

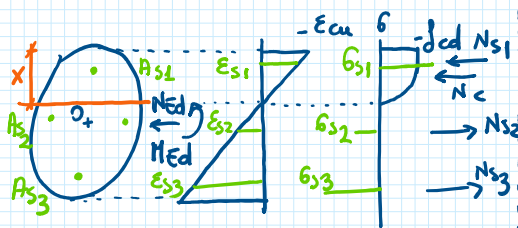
## VERIFICA A SLU

0) SEZ. PARZIALIZZATA O TUTTA COMPRESSA?

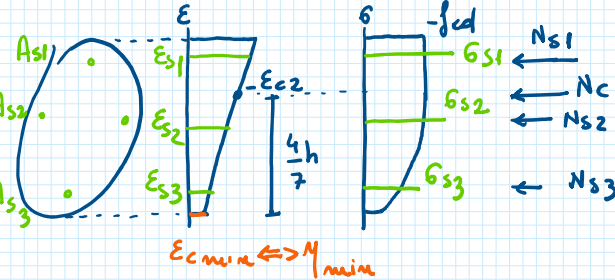
1) DIAGR.  $\epsilon_{LIM}$

2)  $M_{rd}(N_{Ed})$

### SEZ. PARZIALIZZATA

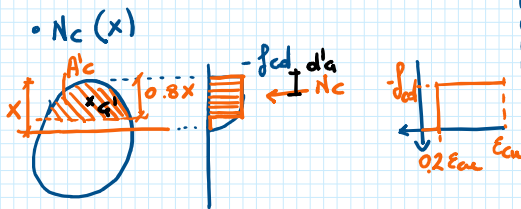


### SEZ. TUTTA COMPRESSA



### DIAGR. $\epsilon_{LIM}$

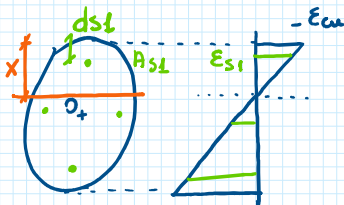
$$N_c(x) + N_{s1}(x) + N_{s2}(x) + N_{s3}(x) = N_{Ed} \quad N_c(\eta_{min}) + N_{s1}(\eta_{min}) + N_{s2}(\eta_{min}) + N_{s3}(\eta_{min}) = N_{Ed}$$



$$N_c = -A'_c f_{cd} \text{ applicato in } a'$$

$$A'_c = f(0.8x)$$

$$N_{s1}(x) = A_{s1} \sigma_{s1}$$

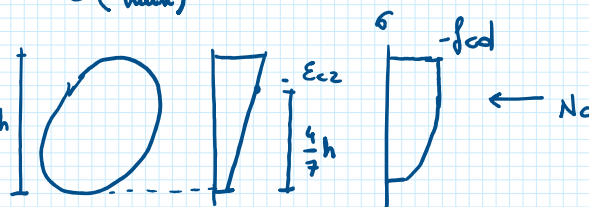


$$\sigma_{s1} \rightarrow \frac{\epsilon_{s1}}{-(x - d_{s1})} = \frac{-\epsilon_{cu}}{-x}$$

$$\epsilon_{s1} = -\frac{x - d_{s1}}{x} \epsilon_{cu}$$

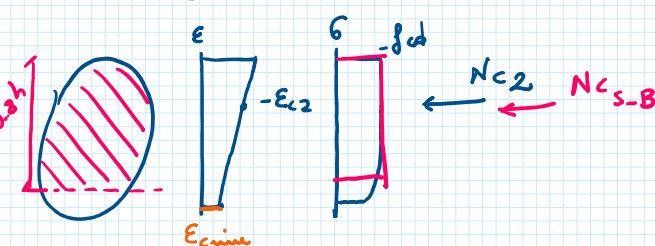
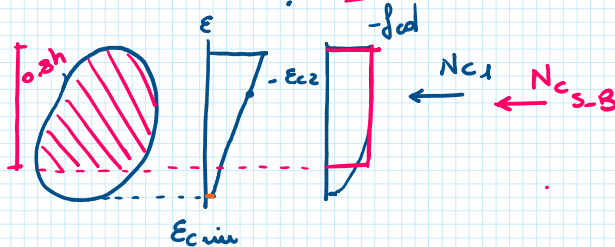
$$\sigma = f_c \cdot \epsilon \Rightarrow \sigma_c = -f_{cd}$$

$$N_c(\eta_{min})$$



COME POSSO CALCOLARE  $N_c$ ?

STRESS BLOCK? NO



PER CALCOLARE  $N_c$ :

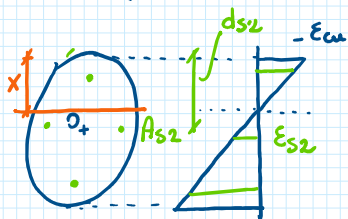


$$\text{se } \varepsilon_{s1} \leq -\varepsilon_{yd} \Rightarrow G_{s1} = -f_{yd}$$

$$\text{se } -\varepsilon_{yd} \leq \varepsilon_{s1} \leq \varepsilon_{yd} \Rightarrow G_{s1} = \frac{\varepsilon_{s1} f_{yd}}{\varepsilon_{yd}}$$

$$\text{se } \varepsilon_{s1} \geq \varepsilon_{yd} \Rightarrow G_{s1} = f_{yd}$$

$$N_{s2}(x) = A_{s2} \cdot G_{s2}$$



$$G_{s2} \rightarrow \frac{\varepsilon_{s2}}{ds_2 - x} = \frac{-\varepsilon_{cw}}{-x}$$

$$\varepsilon_{s2} = \frac{ds_2 - x}{x} \varepsilon_{cw}$$

$$\text{se } \varepsilon_{s2} \leq -\varepsilon_{yd} \Rightarrow G_{s2} = -f_{yd}$$

$$\text{se } -\varepsilon_{yd} \leq \varepsilon_{s2} \leq \varepsilon_{yd} \Rightarrow G_{s2} = \frac{\varepsilon_{s2} f_{yd}}{\varepsilon_{yd}}$$

$$\text{se } \varepsilon_{s2} \geq \varepsilon_{yd} \Rightarrow G_{s2} = f_{yd}$$

PER IL GENERICO STRATO  $A_{si}$ :

$$N_{si} = A_{si} G_{si}$$

$$G_s \rightarrow \frac{\varepsilon_{si}}{ds_i - x} = \frac{-\varepsilon_{cw}}{-x}$$

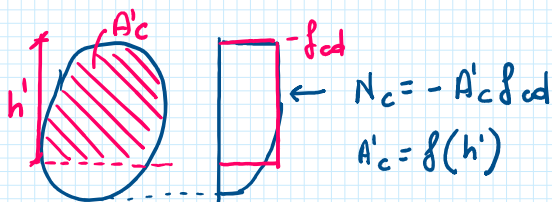
$$\varepsilon_{si} = \frac{ds_i - x}{x} \varepsilon_{cw}$$

$$\text{se } \varepsilon_{si} \leq -\varepsilon_{yd} \Rightarrow G_{si} = -f_{yd}$$

$$\text{se } -\varepsilon_{yd} \leq \varepsilon_{si} \leq \varepsilon_{yd} \Rightarrow G_{si} = \frac{\varepsilon_{si} f_{yd}}{\varepsilon_{yd}}$$

$$\text{se } \varepsilon_{si} \geq \varepsilon_{yd} \Rightarrow G_{si} = f_{yd}$$

PER CALCOLARE  $N_c$ :

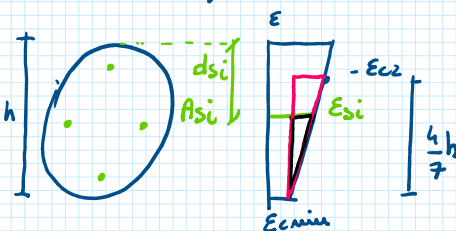


$$N_c = -A'_c f_{cd}$$

$$A'_c = b(h')$$

$$h' = h \left[ 1 - 0.2(1 - \eta_{min})^2 \right]$$

$$N_{si}(\eta_{min})$$



$$N_{si} = A_{si} G_{si}$$

$$G_{si} \rightarrow \varepsilon_{si}$$

$$\frac{\varepsilon_{si} - \varepsilon_{cmin}}{h - ds_i} = \frac{-\varepsilon_{c2} - \varepsilon_{cmin}}{\frac{4}{7}h}$$

$$\varepsilon_{si} - \varepsilon_{cmin} = \frac{h - ds_i}{\frac{4}{7}h} (-\varepsilon_{c2} - \varepsilon_{cmin})$$

$$\varepsilon_{si} = \frac{h - ds_i}{\frac{4}{7}h} (-\varepsilon_{c2} - \varepsilon_{cmin}) + \varepsilon_{cmin}$$

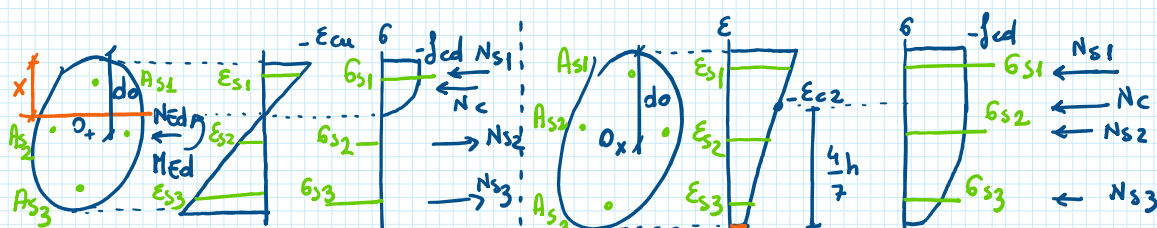
$$\varepsilon_{si} = -\varepsilon_{c2} \left[ \frac{h - ds_i}{\frac{4}{7}h} (1 - \eta_{min}) + \eta_{min} \right]$$

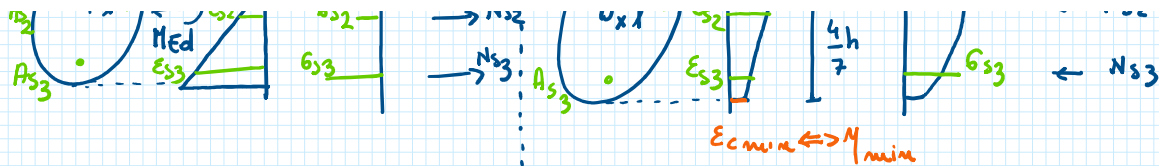
$$\text{se } \varepsilon_{si} \leq -\varepsilon_{yd} \Rightarrow G_{si} = -f_{yd}$$

$$\text{se } -\varepsilon_{yd} \leq \varepsilon_{si} \leq \varepsilon_{yd} \Rightarrow G_{si} = \frac{\varepsilon_{si} f_{yd}}{\varepsilon_{yd}}$$

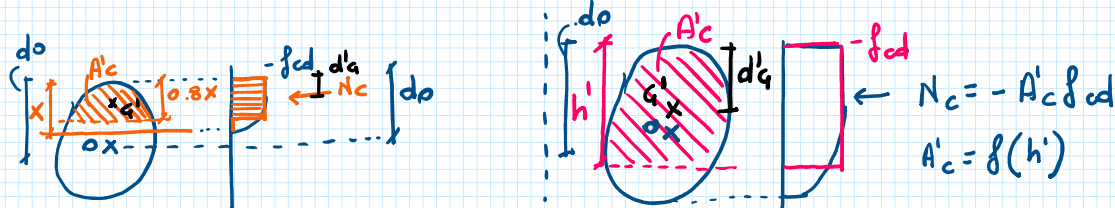
$$\text{se } \varepsilon_{si} \geq \varepsilon_{yd} \Rightarrow G_{si} = f_{yd}$$

$M_{rd}(N_{ed})$





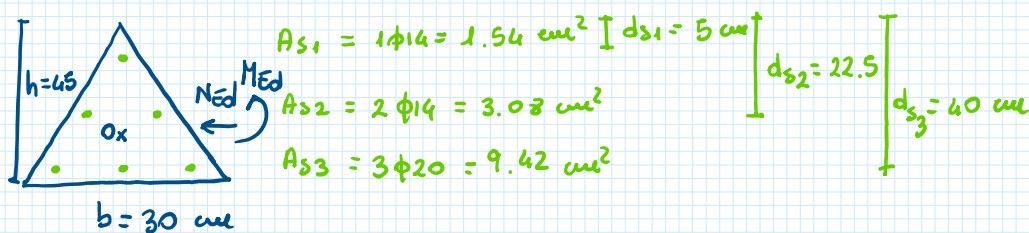
EQ. ALLA ROTAZIONE "O"



$$M_{Rd}(N_{Ed}) = -N_c (d_o - d'_4) + \underbrace{-N_{s1} (d_o - d_{s1}) + N_{s2} (d_{s2} - d_o) + N_{s3} (d_{s3} - d_o)}_{M_{STRATI}}$$

$$\sum_{i=1} N_{si} (d_{si} - d_o)$$

### ESEMPIO 1

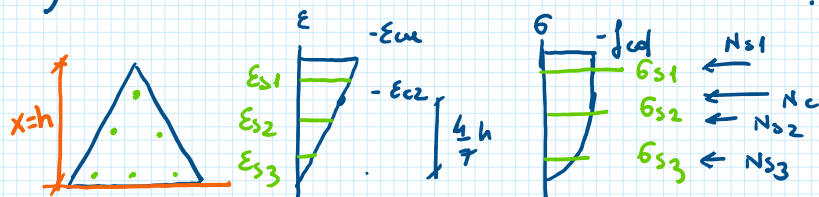


$$N_{Ed} = -400 \text{ kN}$$

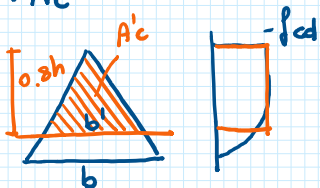
VERIFICA A SW

$$M_{Ed} = 100 \text{ kNm}$$

0) SEZ. PARZIALIZZATA O TUTTA COMPRESSA?



•  $N_c$



$$N_c = -f_{cd} A'_c = 432 \cdot \left( \frac{-14.17}{10} \right) = -612.14 \text{ kN}$$

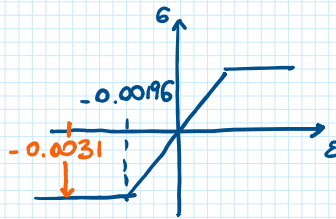
$$A'_c = \frac{b' (0.8h)}{2} = \frac{24 \cdot 0.8 \cdot 45}{2} = 432 \text{ cm}^2$$

$$\frac{b'}{0.8h} = \frac{b}{h} \Rightarrow b' = \frac{0.8h}{h} b = 0.8 \cdot 30 = 24 \text{ cm}$$

$$\bullet N_{s1} = A_{s1} \sigma_{s1} = 1.54 \cdot (-391.3) / 10 = -60.3 \text{ kN}$$

$$\varepsilon_{s1} = \frac{ds_1 - x_h}{x_h} \varepsilon_w = \frac{5 - 45}{45} 0.0035 = -0.0031$$

$$\varepsilon_{s1} < -\varepsilon_{yd} \Rightarrow \sigma_{s1} = -391.3$$

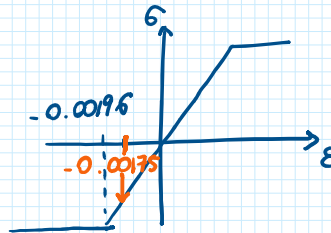


$$\bullet N_{s2} = A_{s2} \sigma_{s2} = -349.3 \cdot 3.04 / 10 = -106.5 \text{ kN}$$

$$\varepsilon_{s2} = \frac{ds_2 - x_h}{x_h} \varepsilon_w = \frac{22.5 - 45}{45} 0.0035 = -0.00175$$

$$-\varepsilon_{yd} \leq \varepsilon_{s2} \leq \varepsilon_{yd}$$

$$\sigma_{s2} = \frac{-0.00175}{0.00196} \times 391.3 = -349.3$$



$$\bullet N_{s3} = A_{s3} \cdot \sigma_{s3} = -77.5 \times 9.42 / 10 = -73.0 \text{ kN}$$

$$\varepsilon_{s3} = \frac{ds_3 - x}{x} \varepsilon_w = \frac{40 - 45}{45} 0.0035 = -0.00388$$

$$-\varepsilon_{yd} \leq \varepsilon_{s3} \leq \varepsilon_{yd}$$

$$\sigma_{s3} = \frac{-0.00388}{0.00196} \times 391.3 = -77.5 \text{ MPa}$$

QUINDI

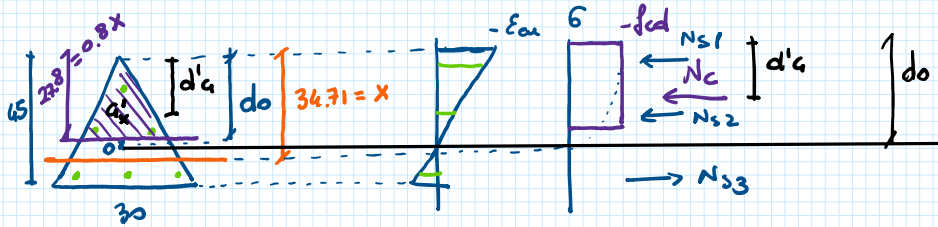
$$| 612.14 + 60.3 + 106.5 + 73 | = | 851.94 |$$

$$| N_c + \sum N_{si} | > | N_{ed} | \Rightarrow \text{SEZ. PARZIALIZZATA}$$

1) DIAGR.  $\varepsilon_{LH} \Rightarrow x$

X	34.71 cm				
0.8X	27.77134				
b'	18.51423 cm				
A'c	257.0825 cm <sup>2</sup>				
d'G	18.51423 cm				
d0	30 cm				
				Nc	-364.3 kN
εs1	-0.002996	σs1	-391.30 Mpa	Ns1	-60.2602 kN
εs2	-0.001231	σs2	-246.29 Mpa	Ns2	-75.85882 kN
εs3	0.000533	σs3	106.59 Mpa	Ns3	100.40 kN
				Somma N	-400.0 kN

2) M<sub>rd</sub> (N<sub>ed</sub>) RISPETTO "0"



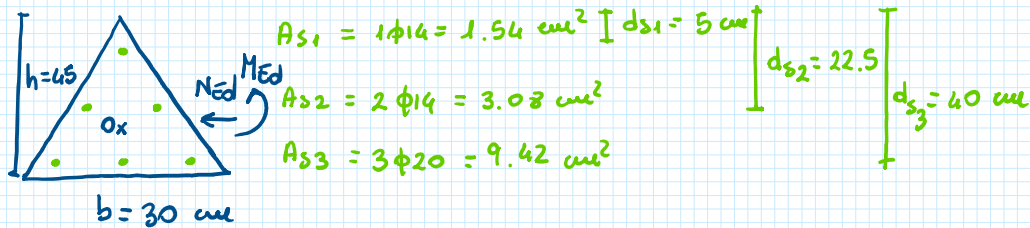
$$d_o = \frac{2}{3}h = \frac{2}{3}45 = 30 \text{ cm} \quad d'_4 = \frac{2}{3}(0.8x) = \frac{2}{3}(27.8) = 18.5 \text{ cm}$$

$$M_{Rd}(N_{Ed}) = -364.3 \left[ -\left(30 - \frac{18.5}{100}\right) \right] - 60.26 \left[ -\left(\frac{30}{100} - 5\right) \right] - 75.86 \left[ -\left(\frac{30}{100} - 22.5\right) \right] + 100.4 \left( \frac{40}{100} - 30 \right) = 72.7 \text{ kNm}$$

bc	-0.115 m	Mc	41.84 kNm
bs1	-0.250 m	Ms1	15.07 kNm
bs2	-0.075 m	Ms2	5.69 kNm
bs3	0.100 m	Ms3	10.04 kNm
		Somma M	72.6 kNm

$$M_{Rd} \leq M_{Ed} \quad \underline{\text{NO}}$$

## ESEMPIO 2



$$N_{Ed} = -1000 \text{ kN}$$

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$$M_{Ed} = 100 \text{ kNm}$$

0) SEZ. PARZ. O TUTTA COMPRESSA



VEDI CALCOLI ES. 1...

... QUINDI

$$|612.14 + 60.3 + 106.5 + 73| = 1851.94$$

$$|N_c + \sum N_{si}| < |N_{Ed}| \Rightarrow \text{SEZ. TUTTA COMPRESSA}$$

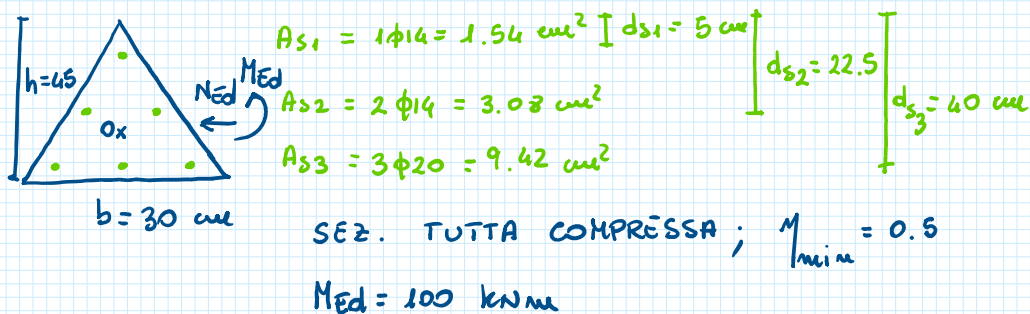
1) DIAGR  $\epsilon_{lim} \Rightarrow \eta_{min}$

$\eta_{min}$	0.16				
$h'$	38.69 cm				
$b'$	25.79 cm				
$A'_c$	498.86 cm <sup>2</sup>				
$d'G$	25.79 cm				
$d_0$	30 cm				
				$N_c$	-706.9 kN
$\epsilon_{s1}$	-0.00293	$\sigma_{s1}$	-391.30 Mpa	$N_{s1}$	-60.2602 kN
$\epsilon_{s2}$	-0.00179	$\sigma_{s2}$	-358.12 Mpa	$N_{s2}$	-110.301 kN
$\epsilon_{s3}$	-0.00065	$\sigma_{s3}$	-130.10 Mpa	$N_{s3}$	-122.556 kN
				<b>Somma N</b>	<b>-1000.0 kN</b>

2)  $M_{rd}(N_{ed})$  RISPETTO "3"

$N_c$	-706.9 kN	$b_c$	-0.042 m	$M_c$	29.75686 kNm
$N_{s1}$	-60.2602 kN	$b_{s1}$	-0.250 m	$M_{s1}$	15.06505 kNm
$N_{s2}$	-110.301 kN	$b_{s2}$	-0.075 m	$M_{s2}$	8.272556 kNm
$N_{s3}$	-122.556 kN	$b_{s3}$	0.100 m	$M_{s3}$	-12.2556 kNm
<b>Somma N</b>	<b>-1000.0 kN</b>			<b>Somma M</b>	<b>40.8 kNm</b>

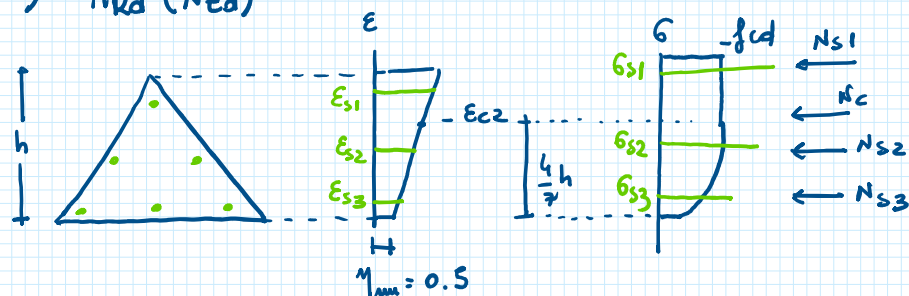
### ESEMPIO 3



0) SEZ È ASSEGNATA TUTTA COMPRESSA

1) DIAGR.  $\epsilon_{LH} \Rightarrow \eta_{min} = 0.5$

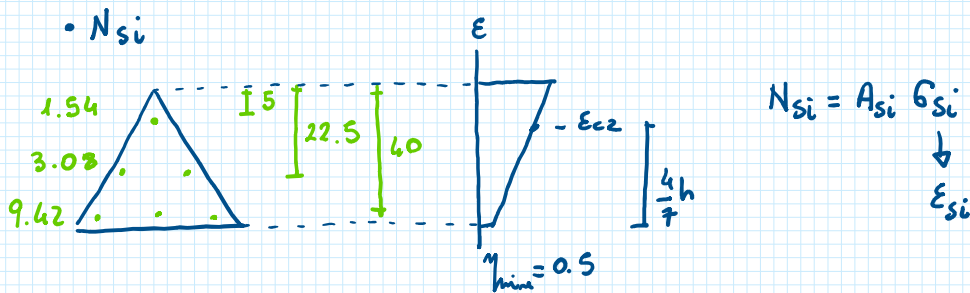
2)  $M_{rd}(N_{ed})$



$N_c$   
 $A'_c$   
 $h'$   
 $b'$   
 $N_c = -f_{cd} A'_c = -16.17 \times \frac{609.2}{10} = -863.2 \text{ kN}$   
 $h' = h [1 - 0.2 (1 - \eta_{min})^2]$   
 $h' = 45 [1 - 0.2 (1 - 0.5)^2] = 42.75 \text{ cm}$

$$\frac{b'}{h'} = \frac{b}{h} \Rightarrow b' = \frac{42.75}{45} \cdot 30 = 28.5 \text{ cm}$$

$$A'_c = \frac{28.5 \cdot 42.75}{2} = 609.2 \text{ cm}^2$$



$$\begin{aligned} \varepsilon_{S1} &= -\varepsilon_{c2} \left[ \frac{h - ds_1}{\frac{4}{7}h} (1 - \eta_{\min}) + \eta_{\min} \right] = \\ &= -0.002 \left[ \frac{45 - 5}{\frac{4}{7} \cdot 45} (1 - 0.5) + 0.5 \right] = -0.0026 \end{aligned}$$

$$\varepsilon_{S1} < -\varepsilon_{yd} \Rightarrow \sigma_{S1} = -391.3 \text{ MPa}$$

$$N_{S1} = -1.54 \times \frac{391.3}{10} = -60.26 \text{ kN}$$

$$\begin{aligned} \varepsilon_{S2} &= -\varepsilon_{c2} \left[ \frac{h - ds_2}{\frac{4}{7}h} (1 - \eta_{\min}) + \eta_{\min} \right] = \\ &= -0.002 \left[ \frac{45 - 22.5}{\frac{4}{7} \cdot 45} (1 - 0.5) + 0.5 \right] = -0.00188 \end{aligned}$$

$$\text{POI CHE } \varepsilon_{S2} > -\varepsilon_{yd} \Rightarrow \sigma_{S2} = \frac{-0.00188}{0.00196} \times 391.3 = -375.3 \text{ MPa}$$

$$N_{S2} = -375.3 \cdot \frac{3.08}{10} = -115.6 \text{ kN}$$

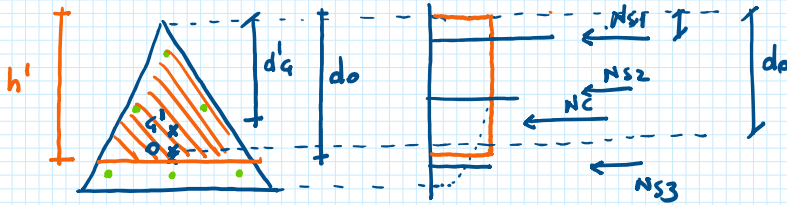
$$\begin{aligned} \varepsilon_{S3} &= -\varepsilon_{c2} \left[ \frac{h - ds_3}{\frac{4}{7}h} (1 - \eta_{\min}) + \eta_{\min} \right] = \\ &= -0.002 \left[ \frac{45 - 40}{\frac{4}{7} \cdot 45} (1 - 0.5) + 0.5 \right] = -0.001194 \end{aligned}$$

$$\text{POI CHE } \varepsilon_{S3} < -\varepsilon_{yd} \Rightarrow \sigma_{S3} = \frac{-0.001194}{0.00196} \times 391.3 = -238.4$$

$$N_{s3} = -238.4 \times \frac{9.42}{10} = -224.6 \text{ kN}$$

$$N_{Ed} = -863.2 - 115.6 - 60.26 - 224.6 = -1263.6 \text{ kN}$$

$$M_{Rd}(N_{Ed}) \Rightarrow \text{EQ. ROTAZIONE SU } O^u$$



$$d_0 = \frac{2}{3}h = \frac{2}{3}45 = 30 \text{ cm}$$

$$h' = 42.75 \text{ cm} \quad d'_g = \frac{2}{3}h' = \frac{2}{3}42.75 = 28.5 \text{ cm}$$

$$M_{Rd}(N_{Ed}) = -863.1 \left[ -\left( \frac{30-28.5}{100} \right) \right] + 60.26 \left[ -\left( \frac{30-5}{100} \right) \right] - 115.6 \left[ -\left( \frac{30-22.5}{100} \right) \right] - 224.6 \left[ \left( \frac{40-30}{100} \right) \right] =$$

$$= 14.03 \text{ kNm}$$