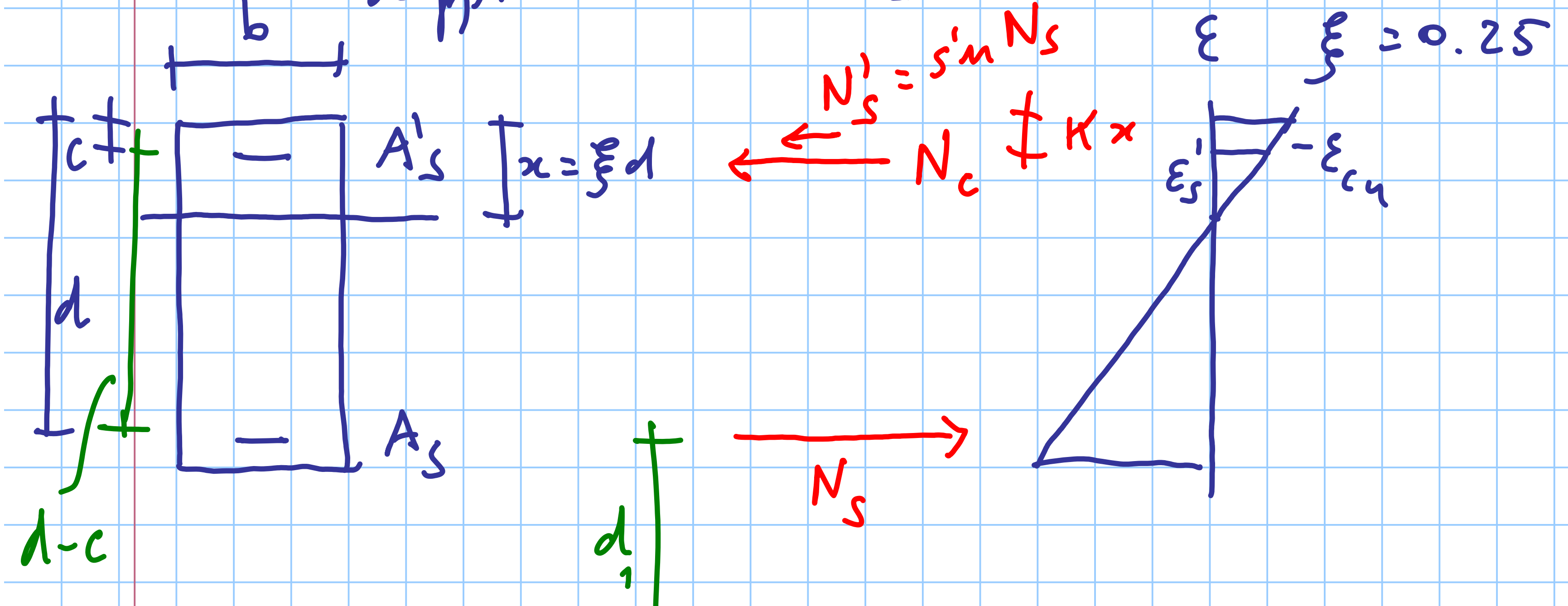
FLESSIONE – PROGETTO SLU

doppia armatura



$$N_c = -\beta\, b\, x\, f_{cd}$$

$$N_s = A_s\, f_{yd}$$

$$N'_s = A'_s \, \sigma'_s \qquad \varepsilon'_s = -\frac{x-c}{x}\,\varepsilon_{cu} \Rightarrow \sigma'_s$$

$$A'_s = n\,A_s \qquad \sigma'_s = -s'\,f_{yd}$$

$s' = 1 \rightarrow$ snerv

$s' < 1 \rightarrow$ elast.

$$N'_s = -s'\,n\,A_s\,f_{yd} = -s'\,n\,N_s$$

per ricavare d_1

$$|N'_s|\,(d - c + d_1) = N_s\,d_1$$

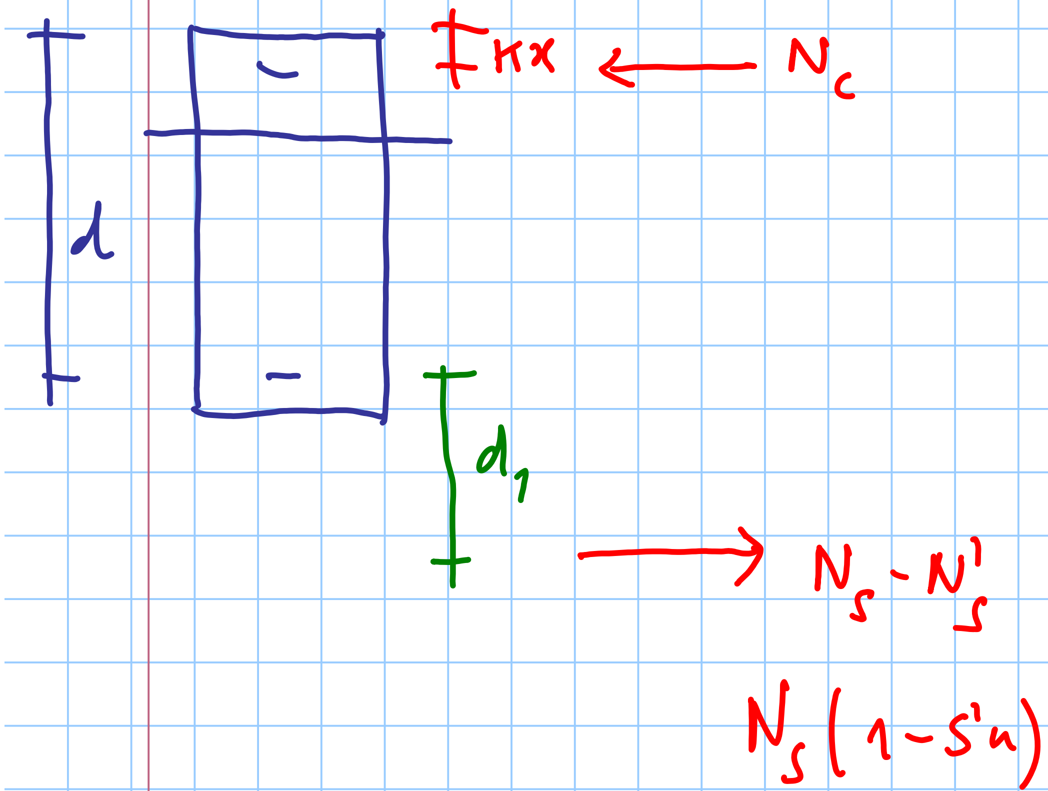
$$s'\,n\,\cancel{N_s}\,(d - c + d_1) = \cancel{N_s}\,d_1$$

$$s'u(d-c) + s'u\,d_1 = d_1$$

$$\gamma = \frac{c}{d}$$

$$s'u(d-c) = (1-s'u)\,d_1$$

$$d_1 = \frac{s'u}{1-s'u}(d-c) = \frac{s'u}{1-s'u}(1-\gamma)\,d$$



$$M = N_c \left(d - Kx + d_1 \right)$$

$$M = N_s (1 - s'_u) \left(d - Kx + d_1 \right)$$

$$M = \beta\, b\, x\, f_{cd}\, (d - \kappa x + d_1) =$$

$$= \beta\, b\, \xi d\, f_{cd} \left[d - \kappa \xi d + \frac{s' \mu}{1 - s' \mu} (1 - \gamma) d \right] =$$

$$= b\, d^2\, \beta\, \xi\, f_{cd} \left[1 - \kappa \xi + \frac{s' \mu}{1 - s' \mu} (1 - \gamma) \right] =$$

$$= b\, d^2\, \underbrace{\beta\, \xi\, f_{cd}\, (1 - \kappa \xi) \left[1 + \frac{s' \mu}{1 - s' \mu} \frac{1 - \gamma}{1 - \kappa \xi} \right]}_{\frac{1}{r'^2}}$$

$$r' = \frac{1}{\sqrt{\beta \xi (1 - k\xi) f_{cd} \left[1 + \frac{s' u}{1 - s' u} \frac{1 - \gamma}{1 - k\xi} \right]}} = r \frac{1}{\sqrt{1 + \frac{s' u}{1 - s' u} \frac{1 - \gamma}{1 - k\xi}}}$$

$\gamma \simeq 0.2$ travi a spessore

$\gamma \simeq 0.1$ solai

$\gamma \simeq 0.05$ trave emergente

$$\frac{1 - \gamma}{1 - k\xi} \simeq 1$$

$$\frac{1}{\sqrt{1+\frac{s'u}{1-s'u}\,\frac{1-\gamma}{1-K_\xi}}} \simeq \frac{1}{\sqrt{1+\frac{s'u}{1-s'u}}} = \sqrt{1-s'u}$$

$$r' \simeq r\sqrt{1-s'u}$$ APPROSSIMATA

$$M = N_s (1 - s'_u)(d - \kappa x + d_1) =$$

$$= A_s f_{yd} (1 - s'u) \left[d - \kappa \xi d + \frac{s'u}{1 - s'u} (1 - \gamma) d \right] =$$

$$= A_s f_{yd} d \left[(1 - s'u)(1 - \kappa \xi) + s'u (1 - \gamma) \right] =$$

$$= A_s f_{yd} d \left[1 - \kappa \xi - \cancel{s'u} + s'u \kappa \xi + \cancel{s'u} - s'u \gamma \right] =$$

$$= A_s f_{yd} d \left[1 - \kappa \xi + s'u (\kappa \xi - \gamma) \right]$$

$$z = d(1 - K\xi) \cong 0.9\, d$$

SEMPLICE ARMATURA

$$z = d\left[1 - K\xi + \underbrace{s'u\,(K\xi - \gamma)}_{\text{spesso trascurabile}}\right]$$

DOPPIA ARMATURA

$$z \cong 0.9\, d$$

PROGETTO DELLA SEZIONE

$$\underbrace{M_{Rd} = \frac{b\,d^2}{r'^2}}_{\text{VERIFICA (CLS)}} \qquad \underbrace{d = r'\sqrt{\frac{M_{Ed}}{b}} \qquad b = \frac{M_{Ed}\,r'^2}{d^2}}_{\text{PROGETTO SEZIONE}}$$

$$r' \simeq r\sqrt{1 - s'u}$$

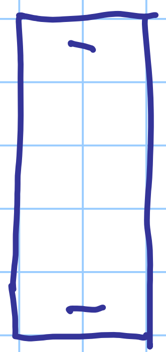
PROGETTO DELL' ARMATURA TESA

$$\underbrace{A_s = \frac{M_{Ed}}{z\,f_{yd}}}_{\text{PROGETTO ARMATURA}} \qquad z \simeq 0.9\,d \qquad \underbrace{M_{Rd} = A_s\,z\,f_{yd}}_{\text{VERIFICA (ACC)}}$$

PROGETTO   Trave emergente

$M_{Ed} = 300$ KNm

$c = 4$



$h = 50 ; 60 ; 70$ cm

$x = 11,5 ; 14 ; 16.5$

$$\varepsilon'_s = -\frac{x - c}{x} \varepsilon_{cu}$$

con $x = 11.5$ cm

$$\varepsilon'_s = -\frac{11,5 - 4}{11.5} \varepsilon_{cu} = -2.28 \times 10^{-3}$$

SNERVATA

$S' = 1$

$$\delta' = 1 \qquad \mu = 0.25$$

$$r' \simeq r\sqrt{1-\delta'\mu} = 0.0197\sqrt{1-0.25} = 0.017$$

$$d = r'\sqrt{\frac{M}{b}} = 0.017\sqrt{\frac{300}{0.30}} = 0.54\ \text{m} = 54\ \text{cm}$$

$$30 \times 60$$

$$A_s = \frac{M}{0.9\, d\, f_{yd}} = \frac{300 \times 10}{0.9 \times 0.56 \times 391.3} = 15.2\ \text{cm}^2$$

$\delta' = 1$ $\quad\quad\quad\quad$ $n = 0.5$

$$r' \simeq 0.0197 \sqrt{1 - 0.5} = 0.014$$

può andare bene?

$$d = 0.014 \sqrt{\frac{300}{0.30}} = 0.44 \text{ m} = 44 \text{ cm}$$

30×50

$$A_s = \frac{300 \times 10}{0.9 \times 0.46 \times 391.3} = 18.5 \text{ cm}^2$$

parecchi (forse troppi)

$$M_{Rd} = 0.9\, d\, A_s\, f_{yd}$$

$$\frac{A_s}{bd} = \rho$$ percentuale geometrica

es. $\rho = 0.01$ $A_s = 1\%$ di $b\,d$

è già parecchio

$$M = 0.9\, d\, \rho\, b\, d\, f_{yd} = b\, d^2\, 0.9\, \rho\, f_{yd}$$

$$M = \frac{b\,d^2}{r_s^{\,2}} \qquad r_s = \frac{1}{\sqrt{0.9\ \rho\ f_{yd}}}$$

$\rho = 0.01$

$f_{yd} = 391.3\ MPa = 391.3 \times 10^3\ kPa$

$$r_s = \frac{1}{\sqrt{0.9 \times 0.01 \times 391.3 \times 10^3}} = 0.0169$$

$\rho = 0.015 \qquad r_s = 0.0138$

$M_{Ed} = 300\ KNm$

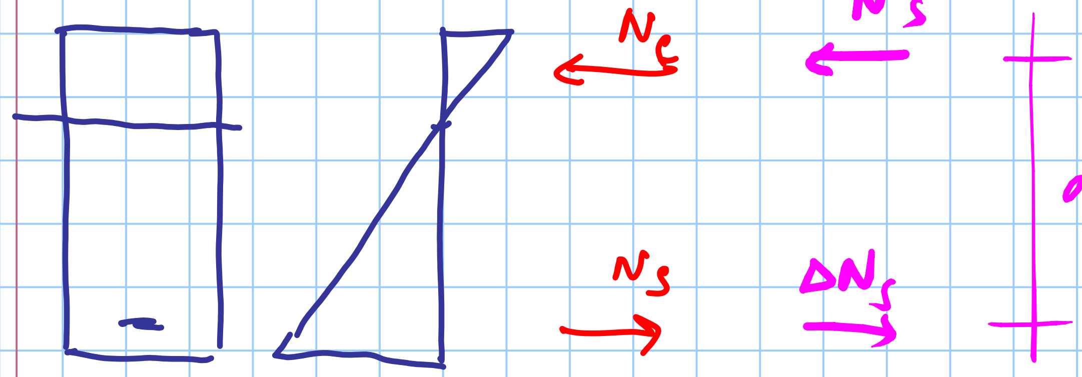
$d = r' \sqrt{\frac{M}{b}} = 0.54\ m \rightarrow 30 \times 60 \qquad d = 0.56\ m$

$A_s = \frac{M}{0.9\ d\ f_{yd}} \rightarrow 15.4\ cm^2 \rightarrow 5\phi 20 = 15.7\ cm^2$

$A'_s = ?$

se $A'_s = 0 \qquad M_{Rd} = \frac{b\ d^2}{r^2} = \frac{0.30 \times 0.56^2}{0.0197^2} = 242.4\ KNm$

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



$$M_{Rd} = 242.6 \text{ kNm}$$

$$\Delta M = 300 - 242.6 = 57.6 \text{ kNm}$$

$$A'_s = \frac{\Delta M}{(d-c)\,\sigma'_s} = \frac{57.6 \times 10}{0.52 \times 391.3} = 2.8 \text{ cm}^2$$

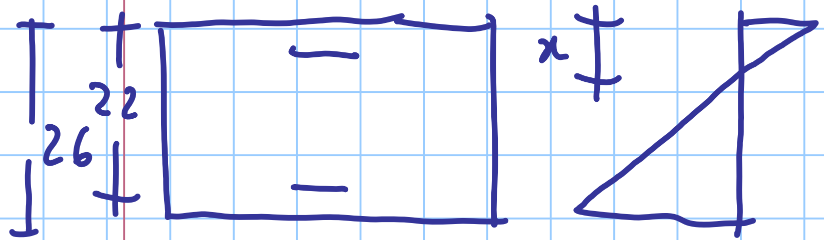
$\sigma'_s \rightarrow f_{yd}$

TRAVE A SPESSORE

$h = 26\ cm$

$d = 22\ cm$

$M_{Ed} = 150\ kN\,m$



$x = 0.25 \times 22 = 5.5\,cm$

$$\varepsilon'_s = -\frac{x-c}{x}\,\varepsilon_{cu} = -\frac{5.5-4}{5.5}\,3.5\times10^{-3} = -0.955\times10^{-3}$$

ELASTICO

$\sigma'_s = E_s\,\varepsilon'_s = -191\ MPa$

$$s' = \frac{191}{391.3} = 0.488 \simeq 0.5$$

$$r' \simeq r\sqrt{1 - s'\mu}$$

$s' = 0.5 \quad \mu = 0.25$

$r' = 0.0184$

posso provare anche con $r' = 0.018$

$$b = \frac{M_{Ed}\, r'^2}{d^2} = \frac{150 \times 0.018^2}{0.22^2} = 1.00 \text{ m}$$

$$A_s = \frac{M}{0.9\, d\, f_{yd}} = \frac{150 \times 10}{0.9 \times 0.22 \times 391.3} = 19.4 \text{ cm}^2$$

$$M_{Rd\,(A'_s = 0)} = \frac{b\, d^2}{r^2} = \frac{1.00 \times 0.22^2}{0.0197^2} = 124.7 \text{ kNm}$$

$$\Delta M = 150 - 124.7 = 25.3 \text{ kNm}$$

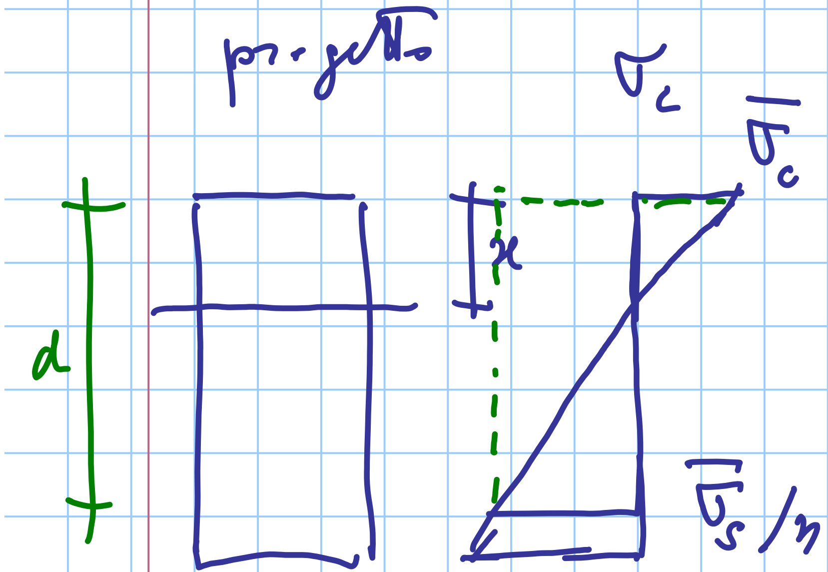
$$A'_s = \frac{M}{(d - c)\, \sigma'_s} = \frac{25.3 \times 10}{0.18 \times 191} = 7.4 \text{ cm}^2$$

$\sigma'_s \rightarrow$ 191 MPa

NEL PASSATO T.A.

2° MOD. DI COMP.

progetto



$$\xi = \frac{x}{d} = \frac{\bar{\sigma}_c}{\bar{\sigma}_c + \frac{\bar{\sigma}_s}{n}}$$

C20/25 0.333

C25/30 0.364

$\bar{\sigma}_c = 8.5\ MPa$ C20/25

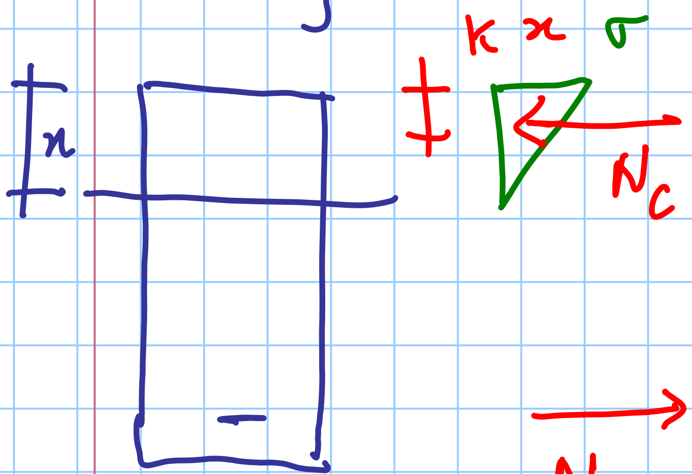
$\bar{\sigma}_c = 9.75\ MPa$ C25/30

FeB44K = 255 MPa

$n = 15$

$x = \xi d$

$\kappa = 0.333$



$N_c = \beta\, b\, x\, \bar{\sigma}_c$

$\beta = 0.5$

$N_s = A_s\, \bar{\sigma}_s$

$$r = \frac{1}{\sqrt{\beta \xi (1 - \kappa \xi)\, \bar{\sigma}_c}}$$

$$M_{Rd} = N_c\,(d - \kappa x)$$

$$d = r \sqrt{\frac{M}{b}}$$

$$M_{Rd} = N_s\,(d - \kappa x)$$

$$A_s = \frac{M}{0.9\, d\, \bar{\sigma}_s}$$

$$r = \frac{1}{\sqrt{\beta \xi (1 - k\xi) \bar{\sigma}_c}} = \frac{1}{\sqrt{0.5 \times 0.364 \underbrace{(1 - 0.333 \times 0.364)}_{0.879} 9.75 \times 10^3}}$$

C25/30

$$= 0.0253$$

$$M_{SLU} \cong 1.4\, M_{TA}$$

$M_{SLU} = 300$ kNm $\longrightarrow d = 0.63$ cm

$M_{TA} = 210$ kNm $\longrightarrow d = r\sqrt{\frac{M}{b}} = 0.67$ cm

un po' di più (p.c.)

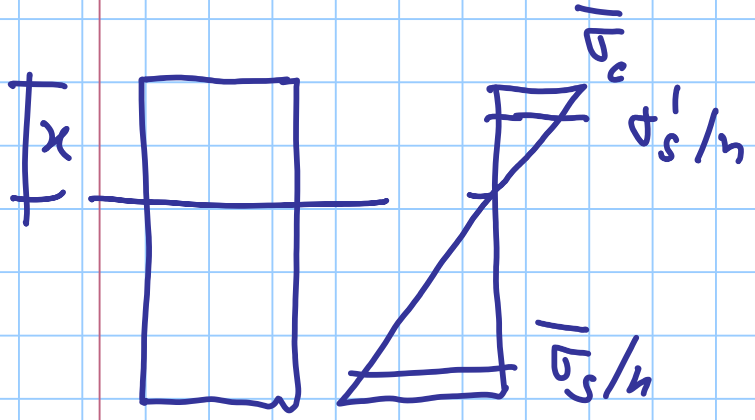
$h = 70$ cm $\qquad d = 66$ cm

$$SLU \Rightarrow A_s = \frac{300 \times 10}{0.9 \times 0.66 \times 391.3} = 12.9 \text{ cm}^2$$

$$TA \Rightarrow A_s = \frac{210 \times 10}{0.9 \times 0.66 \times 255} = 13.8 \text{ cm}^2$$

con armature compresse (TA)

$$\tau' \simeq \tau \sqrt{1 - \delta' \mu}$$



$$\frac{\sigma'_s}{n} = \frac{x-c}{x}\,\bar\sigma_c$$

$$\sigma'_s = n\,\bar\sigma_c\,\frac{x-c}{x} = 121.7$$

$n \downarrow 15$ $\quad \bar\sigma_c \downarrow 9.75$ $\quad \frac{x-c}{x} \downarrow 0.83$ $\quad \delta' \simeq 0.5$

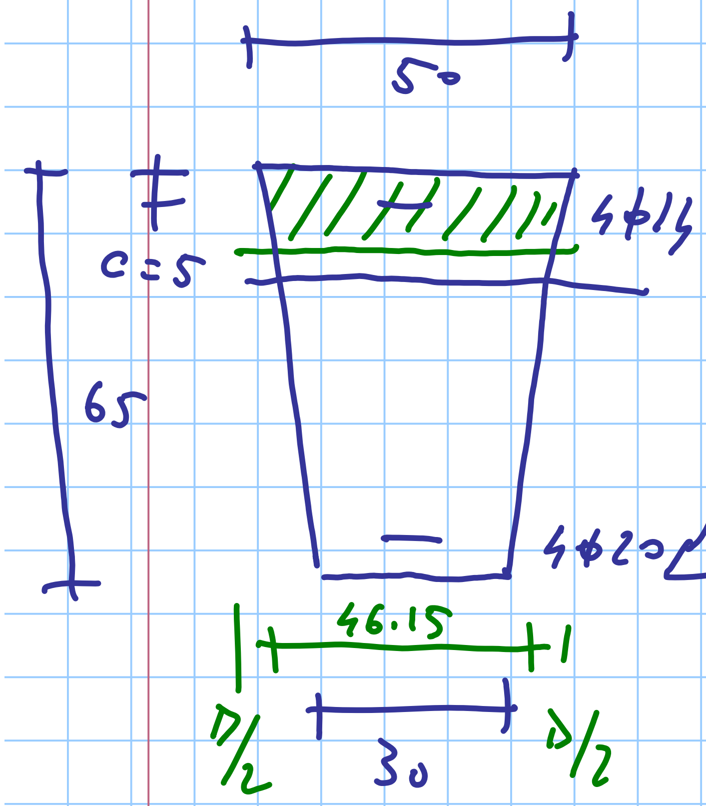
$\underbrace{15 \quad 9.75}_{146}$

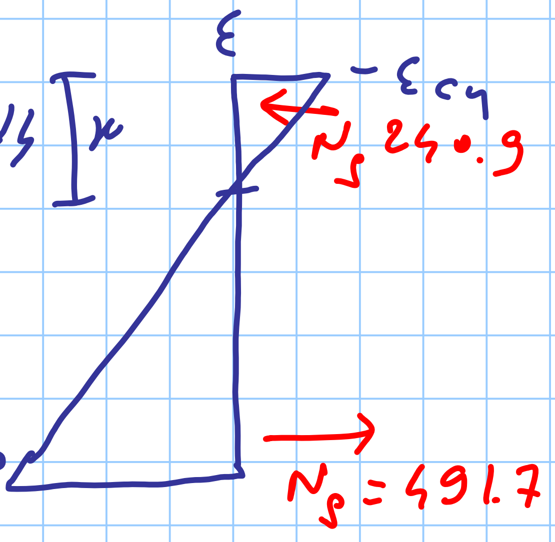
C25/30

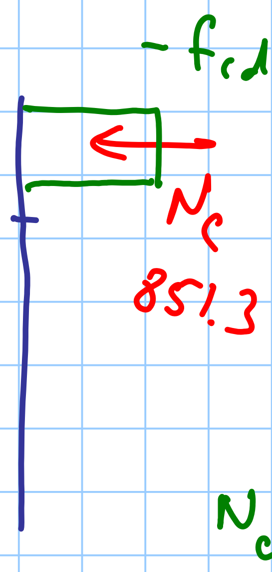
$x \simeq 0.364\, d$

30×70 $\quad x = 24$ cm

$x = 15.63\ cm$







$0.8\,x =$

$= 12.5\ cm$

$A_c = 600.8\ cm^2$

$N_c = -A_c\, f_{cd} =$

$= -851.3\ kN$

C 25/30

B 450 C

$$\frac{\Delta}{12.5} = \frac{50-30}{65}$$

$\sigma_s = ?$

$N_c = ?$

$$\varepsilon_s = \frac{d-x}{x-c}\,\varepsilon_{cu} > \varepsilon_{yd}$$

$\sigma_s = f_{yd} = 391.3$ MPa