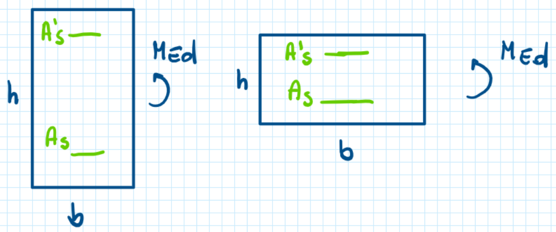


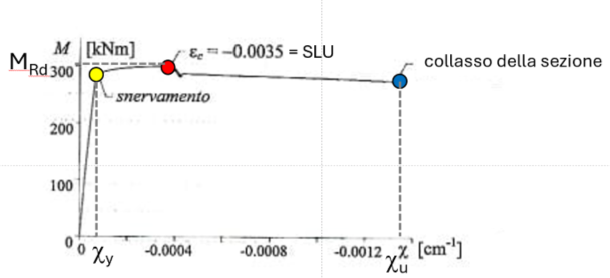
$\underbrace{b, h}_{CLS}$ $\underbrace{A'_s, A_s}_{ARM.}$

① REQUISITO DI RESISTENZA

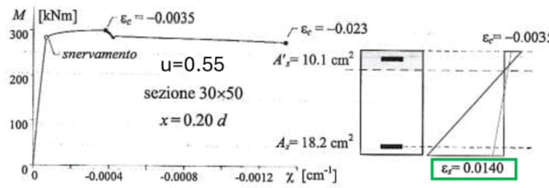
$$\boxed{M_{Rd} = M_{Ed}}$$

② REQUISITO DI DUTTILITA'

Diagramma Momento – curvatura di una sezione in c.a.

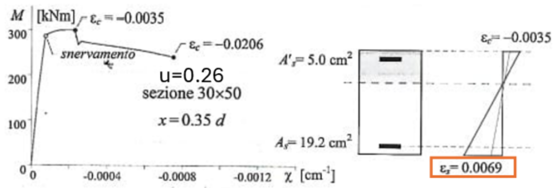


1) Sezione molto duttile



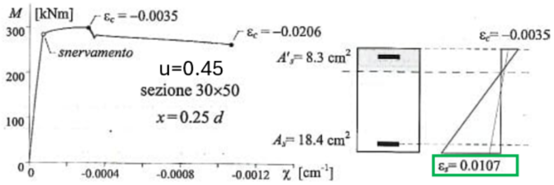
χ_y=-0.000071, χ_u=-0.001338, χ_u/χ_y= 18.8

3) Sezione mediamente duttile



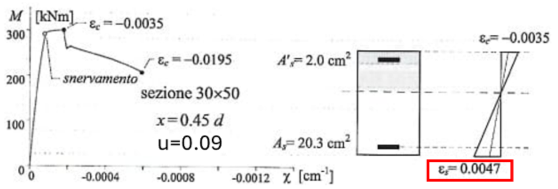
χ_y=-0.0000768, χ_u=-0.000761, χ_u/χ_y= 9.9

2) Sezione duttile



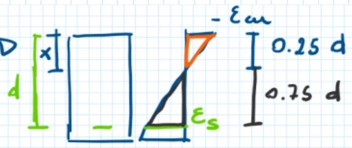
χ_y=-0.000073, χ_u=-0.001070, χ_u/χ_y= 14.7

4) Sezione mediamente (quasi poco) duttile



χ_y=-0.0000848, χ_u=-0.000594, χ_u/χ_y= 7.0

$\varepsilon_s \geq 0.01 \Longleftrightarrow$



$$\boxed{\xi = \frac{x}{d} = 0.25}$$

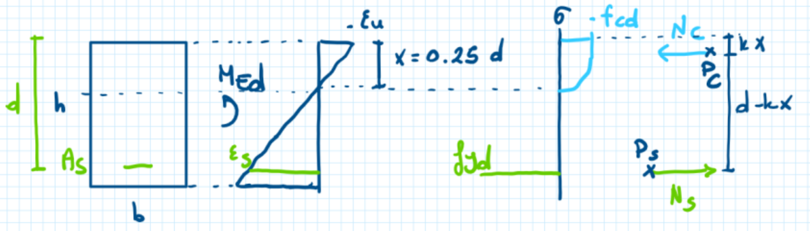
$$\frac{\varepsilon_s}{0.75\,\cancel{d}} = \frac{\cancel{-}\varepsilon_{cu}}{\cancel{-}0.25\,\cancel{d}} \Rightarrow \varepsilon_s = \frac{0.75}{0.25}\varepsilon_{cu}$$

$$\varepsilon_s = \frac{0.75}{0.25}\,0.0035 = 0.0105$$

FORMULE DI PROGETTO SEZIONI RETTANGOLARI

1. SEZIONI A SEMPLICE ARMATURA ($A'_s = 0$)
2. SEZIONI A DOPPIA ARMATURA

1. SEZIONI A SEMPLICE ARMATURA



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

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

PROG. LA SEZ. IN CLS :

POLO P_s :

$$M = -N_c\,(d - kx)$$

$$M = +\beta\, b\, \underset{\xi d}{x}\, f_{cd}\, d \left(1 - k \underset{\xi}{\frac{x}{d}}\right) \qquad \xi = \frac{x}{d} \Rightarrow x = \xi d$$

$$M = +\beta\, b\, \xi\, d\, f_{cd}\, d\,(1 - k\xi)$$

$$M = b\, d^2 \underbrace{\beta\, \xi\, f_{cd}\,(1 - k\xi)}_{\frac{1}{r^2}} \qquad r = \frac{1}{\sqrt{\beta\, \xi\, f_{cd} \times 10^3\,(1 - k\xi)}} = \frac{1}{\sqrt{0.81 \times 0.25 \times 14.17 \times 10^3\,(1 - 0.416 \times 0.25)}} = 0.0197$$

$$M = \frac{b d^2}{r^2}$$

C 25/30 $f_{cd} = 14.17$ MPa

$M \to [kNm]$ $\quad f_{cd} \to \left[\frac{kN}{m^2}\right] \to 10^3$

$b, d \to [m]$

$$M = M_{Ed} = \frac{b d^2}{r^2}$$

PROG. TRAVI EMERGENTI : fisso b $\Rightarrow$ $\boxed{d = \sqrt{\frac{M_{Ed}\, r^2}{b}} = r\sqrt{\frac{M_{Ed}}{b}}}$

PROG. TRAVE SPESSORE : fisso d (da solaio) $\Rightarrow$ $\boxed{b = M_{Ed}\,\frac{r^2}{d^2}}$

PROG. ARM. TESA A_s :

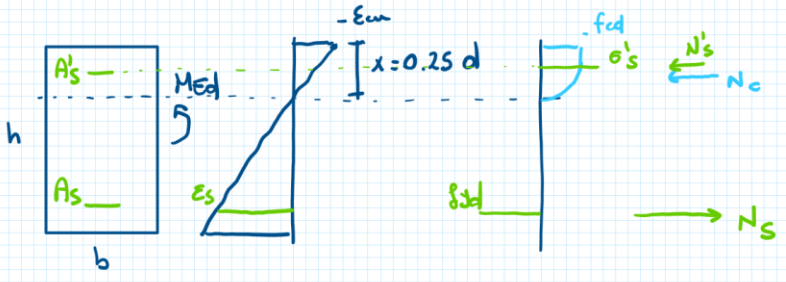
POLO P_c :

$$N_s\,(d - kx) = M \qquad M = M_{Ed} \Rightarrow \boxed{A_s = \frac{M_{Ed}}{0.9\, d\, f_{yd}}}$$

$$A_s\, f_{yd}\, d\, \underbrace{(1 - k\xi)} = M$$

$$1 - 0.416 \cdot 0.25 = 0.\cancel{896}\ 0.9$$

② SEZIONE A DOPPIA ARMATURA



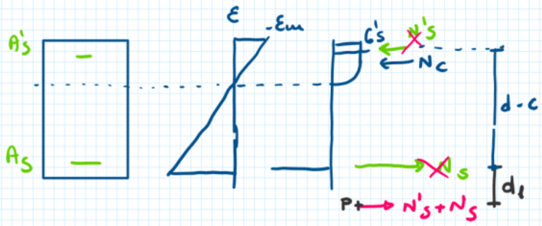
$$N_c = -\beta\, b\, x\, f_{cd}$$

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

$$N'_s = A'_s\, \sigma'_s = -\mu A_s s' f_{yd}$$

$$\begin{cases} A'_s = \mu A_s \\ \sigma'_s = -s' f_{yd} \quad (s' \leq 1) \end{cases}$$

MI RICONDUCO A $N'_s + N_s$:



$$(N'_s + N_s) = N'_s + N_s$$

$$|N'_s + N_s| < |N_s|$$

$$M_{N'_s + N_s} = M_{N'_s} + M_{N_s}$$

Ricavo d_1:

$$-N'_s\,(d_1 + d - c) - N_s\, d_1 = 0$$

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

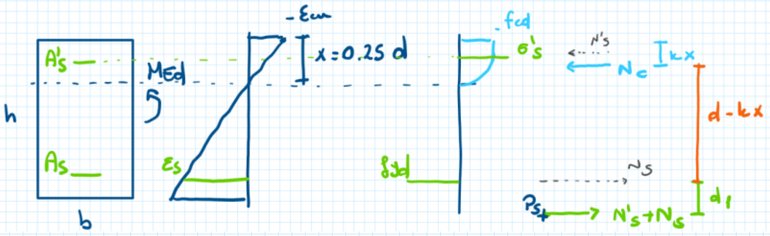
$$\underbrace{\mu A_s s' f_{yd}\, d_1} + \mu A_s s' f_{yd}\,(d - c) - \underbrace{A_s f_{yd}\, d_1} = 0$$

$$\cancel{A_s}\,\cancel{f_{yd}}\, d_1\,(\mu s' - 1) + \mu \cancel{A_s}\, s' \cancel{f_{yd}}\,(d - c) = 0$$

$$d_1\,(\mu s' - 1) = -\mu s' d \left(1 - \overset{\gamma}{\frac{c}{d}}\right) \qquad \gamma = \frac{c}{d}$$

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

MI RICONDUCO A UN SISTEMA DI DUE FORZE :



PROG. LA SEZ. IN CLS :

POLO P_s :

$$M = -N_c\,(d_1 + d - kx)$$

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

$$M = \beta\, b\, \xi d\, f_{cd}\, d \left(\frac{d_1}{d} + 1 - k \overset{\xi}{\frac{x}{d}}\right)$$

$$M = b d^2 \beta \xi f_{cd} (1 - k\xi) \left[\frac{d_1}{d(1-k\xi)} + 1 \right]$$

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

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

$$\frac{1}{z^2} \cdot \frac{1}{K^2} = \frac{1}{z'^2}$$

$$\boxed{M = \frac{b d^2}{z'^2}}$$

PROG. TRAVI EMERGENTI : fisso b $\Rightarrow$ $\boxed{d = \sqrt{\frac{M_{Ed} \, z'^2}{b}} = z' \sqrt{\frac{M_{Ed}}{b}}}$

PROG. TRAVE SPESSORE : fisso d (da solaio) $\Rightarrow$ $\boxed{b = M_{Ed} \frac{z'^2}{d^2}}$

OSSERVO z':

$$z' = z K$$

↳ STUDIO K

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

$\gamma = \frac{c}{d} \approx 0.1$ TRAVI EMERGENTI

$1 - k\xi = 0.\cancel{896}$ 0.9

$$\frac{1}{K^2} = \frac{us'}{1-us'} + 1 \quad \Rightarrow \quad \frac{1}{K^2} = \frac{\cancel{us'} + 1 - \cancel{us'}}{1-us'}$$

$$\frac{1}{K^2} = \frac{1}{1-us'}$$

$$\boxed{K = \sqrt{1-us'}} < 1$$

$$\Downarrow$$

$$z' = zK < z$$

Calcestruzzo:		f_{ck} =	25.0	MPa	f_{cd} =	14.17	MPa
Acciaio:		f_{yk} =	450.0	MPa	f_{yd} =	391.3	MPa
					ξ = x/d =	0.2500	
				TR. EMER.		TR. SPESS.	
		γ =	0.05	0.10	0.15	0.20	0.25
		s' =	1.0000	1.0000	0.7156	0.3578	0.0000
u =	0.00	r =			0.0197		
u =	0.10	r' =	0.0187	0.0187	0.0190	0.0194	0.0197
u =	0.20	r' =	0.0175	0.0176	0.0183	0.0191	0.0197
u =	0.30	r' =	0.0164	0.0165	0.0176	0.0187	0.0197
u =	0.40	r' =	0.0151	0.0153	0.0168	0.0184	0.0197
u =	0.50	r' =	0.0137	0.0139	0.0160	0.0181	0.0197

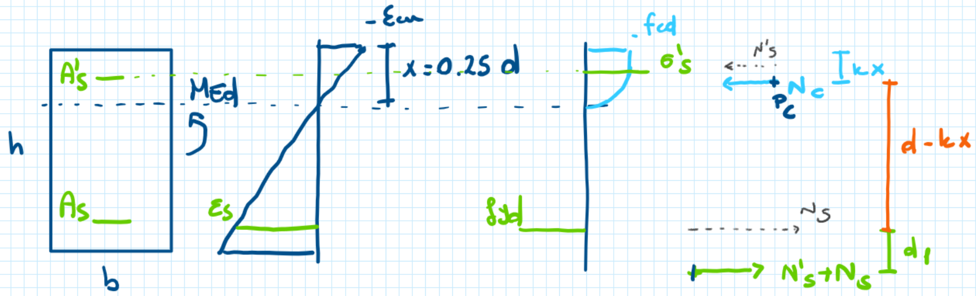
$s' \Rightarrow \quad \sigma'_s = -s f_{yd}$

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

TRAVE EMERG. : $\gamma = \frac{c}{d} \approx 0.1 \qquad s' = \frac{0.25 - 0.1}{0.25} \frac{0.0035}{0.00196} = \cancel{1.07}\ 1.0$

TRAVE A SPESS. : $\gamma = \frac{c}{d} \approx 0.2 \qquad s' = \frac{0.25 - 0.2}{0.25} \frac{0.0035}{0.00196} = 0.36$

PROG. L'ARMATURA TESA A_s:



Polo su P_c: $(N'_s + N_s)(d_1 + d - kx) = M$

$$(-u A_s s' f_{yd} + A_s f_{yd})(d_1 + d - kx) = M$$

$$A_s f_{yd} (1 - us')\, d \left(\frac{d_1}{d} + 1 - k \overbrace{\frac{x}{d}}^{\xi}\right) = M$$

$$A_s f_{yd}\, d\, (1 - us') \underbrace{(1 - k\xi)}_{\approx 0.9} \left[\frac{d_1}{d\,(1 - k\xi)} + 1\right] = M$$

$$A_s f_{yd}\, d\ 0.9\ (1 - us') \left[\frac{us' \cancel{d}}{(1 - us') \cancel{d}} \overbrace{\frac{(1 - \gamma)}{(1 - k\xi)}}^{\approx 1} + 1\right] = M$$

$$0.9\ d\ A_s f_{yd} (1 - us') \left[\frac{us'}{1 - us'} + 1\right] = M$$

$$0.9\ d\ A_s f_{yd} \cancel{(1 - us')} \left[\frac{\cancel{us'} + 1 - \cancel{us'}}{\cancel{1 - us'}}\right] = M$$

$$M = 0.9\ d\ A_s f_{yd}$$

$$M = M_{Ed} \implies \boxed{A_s = \frac{M_{Ed}}{0.9\ d\ f_{yd}}}$$