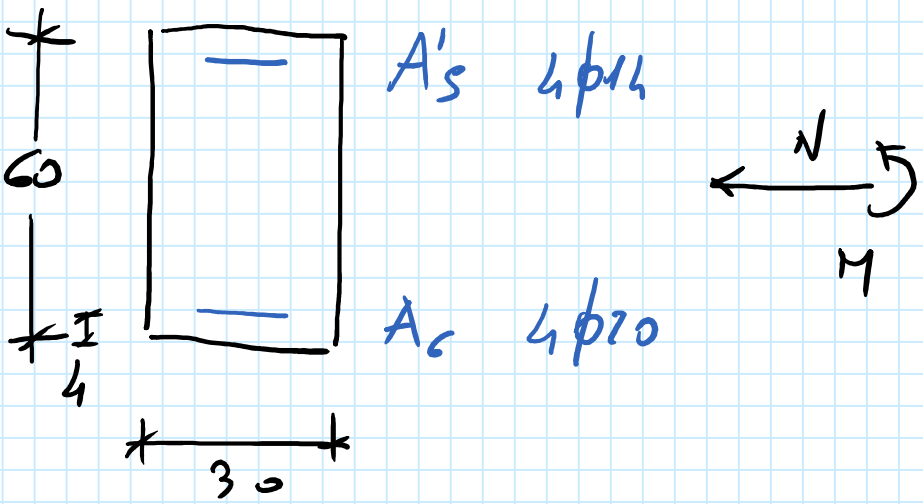


C30/37

B450C

$N = -1000\ kN$

$M = 150\ kN\,m$

$A'_s = 6,16\ cm^2$

$A_s = 12,56\ cm^2$

$$d_c = e + \frac{h}{2} = \frac{M}{N} + \frac{h}{2} = \frac{150}{-1000} \times 10^2 + 30 = 15\ cm$$

1. Determinazione dell'asse neutro

$$x^3 - 3 d_c x^2 + \frac{6n}{b}\left[A'_s (c - d_c) + A_s (d - d_c)\right] x +$$

$$- \frac{6n}{b}\left[A'_s c (c - d_c) + A_s d (d - d_c)\right] = 0$$

$A = 1$

$B = -3 d_c = -3 \times 15 = -45$ cm

$$C = \frac{6 \times 15}{30} \times \left[6{,}16 \times (4 - 15) + 12{,}56 \times (56 - 15)\right] = 1341{,}6 \text{ cm}^2$$

$$D = -\frac{6 \times 15}{30} \times \left[6{,}16 \times 4 \times (4 - 15) + 12{,}56 \times 56 \times (56 - 15)\right] = -85700{,}2 \text{ cm}^3$$

Risolvo per tentativi ...

$x = 51{,}4$ cm

2. Determino S_n

$$S_n = -\frac{b x^2}{2} - n A'_s (x - c) + n A_s (d - x)$$

$$= -\frac{30 \times 51{,}4^2}{2} - 15 \times 6{,}16 \times (51{,}4 - 4) + 15 \times 17{,}56 \times (56 - 51{,}4)$$

$$= -43142{,}5 \ cm^3$$

3. Verifico le tensioni

$$\sigma_c = -\frac{N}{S_n} x = -\frac{-1000}{-43142{,}5} \times 51{,}4 \times 10 = -11{,}9 \ MPa$$

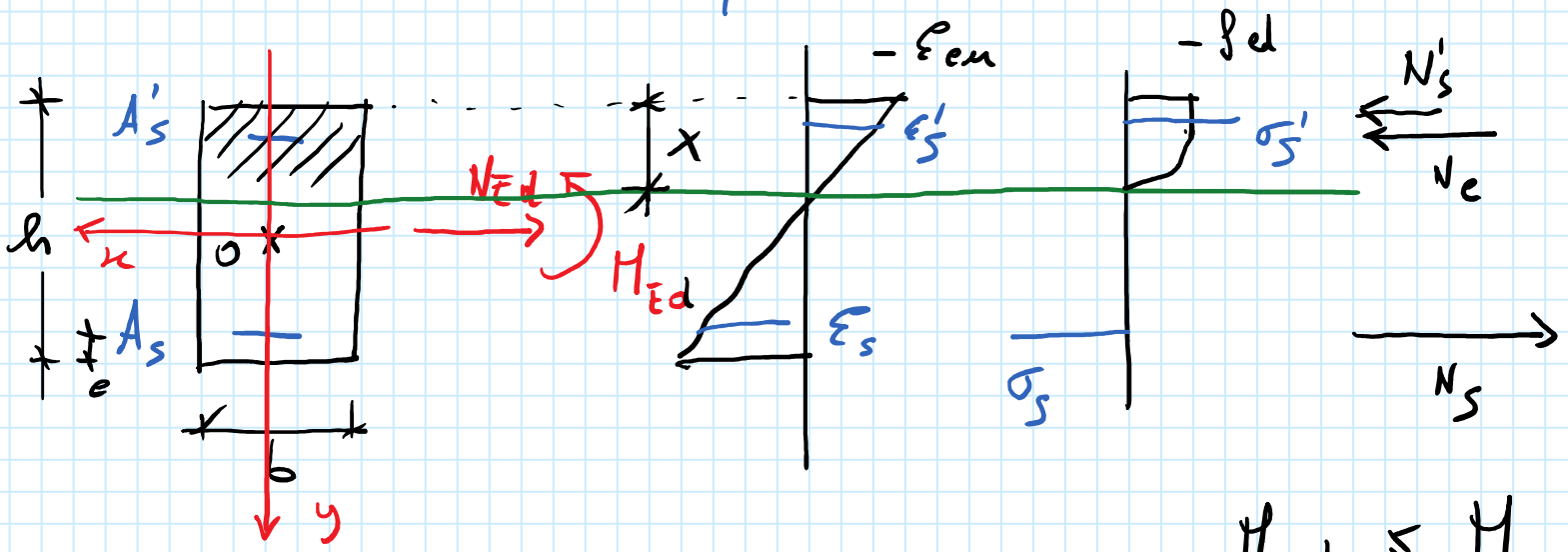
$$|\sigma_c| = 11{,}9 < 0{,}6 f_{ck} = 18 \ MPa \qquad \text{Ok!}$$

$$\sigma_s = n \frac{N}{S_n} (d - x) = 15 \times \frac{-1000}{-43142{,}5} \times (56 - 51{,}4) \times 10 = 16 \ MPa$$

$$\sigma_c = 16 \ MPa < 0{,}8 f_{yk} = 360 \ MPa \qquad \text{ok!}$$

Verifica allo SLU, III stadio di comportamento

Caso della sezione parzializzata



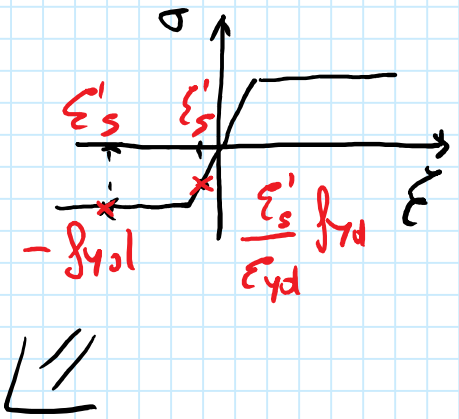
$$M_{Ed} \leq M_{Rd}(N_{Ed})$$

1. Determino x

$$\int \sigma \, dA = N_{Ed}$$

$$N_c = -\beta \, b \, x \, f_{cd} \qquad \beta = 0{,}81$$

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



$\varepsilon'_s < -\varepsilon_{yd}$ $\quad \sigma'_s = -f_{yd}$

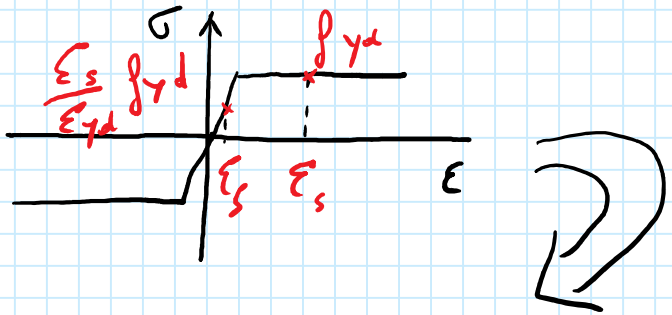
$\varepsilon'_s \quad -\varepsilon_{yd} \le \varepsilon'_s \le \varepsilon_{yd}$ $\quad \sigma'_s = \frac{\varepsilon'_s}{\varepsilon_{yd}} f_{yd}$ $\quad$ Arm. A'_s

$\varepsilon'_s > \varepsilon_{yd}$ $\quad \sigma'_s = f_{yd}$

$N'_s = A'_s \sigma_s$

Il procedimento si ripete per l'armatura A_s

$$\varepsilon_s = \frac{d-x}{x}\,\varepsilon_{cu} \Rightarrow$$



$\Rightarrow$

$\varepsilon_s < -\varepsilon_{yd}$ $\quad \sigma_s = -f_{yd}$

$\varepsilon_s \quad -\varepsilon_{yd} \le \varepsilon'_s \le \varepsilon_{yd}$ $\quad \sigma'_s = \frac{\varepsilon'_s}{\varepsilon_{yd}} f_{yd}$ $\quad$ Arm. A_s

$\varepsilon_s > \varepsilon_{yd}$ $\quad \sigma_s = f_{yd}$

$N_s = A_s \sigma_s$

Equilibrio alla traslazione

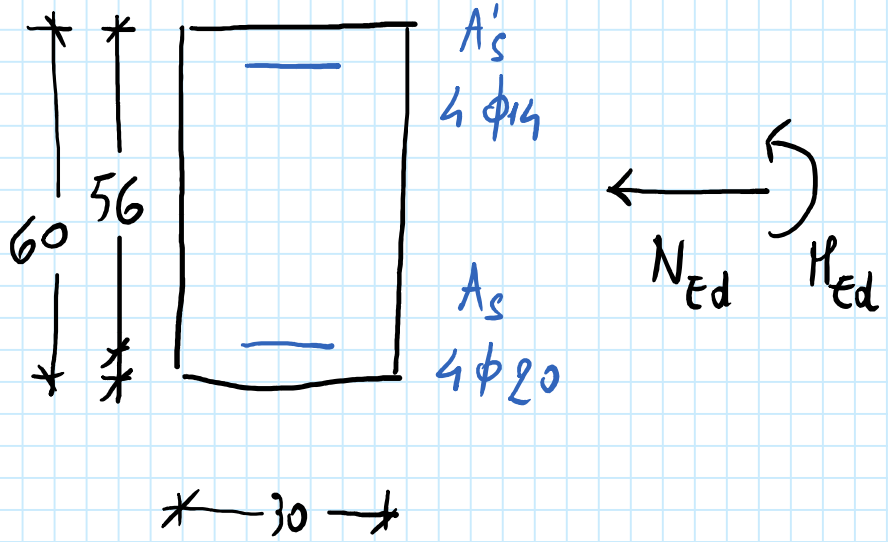
$$\boxed{N_c + N'_s + N_s = N_{Ed}} \Rightarrow \text{determino } x$$

2. Determino $M_{Rd}(N_{Ed})$

$$M_{Rd} = -N_c\left(\frac{h}{2} - kx\right) - N_s'\left(\frac{h}{2} - e\right) + N_s\left(\frac{h}{2} - e\right)$$

$$= \beta b x f_{cd}\left(\frac{h}{2} - kx\right) - A_s'\sigma_s'\left(\frac{h}{2} - e\right) + A_s\sigma_s\left(\frac{h}{2} - e\right)$$

$$= \beta b x f_{cd}\left(\frac{h}{2} - kx\right) + \left(A_s\sigma_s - A_s'\sigma_s'\right)\left(\frac{h}{2} - e\right)$$



C30/37

B450C

N_{Ed} : -1400 kN

M_{Ed} : 210 kN m

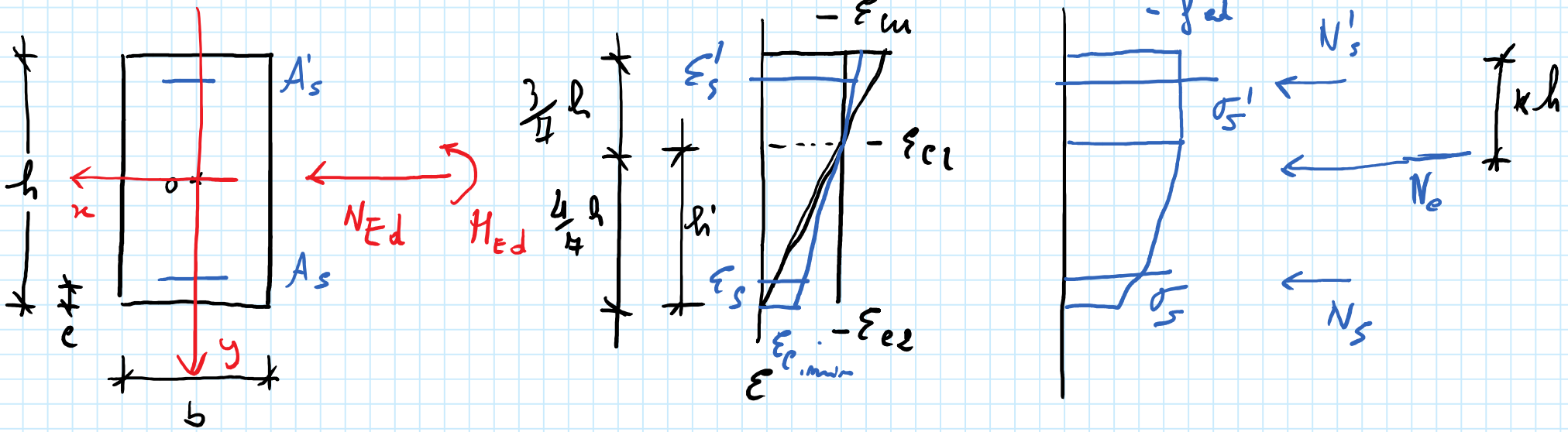
1. Determino X : 38,07 cm

2. Valuto M_{Rd} : 393,0 kN m

M_{Ed} = 210 kNm < M_{Ed} : 393,0 kNm OK.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	B	30	cm										
2	H	60	cm				fcd	17	Mpa		fyd	391.3	Mpa
3	c	4	cm				EpsCU	0.0035			Es	200000	Mpa
4	d	56	cm				EpsC2	0.002			EpsYd	0.001957	
5	AsP	6.16	cm2										
6	As	12.56	cm2				Beta	0.81					
7							K	0.416					
8													
9													
10	X	38.0749	cm										
11													
12													
13													
14					Nc	-1572.9	kN	Mc	222.7	kNm			
15	EpsSp	-0.00313	SigSp	-391.3	NsP	-241.0	kN	MsP	62.7	kNm			
16	EpsS	0.001648	SigS	329.5497	Ns	413.9	kN	Ms	107.6	kNm			
17					Ned	-1400.0	kN	Mrd	393.0	kNm			
18													

Caso delle sezioni interamente compresse



$$-\frac{\varepsilon_{cu}}{h} = \frac{-\varepsilon_{c2}}{h'} \Rightarrow h' = \frac{\varepsilon_{c2}}{\varepsilon_{cu}} h = \frac{2 \times 10^{-3}}{3{,}5 \times 10^{-3}} h = \frac{4}{7} h$$

$$\eta_{min} = -\frac{\varepsilon_{c,min}}{\varepsilon_{c2}}$$

1. Determino η_{min}

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

$$0{,}81 \leq \beta(\eta_{min}) \leq 1 \qquad \text{con} \quad \beta = 1 - \frac{4}{21}\left(1 - \eta_{min}\right)^2$$

$$\varepsilon_s = -\left[\frac{e}{4/7\, h}\left(1 - \eta_{min}\right) + \eta_{min}\right] \varepsilon_{c2} \Rightarrow \sigma_s$$

$$N_s = A_s \sigma_s$$

$$\varepsilon'_s = -\left[\frac{d}{4/7\, h}\left(1 - \eta_{min}\right) + \eta_{min}\right] \varepsilon_{c2} \Rightarrow \sigma'_s$$

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

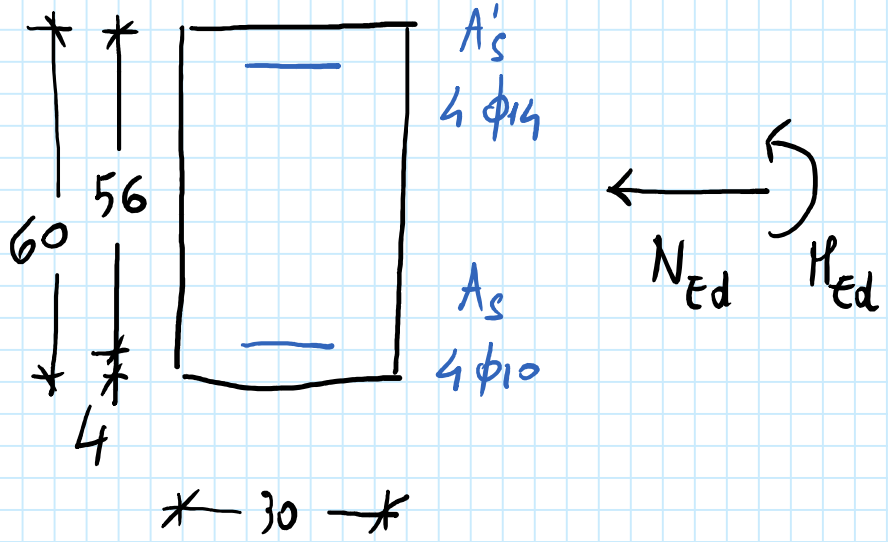
$$N_e + N'_s + N_s = N_{Ed} \Rightarrow \eta_{min}$$

2. Determino M_{Rd} col segno che verifica

$$M_{Rd} = -N_e\left(\frac{h}{2} - kh\right) - N'_s\left(\frac{h}{2} - c\right) + N_s\left(\frac{h}{2} - c\right)$$

$$K = \frac{1}{2}\,\frac{1 - \frac{16}{49}\left(1 - \eta_{min}\right)^2}{1 - \frac{4}{21}\left(1 - \eta_{min}\right)^2}$$

$$M_{Ed} \leq M_{Rd}(N_{Ed})$$



C30/37

B450C

$N_{Ed} = -2900$ kN

$M_{Ed} = 210$ kN m

1. Determinare $\eta_{min} = 0{,}00788$

2. Valuto $M_{Rd} = 144{,}3$ kN m

$M_{Ed} = 210$ kNm $\leq$ $M_{Rd} = 144{,}3$ kNm NO

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	B	30	cm										
2	H	60	cm				fcd	17	Mpa		fyd	391.3	Mpa
3	c	4	cm				EpsCU	0.0035			Es	200000	Mpa
4	d	56	cm				EpsC2	0.002			EpsYd	0.001957	
5	AsP	6.16	cm2										
6	As	12.56	cm2				Beta	0.84					
7							K	0.43114					
8													
9													
10	EtaMin	0.078796											
11													
12													
13													
14					Nc	-2565.4	kN	Mc	106.0	kNm			
15	EpsSp	-0.00317	SigSp	-391.3	NsP	-241.0	kN	MsP	62.7	kNm			
16	EpsS	-0.00037	SigS	-74.5078	Ns	-93.6	kN	Ms	-24.3	kNm			
17					Ned	-2900.0	kN	Mrd	144.3	kNm			
18													