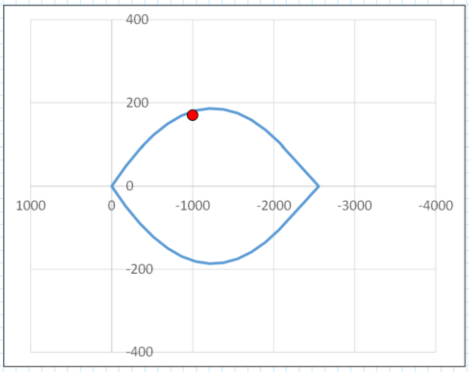
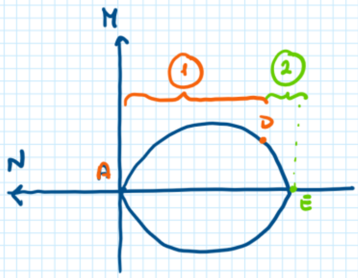
DOMINIO M-N SOLO CLS:



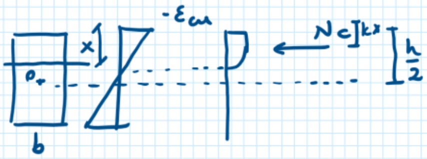
ESPRESSIONI RICAVATE PER $\begin{cases}\text{SEZIONE RETTANGOLARE} \\ \text{CON } A'_s = A_s\end{cases}$

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)

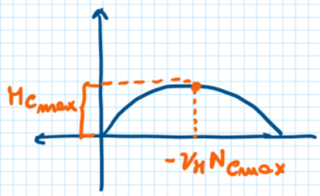
SOSTITUISCO (3) IN (2) $\Rightarrow$ $M_c = -N_c \left(\dfrac{h}{2} + k \dfrac{N_c}{\beta\, b\, f_{cd}} \right)$

$\Downarrow$

PARABOLA

$\Downarrow$

VOGLIO TROVARE $M_{c\,max}$



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

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

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

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

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

$$N_c=-\underbrace{\frac{\overset{0.81}{\beta}}{\underset{0.416}{4k}}}_{0.487=\nu_1}\underbrace{b h f_{cd}}_{N_{c\,max}} \quad (4)$$

$$N_c=-\nu_1 N_{c\,max}$$

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):

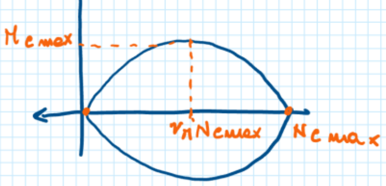
$$M_c=-N_c\left(\frac{h}{2}-kx\right) \quad (2)$$

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

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

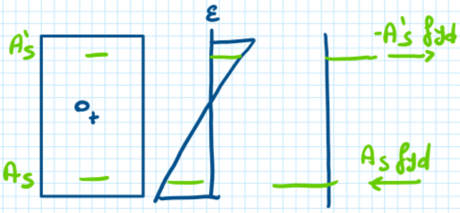
$$M_{c\,max}=\frac{\beta}{16k}bh^2f_{cd}=0.122\,bh^2f_{cd}$$

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



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

CONSIDERO IL CONTRIBUTO DELLE ARMATURE:



IL CONTRIBUTO MAX DOVUTO ALLE ARMATURE = $M_{S\,max}$

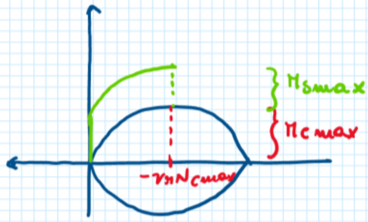
$$M_{S\,max} = -N'_s\left(\frac{h}{2}-c\right) + N_s\left(\frac{h}{2}-c\right)$$

$$M_{S\,max} = +A'_s f_{yd}\left(\frac{h}{2}-c\right) + A_s f_{yd}\left(\frac{h}{2}-c\right)$$

POICHÉ $A'_s = A_s$

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

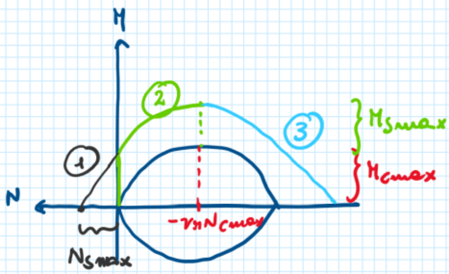
POSSO VEDERE $M_{Rd} = M_{Rd\,cls} + M_{S\,max}$



$-\nu_N N_{c\,max} \le N_{Ed} \le 0$

$$M_{Rd} = \underbrace{M_{c\,max}\left[1-\left(\frac{N_{Ed}+\nu_N N_{c\,max}}{\nu_N N_{c\,max}}\right)^2\right]}_{CLS} + \underbrace{M_{S\,max}}_{ARM.}$$

$\boxed{\text{DOMINIO IN 3 TRATTI :}}$



① $N_{Ed} > 0$

$$M_{Rd} = M_{S\,max}\left(1-\frac{N_{Ed}}{N_{S\,max}}\right)$$

$$N_{S\,max} = 2A_s f_{yd}$$

② $-\nu_N N_{c\,max} \le N_{Ed} \le 0$

$$M_{Rd} = \underbrace{M_{c\,max}\left[1-\left(\frac{N_{Ed}+\nu_N N_{c\,max}}{\nu_N N_{c\,max}}\right)^2\right]}_{CLS} + \underbrace{M_{S\,max}}_{ARM.}$$

③ $N_{Ed} \le -\nu_N N_{c\,max}$

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

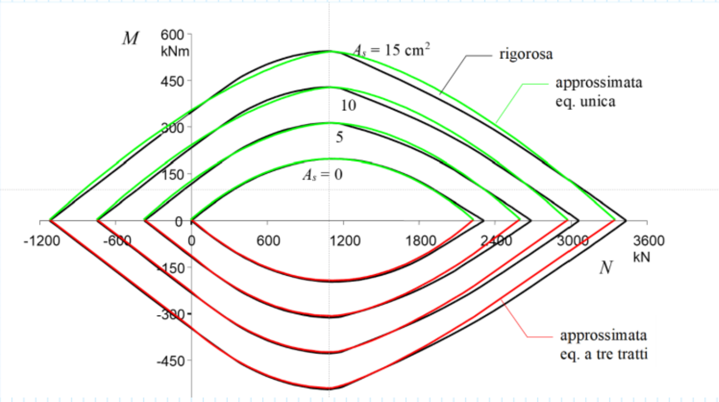
$$m = 1 + \left(\frac{\nu_N N_{c\,max}}{(1-\nu_N)N_{c\,max}+N_{S\,max}}\right)^2$$

EQUAZIONE DEL DOMINIO A UN UNICO TRATTO :

$$M_{Rd} = \left(M_{c\,max} + M_{s\,max}\right)\left[1 - \left|\frac{N_{Ed} + \nu_1 N_{c\,max}}{\nu_1 N_{c\,max} + N_{s\,max}}\right|^{m}\right]$$

$$m = 1 + \frac{\nu_1 N_{c\,max}}{\nu_1 N_{c\,max} + N_{s\,max}}$$

CONFRONTO TRA DOMINIO RIGOROSO VS EQUAZIONI



ESEMPIO

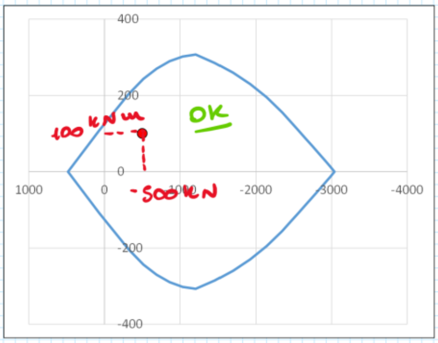
30x60 c: 5 cm

$A'_s = A_s = 4\phi 14 = 6.16\ cm^2$

$N_{Ed} = -500\ kN$

$M_{Ed} = 100\ kNm$

1) DA DOMINIO M-N



PER $N_{Ed} = -500\ kN$ TROVO

DAL DOMINIO $M_{Rd}(N_{Ed}) = 240.4\ kNm$

2) EQ. A 3 TRATTI

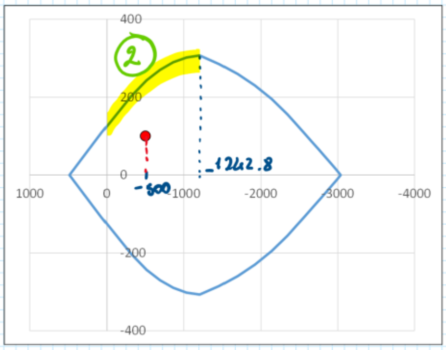
$$\nu_1 N_{c\,max} = 0.487 \cdot 30 \times 60 \times \frac{14.17}{10} = 1242.8 \text{ kN}$$

$N_{Ed} = -500$ kN

$-\nu_1 N_{c\,max} = -1242.8$

⇓

EQ. TRATTO 2



$$M_{Rd} = M_{c\,max}\left[1 - \left(\frac{N_{Ed} + \nu_1 N_{c\,max}}{\nu_1 N_{c\,max}}\right)^2\right] + M_{s\,max}$$

$$M_{c\,max} = 0.122\, bh^2 f_{cd} = 0.122 \times 30 \times 60^2 \times \frac{14.17}{10^3} = 186.7 \text{ kNm}$$

$$M_{s\,max} = 2 A_s f_{yd}\left(\frac{h}{2} - c\right) = 2 \times 6.16 \times 391.3 \left(\frac{60}{2} - 5\right)\frac{1}{10^3} = 120.5 \text{ kNm}$$

$$M_{Rd} = 186.7 \underbrace{\left[1 - \left(\frac{-500 + 1242.8}{1242.8}\right)^2\right]}_{0.643} + 120.5 =$$

$M_{Rd} = 240.5 > 100$ kNm OK

CON UNICO TRATTO ?

$$M_{Rd} = (M_{c\,max} + M_{s\,max})\left[1 - \left|\frac{N_{Ed} + \nu_1 N_{c\,max}}{\nu_1 N_{c\,max} + N_{s\,max}}\right|^m\right]$$

$$m = 1 + \frac{\nu_1 N_{c\,max}}{\nu_1 N_{c\,max} + N_{s\,max}}$$

$$N_{s\,max} = 2 A_s f_{yd} = 2 \times 6.16 \times \frac{391.3}{10} = 482.0 \text{ kN}$$

$$m = 1 + \frac{1242.8}{1242.8 + 432} = 1.72$$

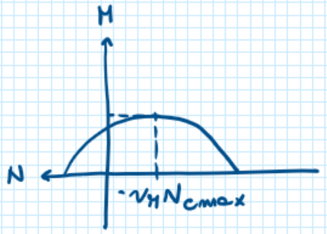
$$M_{Rd} = (186.7 + 120.5)\left[1 - \left|\frac{-500 + 1242.8}{1242.8 + 432}\right|^{1.72}\right] = 235.0 \text{ kNm}$$

$235 > 100$ ok!

PROGETTO A FLESSIONE COMPOSTA

1) PROG. LA SEZ IN CLS

$\Rightarrow N_{Ed}$ (SE È NOTO SOLO N_{Ed} OPPURE È PREDOMINANTE SU M_{Ed})



$$N_{Ed} = -\nu_M N_{cmax}$$

$$N_{Ed} = -\nu_M\, b h f_{cd}$$

$$bh = \frac{N_{Ed}}{\nu_M f_{cd}}$$

$\Rightarrow M_{Ed}$ (SE È PREDOMINANTE SU N_{Ed})

$$M_{Ed} = M_{Rd} = \frac{bd^2}{r'^2}$$

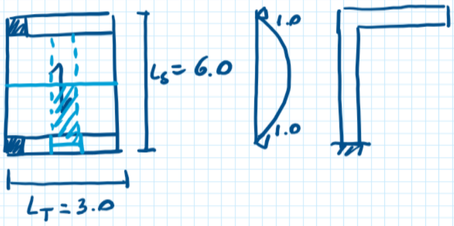
2) PROG. DELLE ARMATURE $A'_s = A_s$

$$M_{Rd} = \underbrace{M_{cmax}\left[1 - \left(\frac{N_{Ed} + \nu_M N_{cmax}}{\nu_M N_{cmax}}\right)^2\right]}_{\text{SEZ. IN CLS}} + \underbrace{M_{Smax}}_{\text{ARMATURE}} \quad (2° \text{ TRATTO})$$

$$\Delta M = M_{Ed} - M_{cmax}\left[1 - \left(\frac{N_{Ed} + \nu_M N_{cmax}}{\nu_M N_{cmax}}\right)^2\right]$$

$$\begin{cases} \Delta M = M_{Smax} \\ M_{Smax} = 2 A_s f_{yd}\left(\frac{h}{2} - c\right) \end{cases} \Rightarrow \boxed{A_s = \frac{\Delta M}{2 f_{yd}\left(\frac{h}{2} - c\right)}}$$

ESEMPIO

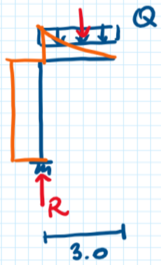


$G_d = 7\ kN/m^2$

$Q_d = 2\ kN/m^2$

$P.P = 3\ kN/m$

PROG. PILASTRO



$$Q = \begin{cases} SOL. = \left(\frac{6.0}{2} \times 1\right)(7+2) = 27\ \frac{kN}{m} \\ P.P = 3\ \frac{kN}{m} \end{cases}$$

$$Q = 27 + 3 = 30\ \frac{kN}{m}$$

$$R = N_{Ed} = 30 \times 3 = 90\ kN$$

$$M_{Ed} = 30 \times \frac{3^2}{2} = 135.0\ kNm$$

⇒ PROGETTO M_{Ed}

$$M_{Ed} = \frac{b\,d^2}{r'^2} \Rightarrow d = \sqrt{\frac{M_{Ed}}{b}}\, r' = \sqrt{\frac{135}{0.30}} \times 0.019 = 0.40\ m$$

$b = 0.30$

$r' = 0.019$

$h = 40 + 5 = \cancel{45}\ 50$ 30x50

⇒ PROGETTO LE ARMATURE

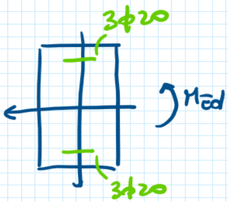
$$\Delta M = M_{Ed} - M_{c\,max}\left[1 - \left(\frac{N_{Ed} + \nu_M N_{c\,max}}{\nu_M N_{c\,max}}\right)^2\right]$$

$$M_{c\,max} = 0.12\ b h^2 f_{cd} = 0.12 \cdot 30 \cdot 50^2 \cdot \frac{14.2}{10^3} = 127.4\ kNm$$

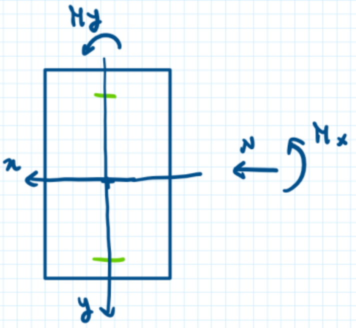
$$N_{c\,max} = b\,h\,f_{cd} = 30 \cdot 50 \cdot \frac{14.2}{10} = 2130\ kN$$

$$\Delta M = 135 - \underbrace{127.4\underbrace{\left[1 - \left(\frac{-90 + 0.487 \cdot 2130}{0.487 \cdot 2130}\right)^2\right]}_{0.166}}_{21.15} = 113.85\ kNm$$

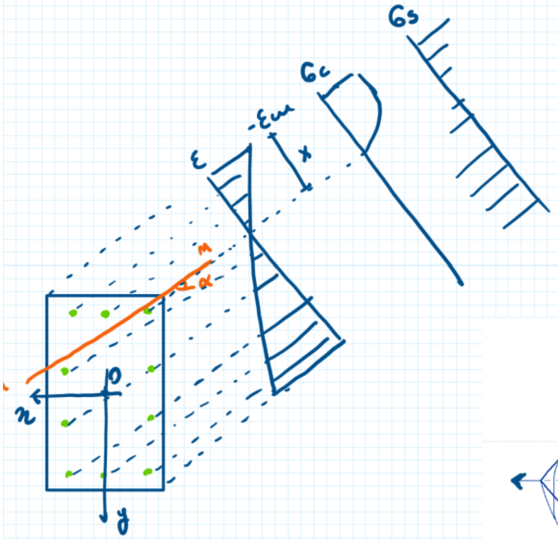
$$A_s = \frac{\Delta M}{2 f_{yd}\left(\frac{h}{2} - c\right)} = \frac{113.85 \cdot 10^3}{2 \cdot 391.3\left(\frac{50}{2} - 5\right)} = 7.27\ cm^2$$



FLESSIONE COMPOSTA DEVIATA



POSSO RICAVARE IL DOMINIO $M_x \cdot M_y \cdot N$ ALLO SW

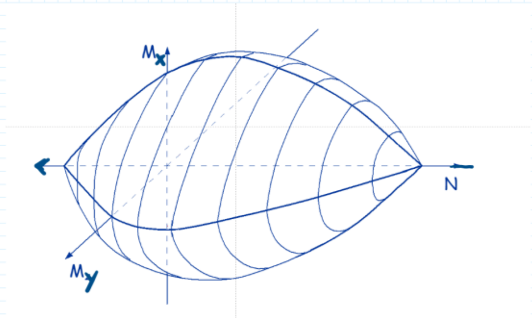


FACENDO VARIARE:

1) L'INCLINAZIONE DELL'ASSE NEUTRO

2) DIAGR. ε_{lim}

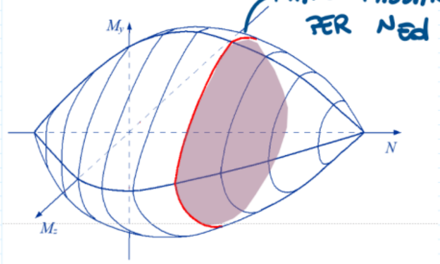
⇓



PER FARE LA VERIFICA:

$$\left(\frac{M_{x,Ed}}{M_{Rd,x}}\right)^{\alpha} + \left(\frac{M_{y,Ed}}{M_{Rd,y}}\right)^{\alpha} \leq 1$$

PIANO PASSANTE PER N_{Ed}



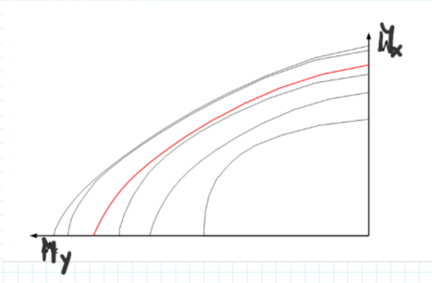
con $N_{Rcd} = A_c \cdot f_{cd}$.

In mancanza di una specifica valutazione, può assumersi:

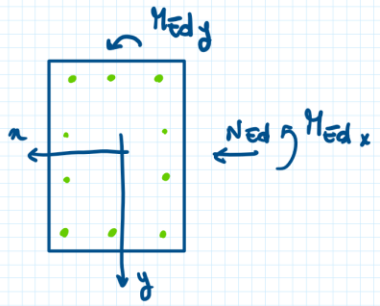
- per sezioni rettangolari:

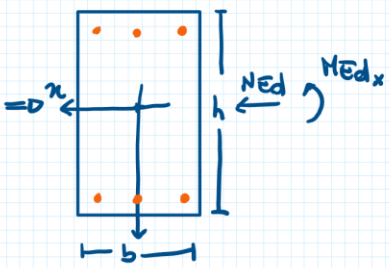
N_{Ed}/N_{Rcd}	0,1	0,7	1,0
α	1,0	1,5	2,0

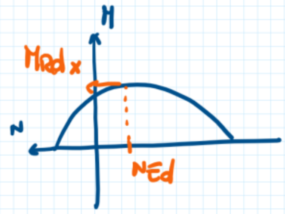
Cautelativamente consiglio di usare α= 1.5

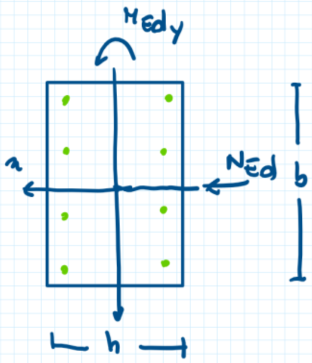


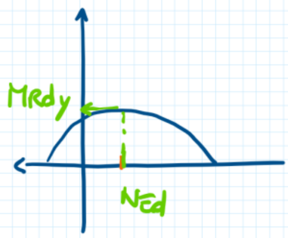
PER VALUTARE $M_{Rd\,x}$ E $M_{Rd\,y}$:





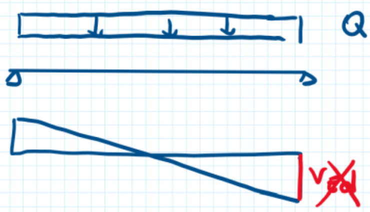






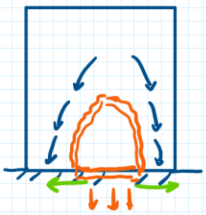
$\boxed{\text{TAGLIO}}$

$V \rightarrow \tau$

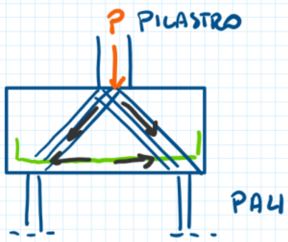


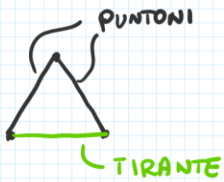
⇒ TEO. DE SAINT VENANT
VALE PER ASTE SNELLE
E LONTANO DA FORZE CONCENTRATE

PER CAPIRE:

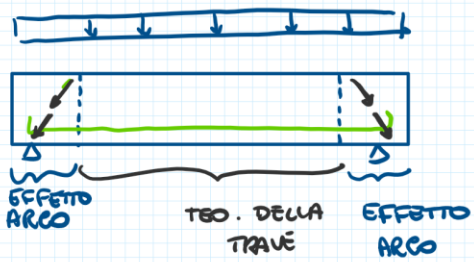


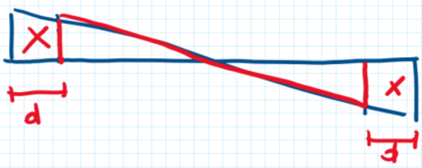
EFFETTO ARCO



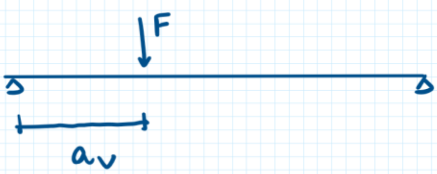


MODELLO
STRUT AND TIE





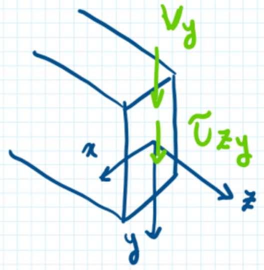
PER CARICHI DISTRIBUITI ⇒ V_{Ed} A DISTANZA d DAL VINCOLO



$a_v \leq 2d$

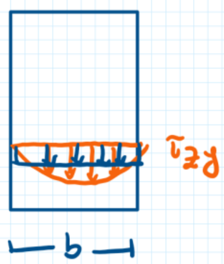
$V_{Ed} = V_F \dfrac{a_v}{2d}$

SEZIONE ELASTICA OMOGENEA



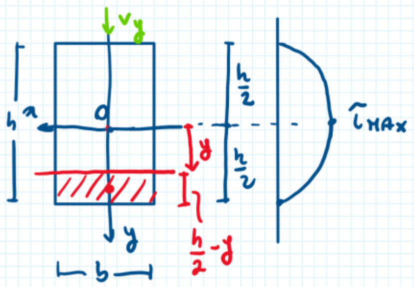
$$\int \tau_{zy}\, dA = V_y$$

$$\int \tau_{zx}\, dA = 0$$



$$\tau_{zy} = \frac{V_y\, S_x}{I_x\, b} \qquad \text{TEO. JOURAWSKY}$$

SEZ. OMOGENEA



$$I_x = \frac{bh^3}{12}$$

b

$$S_x = b\left(\frac{h}{2}-y\right)\left[y + \frac{1}{2}\left(\frac{h}{2}-y\right)\right]$$

$$S_x = b\left(\frac{h}{2}-y\right)\left(y + \frac{h}{4} - \frac{y}{2}\right)$$

$$S_x = b\left(\frac{h}{2}-y\right)\left(\frac{y}{2} + \frac{h}{4}\right)$$

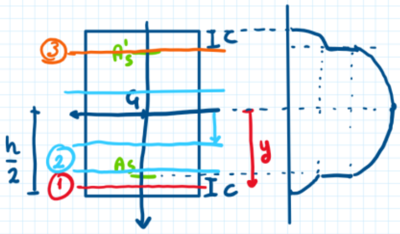
$$S_x = \frac{b}{2}\left(\frac{h}{2}-y\right)\left(\frac{h}{2}+y\right)$$

$$S_x = \frac{b}{2}\left[\left(\frac{h}{2}\right)^2 - y^2\right]$$

$\tau_{max} \rightarrow y_1 = 0$

$$\tau_{zy\,max} = \frac{V\left(\frac{\cancel{b}}{\cancel{2}}\frac{h^2}{4}\right)}{\frac{bh^3}{\cancel{12}\,6}\,\cancel{b}} = \frac{\cancel{6}3\, V\, \frac{h^{\cancel{2}}}{\cancel{4}2}}{bh^{\cancel{3}}} = \frac{3}{2}\frac{V}{bh}$$

I STADIO



$$I_x = \frac{bh^3}{12} + mA'_s\left(\frac{h}{2}-c\right)^2 + mA_s\left(\frac{h}{2}-c\right)^2$$

S_x :

$$S_{x_1} = \frac{b}{2}\left[\left(\frac{h}{2}\right)^2 - y^2\right]$$

$$S_{x_2} = \frac{b}{2}\left[\left(\frac{h}{2}\right)^2 - y^2\right] + mA_s\left(\frac{h}{2}-c\right)$$

$$S_{x_3} = \frac{b}{2}\left[\left(\frac{h}{2}\right)^2 - y^2\right] + mA_s\left(\frac{h}{2}-c\right) - mA'_s\left(\frac{h}{2}-c\right)$$