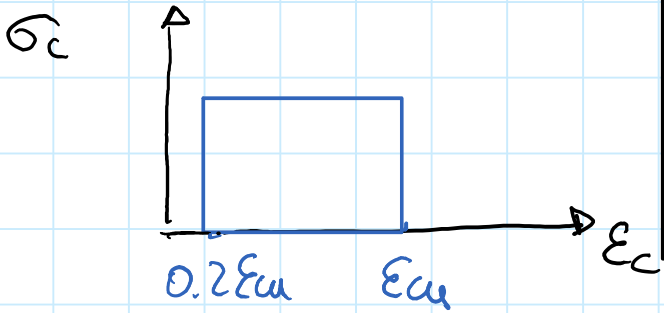
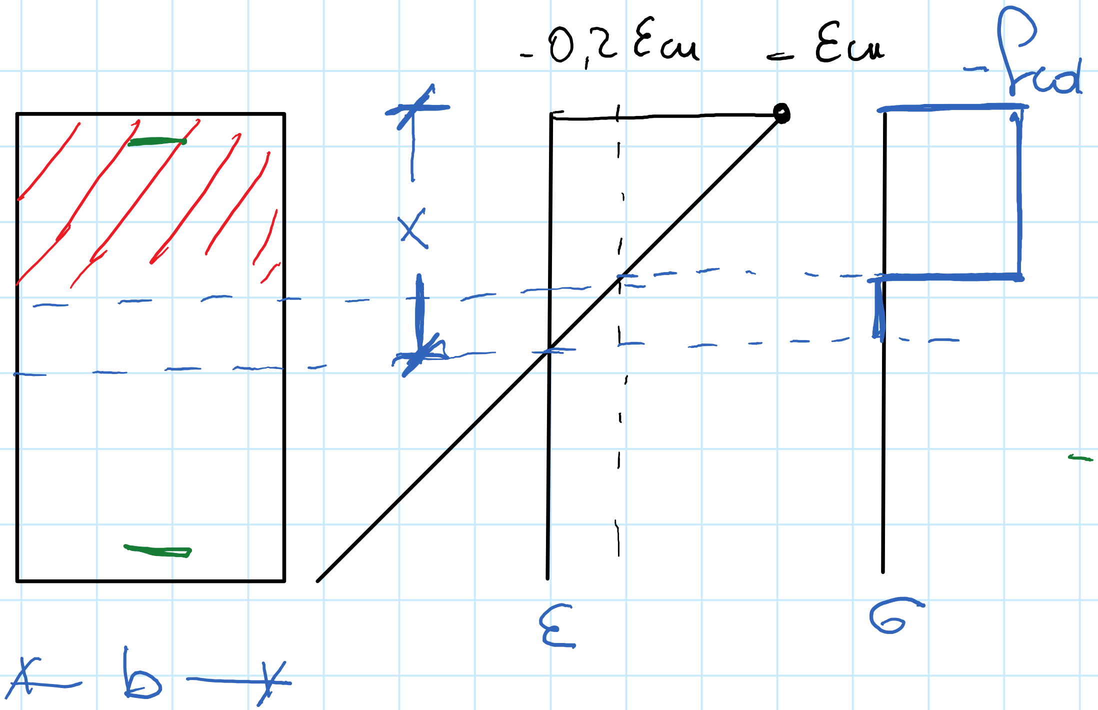
STRESS BLOCK



RISULTATO SIMILE A QUELLO OTTENUTO CON LEGAME PARABOLA RETTANGOLO



$0.8x \leftarrow N_c \quad 0.4x$

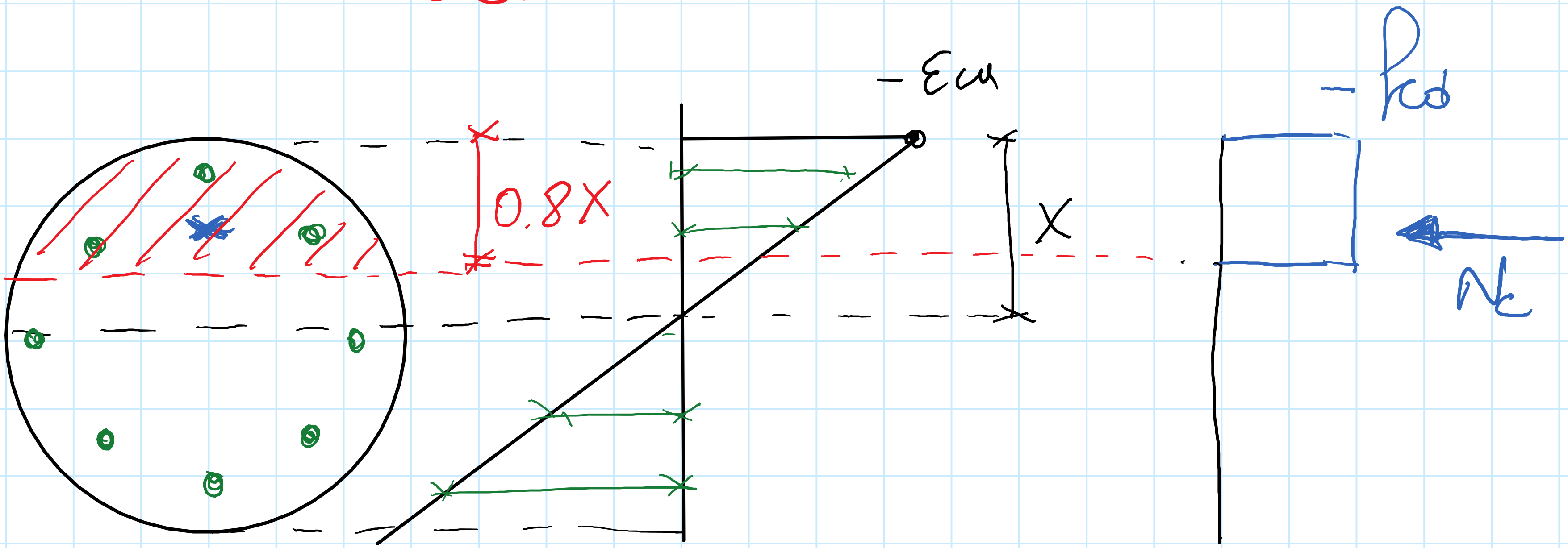
$\Delta x = 0.2x$

$$-\varepsilon_{cu} : x = -0.2\,\varepsilon_{cu} : \Delta x$$

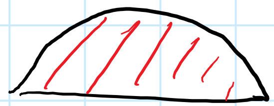
$$\Rightarrow \Delta x = 0.2x$$

$$N_c = -0.8\, b\, x\, f_{cd}$$

SEZIONE GENERICA



$$N_c = -f_{cd} \cdot A_{\text{settore circolare}} \quad (\text{TRATTO } 0{,}8X)$$

APPLICATO NEL BARICENTRO DI 

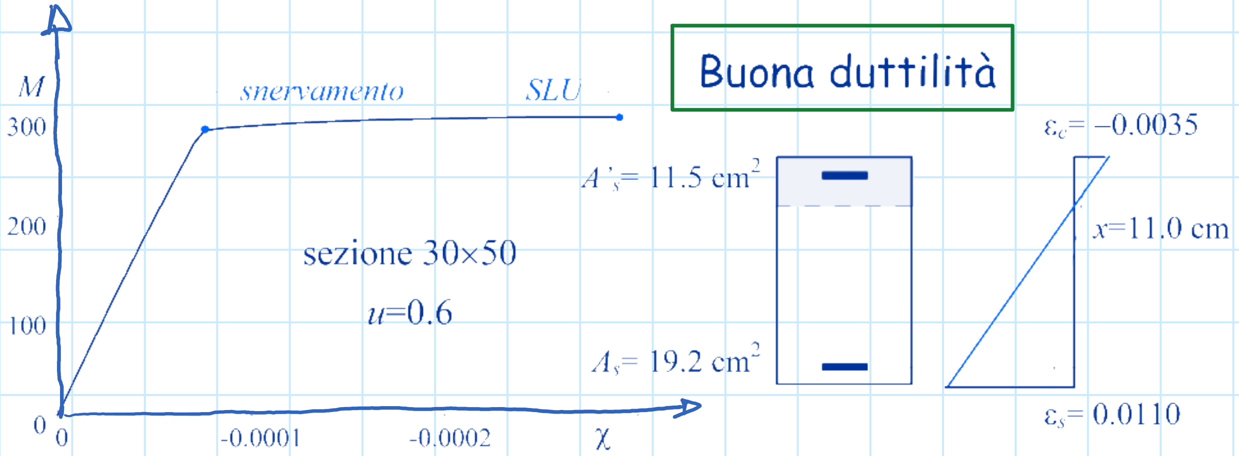
TROVO X: $\quad N_c + \sum N_{s_i} = 0$

DUTTILITÀ

$M_{Rd} = 300\ kNm$

SEZIONE 30x50

Buona duttilità



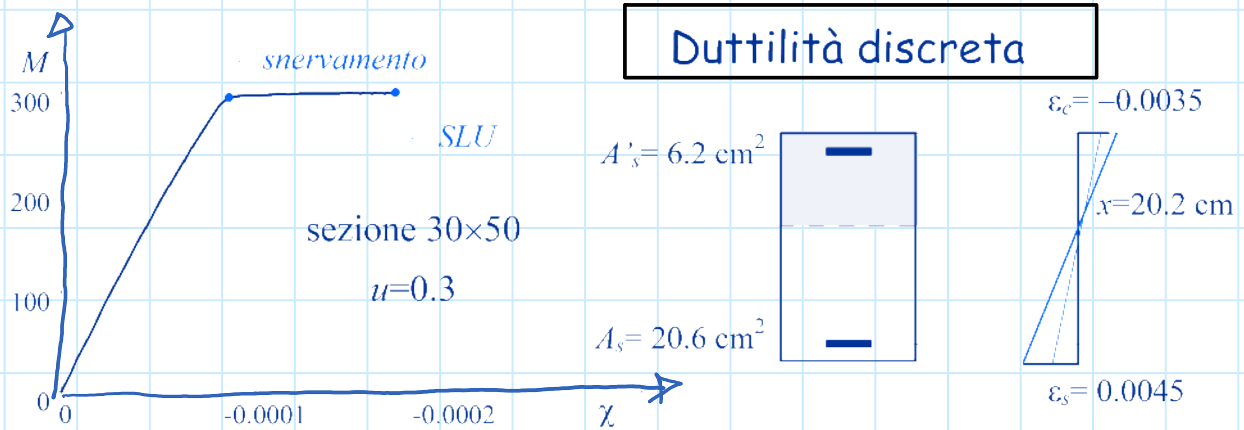
CASO 1

$\varepsilon_s > 1\%$

$x_u = 11\ cm$

$u = A'_s / A_s = 0.6$

Duttilità discreta



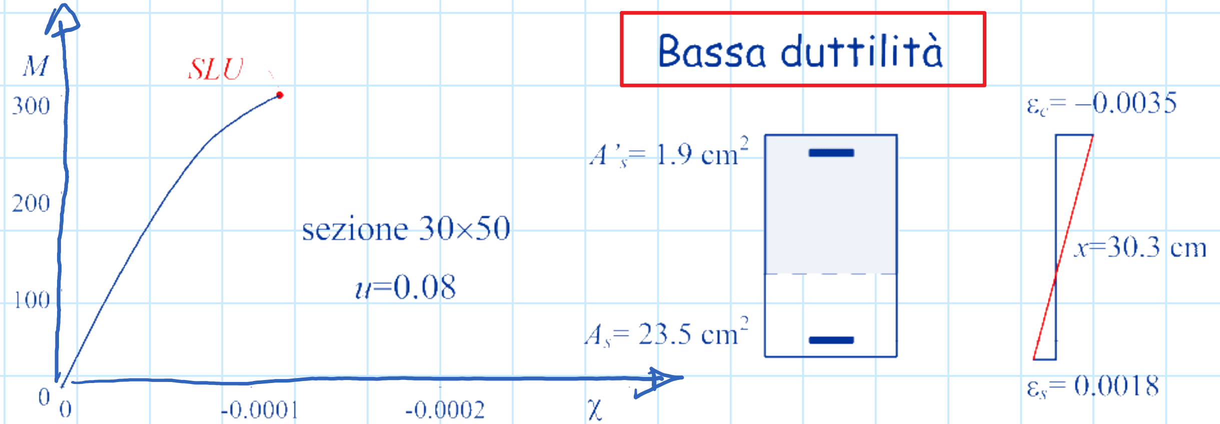
CASO 2

$\varepsilon_{yd} < \varepsilon_s < 1\%$

$x_u = 20.2\ cm$

$u = 0.30$

Bassa duttilità



CASO 3

$\varepsilon_s < \varepsilon_{yd}$

$x_u = 30{,}3\ cm$

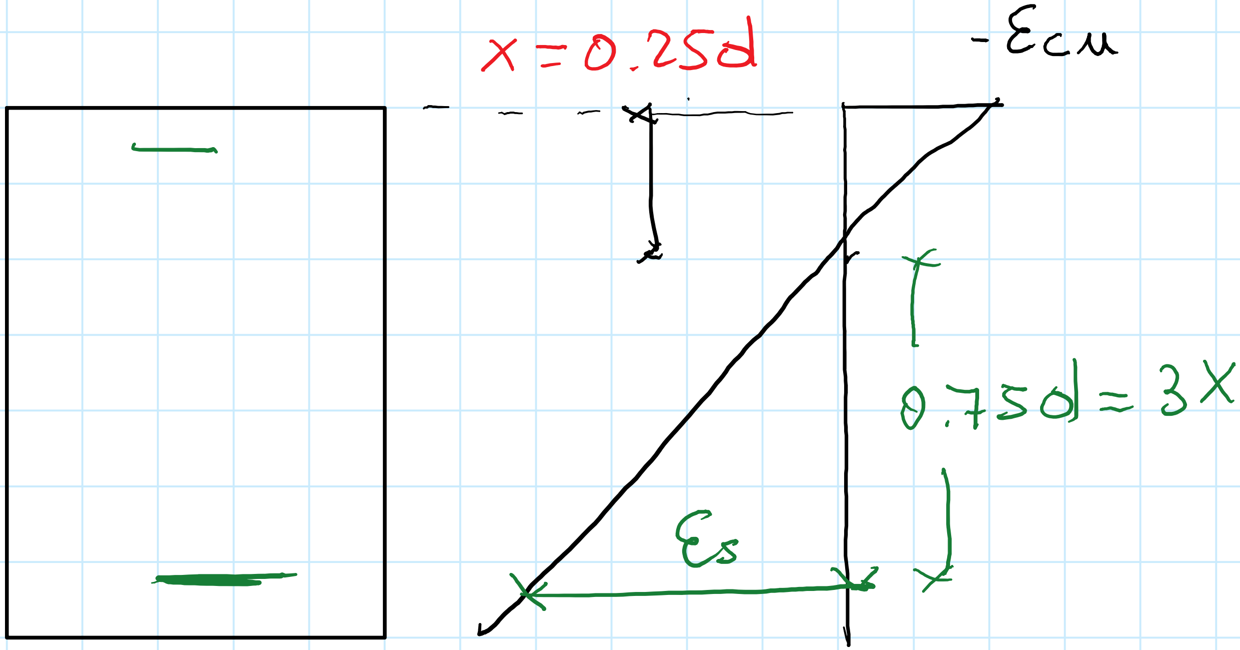
$u = 0{,}08$

RIEPILOGANDO:

ALTA DUTTILITÀ x_u : $\varepsilon_s > 1\%$

MEDIA DUTTILITÀ x_u : $\varepsilon_{yd} < \varepsilon_s < 1\%$

BASSA DUTTILITÀ x_u : $\varepsilon_s < \varepsilon_{yd}$



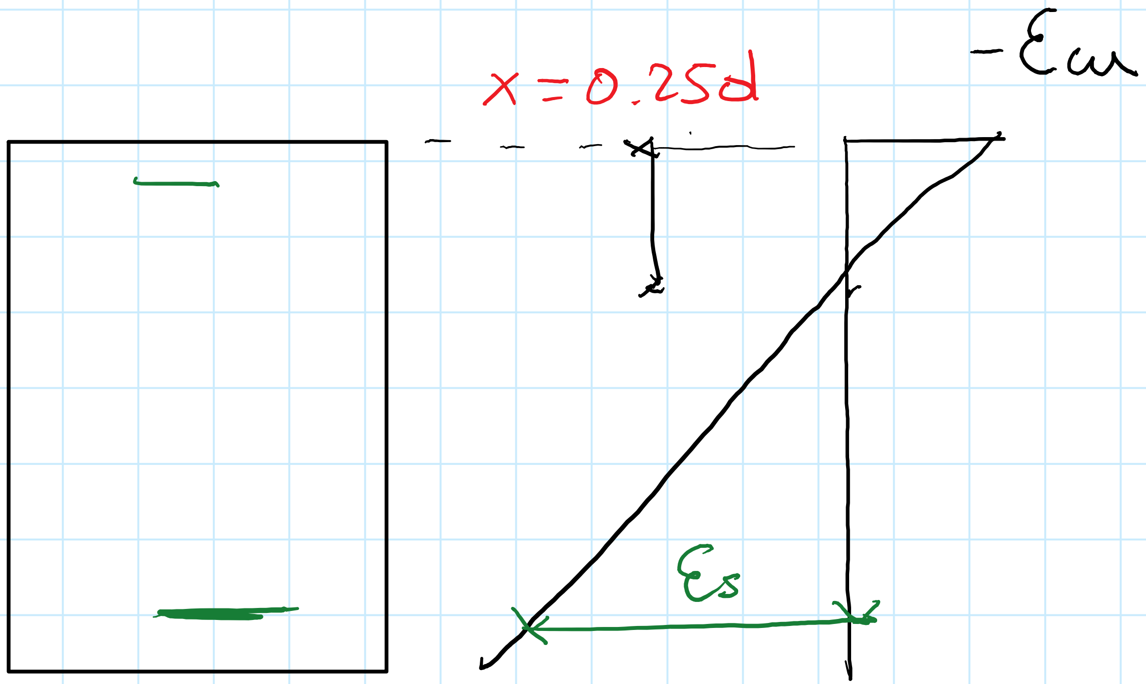
PER AVERE ALTA DUTTILITÀ IMPONGO

$x = 0.25d$

$\downarrow$

$$\varepsilon_s = \frac{0.75\cancel{d}}{0.25\cancel{d}}\varepsilon_{cu} = 3\varepsilon_{cu} = 1{,}05\%$$

PROGETTO A FLESSIONE



DATI:

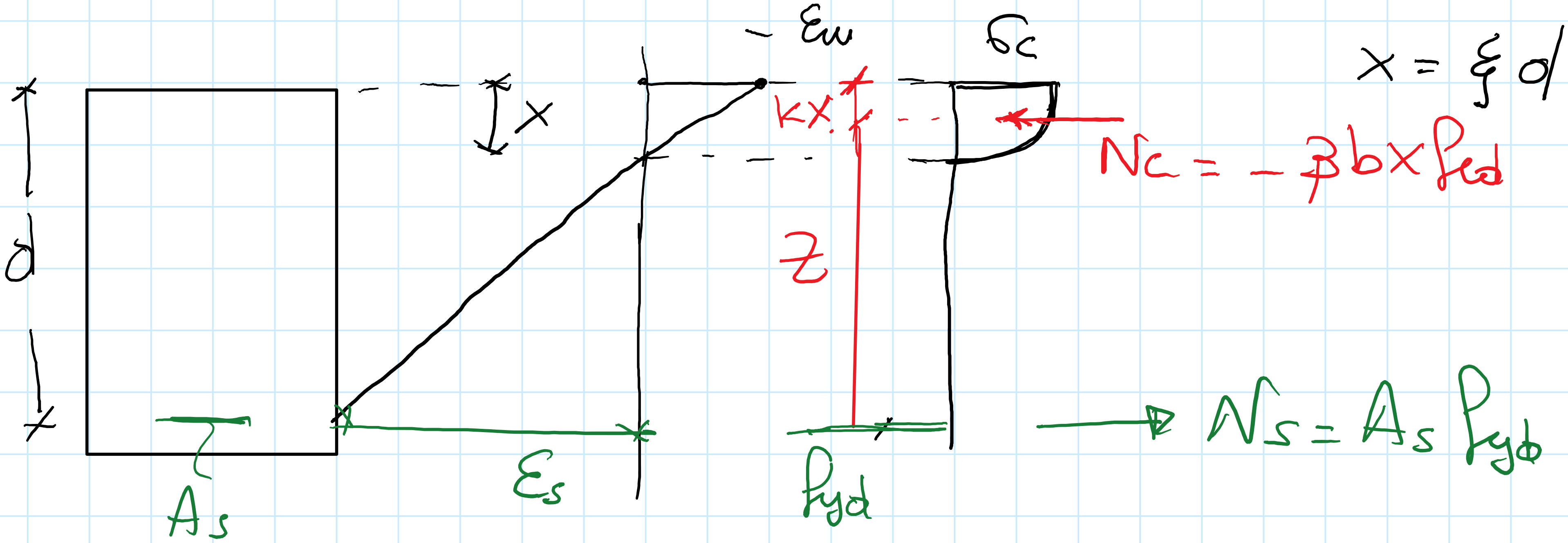
M_{Ed}, BUONA DUTT

$\Rightarrow$ $x = 0.25d = \xi d$

INCOGNITE:

b, h, A_s, A_s'

PROGETTO SEZIONE A SEMPLICE ARMATURA



EQ. ROTAZIONE RISPETTO ALL'ARMATURA

$$M_{Ed} = -N_c\,(d - kx) \qquad \boxed{z = d - kx}$$

$$= \beta b x f_{cd}\,(d - kx) = \beta b \xi d f_{cd}\,(d - k\xi d)$$

$$= bd^2 \cdot \underbrace{\beta \xi f_{cd}\,(1 - k\xi)}_{1/\tau^2}$$

FORMULA PROGETTO SEZIONE

$$\boxed{M = \frac{bd^2}{r^2}}$$

DOVE $\frac{1}{r^2} = \beta \xi f_{cd} (1 - k\xi) \Rightarrow$

$$r = \sqrt{\frac{1}{\beta \xi f_{cd} (1 - k\xi)}}$$

DIPENDE DA
- f_{cd}
- ξ

M [kNm]
b, d [m] $\longrightarrow f_{cd}$ [kN/m²]

ES: C 30/37 $\rightarrow f_{cd} = 17\ MPa = 17 \cdot 10^3\ kN/m^2$

$$r = \sqrt{\frac{1}{0{,}81 \cdot 0{,}25 \cdot 17'000 (1 - 0.416 \cdot 0.25)}} \Rightarrow r = 0.018$$

SE C25/30 $\longrightarrow$ $r = 0.0197$

NOTO $M = \frac{bd^2}{\tau^2} \rightarrow$

TRAVE EMERGENTE

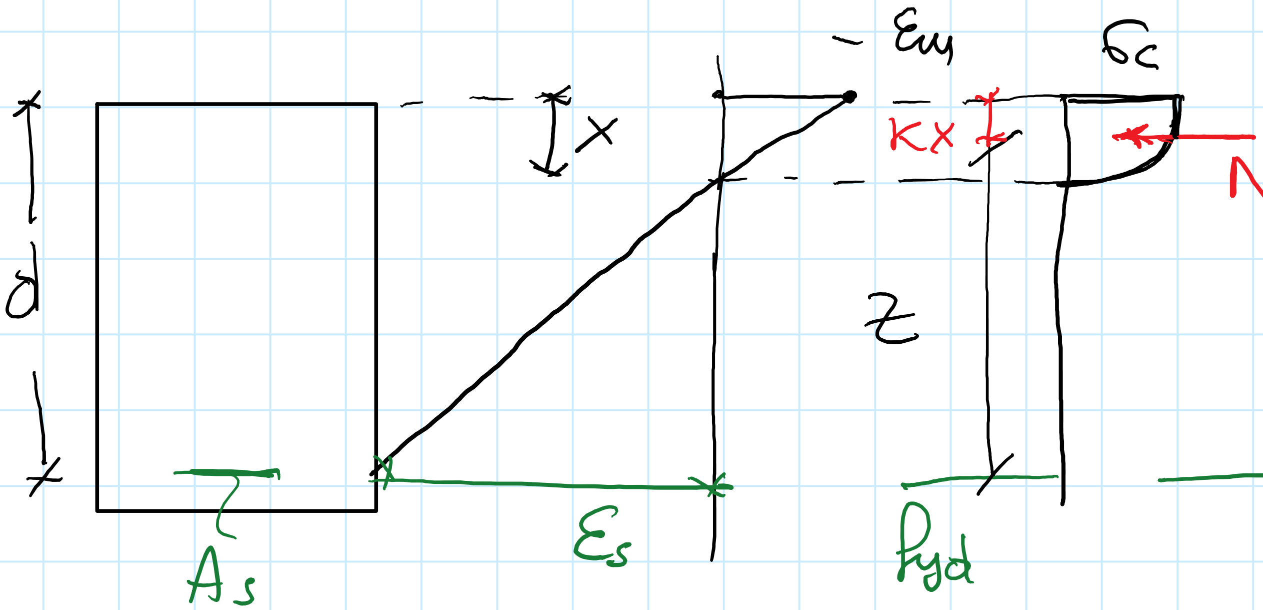
FISSO $b \longrightarrow$ $d = \tau \sqrt{\frac{M}{b}}$

$h = d + c$

TRAVE A SPESSORE

FISSO $d = h_{SOLAIO} - c \longrightarrow$ $b = \tau^2 \frac{M}{d^2}$

PROGETTO ARMATURA



$x = \xi d$

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

$\longrightarrow N_s = A_s f_{yd}$

EQ. ROTAZIONE RISPETTO A N_c

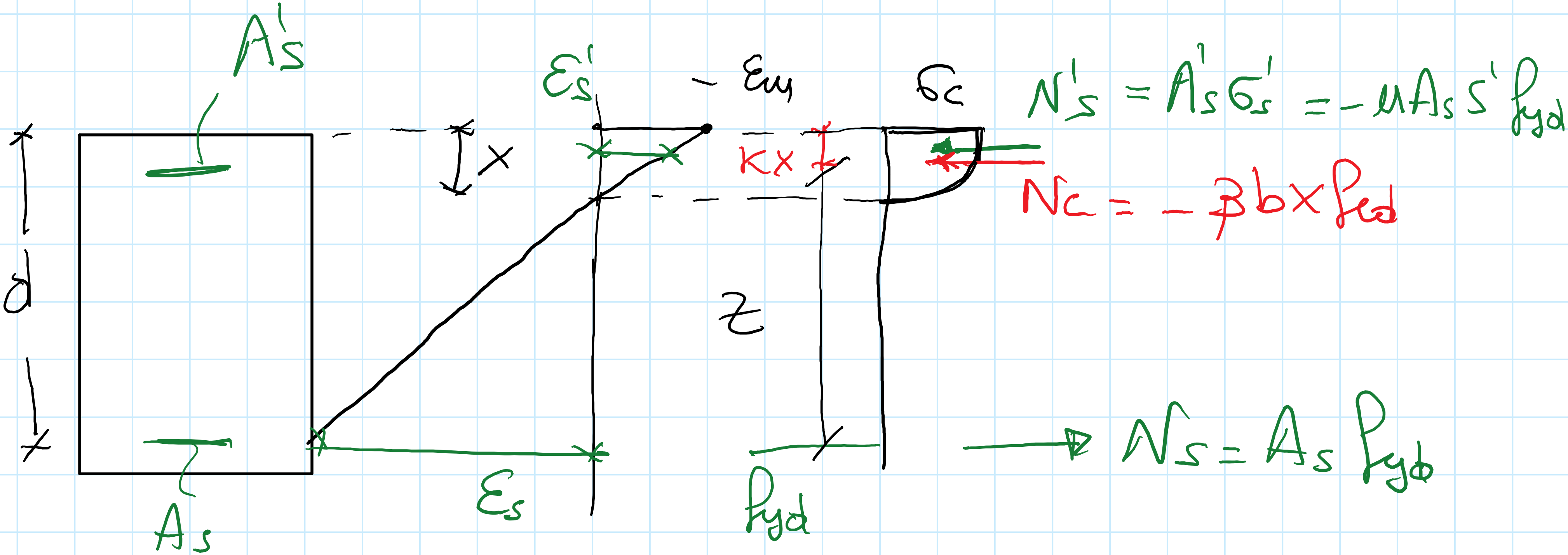
$$M_{Ed} = A_s f_{yd}\, z = A_s f_{yd}\,(d - kx) = A_s f_{yd}\,(d - k\xi d)$$

$$= A_s f_{yd}\, d\,(1 - k\xi) \longrightarrow 1 - 0{,}416 \cdot 0{,}25$$

$$\longrightarrow M_{Ed} = A_s f_{yd} \cdot 0.896\, d \longrightarrow \boxed{A_s = \frac{M_{Ed}}{0{,}9 d\, f_{yd}}}$$

SEZIONE A DOPPIA ARMATURA

FISSO $X = \xi d = 0.25 d$ (DUTTILITÀ)



$A'_s = \mu A_s$; $\sigma'_s = -s' f_{yd}$; $s' = -\dfrac{\varepsilon'_s}{\varepsilon_{yd}} \leq 1$

$$\varepsilon'_s = -\varepsilon_{cu} \frac{(x-c)}{x} = -\varepsilon_{cu} \frac{x/d - c/d}{x/d}$$

SEZIONE A DOPPIA ARMATURA

PONGO $\gamma = c/d \rightarrow \varepsilon'_s = -\varepsilon_{cu} \dfrac{\xi - \gamma}{\xi}$

PER TRAVI EMERGENTI (ES. 30X60) $\rightarrow$

$$\gamma = \frac{c}{d} \simeq \frac{5}{55} = 0.091 \rightarrow \varepsilon'_s = -3.5‰ \, \frac{0.25 - 0.091}{0.25}$$

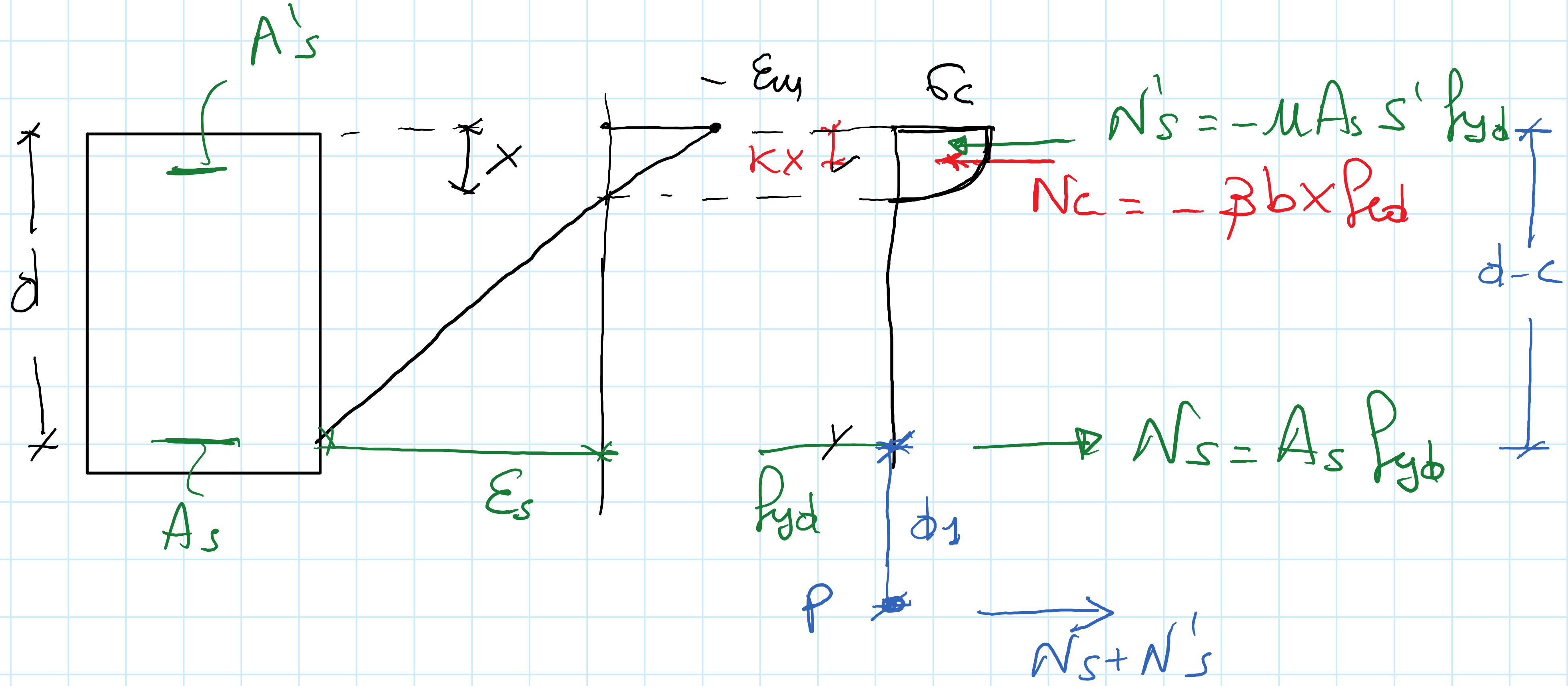
$$= -2‰ \Rightarrow \text{SNERVATA}$$

PER TRAVI A SPESSORE (ES. 80 x 25) $\rightarrow$

$$\gamma = \frac{5}{20} = 0,25 \rightarrow \varepsilon'_s = -3.5‰ \, \frac{0.25 - 0,25}{0,25} = 0$$

$\Rightarrow$ NON SNERVATA

RISULTANTE $N_s + N'_s$

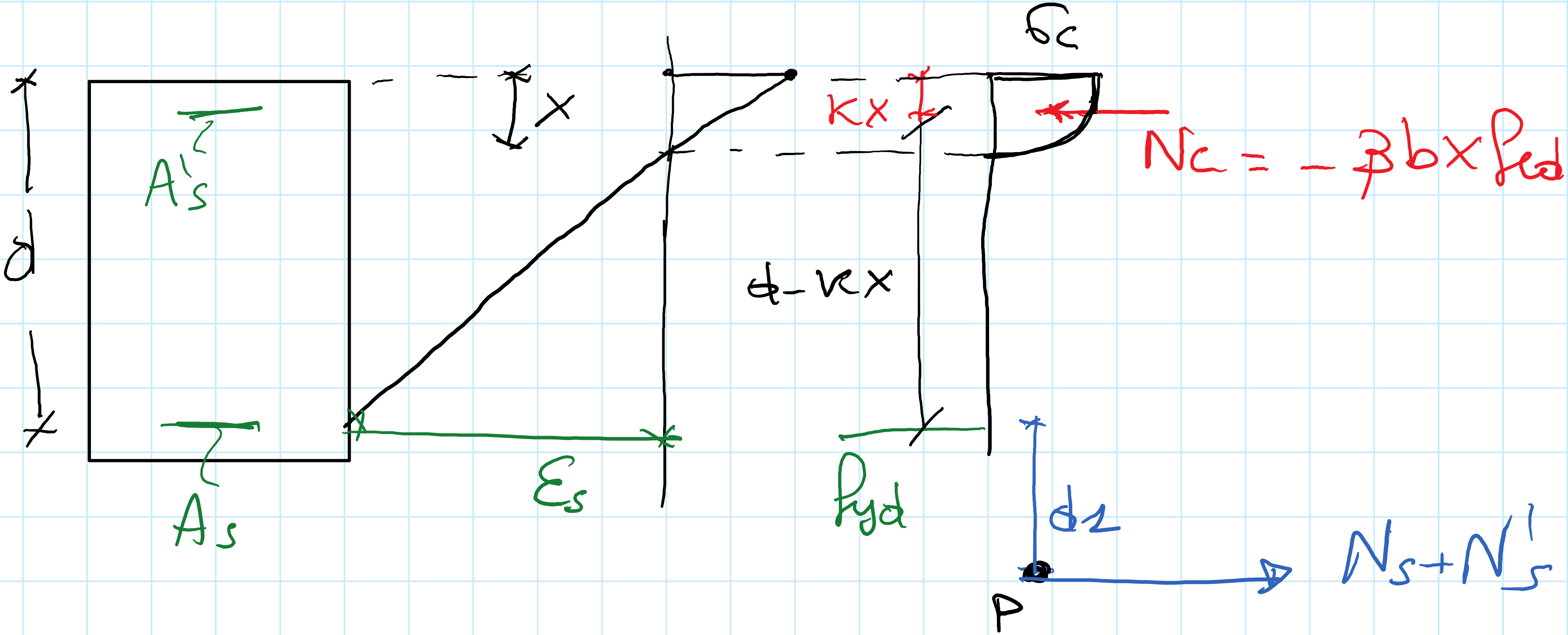


$$N_s d_1 + N'_s (d_2 + d - e) = 0 \Longrightarrow$$

$$\cancel{A_s f_{yd}}\, d_1 - \mu \cancel{A_s}\, s' \cancel{f_{yd}} (d_1 + d - c) = 0 \longrightarrow$$

$$d_1 (1 - \mu s') = \mu s' (d - c) \longrightarrow \boxed{d_1 = \frac{\mu s' (1-\gamma)}{1 - \mu s'} d}$$

PROGETTO DELLA SEZIONE



EQ. RISPETTO A P

$$M_{Ed} = -N_c\,(d_1 + d - kx)$$

$$M_{Ed} = \beta b \underbrace{x}_{\xi d} f_{cd} \cdot \left[\frac{\mu s' (1-\gamma)}{1-\mu s'}\, d + d - k \xi d \right]$$

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

$$M = \underbrace{\underbrace{b d^2 \beta \xi f_{cd} (1-k\xi)}_{1/\tau^2} \cdot \underbrace{\left[\frac{\mu s' (1-\gamma)}{(1-\mu s')(1-k\xi)} + 1 \right]}_{1/k^2}}_{1/\tau'^2}$$

$$\frac{1}{\tau'^2} = \frac{1}{\tau^2} \cdot \frac{1}{k^2} \longrightarrow \tau' = \tau \cdot k$$

$$\frac{1}{k^2} = \frac{\mu s' \cancel{(1-\gamma)}}{(1-\mu s')\cancel{(1-k\xi)}} + 1$$

PER TRAVI EMERGENTI $\longrightarrow$ $\gamma \simeq 0.1 \rightarrow 1-\gamma = 0.9$

$1-k\xi \simeq 0.9$

IN MODO APPROSSIMATO

$$\frac{1}{K^2} \simeq \frac{\mu s'}{1-\mu s'} + 1 = \frac{\cancel{\mu s'} + 1 - \cancel{\mu s'}}{1-\mu s'} \longrightarrow$$

$$K \simeq \sqrt{1-\mu s'} \qquad K < 1 \Rightarrow r' < r$$

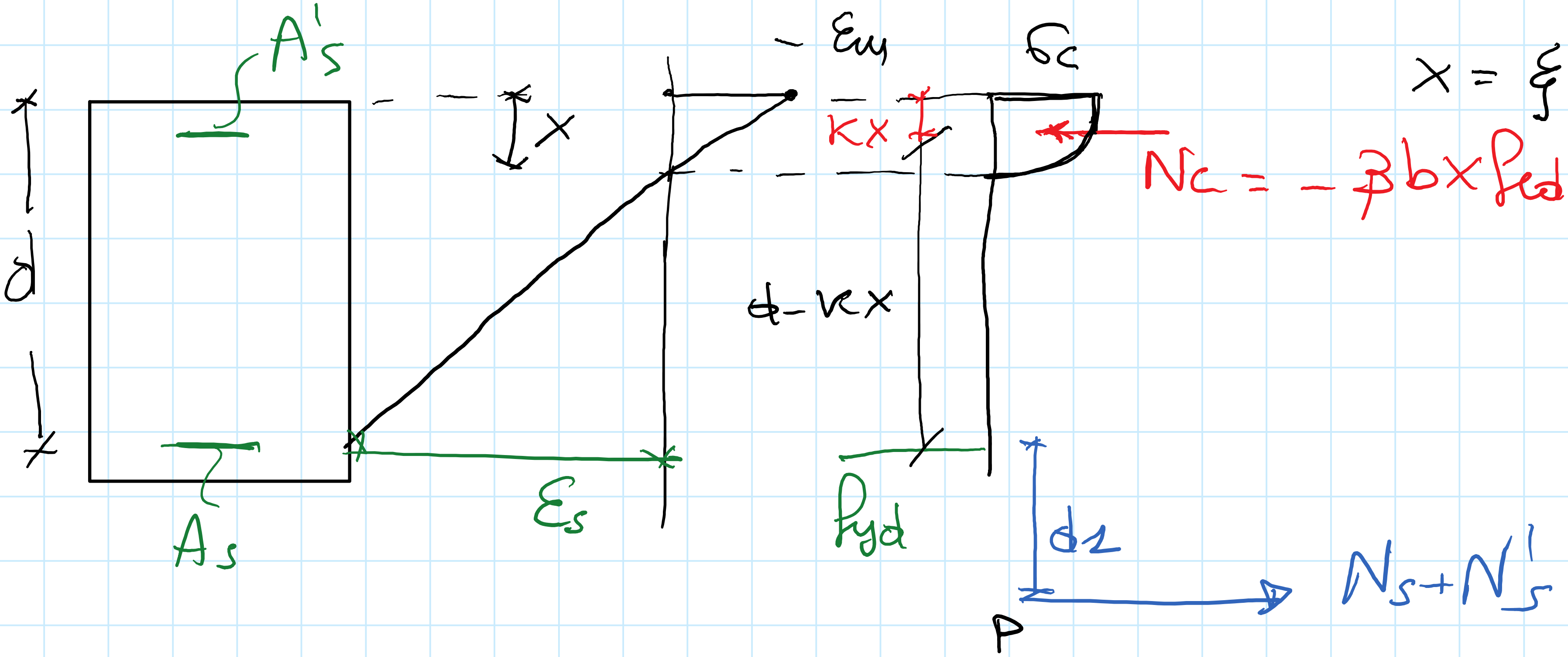
PROGETTO SEZIONE:

$$M = \frac{bd^2}{r'^2} \Rightarrow$$

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

È NECESSARIA UN'ALTEZZA MINORE RISPETTO AL CASO DI SEMPLICE ARMATURA

PROGETTO ARMATURA TESA



$x = \xi d$

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

EQ. ALLA ROTAZ. RISPETTO A N_c $\Rightarrow$

$$M_{Ed} = (N_s + N'_s)(d_1 + d - kx) =$$

$$= (A_s f_{yd} - \mu A_s \delta' f_{yd}) \left[\frac{\mu \delta' (1-\gamma)}{1 - \mu \delta'} d + d - k \xi d \right]$$

$$= A_s f_{yd} (1 - \mu \delta') d \left[\frac{\mu \delta' (1-\gamma)}{1 - \mu \delta'} + 1 - k \xi \right]$$

$$M_{Ed} = A_s f_{yd} \,(1 - \mu s')\, d \left[\frac{\mu s' (1-\gamma)}{1-\mu s'} + 1 - k\xi \right]$$

$$= A_s f_{yd} \cdot d\, (1 - k\xi)\,(1 - \mu s') \cdot \left[\frac{\mu s' (1-\gamma)}{(1-\mu s')(1-k\xi)} + 1 \right]$$

$$= A_s f_{yd}\, d\, (1 - k\xi) \left[\frac{\mu s' \,\cancel{(1-\gamma)}}{\cancel{1-k\xi}} + 1 - \mu s' \right]$$

$$\cong A_s f_{y}\, d\, (1 - k\xi) \left[\cancel{\mu s'} + 1 - \cancel{\mu s'} \right]$$

$$M_{Ed} \simeq A_s f_{yd} \cdot \underbrace{0.9 d}_{z}$$

VALORI DI z/d ($C30/37$, B USO C, $\xi = 0.25$)

TASSO DI LAVORO ARMATURA COMPRESSA

	$\gamma = 0.10$	$\gamma = 0.15$	$\gamma = 0.20$
u	$s' = 1.00$	$s' = 0.72$	$s' = 0.36$
0	0.896		
0.25	0.897	0.888	0.887
0.50	0.898	0.880	0.879

$\boxed{z \simeq 0.9d \quad \text{SEMPRE}}$

TRAVI EMERGENTI

TRAVI A SPESSORE NON TROPPO BASSE

PROGETTO ARMATURA COMPRESSA

NOTO M_{Ed} $\Rightarrow$ SEZIONE : $d = r' \sqrt{\dfrac{M_{Ed}}{b}}$

ARMATURA TESA : $A_s = \dfrac{M_{Ed}}{0.9\, d\, f_{yd}}$

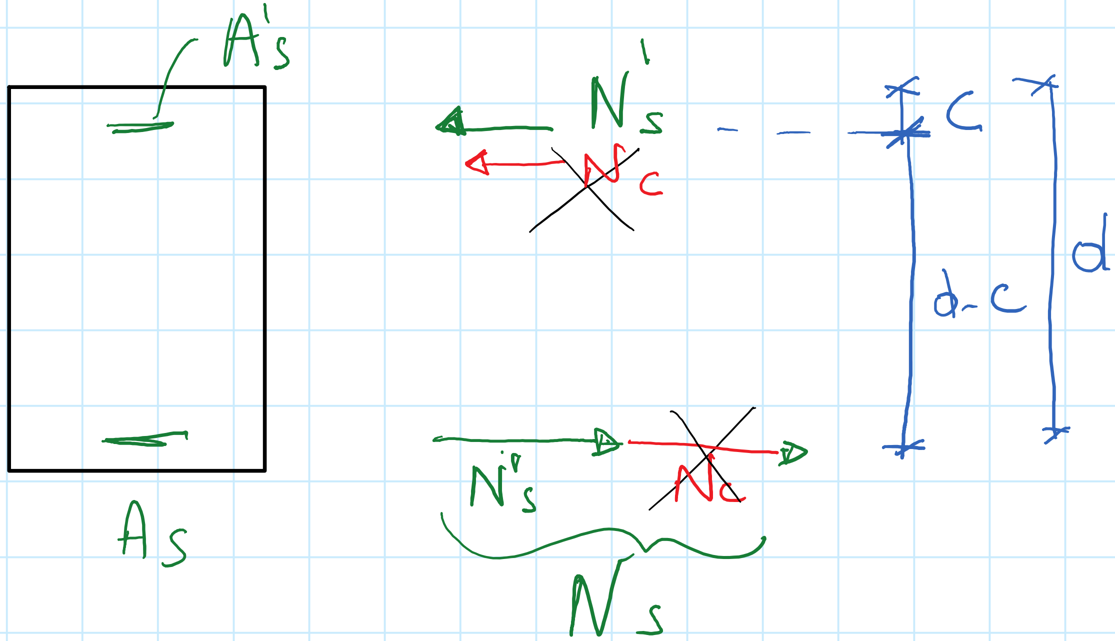
$A'_s = ?$

PROGETTO A'_s PER PORTARE

$$\Delta M = M_{Ed} - \underbrace{\frac{b d^2}{r'^2}}_{\text{MOMENTO RESISTENTE DEL CLS IN ASSENZA DI } A'_s}$$

SE $M_{Ed} < \dfrac{b d^2}{r'^2} \rightarrow A'_s = 0$

PROGETTO ARMATURA COMPRESSA



$$\left.\begin{aligned} N'_s &= -\frac{\Delta M}{(d-c)} \\ N'_s &= -s' A'_s f_{yd} \end{aligned}\right\} \rightarrow A'_s = \frac{\Delta M}{s' f_{yd} (d-c)}$$

$$s' = -\frac{\varepsilon'_s}{\varepsilon_{yd}} \le 1 \Rightarrow$$

$$\varepsilon'_s = -\varepsilon_{cu} \frac{(x-c)}{x} = -\varepsilon_{cu} \frac{\xi-\gamma}{\xi} \longrightarrow s' = \frac{\varepsilon_{cu}}{\varepsilon_{yd}} \frac{\xi-\gamma}{\xi}$$

VALORI r' (C30/37 ; B450C ; $\xi = 0.25$)

	$\gamma = 0.10$	$\gamma = 0.15$	$\gamma = 0.20$
u	$s' = 1.00$	$s' = 0.72$	$s' = 0.36$
0	0.0180		
0.25	0.0156	0.0164	0.0173
0.50	0.0127	0.0146	0.0165

r' SI RIDUCE POCO RISPETTO A r PERCHÉ IN TRAVI A SPESSORE s' È BASSO

AL CRESCERE DI u SI RIDUCE MOLTO r' PERCHÉ A'_s È SNERVATA IN TRAVI EMERGENTI

QUALE VALORE DI r' USARE?

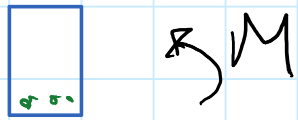
VALORI SUGGERITI r'

SE USO r' BASSI → $d = r'\sqrt{\frac{M}{b}}$ ⇒ d BASSA

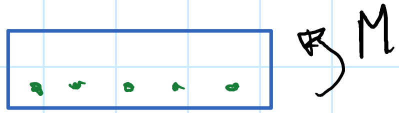
⇒ $A_s = \frac{M}{0{,}9\, d\, f_{yd}}$ (FORTE ARMATURA TESA)

MINIMO VALORE DI r' TALE CHE

$A_s \simeq 1\%\, bd$ TRAVI EMERGENTI



$A_s \simeq 1.5\%\, bd$ TRAVI A SPESSORE



IN GENERALE $A_s = \rho_s\, bd$ →

$$M = A_s\, 0{,}9\, d\, f_{yd} = \rho_s\, b d \cdot 0{,}9\, d\, f_{yd} = bd^2 \cdot \underbrace{\rho_s\, 0.9\, f_{yd}}_{1/r_s^2} = \frac{bd^2}{r_s^2}$$

$$r_s = \frac{1}{\sqrt{\rho_s\, 0{,}9\, f_{yd}}} \rightarrow r_s = \frac{1}{\sqrt{\frac{1}{100}\cdot 0{,}9 \times 391.3\cdot 10^3}} \rightarrow \boxed{r_s = 0{,}017}$$

ESEMPIO

PROGETTARE TRAVE EMERGENTE CON

$M_{Ed} = 300$ KNm

MATERIALI:
C30/37
B450C

DA $M = \frac{bd^2}{r'^2} \rightarrow d = r' \sqrt{\frac{M}{b}}$

$b = 0{,}30$ m $\longrightarrow$ $d = 0{,}017 \sqrt{\frac{300}{0{,}30}} = 0{,}54$ m

$h \geq d + c = 0{,}54 + 0{,}05 = 0{,}59$ m

FISSO $h = 60$ cm $\Rightarrow d = 55$ cm

$$A_s = \frac{M}{0{,}9\, d\, f_{yd}} = \frac{300 \text{ KN}\cancel{m}}{0{,}9 \times 0{,}55\,\cancel{m} \times 391.3 \text{ N/mm}^2} \times 10 = 15.48 \text{ cm}^2$$

$A_{\phi 20} = 3.14 \rightarrow 15.48 / 3.14 = 4.93 \Rightarrow 5\phi 20$

È NECESSARIA A'_s?

$$M_{Rd,\, A'_s=0} \quad \frac{bd^2}{r^2} = \frac{0{,}30 \times 0{,}55^2}{0.018^2} = 280.1 \text{ KNm}$$

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

$\Rightarrow$

PROGETTO A'_s PER $\Delta M = 300 - 280.1 = 20 \text{ KNm}$

$$A'_s = \frac{\Delta M}{s' f_{yd} (d - c)}$$

$$s' = -\frac{\varepsilon'_s}{\varepsilon_{yd}} = \frac{\varepsilon_{cu}}{\varepsilon_{yd}} \frac{(\xi - \gamma)}{\xi} = \frac{3.5}{1.96} \times \frac{(0.25 - 5/55)}{0.25} = \cancel{1.14}\ 1.0$$

$$A'_s = \frac{20 \text{ KNm}}{1 \cdot 391{,}3 \frac{N}{mm^2} (0{,}55 - 0.05) m} \times 10 = 1 \text{ cm}^2$$

DISPONGO ALMENO $A'_s = 0.25 A_s$

CONSIDERAZIONI

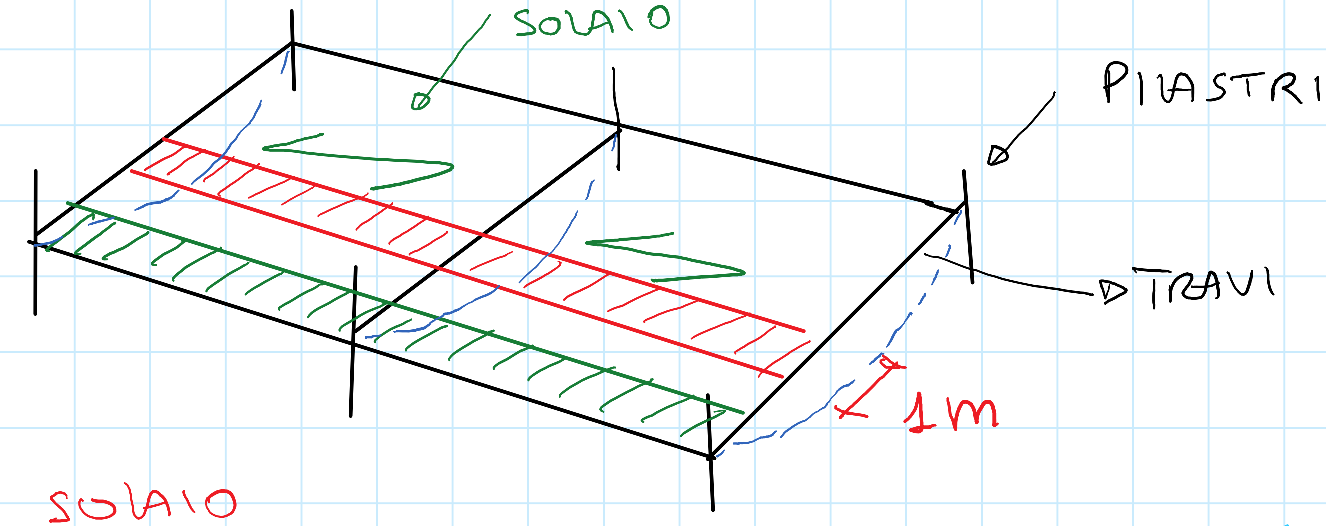
ARMATURA COMPRESSA NECESSARIA MODESTA

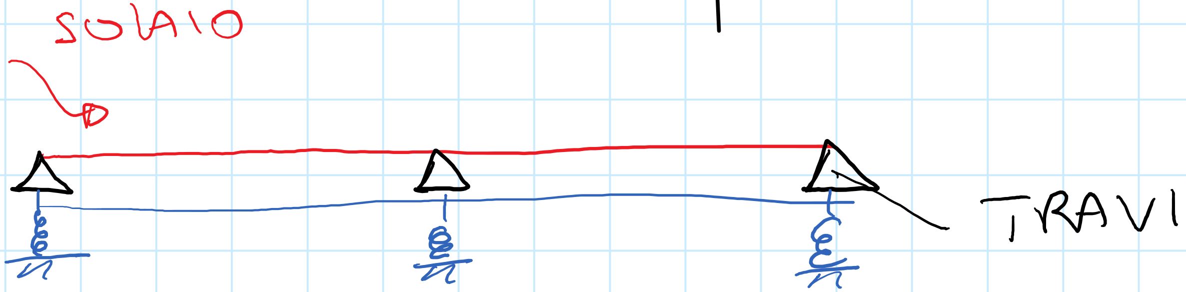
PERCHÉ
- PER C30/37 $r = 0{,}018$
- PER LIMITARE A_s $r' = 0.017$
- r E r' SONO SIMILI

PER C25/30 $\Rightarrow$ $r = 0{,}0197$

$\Rightarrow$ SERVIREBBE MAGGIORE A'_s

MODELLO SOLAIO

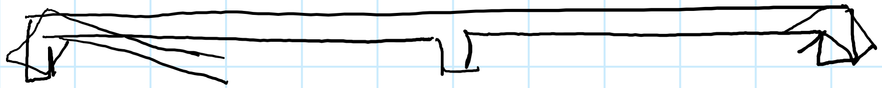




SOLO I CEDIMENTI DIFFERENZIALI PRODUCONO SOLLECITAZIONI SUL SOLAIO

↓

CONSIDERO APPOGGI (RIGIDEZZA TORSIONALE TRAVI MODESTA)



CRITERIO DI FASCIA

IN PROSSIMITÀ DEI PILASTRI ANCHE LA LORO K FLESSIONALE VINCOLA LA ROTAZIONE