

$$M_{Rd} \geq M_{Ed}$$

1) DETERMINATO IL DIAGR. E_{lim}
 RICAVALARE $x \Rightarrow N'_s + N_s + N_c = 0$

2) M_{Rd}

SEZ. RETTANGOLARE $\left\{ \begin{array}{l} A'_s \text{ SNERVATA} \Rightarrow x : \text{eq. 1° grado} \\ A'_s \text{ ELASTICO} \Rightarrow x : \text{eq. 2° grado} \end{array} \right.$

PER FARE LA VERIFICA:

1) IPOTIZZO A'_s SNERVATA \Rightarrow

$$x = \frac{(A_s - A'_s) f_{yd}}{\beta b f_{cd}}$$

2) VERIFICO : $x \geq 2.27 c$ $\xrightarrow{\text{NO}}$ DEVO RICALCOLARE x

SI

3)

$$\beta x^2 + \omega d (\mu_1 - 1) x - \mu_1 \omega c d = 0 \Rightarrow x$$

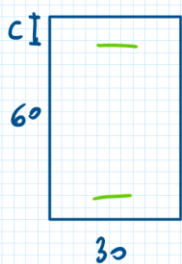
$$\mu = \frac{A'_s}{A_s}$$

$$\mu_1 = \mu \frac{E_{cu}}{E_{yd}}$$

$$\omega = \frac{A_s f_{yd}}{b d f_{cd}}$$

4) $M_{Rd} = -N'_s (x - c) + N_s (d - x)$

ESEMPIO



$$A'_s = 2\phi 14 = 2 \times 1.54 = 3.08 \text{ cm}^2$$

M_{Ed}

$$A_s = 4\phi 20 = 4 \times 3.14 = 12.56 \text{ cm}^2$$

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

$$c = 5 \text{ cm}$$

$$d = 60 - 5 = 55 \text{ cm}$$

$$M_{Rd} = ?$$

1) IPOTIZZO A'_S SNERVATA

$$x = \frac{(A_S - A'_S) f_{yd}}{\beta b f_{cd}} = \frac{(12.56 - 3.08) \cdot 391.3}{0.81 \times 30 \times 16.17} = 10.77 \text{ cm}$$

2) $x \stackrel{?}{\geq} 2.27 \text{ cm}$

$$10.77 < 2.25 \times 5 = 11.35 \Rightarrow A'_S \text{ NON E' SNERVATA}$$

3)

$$\underbrace{\beta x^2}_A + \underbrace{\omega d (\mu_1 - 1) x}_B - \underbrace{\mu_1 \omega c d}_C = 0$$

$$A = 0.81$$

$$B = \omega d (\mu_1 - 1) = 0.210 \times 55 \times (0.438 - 1) = -6.49$$

$$\omega = \frac{A_S f_{yd}}{b d f_{cd}} = \frac{12.56 \times 391.3}{30 \times 55 \times 16.17} = 0.210$$

$$\mu_1 = \mu \frac{\epsilon_w}{\epsilon_{yd}} = \frac{A'_S}{A_S} \frac{\epsilon_w}{\epsilon_{yd}} = \frac{3.08}{12.56} \frac{0.0035}{0.00196} = 0.438$$

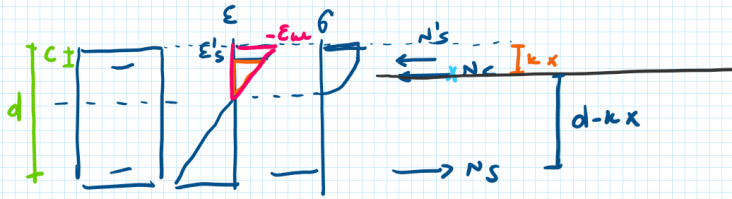
$$C = -\mu_1 \omega c d = -0.438 \times 0.210 \times 5 \times 55 = -25.29$$

$$0.81 x^2 - 6.49 x - 25.29 = 0$$

$$x = \frac{+6.49 \pm \sqrt{6.49^2 + 4 \times 0.81 \times 25.29}}{2 \times 0.81}$$

$(-) \quad x = -9.38$
 $(+) \quad x = 10.88$

$$4) M_{Rd} = -N'_s (kx - c) + N_s (d - kx)$$

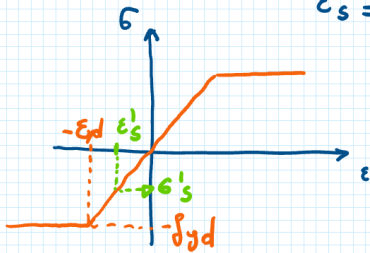


$$N_s = A_s f_{yd}$$

$$N'_s = A'_s \sigma'_s$$

$$\frac{\epsilon'_s}{-(x-c)} = \frac{\epsilon_{cu}}{x} \Rightarrow \epsilon'_s = -\frac{x-c}{x} \epsilon_{cu}$$

$$\epsilon'_s = -\frac{10.88 - 5}{10.88} \times 0.0035 = -0.00189$$



$$\sigma'_s = \frac{\epsilon'_s}{\epsilon_{yd}} f_{yd} = -\frac{0.00189}{0.00197} \times 391.3 = -375.7 \text{ MPa}$$

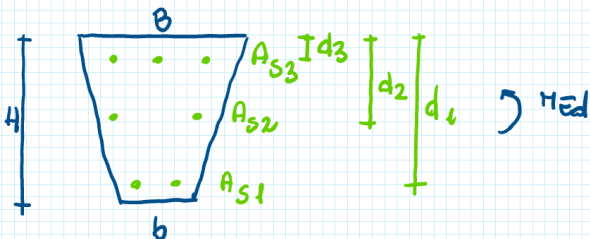
$$M_{Rd} = + 3.08 \times 375.7 \left(\frac{0.416 \times 10.88 - 5}{10^3} \right) + 12.56 \times 391.3 \times \left(\frac{55 - 0.416 \times 10.88}{10^3} \right) =$$

$$M_{Rd} = 250.9 \text{ kNm}$$

$$\frac{\text{cm}^2 \text{ kN}}{\text{mm}^2} \text{ cm} \times \frac{10^2}{10^3} \frac{1}{10^2} = \frac{1}{10^3}$$

$$M_{Rd} > M_{Ed} = 100 \text{ kNm} \quad \underline{\text{OK!}}$$

SEZIONE NON RETTANGOLARE

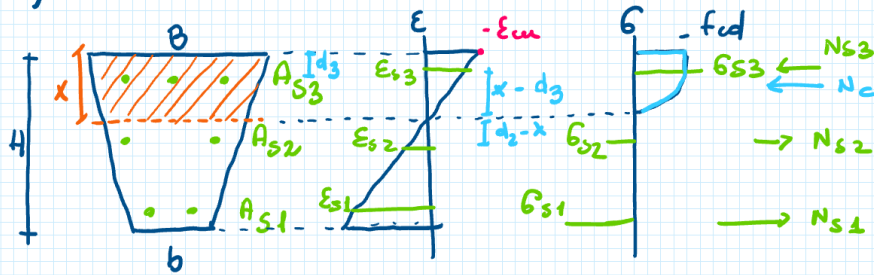


$$M_{Rd} > M_{Ed}$$

$$1) \text{ DET. } \epsilon_{LH} \rightarrow \times$$

$$2) M_{Rd}$$

1) DETERMINARE $\epsilon_{lim} \Leftrightarrow x$



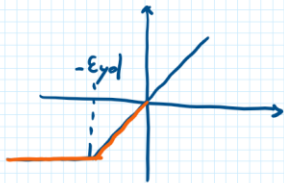
$$\sum N_i(x) = 0$$

$$N_c(x) + N_{s3}(x) + N_{s2}(x) + N_{s1}(x) = 0$$

$$N_{s3} = A_{s3} \cdot \sigma_{s3}$$

$$\hookrightarrow \epsilon_{s3}: \frac{\epsilon_{s3}}{-(x-d_3)} = \frac{-\epsilon_{cm}}{x}$$

$$\epsilon_{s3} = -\frac{x-d_3}{x} \epsilon_{cm}$$

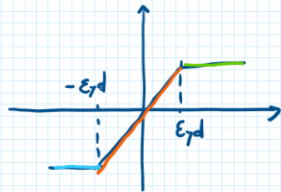


$$\text{se } \epsilon_{s3} \leq -\epsilon_{yd} \Rightarrow \sigma_{s3} = -f_{yd}$$

$$\text{se } 0 > \epsilon_{s3} > -\epsilon_{yd} \Rightarrow \sigma_{s3} = \frac{\epsilon_{s3}}{\epsilon_{yd}} f_{yd}$$

$$N_{s2} = A_{s2} \cdot \sigma_{s2}$$

$$\hookrightarrow \epsilon_{s2}: \frac{\epsilon_{s2}}{d_2-x} = \frac{-\epsilon_{cm}}{-x} \Rightarrow \epsilon_{s2} = \frac{d_2-x}{x} \epsilon_{cm}$$



$$\text{se } \epsilon_{s2} \leq -\epsilon_{yd} \Rightarrow \sigma_{s2} = -f_{yd}$$

$$\text{se } -\epsilon_{yd} \leq \epsilon_{s2} \leq \epsilon_{yd} \Rightarrow \sigma_{s2} = \frac{\epsilon_{s2}}{\epsilon_{yd}} f_{yd}$$

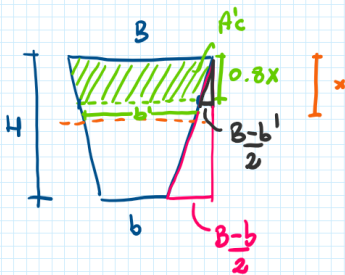
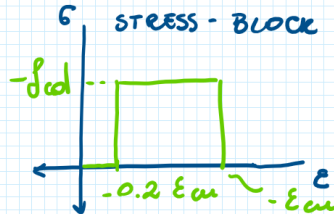
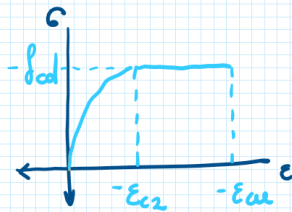
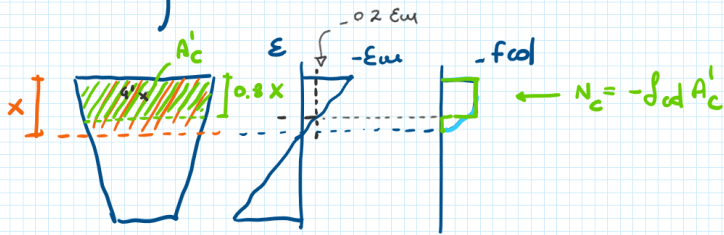
$$\text{se } \epsilon_{s2} \geq \epsilon_{yd} \Rightarrow \sigma_{s2} = f_{yd}$$

Per qualsiasi strato di armatura:

$$N_{si} = A_{si} \cdot \sigma_{si}$$

$$\hookrightarrow \epsilon_{si} = \frac{d_i-x}{x} \epsilon_{cm} \Rightarrow \sigma_{si}$$

$$N_c = \int \sigma_c dA_c$$



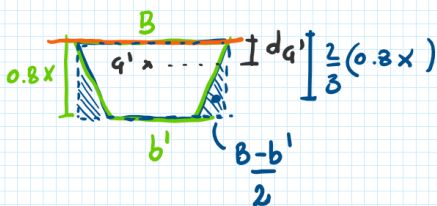
$$A'_c = (B + b') \left(\frac{0.8x}{2} \right)$$

$$\frac{B - b}{H} = \frac{B - b'}{0.8x}$$

$$\frac{B - b}{H} = \frac{B - b'}{0.8x}$$

$$\frac{B - b}{H} (0.8x) = B - b'$$

$$b' = B - \left[\frac{B - b}{H} (0.8x) \right]$$

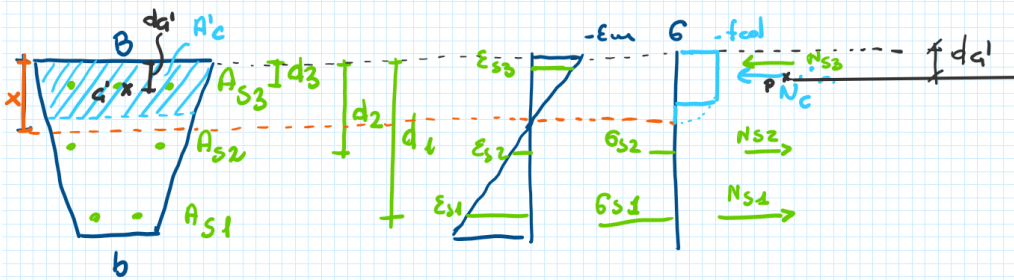


$$S_{sup} = B \left(\frac{0.8x}{2} \right)^2 - \left[\frac{B - b'}{2} \times \frac{0.8x}{2} \times \frac{2}{3} (0.8x) \right]$$

$$S_{sup} = B \left(\frac{0.8x}{2} \right)^2 - \left[\frac{(B - b')}{3} (0.8x)^2 \right]$$

$$d_{g'} = \frac{S_{sup}}{A'_c}$$

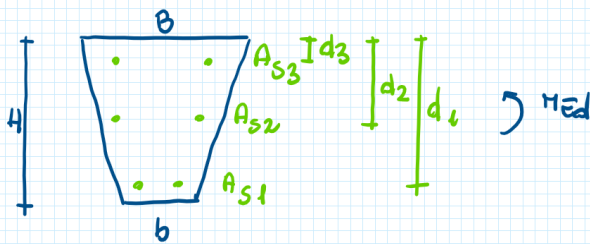
2) DETERMINARE M_{rd}



$$M_{rd} = -N_{s3} (d_3 - d_3) + N_{s2} (d_2 - d_3) + N_{s1} (d_1 - d_2)$$

$$M_{rd} = \sum N_{si} (d_i - d_i')$$

ESEMPIO



$$\begin{aligned} A_{s3} &= 2 \phi 20 & d_3 &= 5 \text{ cm} \\ A_{s2} &= 2 \phi 20 & d_2 &= 45 \text{ cm} \\ A_{s1} &= 3 \phi 20 & d_1 &= 85 \text{ cm} \end{aligned}$$

$$M_{Ed} = 300 \text{ kNm}$$

$$\begin{aligned} B &= 70 \text{ cm} \\ b &= 40 \text{ cm} \\ H &= 90 \text{ cm} \end{aligned}$$

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Recupera dati Aggiorna tutti Azioni Valute Ordina Filtro Cancellazione Riapplica Avanzate Testo in colonne Strumenti dati Analisi di simulazione Foglio previsione Previsione Struttura

B9

| | | | | | | | | | | | | | | |
|----|------------------|-----------------------|-----------------|--------------|-----------------|----------------|----------------|-----------------|---------|------------|-------------------|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
| 1 | B | 70 cm | | | f _{cd} | 14.1 MPa | | ε _{cu} | 0.0035 | | | | | |
| 2 | b | 40 cm | | | f _{yd} | 391.3 MPa | | ε _{yd} | 0.00196 | | | | | |
| 3 | H | 90 cm | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | |
| 5 | A _{s3} | 6.28 cm ² | | | d _{s3} | 5 cm | | | | | | | | |
| 6 | A _{s2} | 6.28 cm ² | | | d _{s2} | 45 cm | | | | | | | | |
| 7 | A _{s1} | 9.42 cm ² | | | d _{s1} | 85 cm | | | | | | | | |
| 8 | | | | | | | | | | | | | | |
| 9 | X | 6.55 cm | | | | | | | | | | | | |
| 10 | 0.8X | 5.238526 cm | | | | | | | | | | | | |
| 11 | b' | 68.3 cm | | | | | | | | | | | | |
| 12 | A'c | 362.1 cm ² | | | | | | | | | | | | |
| 13 | S _{sup} | 944.5 cm ³ | | | | | | | | | | | | |
| 14 | d'G | 2.6 cm | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | |
| 16 | ε _{s3} | -0.000827 | σ _{s3} | -165.203 MPa | | Nc | -510.594 kN | | | MRd_3 | -2.48 kNm | | | |
| 17 | ε _{s2} | 0.020553 | σ _{s2} | 391.3 MPa | | Ns3 | -103.747 kN | | | MRd_2 | 104.17 kNm | | | |
| 18 | ε _{s1} | 0.041933 | σ _{s1} | 391.3 MPa | | Ns2 | 245.7364 kN | | | MRd_1 | 303.70 kNm | | | |
| 19 | | | | | | Ns1 | 368.6046 kN | | | | | | | |
| 20 | | | | | | Somma N | 0.00 kN | | | MRd | 405.39 kNm | | | |
| 21 | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | |

Ricerca obiettivo

Imposta la cella:

\$G\$19

Al valore:

0

Cambiando la cella:

\$B\$9

OK

Annulla

$$b' = B - \left[\frac{B-b}{H} (0.8x) \right]$$

$$S_{sup} = B \frac{(0.8x)^2}{2} - \left[\frac{(B-b') (0.8x)^3}{3} \right]$$

$$\epsilon_{si} = \frac{d_i - x}{x} \epsilon_{cu}$$

$$M_{rd} = \sum N_{si} (d_i - d'_i)$$