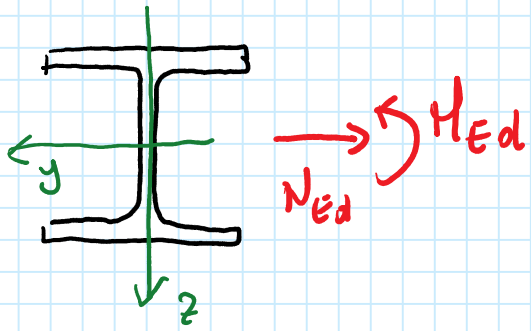
Domini di resistenza M-N di sezioni di classe 3

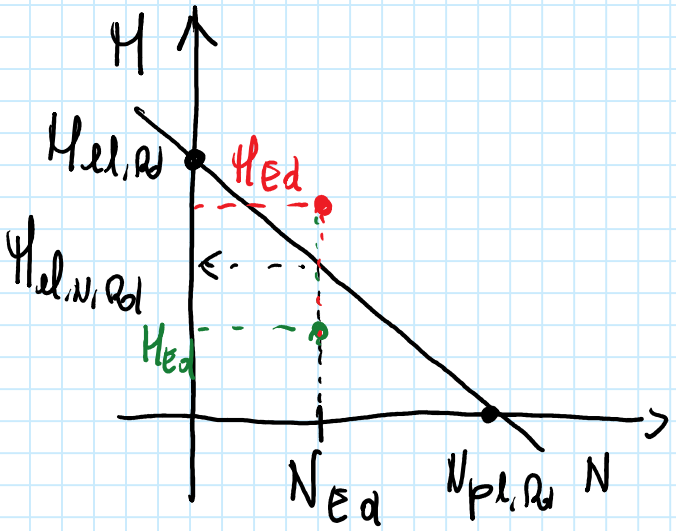


$$M_{Ed} \leq M_{el,N,Rd} = M_{el,Rd}\left(1 - \frac{N_{Ed}}{N_{pl,Rd}}\right)$$

Fisso $N_{Ed} \rightarrow M_{el,N,Rd}$

1. $N_{Ed} = 0 \longrightarrow M_{el,N,Rd} = M_{el,Rd}$

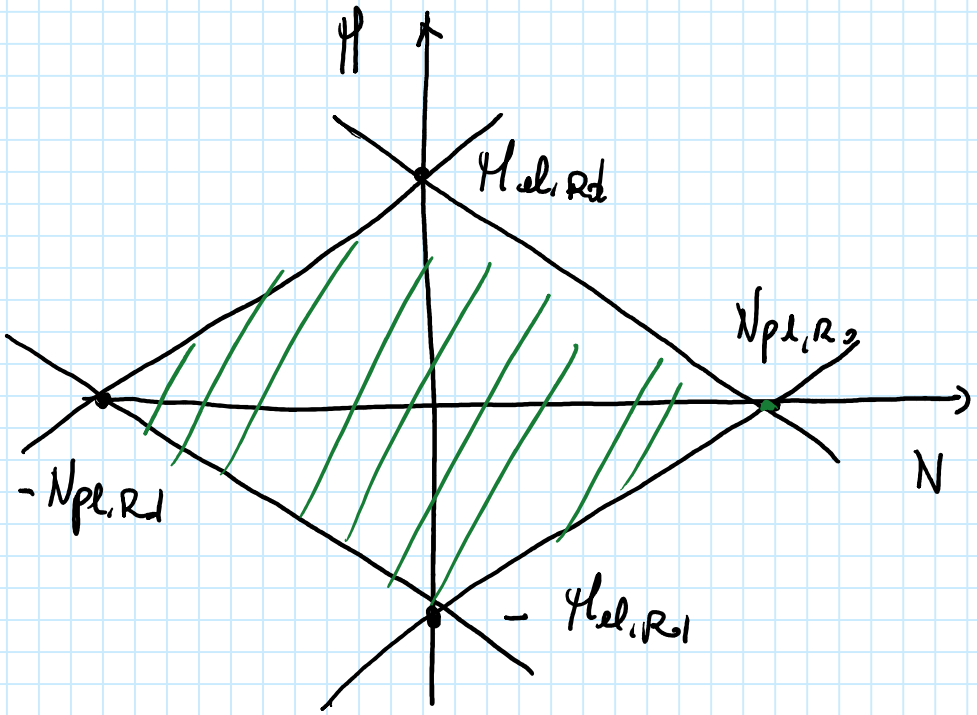
2. $N_{Ed} = N_{pl,Rd} \rightarrow M_{el,N,Rd} =$



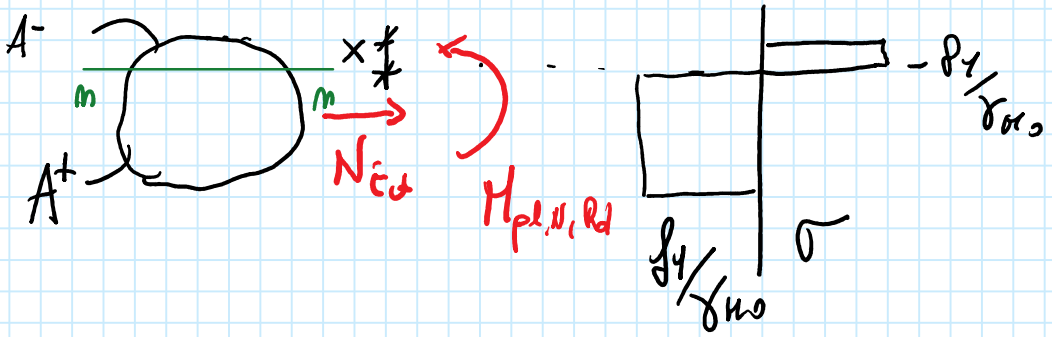
$$M_{Ed} \leq M_{el,Rd}\left(1 - \frac{N_{Ed}}{N_{pl,Rd}}\right)$$

$$\frac{M_{Ed}}{M_{el,Rd}} + \frac{N_{Ed}}{N_{pl,Rd}} \leq 1$$

$$\frac{|M_{Ed}|}{M_{el,Rd}} + \frac{|N_{Ed}|}{N_{pl,Rd}} \leq 1$$

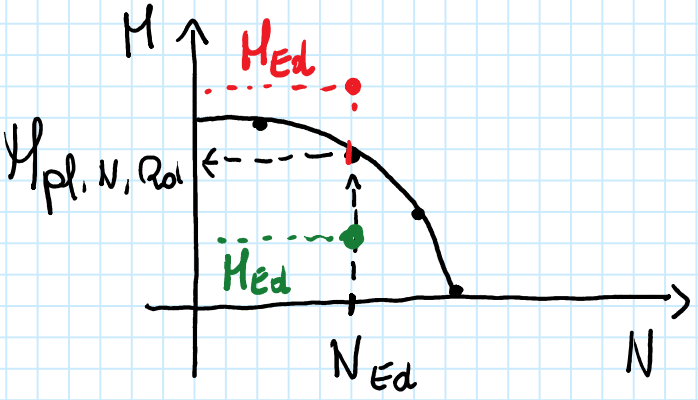


Domini di resistenza M-N di sezioni di classe 1 o 2



Noto N_{Ed} $\rightarrow$ $A^+ + A^- = A$, $A^+ - A^- = N_{Ed}/\gamma_{M0}$ $\rightarrow$ determino: $X \rightarrow A^+$ e A^- $\rightarrow$ $\Rightarrow$ Ho un punto del dominio

$$\rightarrow M_{pl,N,Rd} = \int_A \sigma z\, dA = 2S^+ \frac{f_y}{\gamma_{M0}} = -2S^- \frac{f_y}{\gamma_{M0}}$$

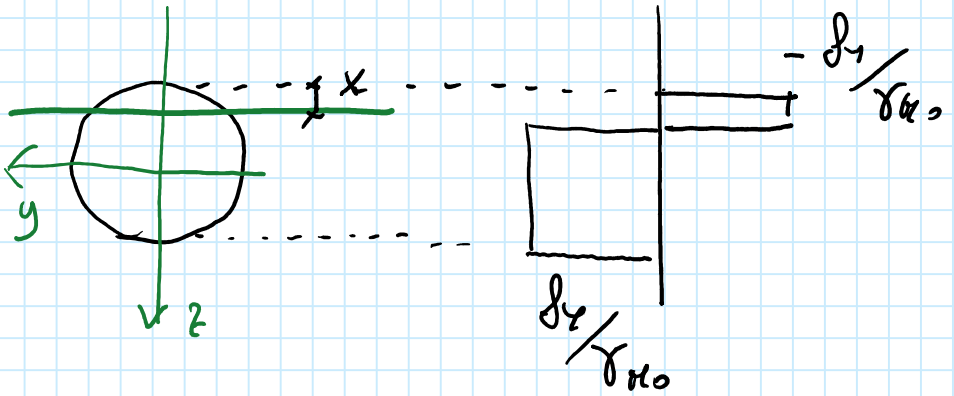


Faccio variare N_{Ed} determino più punti che uniti restituiscono il dominio M-N.

Posso usarlo per la verifica.

Ma esiste un procedimento più efficace...

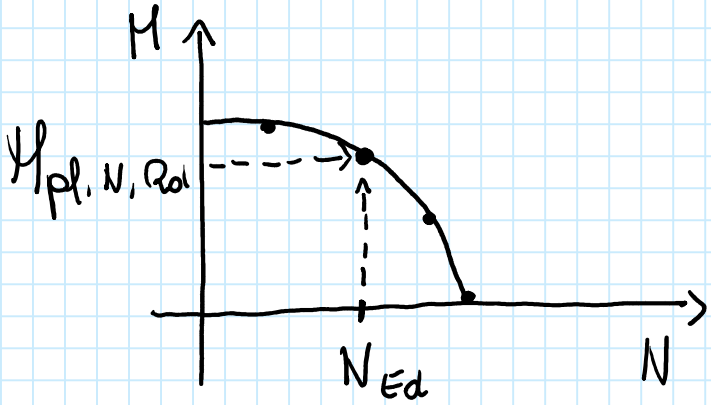
... facendo variare la posizione dell'asse neutro.



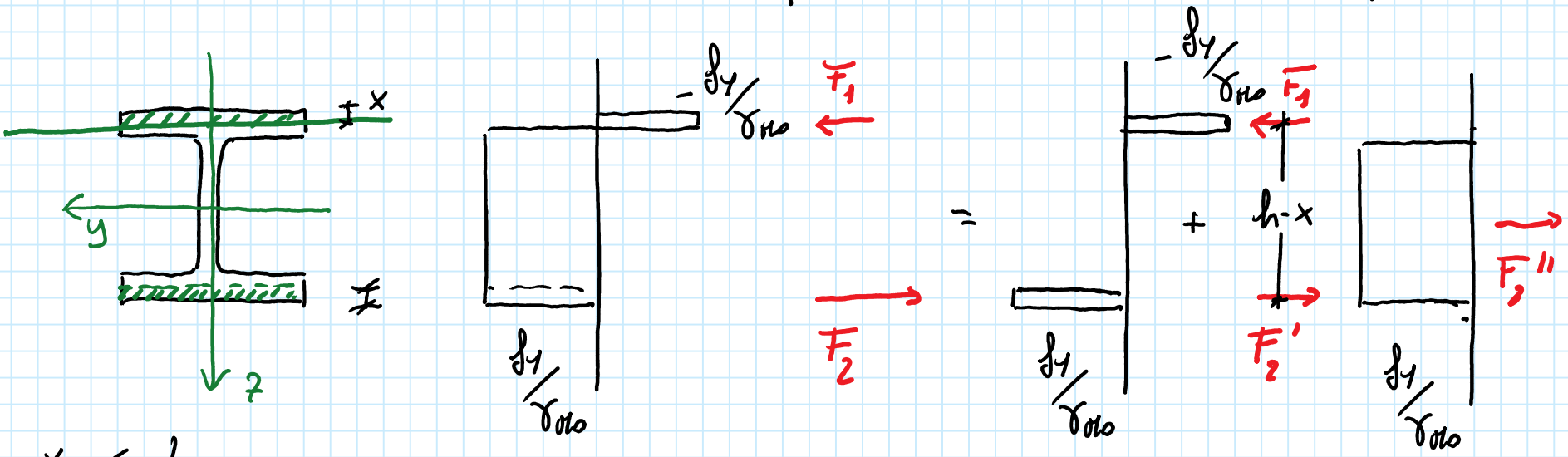
1. Fisso x

2. $N_{Ed} = \int_A \sigma \, dA$

3. $M_{pl,N,Rd} = \int_A \sigma \, z \, dA$



Caso delle sezioni a doppio T con N e M_y



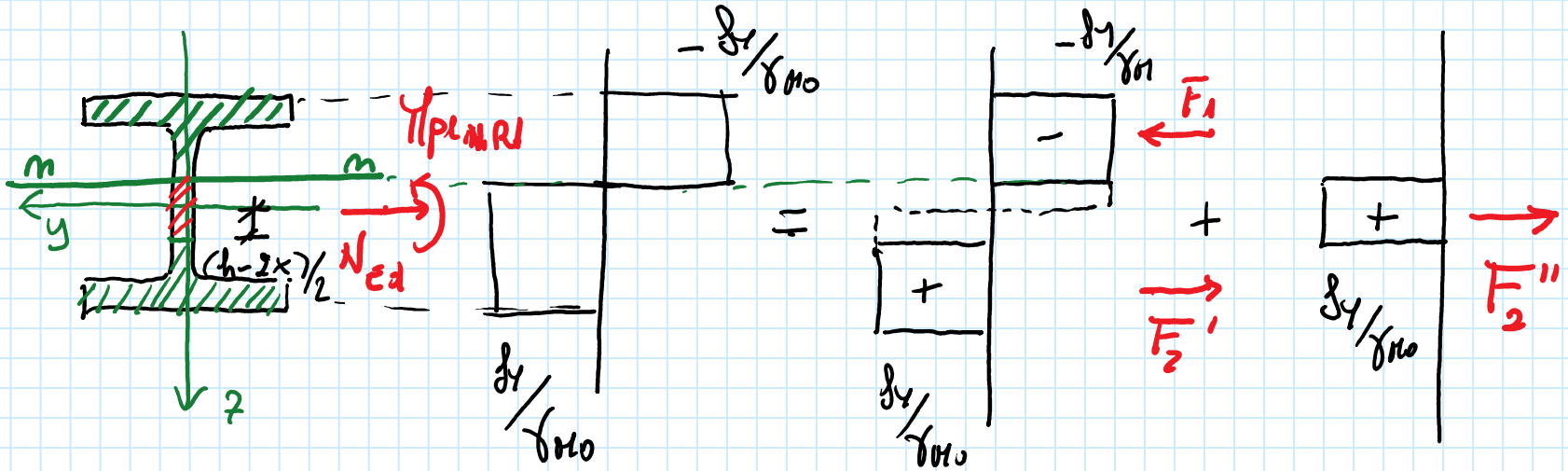
$x \leq t_f$

$$N_{Ed} = -F_1 + F_2' + F_2'' = (A - 2bx)\frac{f_y}{\gamma_{M0}}$$

$$|F_1| = |F_2'| = bx\frac{f_y}{\gamma_{M0}}$$

$$F_2'' = (A - 2bx)\frac{f_y}{\gamma_{M0}}$$

$$M_{pl,N,Rd} = F_2'(h-x) = bx(h-x)\frac{f_y}{\gamma_{M0}}$$



$$x > t_f$$

$$N_{Ed} = F_2'' = t_w (h - 2x) \frac{f_y}{\gamma_{M0}}$$

$$M_{pl,N,Rd} = W_{pl} \frac{f_y}{\gamma_{M0}} - 2 \, t_w \frac{h-2x}{2} \frac{h-2x}{4} \frac{f_y}{\gamma_{M0}}$$

$$= \left[W_{pl} - t_w \frac{(h-2x)^2}{4} \right] \frac{f_y}{\gamma_{M0}}$$

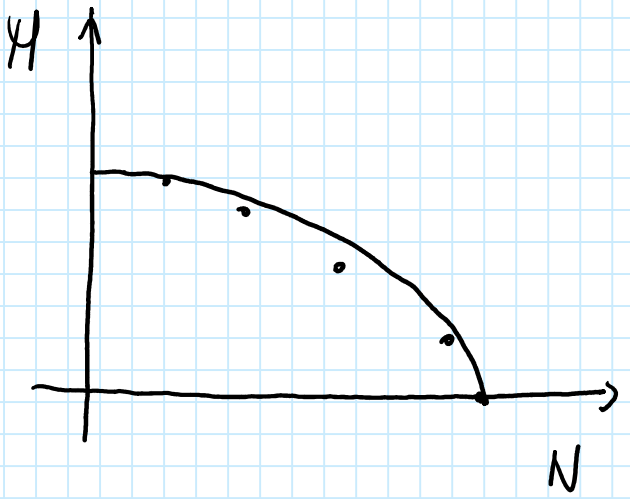
Equazioni del dominio

Per ogni valore di x ho un punto del dominio...
... posso disegnarlo con EXCEL

$x \leq t_f$

$$N_{Ed} = (A - 2bx)\, f_y / \gamma_{M0}$$

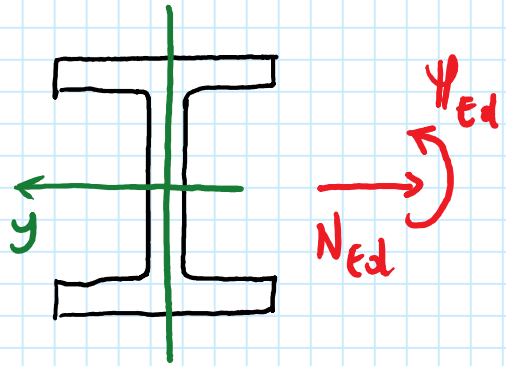
$$M_{pl,N,Rd} = b \times (h - x)\, \frac{f_y}{\gamma_{M0}}$$



$x > t_f$

$$N_{Ed} = t_w (h - 2x)\, f_y / \gamma_{M0}$$

$$M_{pl,N,Rd} = \left[W_{pl} - t_w \frac{(h-2x)^2}{4} \right] f_y / \gamma_{M0}$$



HEB 260

S 235 Classe 3

$N_{Ed} = 500\ kN$

$M_{Ed} = 50\ kN\,m$

1. $N_{Ed} = 0$

$$M_{el,N,Rd} = M_{el,Rd}\left(1 - \frac{N_{Ed}}{N_{pl,Rd}}\right) = M_{pl,Rd}$$

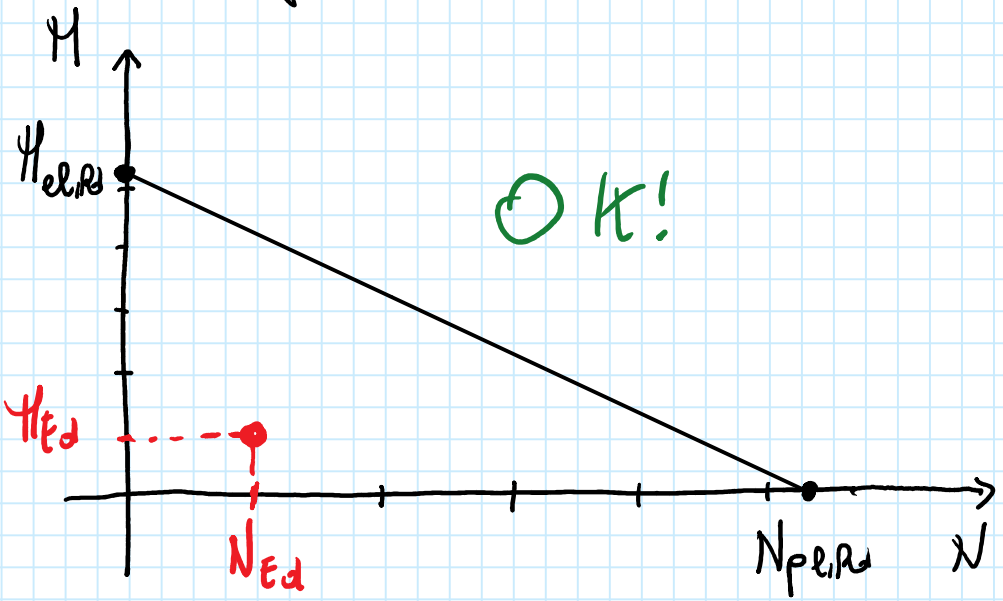
$$M_{el,Rd} = W_{el}\frac{f_y}{\gamma_{M0}} = 1148 \times \frac{235}{1.05} \times \frac{1}{10^3} = 256,8\ kN\,m$$

2. $N_{Ed} = N_{pl,Rd}$

$$N_{pl,Rd} = A\frac{f_y}{\gamma_{M0}} = 118,4 \times \frac{235}{1,05} \times \frac{1}{10} = 2650\ kN$$

$$M_{el,N,Rd} = 0$$

... adesso possiamo disegnare il dominio M-N e fare le verifiche attraverso il grafico.



OK!

50 KNm

500 KN

$N_{pl,Rd} = 2650,0$ KN $\qquad M_{el,Rd} = 256,8$ KNm

$$\frac{50}{256,8} + \frac{500}{2650} = 0,3833 < 1$$

OK!

Per le stesse ragioni, se di classe 1 o 2 ...

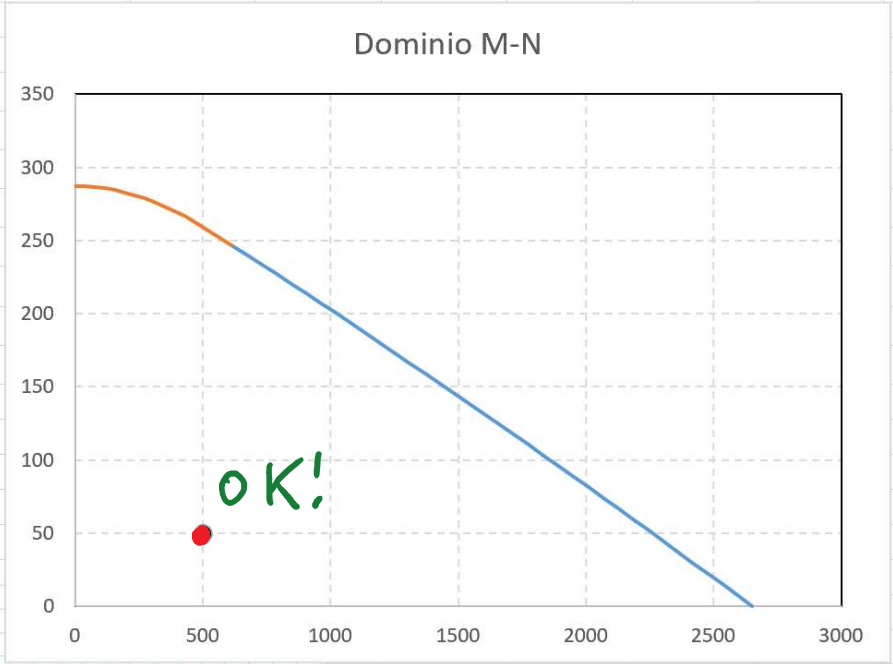
Domini My-N per sezioni a doppio di di classe 1 e 2

Inserire i dati nelle caselle con lo sfondo giallo

HEB 260

b	260	mm	f_y	235	Mpa
h	260	mm	γ_{M0}	1.05	
t_f	17.5	mm			
t_w	10	mm			
A	118.4	cm^2	**Sollecitazioni di progetto**		
W_{pl}	1282.91	cm^3			
			N_{Ed}	500.0	kN
			M_{Ed}	50.0	kNm

X (mm)	Ned (kN)	Mpl,N,Rd
0.0	2649.9	0.00
0.50	2591.7	7.55
1.00	2533.5	15.07
1.50	2475.3	22.56
2.00	2417.1	30.03
2.50	2359.0	37.46
3.00	2300.8	44.86
3.50	2242.6	52.24
4.00	2184.4	59.59
4.50	2126.2	66.90
5.00	2068.0	74.19
5.50	2009.8	81.45
6.00	1951.6	88.68
6.50	1893.4	95.88
7.00	1835.2	103.06
7.50	1777.0	110.20
8.00	1718.9	117.31
8.50	1660.7	124.40



$x \leq t_f$

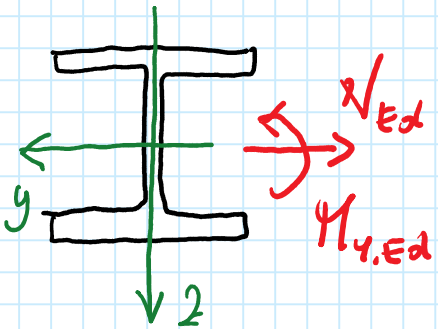
$$\begin{cases} N_{Ed} = (A - 2bx)\dfrac{f_y}{\gamma_{M0}} \\ M_{pl,N,Rd} = bx(h-x)\dfrac{f_y}{\gamma_{M0}} \end{cases}$$

Domini per sezioni di classe 1 e 2 delle NTC18 (in forme analitiche)

Sezione a doppio T con N e M_y

$$M_{pl,N,Rd} = M_{pl,Rd} \qquad n \leq 0,5\,a$$

$$M_{pl,N,Rd} = M_{pl,Rd}\,\frac{1-n}{1-0,5\,a} \qquad n > 0,5\,a$$



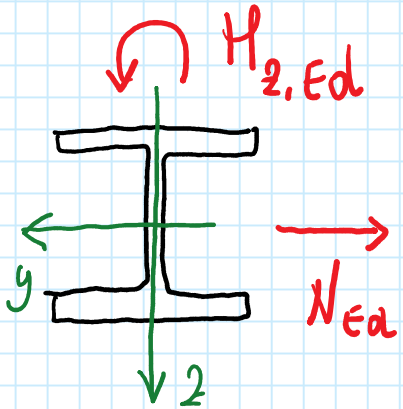
$$n = \frac{N_{Ed}}{N_{pl,Rd}}$$

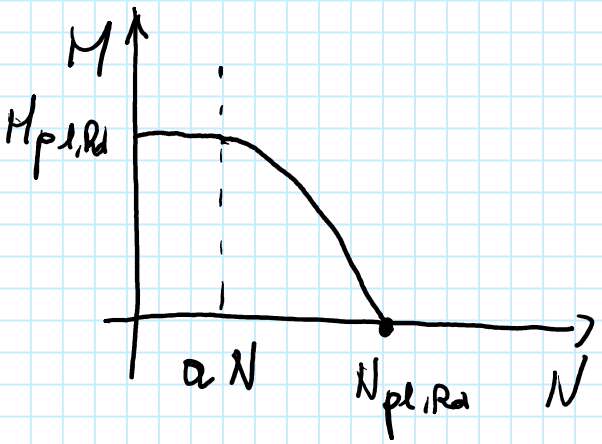
$$a = \frac{A - 2bt_f}{A}$$

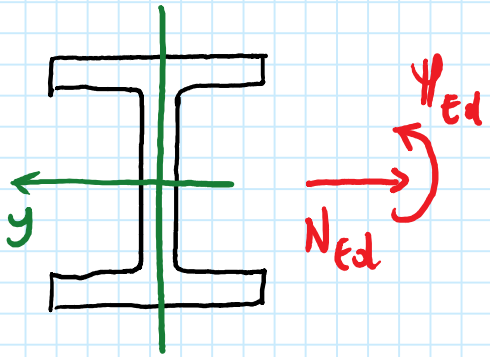
Sezioni a doppio T con N e M_z

$$M_{pl,N,Rd} = M_{pl,Rd} \qquad n \leq a$$

$$M_{pl,N,Rd} = M_{pl,Rd}\left[1 - \left(\frac{n-a}{1-a}\right)^2\right]$$







HEB 260 Classe 1 o 2

S 235

$N_{Ed} = 500$ KN

$M_{Ed} = 50$ KN m

$$N_{pl,Rd} = A \frac{f_y}{\gamma_{M0}} = 118.4 \times \frac{235}{1,05} \times \frac{1}{10} = 2650,0 \text{ KN}$$

$$n = \frac{N_{Ed}}{N_{pl,Rd}} = \frac{500}{2650} = 0,1886 \qquad n > 0,5\,a$$

$$a = \frac{A - 2bt_f}{A} = \frac{118.4 - 2 \times 260 \times 17,5/100}{118.4} = 0,1286$$

$$M_{pl,N,Rd} = M_{pl,Rd} \frac{1-n}{1-0,5a} = 287,1 \times \frac{1-0,1886}{1-0,5 \times 0,1286} = 263,0 \text{ KN m}$$

$$M_{pl,Rd} = W_{pl} \frac{f_y}{\gamma_{M0}} = 1283 \times \frac{235}{1,05} \times \frac{1}{10^3} = 287,1 \text{ KN m}$$

$$M_{Ed} = 50 \text{ kN m} \leq M_{pl,N,Rd} = 263,0 \text{ kN m}$$

OK!