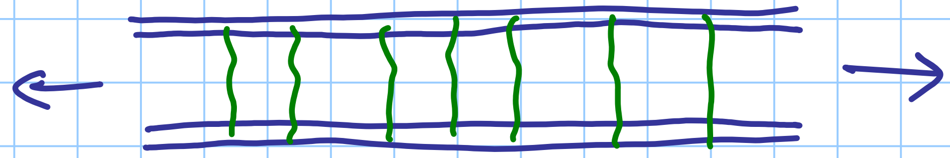
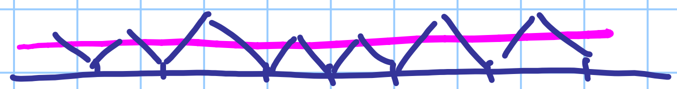
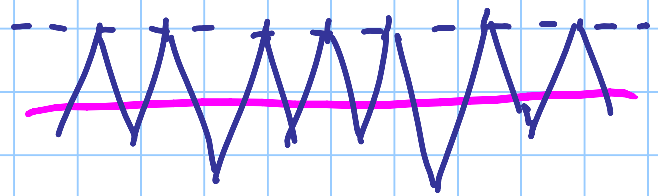


σ_c



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

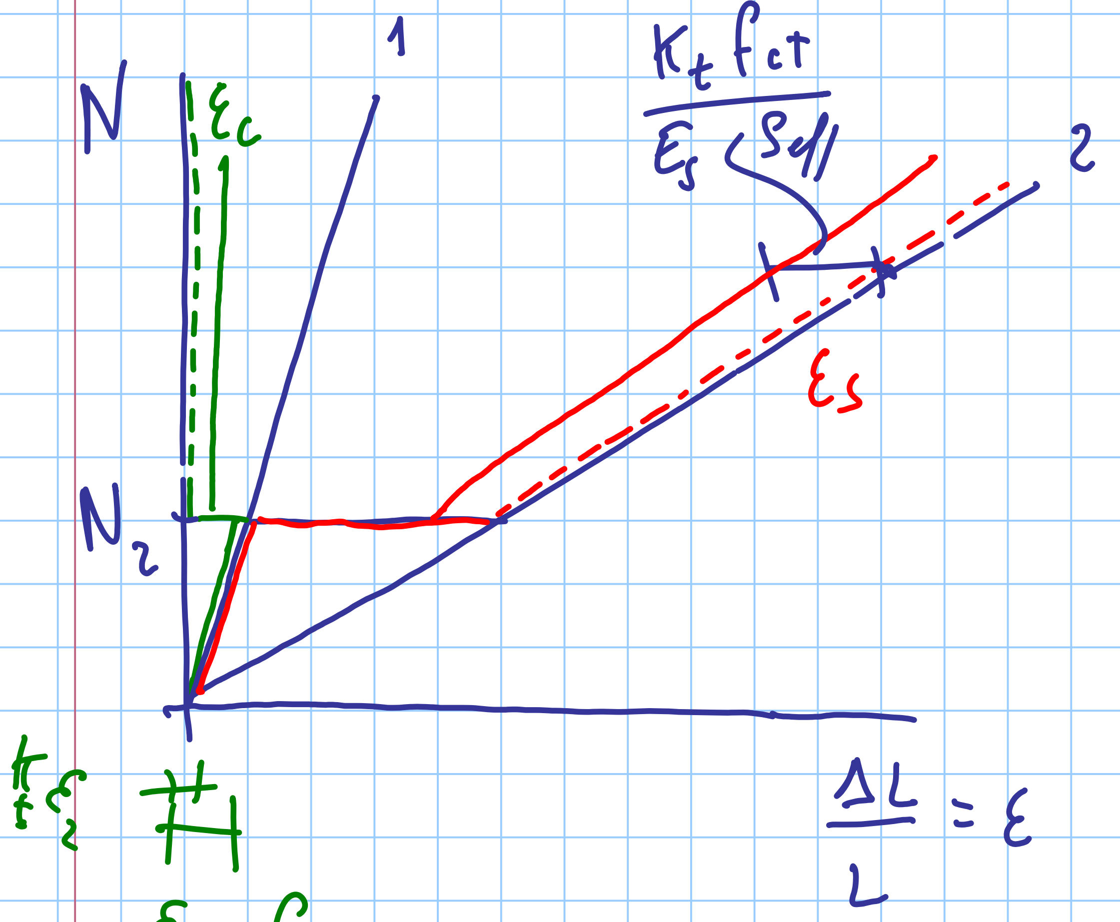
σ_{s2}



σ_{sm} $\qquad$ ε_{sm}

σ_s

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



$\varepsilon_2 = \frac{f_{cT}}{E_c}$

— cls

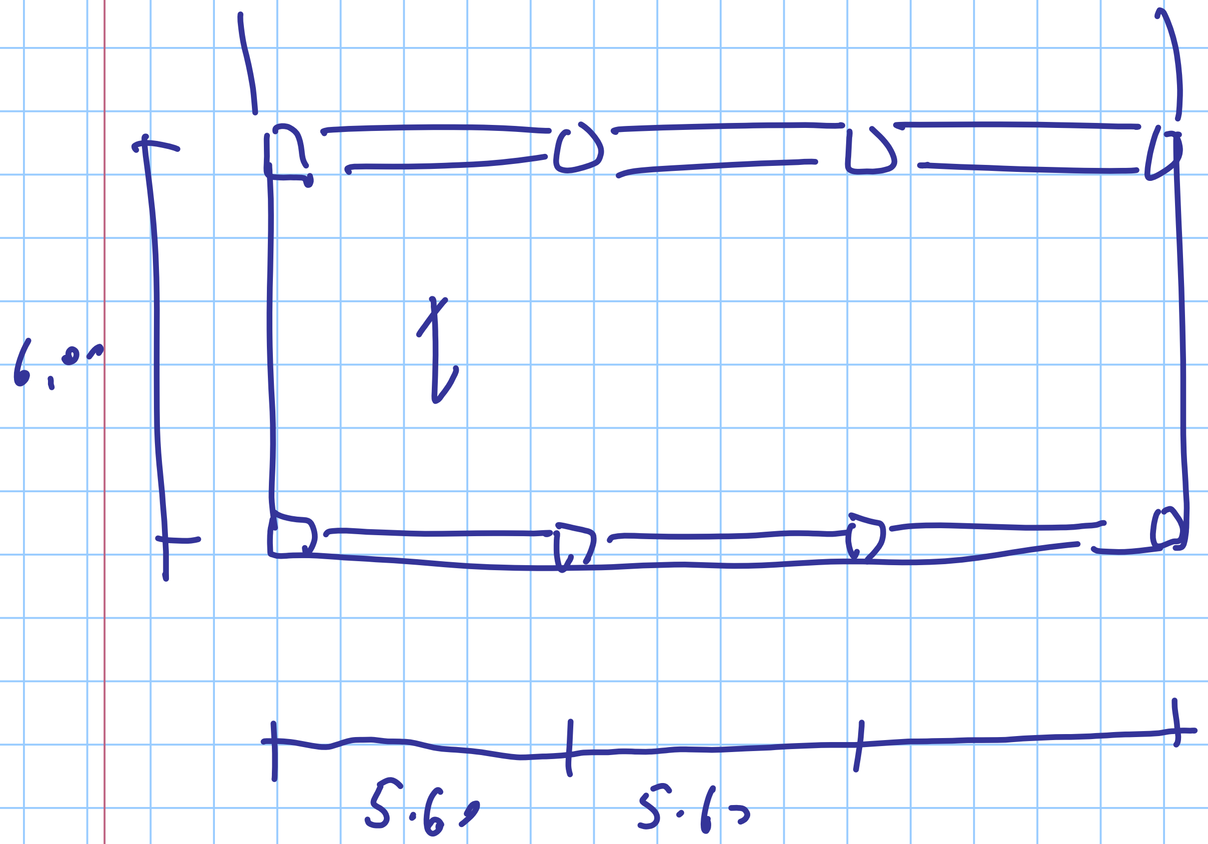
— acc

linee tratteggiate solo da 1° a 2°

linee continue TENSION STIFFENING

$$w_k = \underbrace{s_{r,max}}_{\text{dist. fessure}} \left(\varepsilon_{sm} - \varepsilon_{cm} \right)$$

Condizioni ambientali	Combinazione di carico	
	frequente	quasi permanente
Ordinarie: classe X0, XC1, XC2, XC3, XF1	$w_k \leq 0.4$ mm	$w_k \leq 0.3$ mm
Aggressive: classe XC4, XD1, XS1, XA1, XA2, XF2, XF3	$w_k \leq 0.3$ mm	$w_k \leq 0.2$ mm
Molto aggressive: classe XD2, XD3, XS2, XS3, XA3, XF4	$w_k \leq 0.2$ mm	$w_k \leq 0.2$ mm



solaio

$g_k = 4.0 \ kN/m^2$

$q_k = 4.0 \ kN/m^2$

p.p. Trave

30x60 $\quad g_k = 3.5 \ kN/m$

parapetto

$g_k = 1.2 \ kN/m$

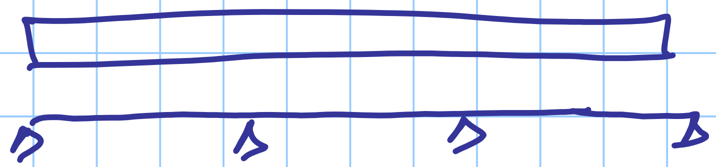
CARICHI SU TRAVE

		g_k	q_k
solaio	3.0 m	12.0	12.0
Trave		3.5	
parapetto		1.2	
		16.7	12.0

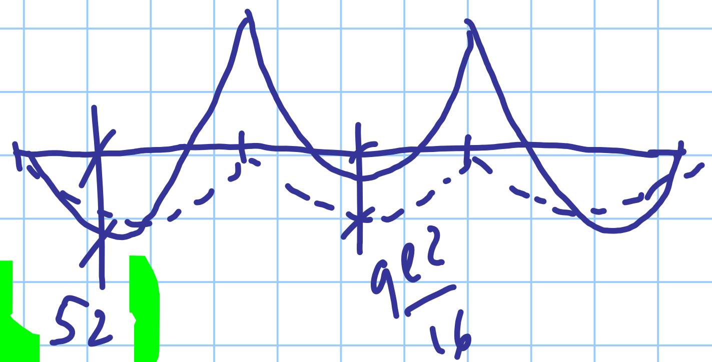
$\psi_1 = 0.7$

$\psi_2 = 0.6$

			Tot
frequente	16.7	$12.0 \times 0.7 = 8.4$ KN/m	25.1
q.perm.	16.7	$12.0 \times 0.6 = 7.2$ KN/m	23,9



23,9 kN/m   Q. PERM.



$$\frac{q/2\, l^2}{8} = \frac{q l^2}{16} = \frac{23{,}9 \times 5.60^2}{16} = 46.8 \text{ KNm}$$

all. SLU 16.7×1.3 12.0×1.5 TOT 39.7 kN/m

21.7 18

M_{Rd} $\frac{ql^2}{16} = 77.8$ $M_{Rd\_max} = 90$ kNm

basterebbero

$3 \phi 14$

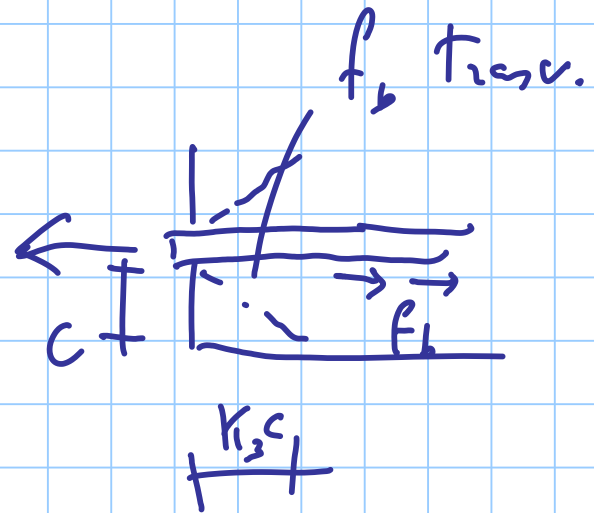
$A_s = \frac{90 \times 10}{0.9 \times 0.56 \times 391.3} = 4.6$ cm^2

il progettista ne ha messi $4 \phi 14$

$$S_{r,max} = \overbrace{\overset{3.4}{k_3}\,\overset{30}{c}}^{102} + \overbrace{\overset{0.8}{k_1}\,\overset{0.5}{k_2}\,\overset{0.425}{k_4}\,\frac{\overset{14}{\phi}}{\underset{\frac{4\times1.54}{300}}{\rho_{eff}}}}^{116.1} = 218.1\ \text{mm}$$

$$A_{eff} = 2.5 \times 4 \times 30 = 300\ \text{cm}^2$$

$$\rho_{eff} = \frac{4 \times 1.54}{300} = 0.0205$$



nota : si avessi messo $2\phi 20$ anziché $4\phi 14$

$$\rho_{eff} = \frac{2 \times 3.14}{300} = 0.0209$$

$$k_1 k_2 k_4 \frac{\phi}{\rho_{eff}} = 162.7$$

$$s_{r\,max} = 264.7 \text{ mm}$$

se si hanno diametri diversi:

$n_1 \quad \phi_1 \qquad\qquad n_2 \quad \phi_2$

$$\phi_{eq} = \frac{n_1 \phi_1^2 + n_2 \phi_2^2}{n_1 \phi_1 + n_2 \phi_2} \qquad\qquad \frac{2 \times 14^2 + 1 \times 20^2}{2 \times 14 + 1 \times 20} = 16.5$$

es. $2\phi 14 + 1\phi 20$

$$\varepsilon_{sm} - \varepsilon_{cm}$$

$$\varepsilon_{s2} - \frac{K_t\, f_{ct}}{E_s\, \rho_{eff}} - \frac{K_t\, f_{ct}}{E_c} =$$

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

$f_{ct} \rightarrow f_{ctm}$

C 25/30 $\quad f_{ctm} = 2.56$ MPa

$K_t = 0.6$

0.4

lunga durata

ε_{s2} rigoroso: verifica 2° stadio

$n = 15$ trovare x $\sigma_s = n \frac{M}{I} y$

$\varepsilon_s = \frac{\sigma_s}{E_s}$

$A_s = \frac{M}{0.9\, d\, \sigma_s} \Rightarrow \sigma_s = \frac{M}{0.9\, d\, A_s}$

Q. PERM. $M = 52.0$ kNm $\sigma_s = \frac{52.0 \times 10}{0.9 \times 0.56 \times 6.16}$

$\sigma_{s2} = 167.5$ MPa

$$\varepsilon_{s2} = \frac{167.5}{200\,000} = 0.000837$$

0.837×10^{-3}

$$\varepsilon_{sm} - \varepsilon_{cm} = \varepsilon_{s2} - \frac{\overset{0.4}{K_t}\ \overset{2.56}{f_{ct}}}{\underbrace{\underset{200000}{E_s}\ \underset{0.0205}{\rho_{eff}}}_{0.250 \times 10^{-3}}} \overbrace{\left(1 + \left(\frac{E_s}{\underset{6.35}{E_c}}\right) \underset{0.0205}{\rho_{eff}}\right)}^{1.13}$$

$$= 0.837 \times 10^{-3} - 0.250 \times 10^{-3} \times 1.13 = 0.555 \times 10^{-3}$$

$$W_k = S_{r,max} \left(\varepsilon_{sm} - \varepsilon_{cm} \right) =$$

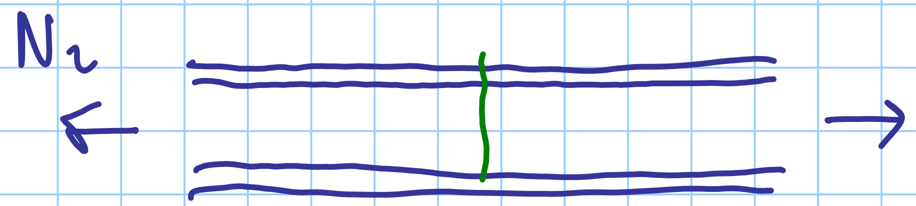
$$= 218.1 \times 0.555 \times 10^{-3} = 0.121 \text{ mm}$$

$$W_k < 0.2 \text{ mm} \qquad \text{OK}$$

per limitare le fessure

- evitare diametri elevati
- evitare eccessive distanze tra le barre

mettere armature tesa non troppo basse (come quantità)



TRAZIONE

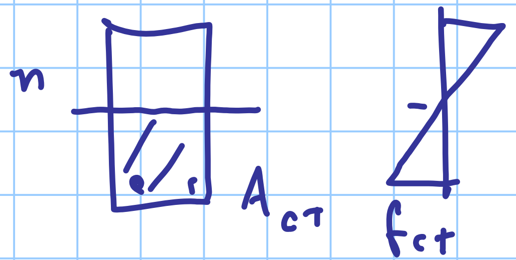
N_r cls $N = A_{ct} f_{ct}$

$k = 1$ Trazione

$A_s f_y > k A_{ct} f_{ct}$

$k = 0.4$ flessione

FLESSIONE



cls $N = A_{ct} \dfrac{f_{ct}}{2}$

$$A_s \geq 0.26 \frac{f_{ct}}{f_{yk}} b d$$ flessione

C 25/30

B450 C

$$A_s \geq 0.00148\, b d \simeq 0.0015\, b d$$

30 x 50

$$A_s \geq 0.00148 \times 30 \times 46 = 2.04\ cm^2$$

ϕ^*

Tensione nell'acciaio [MPa]	Diametro massimo delle barre [mm]		
	$w_k \leq 0.4$ mm	$w_k \leq 0.3$ mm	$w_k \leq 0.2$ 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	–

Nota: i valori della tabella sono ricavati assumendo f_{ctm}=2.9 MPa, h_{cr}=0.5 h, c=0.1 h, k_c=0.4.

$$\varnothing_s = \varnothing_s^* \frac{f_{ctm}}{2.9} \frac{k_c\, h_{cr}}{2\,c}$$ nel caso di flessione

$$\varnothing_s = \varnothing_s^* \frac{f_{ctm}}{2.9} \frac{h_{cr}}{8\,c}$$ nel caso di trazione

$$\phi = 25 \frac{2.56}{2.9} \, 0.4 \, \frac{30}{2 \times 4} =$$

$$= 33$$

Tensione nell'acciaio [MPa]	Spaziatura massima delle barre [mm]		
	$w_k \leq 0.4$ mm	$w_k \leq 0.3$ mm	$w_k \leq 0.2$ mm
160	300	300	200
200	300	250	150
240	250	200	100
280	200	150	50
320	150	100	–
360	100	50	–

DEFORMAZIONI

Tab. 5. Valori limite del rapporto l/h (calcestruzzo C25/30, acciaio B450C)

Sistema strutturale	k	ρ 0.5%	ρ 1.0%	ρ 1.5%
Travi semplicemente appoggiate, piastre semplicemente appoggiate mono o bidirezionali	1.0	20.6	16.4	15.0
Campata terminale di trave continua o piastre continue monodirezionali o piastre bidirezionali continue su un lato lungo	1.3	26.7	21.3	19.5
Campata intermedia di travi o di piastre mono o bidirezionali	1.5	30.8	24.6	22.5
Piastre sorrette da pilastri senza travi (con riferimento alla luce maggiore)	1.2	24.7	19.7	18.0
Mensole	0.4	8.2	6.6	6.0

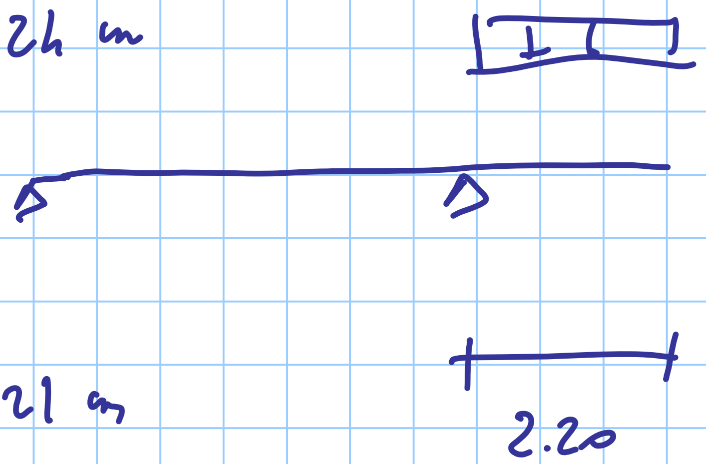
$$\rho = \frac{A_s}{b\,d}$$

$$\frac{l}{h} \le k\left(11 + \frac{0.0015\, f_{ck}}{\rho + \rho'}\right)\frac{500}{f_{yk}}\frac{A_{s,eff}}{A_{s,calc}}$$

$\rho = 0.78\ \%$

$$0.4\left(11 + \frac{0.0015 \times 25}{0.0078}\right)\frac{500}{450} = 7.02$$

$h = 24$ cm



$g_d + q_d = 10.0$ kN/m²   SLU

$$M = \frac{p\, l^2}{2} = 24.2 \text{ kNm}$$

$d = 21$ cm

$$A_s = \frac{M}{0.9\, d\, f_{yd}} = 1.64 \text{ cm}^2/\text{m}$$

2 travetti.   a travetto.

$b = 20$ cm

$$\rho = \frac{A_s}{b\, d}$$

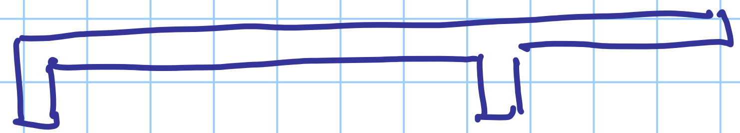
$$\rho = \frac{1.64}{10 \times 21} = 0.0078$$

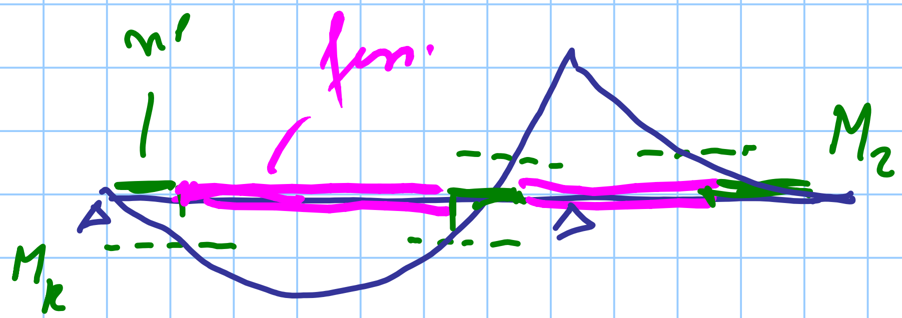
0.78 %

$$\frac{l}{h} = \frac{220}{24} = 9.16 > 7.02$$

NON SODDISFATTA

CALCOLO DELLA FRECCIA





per il calcolo

E I

M_2 mom. fessurazione

modulo elastico

E_c nel tempo $\frac{E_c}{1+\phi}$

coeff. viscosità

I 2° modello di comport.

ma dove $M < M_2$ 1° modello

I varia anche per – variazione armatura
– cambio segno M

e il tension stiffening?

modo semplice e cautelativo

trovo I_{min} e uso quello

sugg. normativi

usa I_2 (2° stadio) $\rightarrow$ δ_2

usa I_1 (1° stadio) $\rightarrow$ δ_1

$$\delta = \zeta\, \delta_2 + (1-\zeta)\, \delta_1$$

$$\zeta = 1 - \beta \left(\frac{M_r}{M} \right)^2$$

$\beta = 0.5$
carichi perman.

Oppure dividere in conci, calcolare la rigidezza
tra EI_1 e EI_2 con ζ
integrare le curvature

TENSIONI IN ESERCIZIO

— effetti viscosi molto forti x σ alte

comb. quasi perm. $\sigma_c \leq 0.45\, f_{ck}$

— fessurazioni per compressione

comb. rare $\sigma_c \leq 0.6\, f_{ck}$

— fessurazione per σ_s elevate $\sigma_s \leq 0.8\, f_{yk}$

tensioni in esercizio

2° modello di comportamento