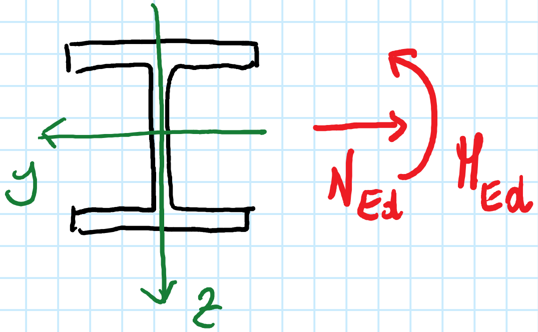
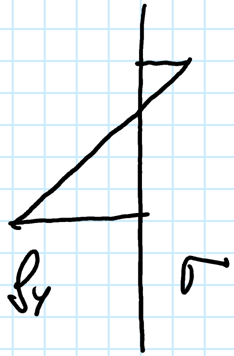
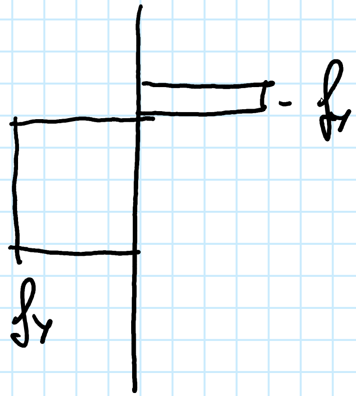
Tenso-flessione (presso-flessione della sezione)







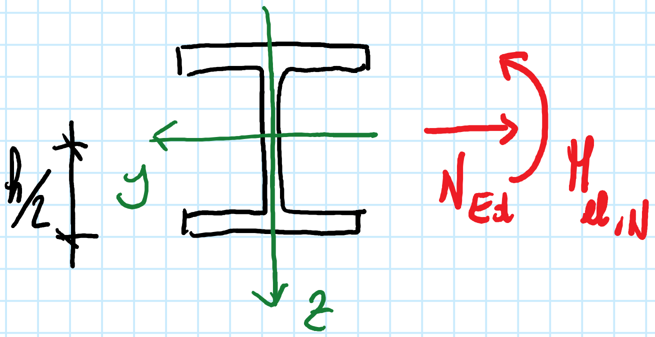
$M_{Ed} \leq M_{N,Rd}$ $\qquad$ $M_{el,N}$ $\qquad$ $M_{pl,N}$

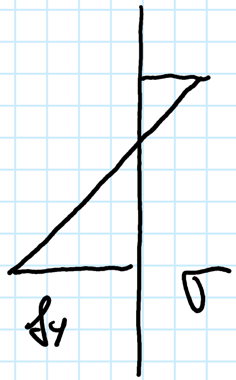
Quale resistenza uso per la verifica?

Classe 1 e 2 $\qquad$ uso $M_{pl,N}$

Classe 3 $\qquad$ uso $M_{el,N}$

Classe 3





Lo SLU si raggiunge alla prima plasticizzazione

$$f_y = \frac{N_{Ed}}{A} + \frac{M_{el,N}}{I}\left(\frac{h}{2}\right)$$

$$\frac{M_{el,N}}{I}\left(\frac{h}{2}\right) = f_y - \frac{N_{Ed}}{A}$$

$$M_{el,N} = \frac{I}{h/2}\left(f_y - \frac{N_{Ed}}{A}\right)$$

$$M_{el,N} = \frac{I}{h/2} f_y \left(1 - \frac{N_{Ed}}{A f_y}\right) = \overbrace{W_{el} f_y}^{M_{el}} \left(1 - \frac{N_{Ed}}{\underbrace{A f_y}_{N_{pl}}}\right)$$

Riassumendo...

Classe 3

1. $N_{Ed} \leq N_{pl,Rd}$

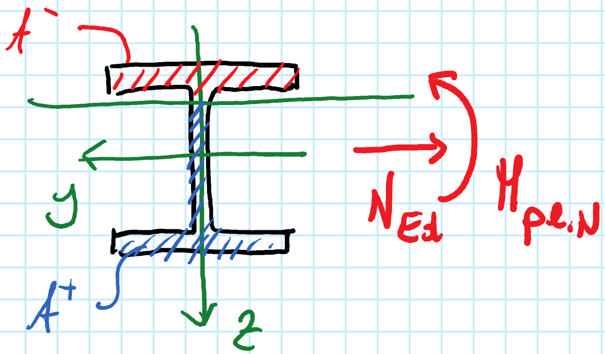
$$N_{pl,Rd} = A \, f_y / \gamma_{M0}$$

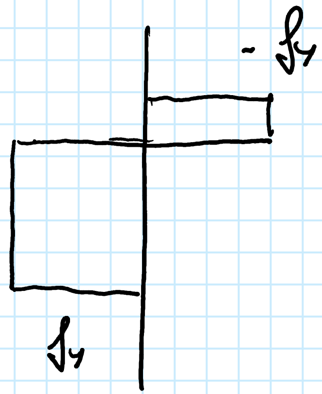
2. $M_{el,N,Rd} = M_{el,Rd}\left(1 - \frac{N_{Ed}}{N_{pl,Rd}}\right)$

$$M_{el,Rd} = W_{el} \, f_y / \gamma_{M0}$$

3. $M_{Ed} \leq M_{Rd} = M_{el,N,Rd}$

Classe 1 e 2





Lo SLU si raggiunge con la completa plasticizzazione della sezione.

$$M_{pl,N} = \int_A \sigma z \, dA = \int_{A^+} \sigma z \, dA + \int_{A^-} \sigma z \, dA = f_y \int_{A^+} z \, dA - f_y \int_{A^-} z \, dA$$

$$= f_y S^+ - f_y S^-$$

$$S^+ + S^- = S = 0 \quad \Rightarrow \quad S^- = -S^+$$

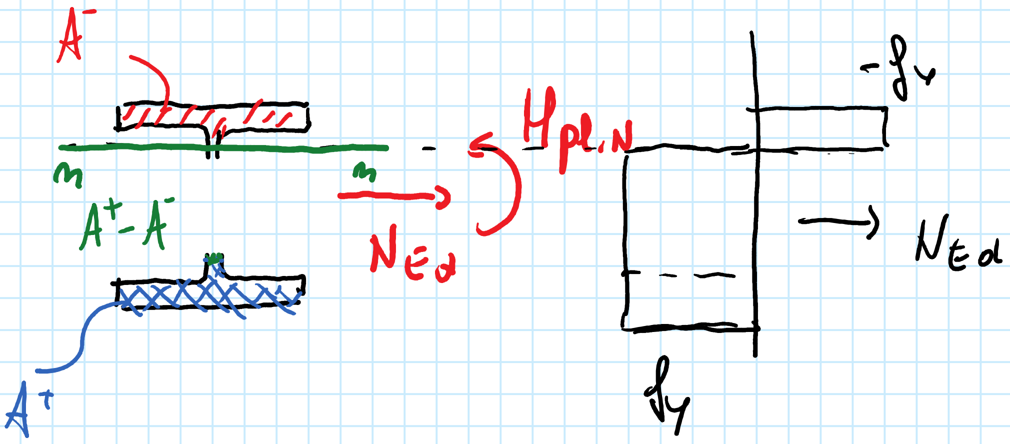
$$M_{pl,N} = 2 S^+ f_y = -2 S^- f_y$$

Ma devo prima determinare le parti tese e compresse della sezione

$$\underbrace{\int_A \sigma \, dA}_{N_{Ed}} = \int_{A^+} \sigma \, dA + \int_{A^-} \sigma \, dA = f_y \int_{A^+} dA - f_y \int_{A^-} dA = (A^+ - A^-) f_y$$

$$(A^+ - A^-) = \frac{N_{Ed}}{f_y}$$

$$A^+ + A^- = A$$



Classe 1 e 2

$$N_{Ed} = \int_A \sigma \, dA = (A^+ - A^-) f_y$$

La parte centrale della sezione porta lo sforzo normale

Solo la parte rimanente può portare il momento flettente.

1. $N_{Ed} \leq N_{pl,Rd}$ Classe 1 e 2

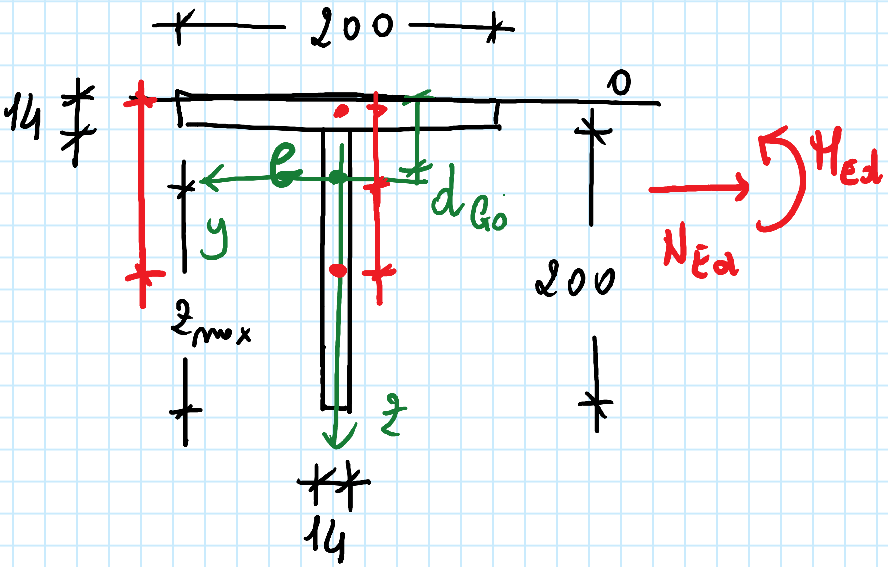
$N_{pl,Rd} = A\, f_y / \gamma_{M0}$

2. $A^+ - A^- = \dfrac{N_{Ed}}{\gamma_{M0}} \longrightarrow A^+, A^-$

$A^+ + A^- = A$

3. $M_{pl,N,Rd} = 2S^+ f_y / \gamma_{M0} = -2S^- f_y / \gamma_{M0}$

4. $M_{Ed} \leq M_{N,Rd} \quad M_{pl,N,Rd}$



S235

$N_{Ed} = 1000 \ kN$

$M_{Ed} = 50 \ kNm$

Classe 3

1. $N_{Ed} \leq N_{pl,Rd}$

$$N_{pl,Rd} = A \frac{f_y}{\gamma_{M0}}$$

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

$$M_{el,Rd} = W_{el} \frac{f_y}{\gamma_{M0}}$$

3. $M_{Ed} \leq M_{el,N,Rd}$

1. $N_{Ed} \leq N_{pl,Rd}$

$$N_{pl,Rd} = A \frac{f_y}{\gamma_{M0}}$$

$$A = 14 \times 200 \times 2 = 5600 \text{ mm}^2$$

$$N_{pl,Rd} = 5600 \times \frac{235}{1{,}05} \times \frac{1}{10^3} = 1253{,}3 \text{ KN}$$

$$N_{Ed} = 1000 \text{ KN} < N_{pl,Rd} = 1253{,}3 \text{ KN}$$ OK!

2. $$S_0 = 200 \times 14 \times \frac{14}{2} + 14 \times 200 \times \left(14 + \frac{200}{2}\right) = 338800 \text{ mm}^3$$

$$d_{G_0} = \frac{S_0}{A} = \frac{338800}{5600} = 60{,}5 \text{ mm}$$

2. Calcolo $M_{el,N,Rd}$

$$I = 200 \times \frac{14^3}{12} + 200 \times 14 \times \left(60{,}5 - \frac{14}{2}\right)^2 +$$

$$+ 14 \times \frac{200^3}{12} + 14 \times 200 \times (100 - 60{,}5 + 14)^2 =$$

$$= 25407667 \text{ mm}^4$$

$$z_{max} = 200 + 14 - 60{,}5 = 153{,}5 \text{ mm}$$

$$W_{el} = \frac{25407667}{153{,}5} = 165522 \text{ mm}^3 = 165{,}5 \text{ cm}^3$$

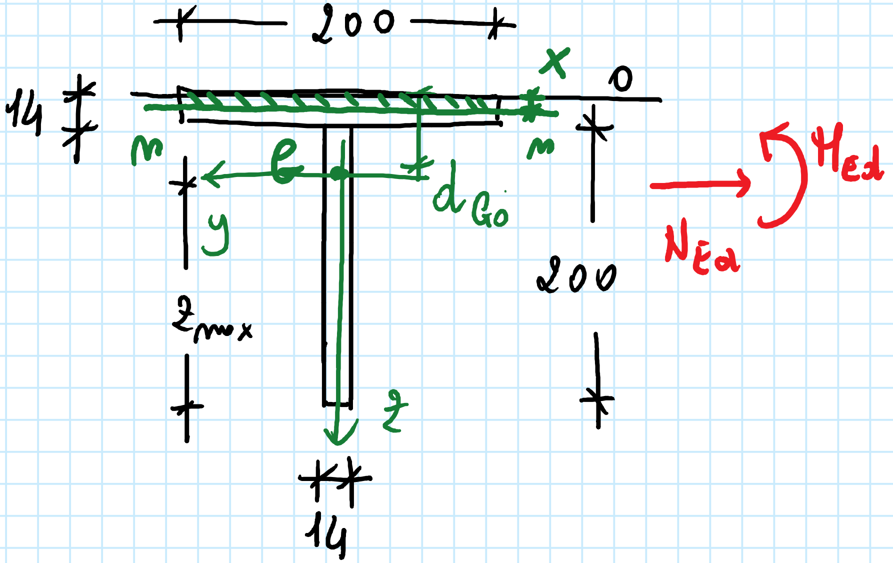
$$M_{el,Rd} = 165{,}5 \times \frac{235}{1{,}05} \times \frac{1}{10^3} = 37{,}0 \text{ KNm}$$

$$M_{el,N,Rd} = 37,0 \times \left(1 - \frac{1000}{1253,3}\right) = 7,5 \text{ KNm}$$

3. Verifica

$$M_{Ed} = 50 \text{ KNm} < M_{Rd,N} = M_{el,N,Rd} = 7,5 \text{ KNm}$$

NO



S235

$N_{Ed} = 1000$ kN

$M_{Ed} = 50$ kNm

Classe 1 o 2

1. $N_{Ed} \leq N_{pl,Rd}$

$$N_{pl,Rd} = A \, f_y / \gamma_{M0}$$

2. $$A^+ - A^- = \frac{N_{Ed}}{\gamma_{M0}} \longrightarrow A^+, A^-$$
$$A^+ + A^- = A$$

3. $$M_{pl,N,Rd} = 2 S^+ \frac{f_y}{\gamma_{M0}} = -2 S^- \frac{f_y}{\gamma_{M0}}$$

4. $$M_{Ed} \leq M_{Rd,N} = M_{pl,N,Rd}$$

1. $N_{Ed} \leq N_{pl,Rd}$

$N_E = 1000\ KN < N_{pl,Rd} = 1253,3\ KN$

2. Determinare A^+ e A^-

$$A^+ - A^- = \frac{1000}{235} \times 1,05 \times 10^3 = 4468\ mm^2$$

$$A^+ - A^- = 4468\ mm^2$$

$$\underline{A^+ + A^- = 5600\ mm^2}$$

$$2A^+ = 4468 + 5600 = 10068\ mm^2$$

$$A^+ = 10068/2 = 5034\ mm^2$$

$$A^- = A - A^+ = 5600 - 5034 = 566\ cm^2$$

$$200x = 566 \text{ mm}^2$$

$$x = \frac{566}{200} = 2.83 \text{ mm}$$

3. Calcolo $M_{pl,N,Rd}$

$$S^- = -200 \times 2{,}83 \times \left(d_{G_0} - \frac{x}{2}\right) = -200 \times 2{,}83 \times \left(60{,}5 - \frac{2{,}83}{2}\right) =$$

$$= -33442 \text{ mm}^3 = -33{,}4 \text{ cm}^3$$

$$M_{pl,N,Rd} = -2S^- \frac{f_y}{\gamma_{M_0}} = +2 \times 33{,}4 \times \frac{235}{1{,}05} \times \frac{1}{10^3} = 14{,}9 \text{ KNm}$$

4. Verifica

$$M_{Ed} = 50 \text{ KNm} < M_{Rd,N} = M_{pl,N,Rd} = 14{,}9 \text{ KNm}$$ NO