Verifica allo stato limite di tensioni in esercizio II stadio

$\sigma_c \leq 0{,}6\, f_{ck}$ $\qquad$ $\sigma_c \leq 0{,}45\, f_{ck}$

$\sigma_s \leq 0{,}8\, f_{yk}$

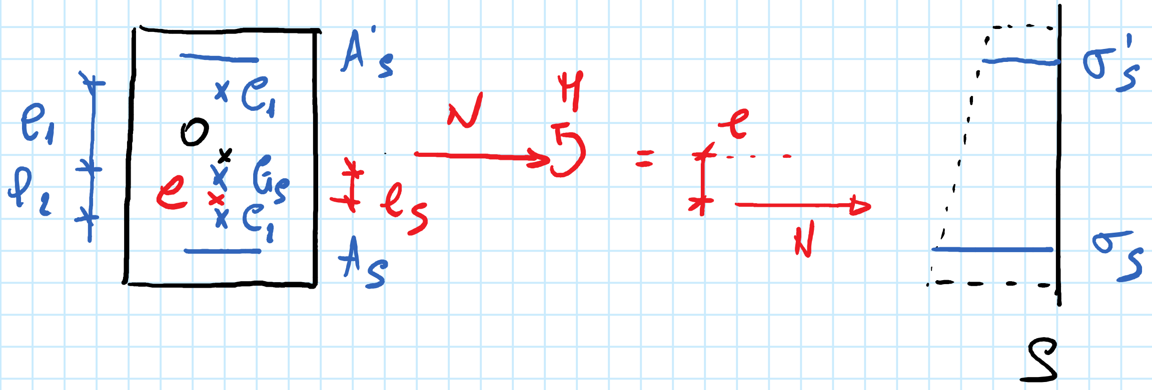
comb. rara $\qquad$ comb. quasi perm.

interno nocciolo → piccola eccentricità → 1 C $\quad$ 1 T

compressione $\quad$ trazione

esterno al nocciolo → grande eccentricità

Sforzo normale di trazione con piccole eccentricità



$$e = \frac{M}{N}$$

1. e_1, e_2 noccciolo delle armature di acciaio

$$e_1 = \frac{I}{A\, d_{G,inf}} \qquad e_2 = \frac{I}{A\, d_{G,sup}}$$

2. $-e_1 \leq e_s \leq e_2 \qquad e_s = e - \left(d_{G,sup} - \frac{h}{2}\right)$

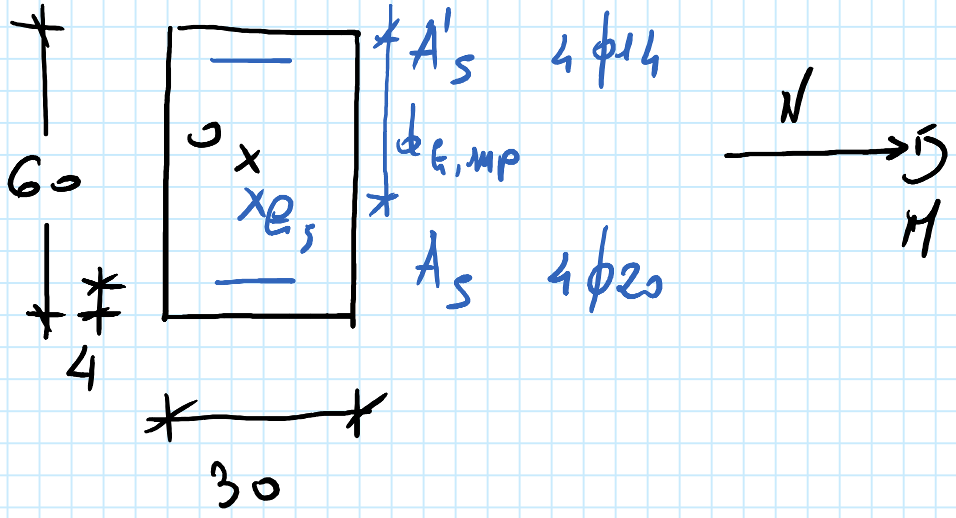
e_s = eccentricità riferita al baricentro delle armature

3. Verifica della tensione dell'armatura

$$\sigma_s = \frac{N}{A} + \frac{N e_s}{I} y \leq 0{,}8\, f_{yk} \qquad \text{comb. rara}$$

A ed I delle armature di acciaio

I si calcola rispetto a G_s



B450C

$N = 1000$ kN

$M : 50$ kNm

1. Determino G_s ed il nocciolo centrale d'inerzia

$S_0 : A'_s c + A_s d = 6{,}16 \times 4 + 12{,}56 \times 56 = 728{,}0 \text{ cm}^3$

$A : A'_s + A_s = 6{,}16 + 12{,}56 = 18{,}72 \text{ cm}^2$

$d_{G,sup} : \dfrac{S_0}{A} = \dfrac{728}{18{,}72} = 38{,}9$ cm

$d_{G,inf} : h - d_{G,sup} : 60 - 38{,}9 = 21{,}1$ cm

$$e_1 = \frac{I}{A\, d_{G,inf}} = \frac{11175,6}{18,72 \times 21,1} = 28,3 \text{ cm}$$

$$I = A'_s \left(d_{G,sup} - e \right)^2 + A_s \left(d_{G,inf} - e \right)^2$$

$$= 6,16 \times \left(38,9 - 4 \right)^2 + 12,56 \times \left(21,1 - 4 \right)^2 = 11175,6 \text{ cm}^4$$

$$e_2 = \frac{I}{A\, d_{G,sup}} = \frac{11175,6}{18,72 \times 38,9} = 15,4 \text{ cm}$$

2. Controllo piccola eccentricità

$$e_s = \frac{M}{N} - \left(d_{G,inf} - \frac{h}{2}\right) = \frac{50}{1000} \times 100 - (38,9 - 30) = -3,90 \text{ cm}$$

$$-28,3 = -e_1 < e_s = -3,90 \text{ cm} < e_2 \; 15,4 \text{ cm} \qquad \text{OK!}$$

3. Verifica delle tensioni

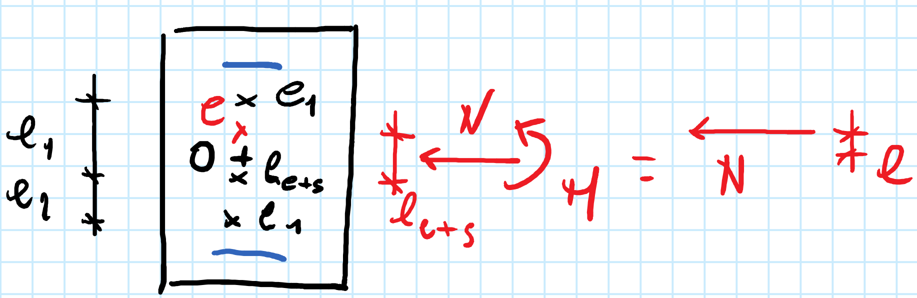
$$\sigma_s = \frac{N}{A} - \frac{N e_s}{I}\left(d_{G,inf} - c\right)$$

$$= \frac{1000}{18,72} \times 10 - \frac{1000 \times (-3,9)}{11175,6} \times (38,9 - 4) \times 10$$

$$534,2 \qquad 121,78$$

$$= 656,0 \text{ MPa} > 0,8 f_{yk} = 360 \text{ MPa} \qquad \text{NO}$$

Sforzo normale di compressione con piccole eccentricità



$$e = \frac{M}{N}$$

1. Nocciolo della sezione omogeneizzata $(n = 15)$

$$e_1 = \frac{I}{A\, d_{G,inf}} \qquad e_2 = \frac{I}{A\, d_{G,sup}}$$

2. $$e_{c+s} = \frac{M}{N} - \left(d_{G,sup} - \frac{h}{2}\right)$$

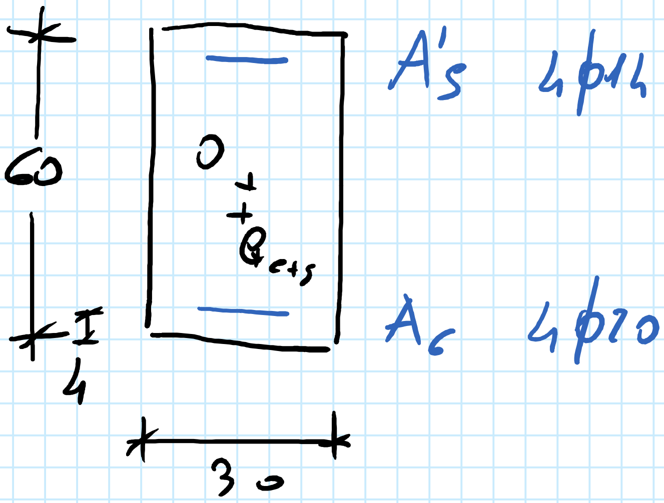
$$-e_1 \leq e_{c+s} \leq e_2$$

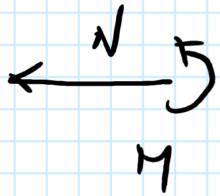
3. Verifica della tensione del calcestruzzo

$$\sigma_c = \frac{N}{A} + \frac{N\, e_{ets}}{I}\, y \leq \begin{cases} 0{,}6 f_{ck} & \text{comb. rare} \\ 0{,}45 f_{ck} & \text{comb. quasi permanente} \end{cases}$$

A ed I della sezione omogeneizzata

I si calcola rispetto a G_{ets}





C30/37

$N = -1000$ kN

$M = 50$ kN m

1. Determina G_{c+s} ed il nocciolo

$$S_o = \frac{bh^2}{2} + n A'_s e + n A_s d = \frac{30 \times 60^2}{2} + 15 \left(6{,}16 \times 4 + 12{,}56 \times 56\right)$$

$$= 64\,731{,}6 \text{ cm}^3$$

$$A = bh + n(A'_s + A_s) = 30 \times 60 + 15 \times (6{,}16 + 12{,}56) = 2080{,}8 \text{ cm}^2$$

$$d_{G,sup} = \frac{S_o}{A} = \frac{64731{,}6}{2080{,}8} = 31{,}1 \text{ cm} \qquad d_{G,inf} = 28{,}9 \text{ cm}$$

$$e_1 = \frac{I}{A\, d_{G,inf}} = \frac{726\,847,4}{2080,8 \times 28,9} = 12,09 \text{ cm}$$

$$I = \frac{b\, d_{G,inf}^3}{3} + \frac{b\, d_{G,sup}^3}{3} + n A'_s \left(d_{G,sup} - c\right)^2 + n A_s \left(d_{G,inf} - c\right)^2$$

$$= 30 \times \frac{28,9^3}{3} + 30 \times \frac{31,1^3}{3} + 15 \times 6,16 \times \left(31,1 - 4\right)^2 + 15 \times 12,56 \times \left(28,9 - 4\right)^2$$

$$= 726\,847,4 \text{ cm}^4$$

$$e_2 = \frac{I}{A\, d_{G,sup}} = \frac{726\,847,4}{2080,8 \times 31,1} = 11,2 \text{ cm}$$

2. Controllo piccola eccentricità

$$e_{c+s} = \frac{M}{N} - \left(d_{G,inp} - \frac{h}{2}\right) = \frac{50}{-1000} \times 100 - (31.1 - 30)$$

$$= -6,1 \text{ cm}$$

$-11,09 = -e_1 < e_{c+s} = -6,1 \text{ cm} < e_1 = 11,23 \text{ cm}$ OK!

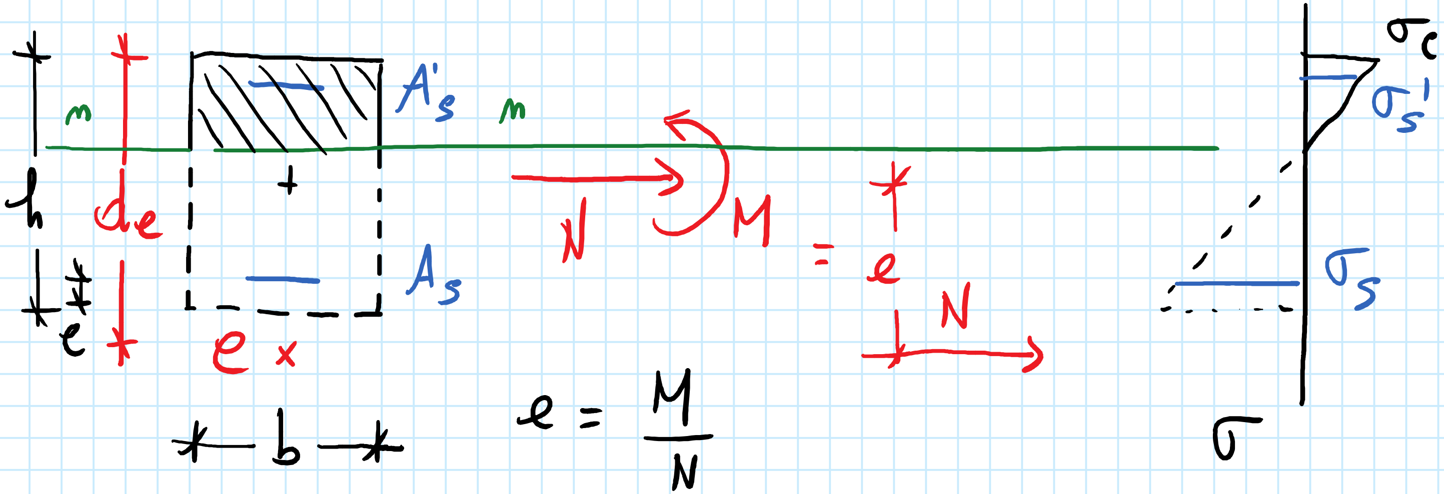
3. Verifica delle tensioni del calcestruzzo

$$\sigma_c = \frac{N}{A} - \frac{N e_{c+s}}{I} d_{G,inp} = \overbrace{\frac{-1000}{2080,8} \times 10}^{-4,8 \text{ MPa}} - \overbrace{\frac{(-1000)(-6,1)}{726847,4} \times 31,1 \times 10}^{-2,61 \text{ MPa}}$$

$$= -7,41 \text{ MPa}$$

$|\sigma_c| = 7,41 \text{ MPa} < 0,6 f_{ck} = 18 \text{ MPa}$ OK!

Sforzo normale con grande eccentricità



$$e = \frac{M}{N}$$

1. Determino asse neutro e sezione reagente omogeneizzata
($n = 15$)

$$e_n = \frac{I_n}{S_n} \Rightarrow d_n S_n = I_n$$

$$d_n = e + \frac{h}{2} - x = d_e - x$$

$$S_n = -\frac{b x^2}{2} - n A'_s (x - e) + n A_s (d - x)$$

$$I_n = b\frac{x^3}{3} + n A'_s (x-c)^2 + n A_s (d-x)^2$$

$$(d_c - x)\left[- \frac{b x^2}{2} - n A'_s (x-c) + n A_s (d-x)\right] = I_n$$

$$(d_c - x)\left(- \frac{b x^2}{2} - n A'_s x + n A'_s c + n A_s d - n A_s x\right) = I_n$$

$$- d_c b \frac{x^2}{2} - n d_c A'_s x + n d_c A'_s e + n d_c A_s d - n d_c A_s x + b\frac{x^3}{2} +$$

$$+ n A'_s x^2 - n A'_s e x - n A_s d x + n A_s x^2 = b\frac{x^3}{3} + n A'_s x^2 + n A'_s c^2 +$$

$$- 2 n A' e x + n A_s d^2 + n A_s x^2 - 2 n A_s d x$$

$$- d_e b \frac{x^2}{2} - m d_e A'_s x + m d_e A'_s e + m d_e A_s d - m d_e A_s x + b \frac{x^3}{2} +$$

$$+ m \cancel{A'_s x^2} - m A'_s e x - m A_s d x + m \cancel{A_s x^2} = b \frac{x^3}{3} + m A'_s \cancel{x^2} + m A'_s e^2 +$$

$$- 2 m A' e x + m A_s d^2 + m \cancel{A_s x^2} - 2 m A_s d x$$

$$b \frac{x^3}{6} - d_e b \frac{x^2}{2} + m \left[A'_s (e - d_e) + A_s (d - d_e) \right] x +$$

$$- m \left[A'_s e (e - d_e) + A_s d (d - d_e) \right] = 0$$

$$\boxed{x^3 - 3 d_e x^2 + \frac{6m}{b} \left[A'_s (e - d_e) + A_s (d - d_e) \right] x - \frac{6m}{b} \left[A'_s e (e - d_e) + A_s d (d - d_e) \right] = 0}$$

2. Calcolo S_n sostituendo la x trovata

$$S_n := b\frac{x^2}{2} - nA'_s(x-e) + nA_s(d-x)$$

3. Verifico le tensioni di calcestruzzo e acciaio

$$\sigma_c := \frac{N}{S_n}x \leq \begin{cases} 0{,}6\, f_{ck} & \text{comb. rara} \\ 0{,}45\, f_{ck} & \text{comb. quasi permanente} \end{cases}$$

$$\sigma_s = n\frac{N}{S_n}(d-x) \leq 0{,}8\, f_{yk} \quad \text{comb. rara}$$