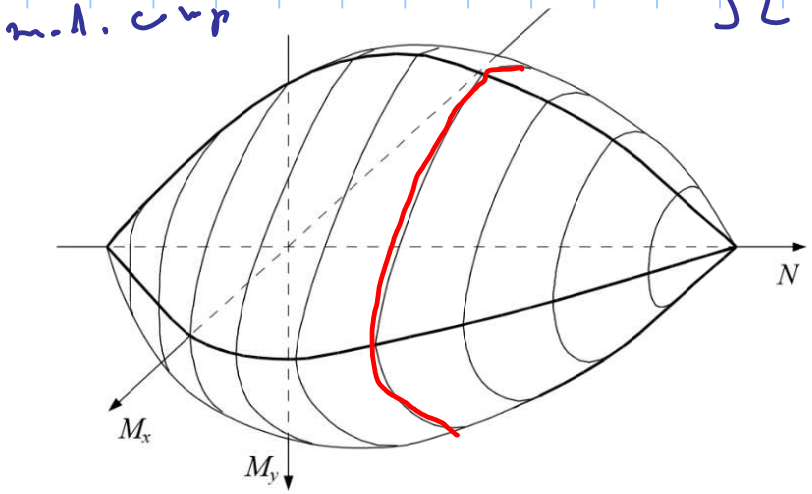
FLESSIONE COMPOSTA DEVIATA

N, M_x, M_y

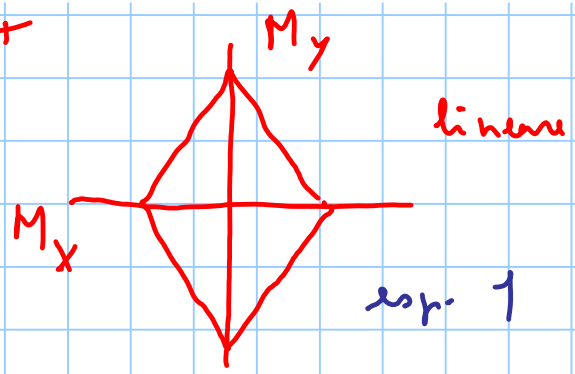
2° m.l. cy. TA



3° m.l. cup SLU

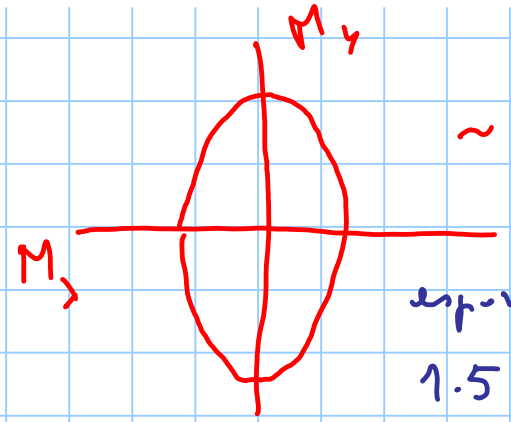


N = cost



lineare

esp. 1



~ ellisse

esponente $1.5 \div 2$

$$\left[\frac{M_{x,Ed}(N)}{M_{x,Rd}(N)}\right]^p + \left[\frac{M_{y,Ed}(N)}{M_{y,Rd}(N)}\right]^p \leq 1$$

$p = 1$ per 2° mod. comp.

$p = 1.5 \div 2$ per 3° mod. comp. usare 1.5 cautelativamente