

### Dati geometrici

$$b = 30 \text{ cm}$$

$$h = 70 \text{ cm}$$

$$c = 4 \text{ cm}$$

$$d = 66 \text{ cm}$$

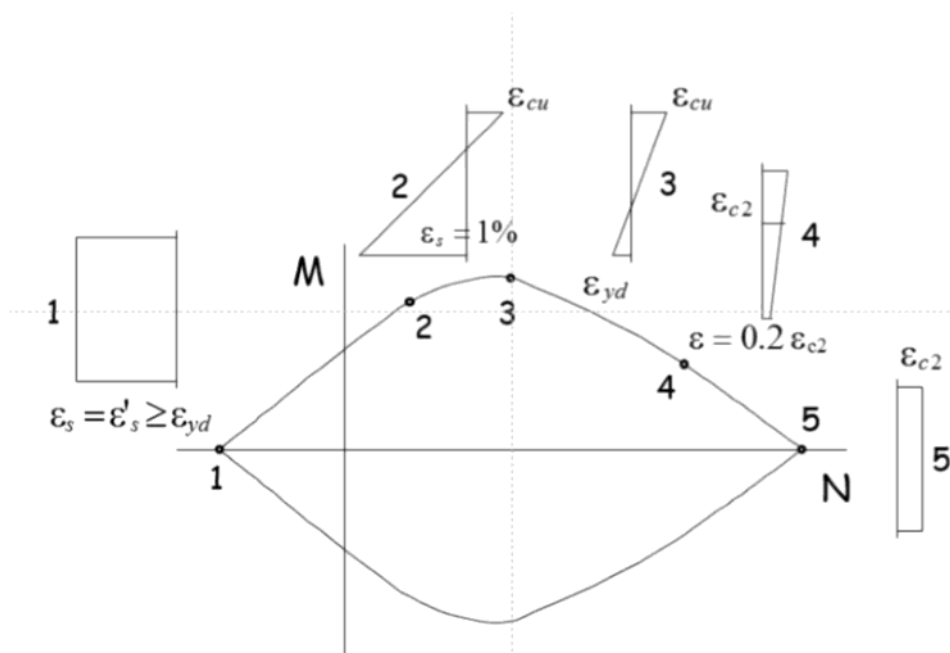
$$A'_s = 4 \varnothing 20 = 12.57 \text{ cm}^2$$

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### Materiali

Acciaio B450C

Conglomerato cementizio C30/37

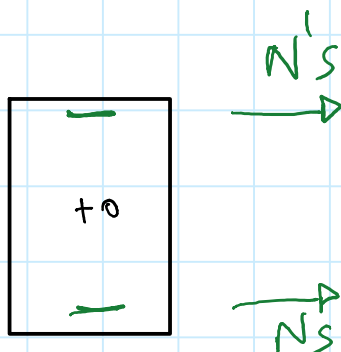


### DIAGRAMMA 1

$$\epsilon > 0 \rightarrow \sigma_c = 0$$

$$\epsilon_s = \epsilon'_s > \epsilon_{yd} \rightarrow \sigma'_s = f_{yd} = 391.3 \text{ N/mm}^2$$

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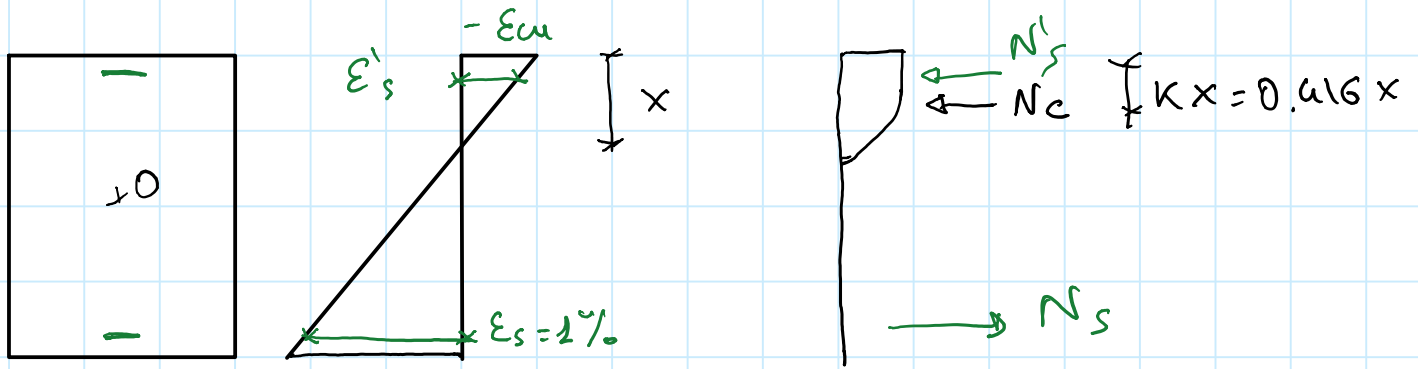
$$N_s = N'_s = 12.57 \text{ cm}^2 \cdot 391.3 \frac{\text{N}}{\text{mm}^2} \cdot \frac{1}{10}$$

$$= 491.86 \text{ kN}$$

$$N_{TOT} = N_s + N'_s = 983.72 \text{ kN}$$

$$M(0) = -N'_s \left( \frac{h}{2} - c \right) + N_s \left( \frac{h}{2} - c \right) = 0$$

## DIAGRAMMA 2



$$\epsilon_{cu} : x = \epsilon_s : (d-x) \rightarrow \frac{3.5}{1000} (66-x) = \frac{10}{1000} x$$

$$\frac{10 + 3.5}{1000} x = \frac{3.5}{1000} 66 \rightarrow x = 17.11 \text{ cm}$$

$$\epsilon'_s : (x-c) = -\epsilon_{cu} : x \rightarrow \epsilon'_s = \frac{(17.11-4)}{17.11} \cdot \frac{3.5}{1000} = -2.60\%$$

$$|\epsilon'_s| > \epsilon_{yd} = \frac{1.96}{100} \rightarrow \sigma'_s = -f_{yd}$$

$$\epsilon_s = \frac{10}{1000} > \epsilon_{yd} \rightarrow \sigma_s = f_{yd}$$

$$N_s = A_s \cdot f_{yd} = 12.57 \cdot 391.3 \cdot \frac{1}{10} = 491.86 \text{ kN}$$

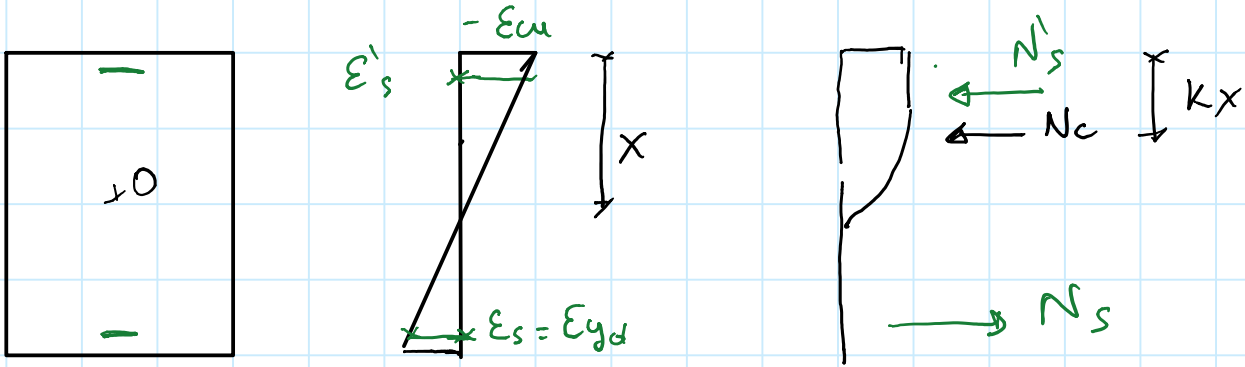
$$N'_s = -A'_s f_{yd} = -491.86 \text{ kN}$$

$$N_c = \beta b x f_{cd} = 0.81 \cdot 30 \text{ cm} \cdot 17.11 \text{ cm} \times 17 \frac{\text{N}}{\text{mm}^2} \cdot \frac{1}{10} = -706.8 \text{ kN}$$

$$N_{TOT} = N_s + N'_s + N_c = -706.8 \text{ kN}$$

$$M_{tot} = \left[ 491.86 (35-4) + 491.86 (35-4) + 706.8 \cdot (35 - 0.416 \cdot 17.11) \right] \frac{1}{100} = 502.02 \text{ kNm}$$

### DIAGRAMMA 3



$$\epsilon_{cu} : x = \epsilon_s : (d - x) \rightarrow \frac{3.5}{1000} (66 - x) = \frac{1.96}{1000} x$$

$$\frac{1.96 + 3.5}{1000} x = \frac{3.5}{1000} 66 \rightarrow x = 42.31 \text{ cm}$$

$$\epsilon'_s : (x - c) = -\epsilon_{cu} : x \rightarrow \epsilon'_s = \frac{(42.31 - 4)}{42.31} \cdot \frac{3.5}{1000} = 3.17 \text{ ‰}$$

$$|\epsilon'_s| > \epsilon_{yd} = \frac{1.96}{100} \rightarrow \sigma'_s = -f_{yd}$$

$$\epsilon_s = \epsilon_{yd} \rightarrow \sigma_s = f_{yd}$$

$$N_s = A_s \cdot f_{yd} = 12.57 \cdot 391.3 \cdot \frac{1}{10} = 491.86 \text{ kN}$$

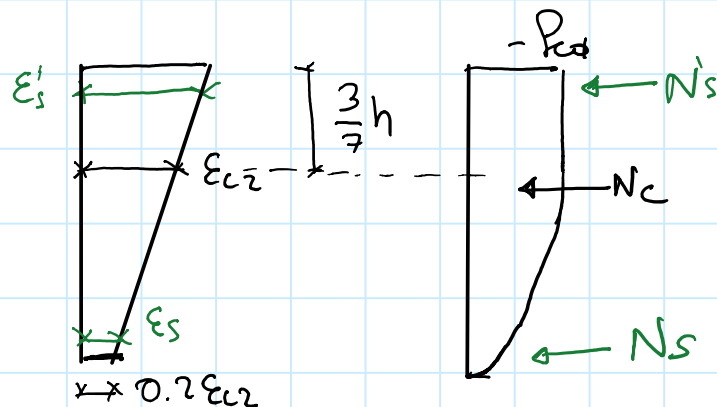
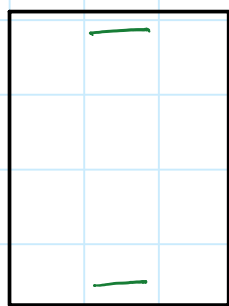
$$N'_s = -A'_s \cdot f_{yd} = -491.86 \text{ kN}$$

$$N_c = \beta b x f_{cd} = 0.81 \cdot 30 \text{ cm} \cdot 42.31 \text{ cm} \cdot 17 \frac{\text{N}}{\text{mm}^2} \cdot \frac{1}{10} = -1747.83 \text{ kN}$$

$$N_{\text{TOT}} = N_s + N'_s + N_c = -1747.83$$

$$M_{\text{tot}} = \left[ 491.86 (35 - 4) + 491.86 (35 - 4) + 1747.83 \cdot (35 - 0.416 \cdot 42.31) \right] \cdot \frac{1}{100} = 608 \text{ kNm}$$

## DIAGRAMMA 4



$$|\epsilon'_s| > \epsilon_{cz} \approx \epsilon_{yd} \rightarrow \sigma'_s = -f_{yd}$$

$$\eta_{min} = \frac{0.2 \epsilon_{cz}}{\epsilon_{cz}} = 0.2$$

$$\epsilon_s = -\epsilon_{cz} \left[ \frac{c}{\frac{4}{7}h} (1 - \eta_{min}) + \eta_{min} \right] = \frac{-2.0}{1000} \left[ \frac{4}{\frac{4}{7}} \cdot 0.8 + 0.2 \right]$$

$$= -0.56\% \rightarrow |\epsilon_s| < \epsilon_{yd} \rightarrow \sigma_s = \epsilon_s E_s$$

$$\sigma_s = -\frac{0.56}{1000} \cdot 210'000 \text{ N/mm}^2 = -117.6 \text{ N/mm}^2$$

$$N_s = -117.6 \text{ N/mm}^2 \times 12.57 \text{ cm}^2 \frac{1}{10} = -147.78 \text{ kN}$$

$$N'_s = -391.3 \text{ N/mm}^2 \times 12.57 \text{ cm}^2 \frac{1}{10} = -491.86 \text{ kN}$$

## CONTRIBUTO CLS

$$\beta = 1 - \frac{4}{21} (1 - \eta_{min})^2 = 1 - \frac{4}{21} (1 - 0.2)^2 = 0.878$$

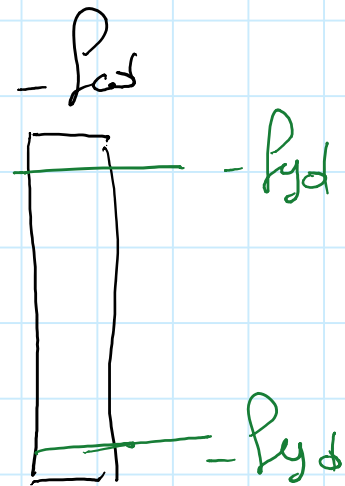
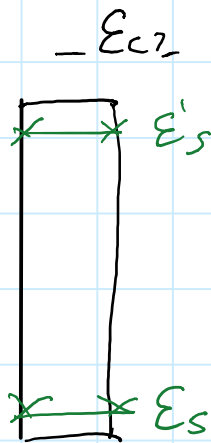
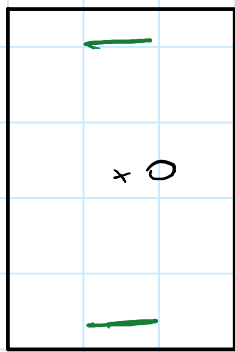
$$K = 0.5 \frac{1 - \frac{16}{49} (1 - \eta_{min})^2}{1 - \frac{4}{21} (1 - \eta_{min})^2} = 0.450$$

$$N_c = \beta b h f_{cd} = 0.878 \cdot 30 \text{ cm} \cdot 70 \text{ cm} \times 17 \frac{\text{N}}{\text{mm}^2} \frac{1}{10} = -3134.8 \text{ kN}$$

$$N_{TOT} = N_s + N'_s + N_c = -147.78 - 491.86 - 3134.8 = -3774.31 \text{ kN}$$

$$M_{tot} = [-147.78 (35 - 4) + 491.86 (35 - 4) + 1747.83 \cdot (35 - 0.450 \cdot 70)] / 100 = 215.4 \text{ kNm}$$

# DIAGRAMMA 5



$$\epsilon_s = \epsilon'_s - \epsilon_{cz} = -\frac{2}{1000} \rightarrow$$

$$\sigma'_s = \sigma_s = -p_{yd} = -381.3 \text{ N/mm}^2$$

$$N_s = N'_s = -12.57 \text{ cm}^2 \cdot \frac{381.3 \text{ N}}{10 \text{ mm}} = -481.86 \text{ kN}$$

$$N_c = -A_c p_{cd} = 30 \cdot 70 \cdot (-17) \frac{\text{N}}{\text{mm}^2} \frac{1}{10} = -3570 \text{ kN}$$

$$N_{TOT} = -481.86 - 481.86 - 3570 = -4533.7 \text{ kN}$$

$$M_{TOT} = 0$$