ESEMPIO $N>0$; $M>0$ PICCOLA ECCENTRICITÀ

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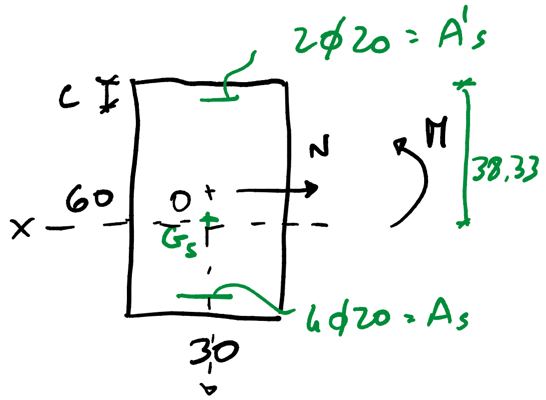


II STADIO, $n = 15$

$N = 360$ KN $\qquad A'_s = 6{,}28\ cm^2$

$M = 54$ KNm $\qquad A_s = 12{,}56\ cm^2$

$c = 5$ cm $\qquad d = 55$ cm

1. DETERMINARE G_s

$$d_{G_S,sup} = \frac{S_{sup}}{A_{s,tot}} = \frac{6{,}28\,cm^2 \times 5\,cm + 12{,}56\,cm^2 \times 55\,cm}{(6{,}28 + 12{,}56)\,cm^2} =$$

$$= 38{,}33\,cm$$

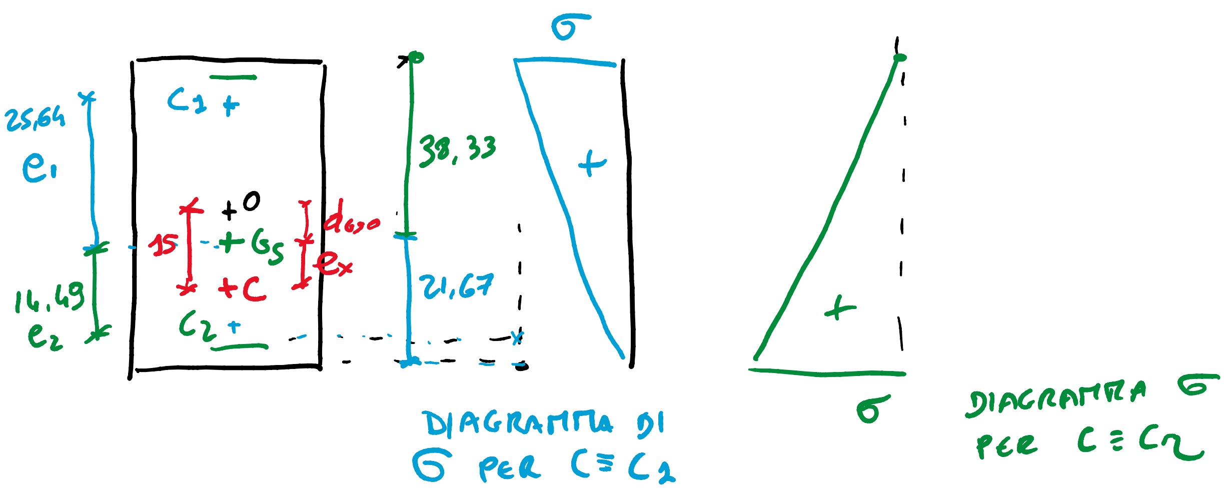
$$d_{G_S,inf} = H - 38{,}33 = 60 - 38{,}33 = 21{,}67\ cm$$

2 DETERMINO

$$I_{s,G_S} = 12{,}56\,cm^2 \times (d_{G_S,inf} - c)^2 + 6{,}28\,cm^2 \times (d_{G_S,sup} - c)^2$$

$$\rightarrow I_{s,G_S} = 12{,}56 \times (21{,}67 - 5)^2 + 6{,}28 \times (38{,}33 - 5)^2 =$$

$$= 10466{,}7\ cm^4$$



$$e_1 = \frac{I_s}{A_{s,tot} \cdot d_{GS\,INF}} \rightarrow e_1 = \frac{10466{,}7\ cm^4}{(12{,}56 + 6{,}28) \times 21{,}67} = 25{,}64\,cm$$

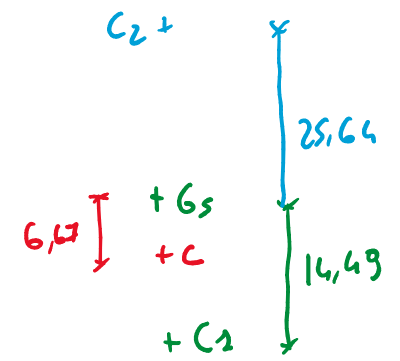
$$e_2 = \frac{I_s}{A_{s,tot} \times d_{GS,SUP}} \rightarrow e_2 = \frac{10466{,}7\ cm^4}{(12{,}56+6{,}28)\,cm^2 \times 38{,}33\,cm} = 14{,}49$$

PER CAPIRE SE SEZ. PARZIALIZZATA, VALUTO C

$$e_0 = \frac{M}{N} = \frac{54\,KNm}{360\,KN} \times 100 = 15\,cm$$

$$e_x = e_0 - d_{Gs,0} = 15\,cm - 8{,}33\,cm = 6{,}67\,cm$$

$$d_{G0} = d_{G\,sup} - h/2$$

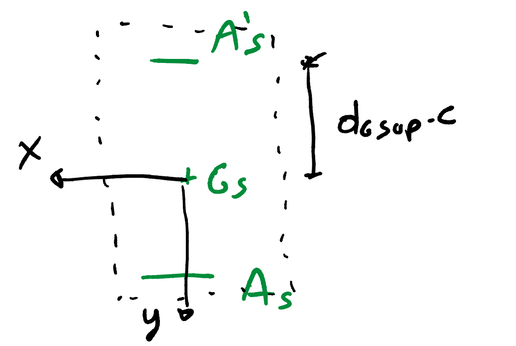


$$-e_2 \le e_x \le e_2 \Rightarrow$$

SEZ. A PICCOLA ECCENTRICITÀ

→ SEZ. INTERAMENTE TESA

$$\sigma_s = \frac{N}{A_{s,tot}} + \frac{N \cdot e_x}{I_{x,Gs}} \cdot y$$



ARMATURE INFERIORI

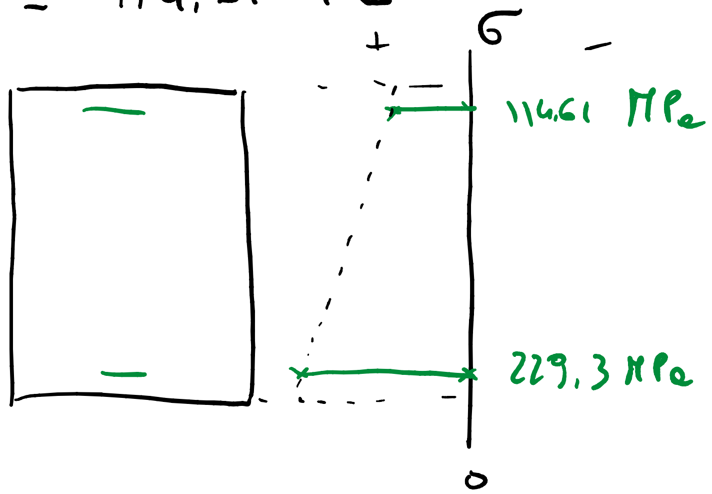
$$\sigma_s = \frac{360\,KN}{(12{,}56+6{,}28)\,cm^2} \times 10 + \frac{360\,KN \cdot 6{,}67\,\cancel{cm}}{10466{,}7\,cm^{\cancel{4}\,2}} \left(\underbrace{d_{GS,INF} - c}_{21{,}67-5}\right)\cancel{cm} \times 10$$

$$= 229{,}3\ MPa$$

ARMATURE SUPERIORI

$$\sigma'_s = \frac{360}{(12{,}56 + 6{,}28)} \times 10 - \frac{360 \times 6{,}67}{10466{,}7}\left(\underset{38{,}33-5}{d_{G\,sup}} - c\right) \times 10$$

$$= 114{,}61 \text{ MPa}$$



II STADIO   N < 0

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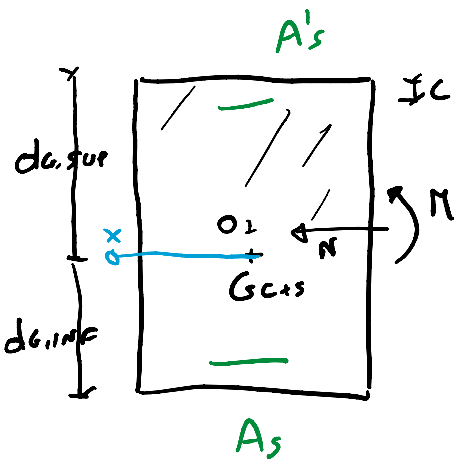
DEVO CAPIRE SE LA SEZIONE È
- INTERAMENTE COMPR.
- PARZ.



1. CALCOLO G_{c+s}

$$d_{G,sup} = \frac{S_{sup}}{A_{ci}} = \frac{bh^2/2 + nA'_s c + nA_s \cdot d}{bh + n(A_s + A'_s)}$$

2. ESTREMI NOCCIOLO

$$e_1 = \frac{I_{G,x}}{A_{ci} \cdot d_{G,INF}} \; ; \; e_2 = \frac{I_{G,x}}{A_{ci}\, d_{G,sup}}$$

$$I_{G,x} = \frac{b d_{G,sup}^3}{3} + \frac{b d_{G,INF}^3}{3} + nA'_s (d_{G,sup} - c)^2 + nA_s (d_{G,INF} - c)^2$$

3. CALCOLARE $e_x = e_0 - d_{G0} = \frac{M}{N} - \left(d_{G,sup} - \frac{h}{2}\right)$

4. SEZIONE INTERAMENTE COMPRESSA SE

$$-e_1 \leq e_x \leq e_2 \Rightarrow$$ PICCOLA ECCENTRICITÀ

$$\sigma_c = \frac{N}{A_{ci}} + \frac{N \cdot e_x}{I_{Gx}} \cdot y$$

$$\sigma_s = \sigma_c \cdot n$$

ESEMPIO N < 0 , PICCOLA ECCENTRICITA'

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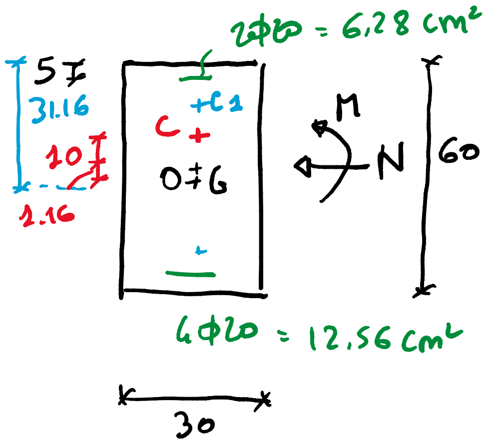


$N = -500\ kN$

$M = 50\ kNm$

$e_0 = \frac{M}{N} = \frac{50}{-500} = -0,10\ m$

II STADIO

CARICHI LUNGA DURATA ⇒ $n = 15$

A'_s: 6,28 cm²

A_s = 12,56 cm²

d = 55 cm

1. BARICENTRO

$$S_{sup} = \frac{30 \times 60^2}{2} + 15 \times 6,28 \times 5 + 15 \times 12,56 \times 55 =$$

$$= 64833\ cm^3$$

$$A_{ci} = 30 \times 60 + 15 \times (6,28 + 12,56) =$$

$$= 2082,6\ cm^2$$

$$d_{G,sup} = \frac{64833}{2082,6} \frac{cm^3}{cm^2} = 31,13\ cm$$

$$\rightarrow d_{G,INF} = 60 - 31,13\ cm = 28,87\ cm$$

2. CALCOLO ESTREMI DEL NOCCIOLO

$$e_1 = \frac{I_{xG}}{A_{ci} \cdot d_{GINF}}$$

$$I_{x,G} = \frac{30 \times 31,13^3}{3} + \frac{30 \times 28,87^3}{3} + 15 \times 6,28 \times (31,13 - 5)^2 +$$

$$+ 15 \times 12,56 \times (28,87 - 5)^2 =$$

$$= 713962\ cm^4$$

$$e_1 = \frac{713962 \ cm^4}{2082,6 \ \cancel{cm^2} \times 28,87 \ \cancel{cm}} = 11.88 \ cm$$

$$e_2 = \frac{713962}{2082,6 \times 31,13} = 11.01 \ cm$$

(NON NECESSARIO PERCHÉ $e_x < 0$)

$$e_x = -11,13 \ cm = e_0 - \underset{\substack{\downarrow \\ d_{G\,sup} - \frac{h}{2}}}{d_{G0}} = -0,10 - \left(31,13 - \frac{6}{2}\right)\frac{1}{100}$$

$$-e_1 \leq e_x < e_2$$

$$-13,87 < -11,13 < 12,87 \Rightarrow$$ SEZ. INTERAMENTE COMPRESSA

CALCOLO σ_c AL BORDO SUPERIORE $(y = -d_{G\,sup})$

$$\sigma_c^{SUP} = \frac{N}{A_{ci}} - \frac{N e_x}{I} \cdot \left(d_{G,sup}\right)$$

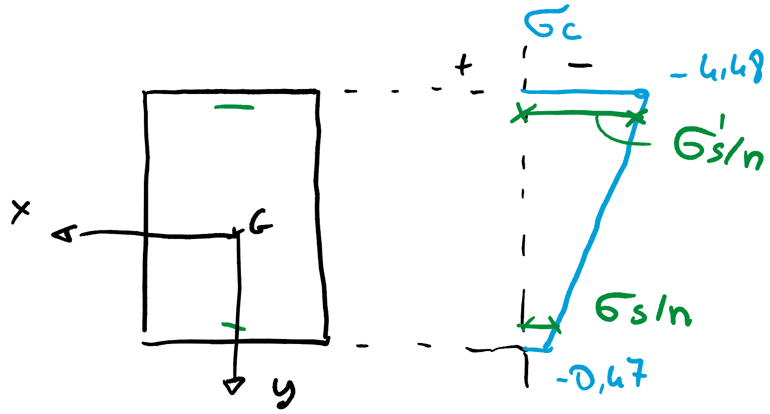
$$= \frac{-500 \ KN \times 10}{2082.6 \ cm^2} - \frac{(-500) \ KN \ (-11.13) \ \cancel{cm}}{713962 \ cm^{4\,2}} \times 31,13 \ \cancel{cm} \times 10$$

$$= -2,4 - 2,43 = -4,83 \ MPa$$

CALCOLO σ_c AL BORDO INFERIORE $(y = d_{G,INF})$

$$\sigma_c^{INF} = -2,4 + 2,25 = -0,15 \ MPa$$

$$y = d_{G,INF} = 28,87$$



TENSIONE ARMATURE SUP. $y = -(d_{G\,sup} - c)$

$$\sigma'_s = \left[\frac{N}{A} - \frac{Nex}{I} \cdot (d_{G\,sup} - c)\right] n$$

$$15 \times \left[-\frac{500}{2086} \times 10 - \frac{(-500) \times (-11.13)\ \text{kNcm}}{713962\ \text{cm}^4} \times (31{,}13 - 5)\,\text{cm} \times 10\right]$$

$$= -66{,}56\ \text{MPa}$$

PRESSO - TENSO FLESSIONE (GRANDE ECCENTRICITÀ)

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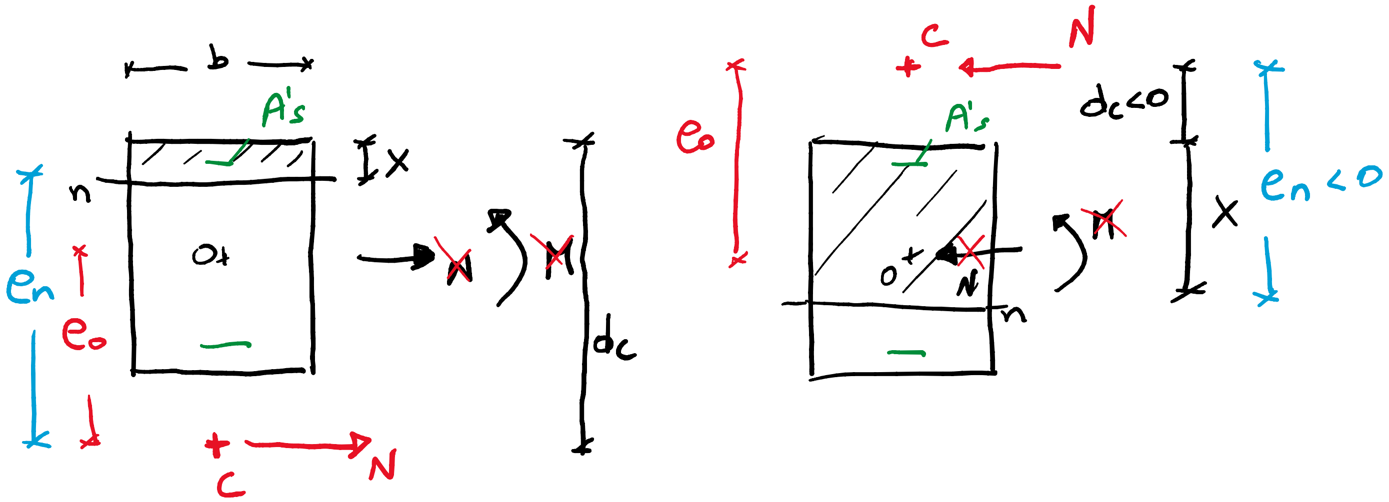


DETERMINO ASSE NEUTRO $e_n = \frac{I_n}{S_n}$

RIFERIMENTO ALLA SEZ. REAGENTE OMOGENEIZZATA

x DISTANZA ASSE NEUTRO DAL BORDO COMPRESSO

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

e_N DISTANZA DI C DALL' ASSE NEUTRO

d_c DISTANZA DI C DAL BORDO COMPRESSO

$e_n = d_c - x$ $\qquad d_c = e_o + \frac{h}{2} \Rightarrow e_n = e_o + \frac{h}{2} - x$

$$I_n = \frac{bx^3}{3} + nA'_s(x-c)^2 + nA_s(d-x)^2$$

$$S_n = -\frac{bx^2}{2} - nA'_s(x-c) + nA_s(d-x)$$

SOSTITUISCO IN $e_n = \frac{I_n}{S_n} \rightarrow e_n \cdot S_n = I_n$

$$(d_c - x)\left[-\frac{bx^2}{2} - nA'_s(x-c) + nA_s(d-x)\right] = \frac{bx^3}{3} + nA'_s(x-c)^2 + nA_s(d-x)^2$$

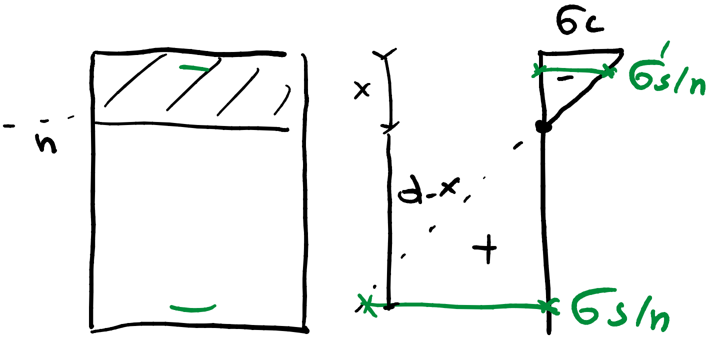
$$x^3 - 3d_c x^2 + \frac{6n}{b}\left[A_s(d-d_c) + A'_s(c-d_c)\right]x + - \frac{6n}{b}\left[A_s d(d-d_c) + A'_s c(c-d_c)\right] = 0$$

$\Rightarrow$ TROVO X

ERRORE $\Rightarrow$ $\sigma = \frac{N}{A} + \frac{M}{I}y$ $\quad A = ?$ $\quad I = ?$

$$\sigma = \frac{N}{S_n}\cdot \partial$$

∂ DISTANZA DEL PUNTO IN CUI CALCOLO σ DA ASSE NEUTRO



$$\sigma_c^{max} = -\frac{N}{S_n}x$$

$$\sigma'_s = n\left[-\frac{N}{S_n}(x-c)\right]$$

$$\sigma_s = n\left[\frac{N}{S_n}(d-x)\right]$$

ESEMPIO

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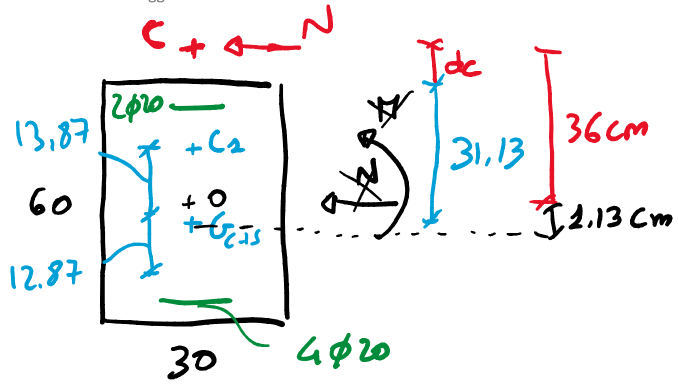


$N = -500$ KN

$M = 180$ KNm

II STADIO

CARICHI LUNGA DURATA

1. PER CAPIRE SE SEZ. < COMPRESSA INT. / PARZ. $\Rightarrow$ CALCOLARE e_1, e_2

$d_{G\,sup}$: 31,13 cm

e_1 : 13,87 cm $\qquad e_2$: 12,87 cm

$$e_0 = \frac{M}{N} = \frac{180\ \text{KNm}}{-500\ \text{KN}} \times 100 = -36\ \text{cm} \Rightarrow$$

e_x : $-37{,}13$ cm

SEZ. PARZIALIZZATA

2. TROVO ASSE NEUTRO $\qquad e_n = \dfrac{I_n}{S_n} \Rightarrow e_n \cdot S_n - I_n = 0$

$$X^3 - \overbrace{3 d_c}^{a_2} X^2 + \overbrace{\frac{6n}{b}\left[A_s(d-d_c) + A'_s(c-d_c)\right]}^{a_1} X +$$

$$\underbrace{-\frac{6n}{b}\left[A_s\, d\,(d-d_c) + A'_s\, c\,(c-d_c)\right]}_{a_0} = 0$$

$a_2 = -3\, d_c \qquad d_c = -6\,\text{cm}/_{100} = -\,0.06\ \text{m}$

$a_2 = -3 \times (-0,06) = +\,0,18$

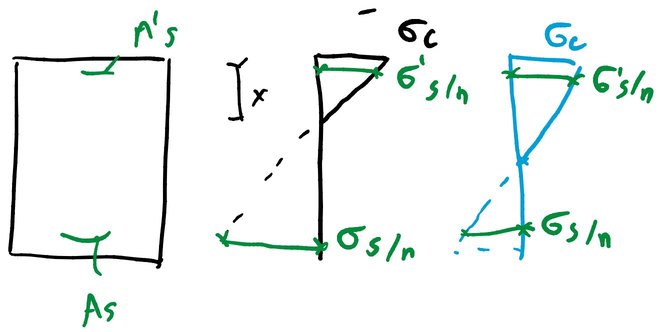
$$a_1 = \frac{6 \times 15}{0,30} \cdot \left[\frac{12,56}{100^2} \left(0,55 + 0,06\right) + \frac{6,28}{100^2} \times \left(0,05 + 0.06\right) \right]$$

$$= 0.251$$

$$a_0 = -\frac{6 \times 15}{0,30} \left[\frac{12,56}{100^2} \times 0,55 \left(0,55 + 0,06\right) + \frac{6,28}{100^2} \times 0,05 \times \left(0,05 + 0.06\right) \right]$$

$$= -\,0,127$$

COSA ASPETTARSI COME x ?



NEL CASO DI FLESSIONE SEMPLICE

$N = 0 \qquad x \simeq \frac{1}{3} \div \frac{1}{4} h$

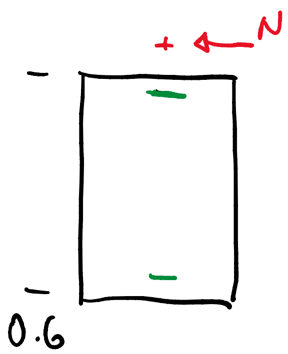
$\int \sigma \, dA = 0$

IN CASO DI PRESSO-FLESSIONE

$N < 0 \qquad \int \sigma \, dA = N$

$\Rightarrow$ DEVE CRESCERE LA ZONA COMPRESSA

PROCEDURA ITERATIVA

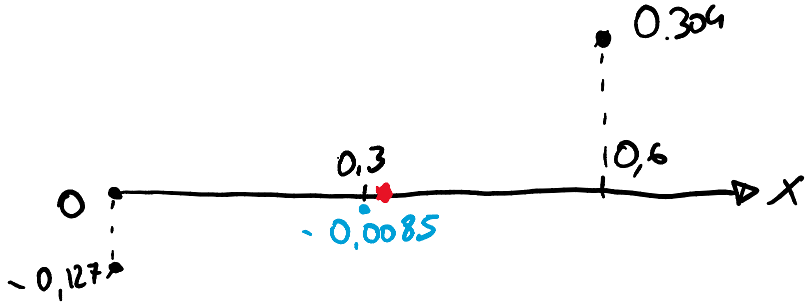


$x = 0 \rightarrow x^3 + a_2 x^2 + a_1 x + a_0 = a_0 = -\,0.127$

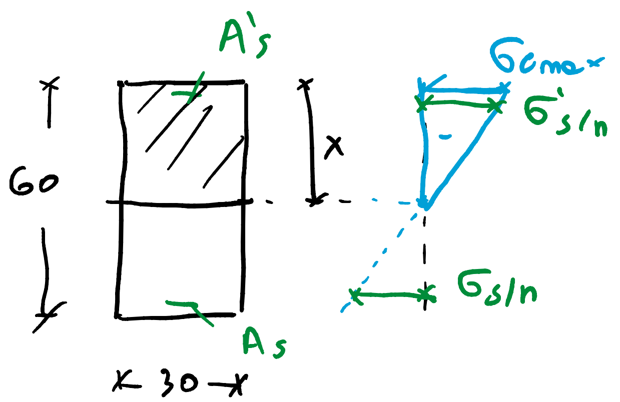
$x = 0.6 \rightarrow 0,6^3 + 0,18 \cdot 0,6^2 + 0,251 \times 0,6 +$
$\qquad - 0.127 = 0.304$

$x = 0,3 \rightarrow 0,3^3 + 0,18 \times 0.3^2 + 0,251 \times 0,3 +$
$\qquad - 0.127 = -\,0.0085$

$X = 0,314\ \text{m}$



CALCOLO LE TENSIONI



$$\sigma_c = \frac{N}{S_n} \cdot y$$

$$\sigma_{cmax} \Rightarrow y = -x$$

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

$$= -\frac{30 \times 31.4^2}{2} + 15 \times 12.56 \times (55-31.4) - 15 \times 6.28 (31.4-5)$$

$$= -12\,830 \quad cm^3$$

$$\sigma_c^{max} = \frac{-500\,kN \times 10}{-12\,830 \quad cm^3} \times (-31.4)\,cm = -12{,}24\ MPa$$

TENSIONE NELL' ARMATURA INFERIORE

$$y = d - x \Rightarrow \sigma_s = n \left[\frac{N}{S_n} \cdot (d-x) \right] =$$

$$= 15 \times \left[\frac{-500\,kN \times 10}{-12830 \quad cm^3} \times (55-31{,}4)\,cm \right]$$

$$\Rightarrow \sigma_s = 137{,}96\ MPa$$

VERIFICA IN CASO DI $M<0$

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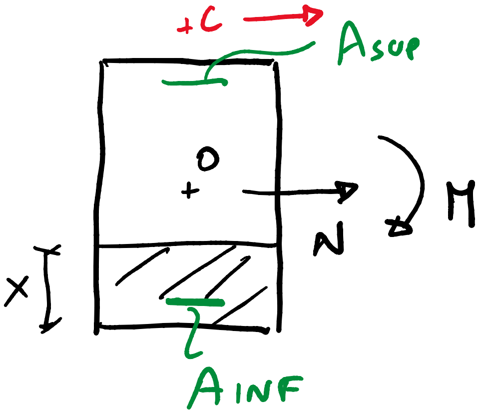
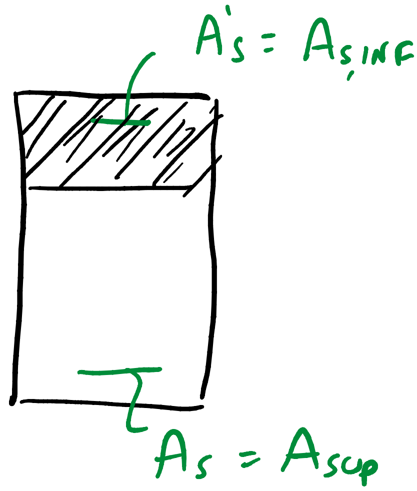


$\Rightarrow$ RUOTARE LA SEZIONE



SEZIONI DIVERSE DALLA RETTANGOLARE

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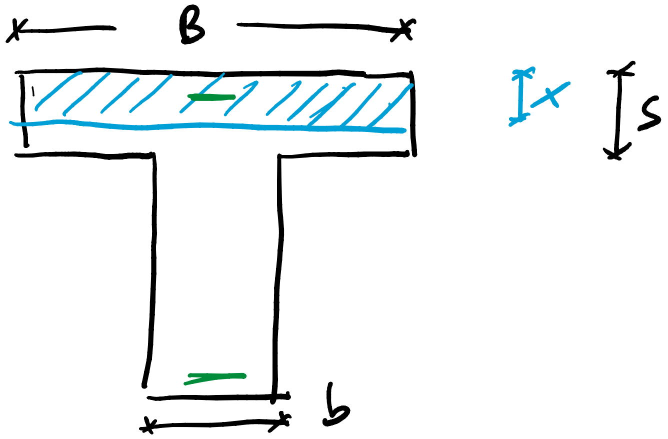
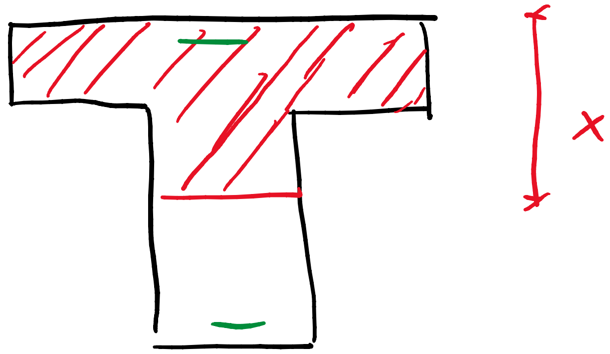


$$e_n = \frac{I_n}{S_n}$$



FISSO x : SE $x \leq a \Rightarrow I_n, S_n$ DA SEZ. RETTANGOLARE $B =$

se $x > a \Rightarrow I_n, S_n$ DA SEZIONE A T

CONDIZIONE DA IMPORRE $\Rightarrow e_n = \frac{I_n}{S_n}$