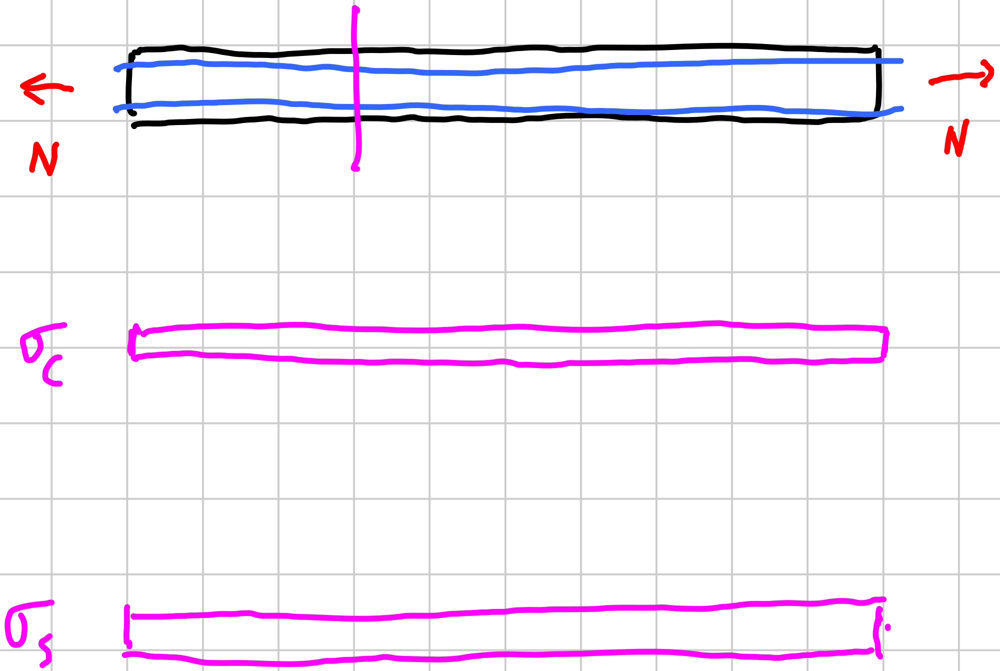
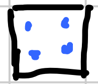
VERIFICA A FESSURAZIONE

Titolo nota 21/05/2015





$$w_k \leq w_{lim}$$

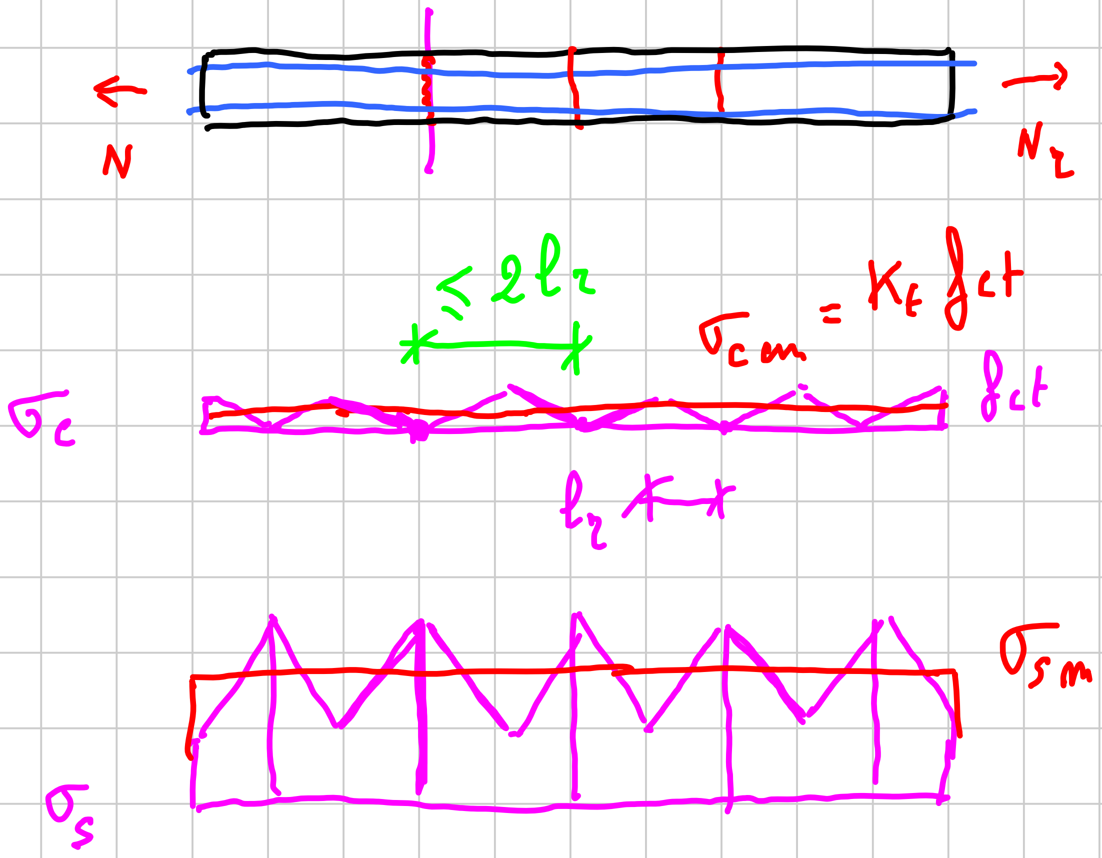
$$\sigma_c = \frac{N}{A_c + n A_s} \qquad n = \frac{E_s}{E_c}$$

$$\sigma_s = n\,\sigma_c$$

$$\varepsilon_c = \frac{\sigma_c}{E_c} = \frac{N}{E_c(A_c + n A_s)}$$

$$\varepsilon_s = \varepsilon_c$$

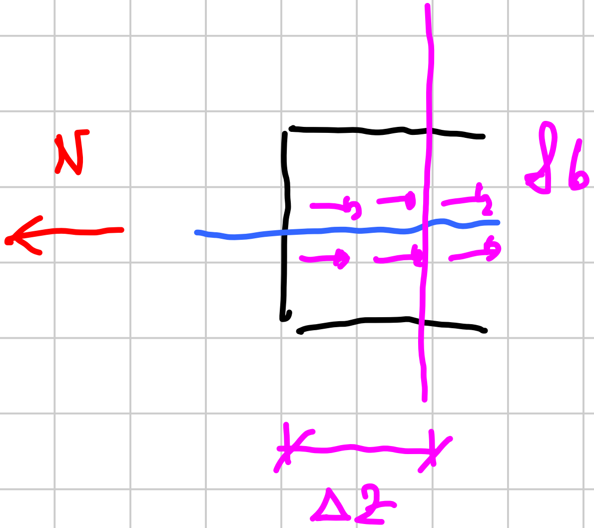
$$\sigma_c = \frac{N}{A_c + nA_s} = f_{ct} \Rightarrow N_r = (A_c + nA_s) f_{ct}$$

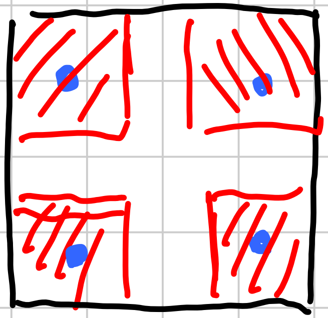


II stadio

$$\sigma_c = 0$$

$$\sigma_s = \frac{N_r}{A_s}$$





$$n\,\pi\,\phi\,\Delta z\,f_b = F_b \qquad \sigma_c = \frac{F_b}{A_{c,eff}} = \frac{n\,\pi\,\phi\,\overset{\ell_t}{\Delta z}\,f_b}{A_{c,eff}} = f_{ct}$$

$$\ell_t = \frac{A_{c,eff}\,f_{ct}}{\cancel{n}\,\cancel{\pi}\,\cancel{\phi}\,f_b}\;\frac{\cancel{n}\,\frac{\cancel{\pi}}{4}\,\phi^{\cancel{2}}}{A_s} = \frac{1}{4}\,\frac{f_{ct}}{f_b}\,\frac{\phi}{\rho_{eff}} \qquad \rho_{eff} = \frac{A_s}{A_{c,eff}}$$

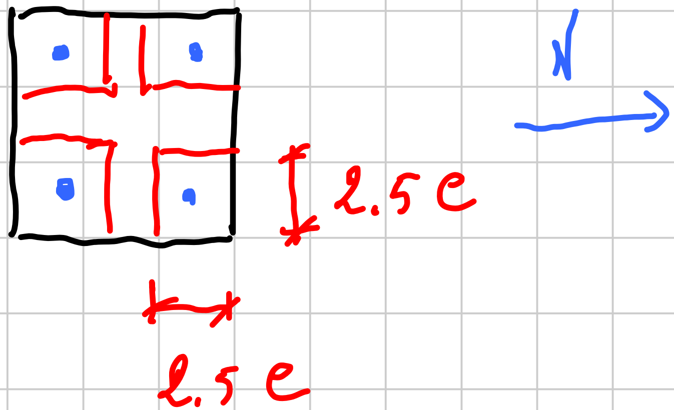
$$w = s_{r,max}(\varepsilon_{sm} - \varepsilon_{cm})$$

$$s_{r,max} = \left[\frac{1}{4}\,\frac{f_{ct}}{f_b}\,\frac{\phi}{\rho_{eff}}\right] \times \ell$$

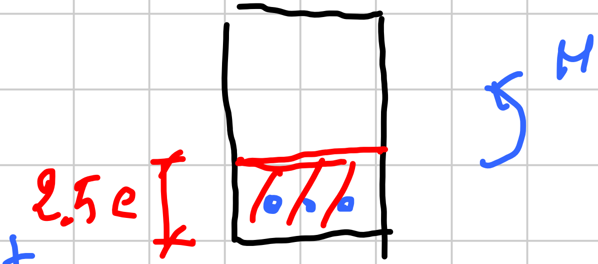
$$s_{r,max} = K_3\,\overset{2}{\cancel{c}} + K_1\,K_2\,K_4\,\frac{\phi}{\rho_{eff}}$$

$$K_1 = \begin{cases} 0.8 & \text{aderenza migliorata} \\ 1.6 & \text{barre lisce} \end{cases}$$

$$K_2 = \begin{cases} 1 & \text{trazione} \\ 0{,}5 & \text{flessione} \end{cases}$$



$$K_4 = 0{,}425$$



$$K_3 = 3{,}4$$

A_s armatura tesa

$$\rho_{eff} = \frac{A_s}{A_{c,eff}}$$

$$\varepsilon_{cm} = \frac{\sigma_{cm}}{E_c} = \frac{k_t f_{ct}}{E_c}$$

$$\sigma_{sm} = \frac{N - A_{c,eff}\, k_t f_{ct}}{A_s} = \sigma_{s2} - \frac{k_t f_{ct}}{\rho_{eff}}$$

$$\varepsilon_{sm} = \varepsilon_{s2} - \frac{k_t f_{ct}}{E_s \rho_{eff}}$$

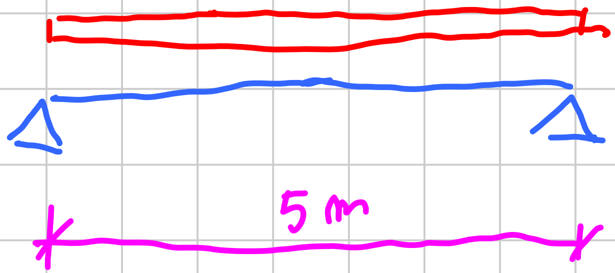
$$\varepsilon_{sm} - \varepsilon_{cm} = \varepsilon_{s2} - \frac{k_t f_{ct}}{E_s \rho_{eff}} - \frac{k_t f_{ct}}{E_c} = \varepsilon_{s2} - \frac{k_t f_{ct}}{E_s \rho_{eff}} \left(1 + \frac{E_s \rho_{eff}}{E_c} \right)$$

$$w_k = s_{r,max}(\varepsilon_{sm} - \varepsilon_{cm})$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \varepsilon_{s2} - \frac{K_t f_{ctm}}{E_s \rho_{eff}} \left(1 + \frac{E_s \rho_{eff}}{E_{cm}}\right) \geq 0.6\ \varepsilon_{s2}$$

$$s_{r,max} = K_3 \cancel{c}^{\,\tau} + K_1 K_2 K_4 \frac{\phi}{\rho_{eff}}$$

$$K_t = \begin{cases} 0.6 & \text{carichi di breve durata} \\ 0.4 & \text{carichi di lunga durata} \end{cases}$$



$G_k = 25$ KN m

$Q_k = 15$ KN m

$G_d = 1,3 \times 25 = 32,5$ KN/m

$Q_d = 1,5 \times 15 = 22,5$ KN/m

$$M_{Ed} = (32,5 + 22,5) \times \frac{5^2}{8}$$

$$= 171,9 \text{ KN m}$$

$$d = r' \sqrt{\frac{M_{Ed}}{b}} = 0,018 \times \sqrt{\frac{171,9}{0,3}} = 0.43 \text{ m}$$

30x50

c = 5 cm

$$A_s = \frac{M_{Ed}}{0.9\, d\, f_{yd}} = \frac{171.9 \times 10}{0.9 \times 0.45 \times 391.3} = 10.9 \text{ cm}^2$$

$$3\phi 20 + 1\phi 14 \qquad A_s = 3 \times 3.14 + 1.54 = 11.0 \text{ cm}^2$$

Gruppi di esigenze	Condizioni ambientali	Combinazione di azioni	Armatura			
			Sensibile		Poco sensibile	
			Stato limite	w_d	Stato limite	w_d
a	Ordinarie	frequente	ap. fessure	$\leq w_2$	ap. fessure	$\leq w_3$
		quasi permanente	ap. fessure	$\leq w_1$	ap. fessure	$\leq w_2$
b	Aggressive	frequente	ap. fessure	$\leq w_1$	ap. fessure	$\leq w_2$
		quasi permanente	decompressione	-	ap. fessure	$\leq w_1$
c	Molto aggressive	frequente	formazione fessure	-	ap. fessure	$\leq w_1$
		quasi permanente	decompressione	-	ap. fessure	$\leq w_1$

$w_1 = 0,2$ mm

$w_2 = 0,3$ mm

$w_3 = 0,4$ mm

$$S_{r,max} = K_3 c + K_1 K_2 K_4 \frac{\phi}{\rho_{eff}}$$

$$K_1 = 0{,}8$$

$$K_2 = 0{,}5$$

$$\phi_{eq} = \frac{n_1 \phi_1^2 + n_2 \phi_2^2}{n_1 \phi_1 + n_2 \phi_2} = \frac{14^2 + 3 \times 20^2}{14 + 3 \times 20} = 18{,}9 \text{ mm}$$

$$A_{c,eff} = 2.5 \times 5 \times 30 = 375 \text{ cm}^2$$

$$\rho_{eff} = \frac{11}{375} = 0{,}029$$

$$s_{r,max} = 3{,}4 \times 30 + 0{,}8 \times 0{,}5 \times 0{,}425 \times \frac{18.9}{0{,}029} = 209 \text{ mm}$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \varepsilon_{s2} - \frac{k_t f_{ctm}}{E_s \rho_{eff}}\left(1 + \frac{E_s \rho_{eff}}{E_{cm}}\right) \geq 0,6\ \varepsilon_{s2}$$

Quasi permanente

$$G_k + \psi_2 Q_k = 25 + 0,3 \times 15 = 29,5\ kN/m$$

$$M = \frac{29,5 \times 5^2}{8} = 92.2\ kNm$$

$$\sigma_{s2} = \frac{M}{0,9\, d\, A_s} = \frac{92.2 \times 10}{0,9 \times 0,45 \times 11} = 206,9\ MPa$$

$$\varepsilon_{s2} = \frac{\sigma_{s2}}{E_s} = \frac{206.4}{200000} = 0,0010$$

$$\varepsilon_{sm} - \varepsilon_{cm} = 0,0010 - \frac{0,4 \times 2,56}{200000 \times 0,029}\left(1 + 6,35 \times 0,029\right)$$

$$= 0,0008$$

$$0,6\ \varepsilon_{s2} = 0,6 \times 0,001 = 0,0006$$

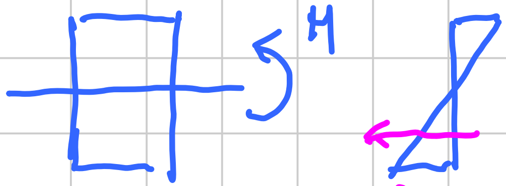
OK!

$$w_k = 209 \times 0,0008 = 0,17\ mm < 0,3\ mm$$

VERIFICA A FESSURAZIONE SENZA CALCOLO DIRETTO

$$\sigma_s = \frac{N}{A_s} \le f_{yk} \Rightarrow A_s \ge \frac{N_r}{f_{yk}} = \frac{A_c f_{ct}}{f_{yk}} = \frac{f_{ct}}{f_{yk}} b h$$

$$A_s \ge \frac{f_{ct}}{f_{yk}} b h$$



forza di trazione

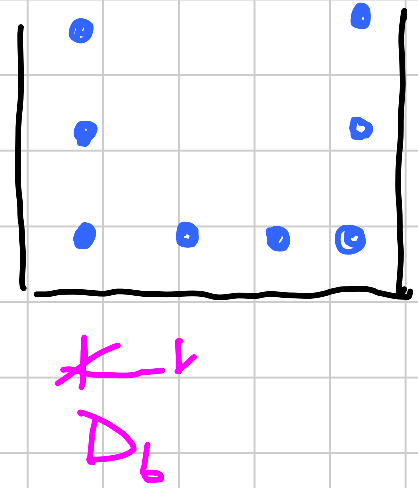
f_{ct} $\quad 0{,}25\, b h f_{ct}$

$$\boxed{A_s \ge 0.26 \frac{f_{ctk}}{f_{yk}} b d}$$

1. Da verificare sempre

2. Diametro delle barre ϕ $\geq$ Valore limite ϕ_s

3. Distanza tra le barre D_b $\geq$ Valore limite



Diametri massimi delle barre ϕ^*_s per il controllo della fessurazione[1)]

Tensione nell'acciaio[2)] [MPa]	Diametro massimo delle barre [mm] w_k = 0,4 mm	w_k = 0,3 mm	w_k = 0,2 mm
160	40	32	25
200	32	25	16
240	20	16	12
280	16	12	8
320	12	10	6
360	10	8	5
400	8	6	4
450	6	5	-

1) I valori nel prospetto sono basati sulle seguenti assunzioni:
c = 25 mm; $f_{ct,eff}$ = 2,9 MPa; h_{cr} = 0,5; $(h - d) = 0{,}1\ h$; k_1 = 0,8; k_2 = 0,5; k_c = 0,4; k = 1,0; k_t = 0,4 e k' = 1,0.

2) Sotto la combinazione di carico pertinente.

$$\sigma_s = \frac{M}{0{,}9\ d\ A_s} = 206{,}9\ \text{MPa}$$

Flessione (almeno una parte della sezione è compressa):

$$\phi_s = \phi^*_s(f_{ct,eff}/2{,}9)\ \frac{k_c h_{cr}}{2(h-d)}$$

Trazione (la sezione è tutta tesa):

$$\phi_s = \phi^*_s(f_{ct,eff}/2{,}9)\ h_{cr}/(8(h\text{-}d))$$

$$\phi_s = 25 \times \frac{2{,}56}{2{,}9} \times \frac{0{,}4 \times 25}{2(50-45)} = 21{,}6\ mm$$

$$\phi = 20 < 21{,}6\ mm$$

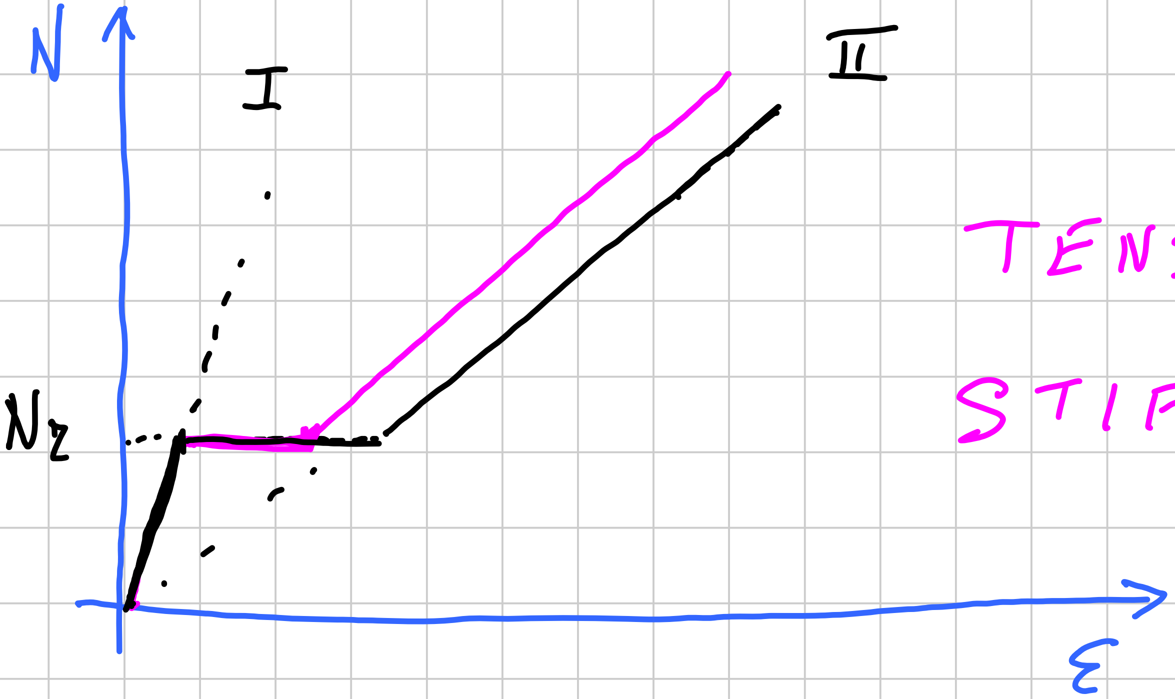
Spaziatura massima delle barre per il controllo della fessurazione[1)]

Tensione nell'acciaio[2)] [MPa]	Spaziatura massima delle barre [mm] $w_k = 0,4$ mm	$w_k = 0,3$ mm	$w_k = 0,2$ mm
160	300	300	200
200	300	250	150
240	250	200	100
280	200	150	50
320	150	100	-
360	100	50	-

Per le note vedere prospetto 7.2N.

$A_s = 11.0 \text{ cm}^2$ OK!

$$A_{s,min} = 0.26 \times \frac{2.56}{450} \times 30 \times 45 = 2.0 \text{ cm}^2$$



$$\varepsilon_s = \frac{N_r}{E_s A_s}$$

TENSION STIFFENING