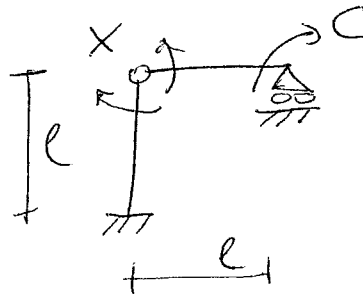
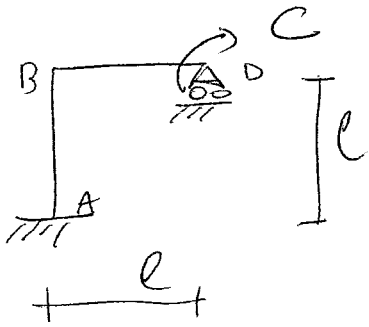
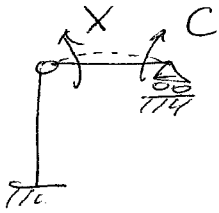


ESERCIZIO

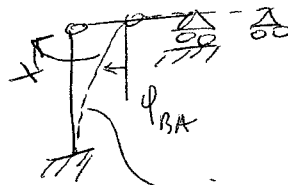
(TEMA 10) (NODI SPOTABILI)



S.P.
 Congruente:
 $\varphi_{BA} = \varphi_{BD}$



$$\varphi_{BD} = + \frac{Xl}{3EI} + \frac{Cl}{6EI}$$

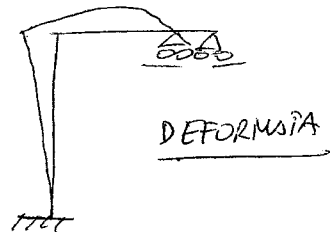
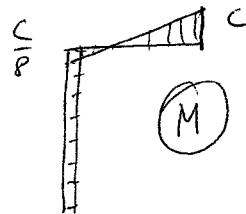
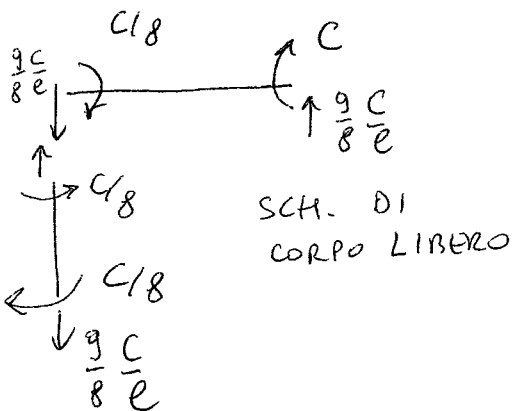
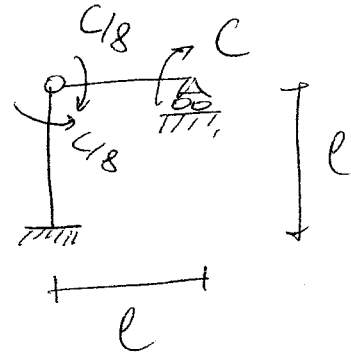


si comporta come
 una mensola

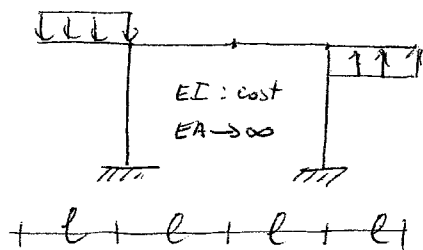
$$\varphi_{BA} = - \frac{Xl}{EI}$$

$$\varphi_{BD} = \varphi_{BA} : \frac{1}{3} + \frac{C}{6} = -X$$

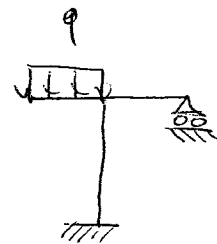
$$\frac{1}{3}X = -\frac{C}{6} \quad X = -\frac{C}{8}$$



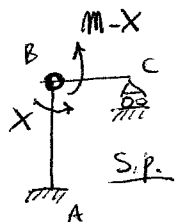
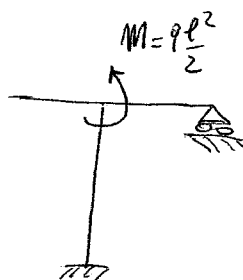
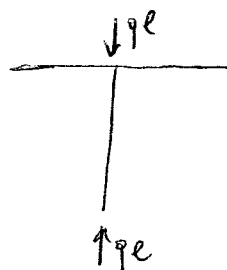
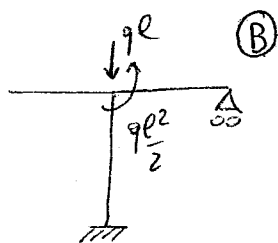
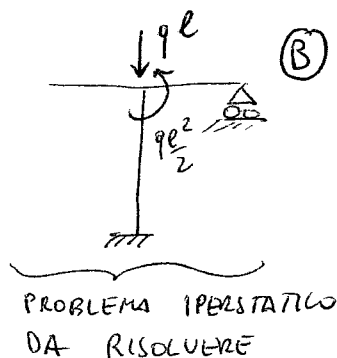
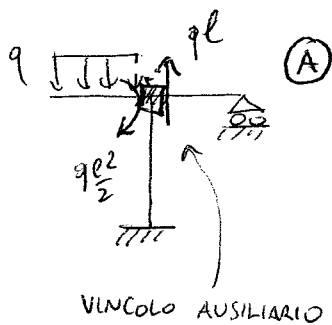
ESERCIZIO (TELAIO A NODI SPOSTABILI)



STR. SIMM. CARICATA
ANTISIMM.

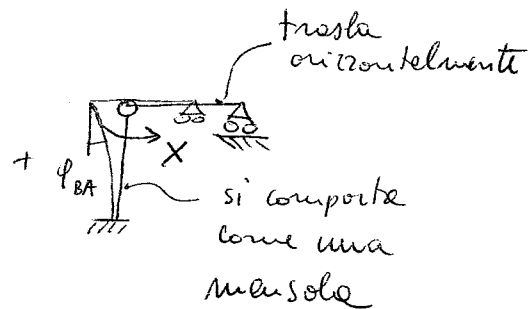
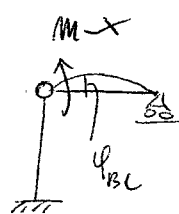


STR. 4 V. STAT. INDET.
TELAIO A NODI SPOSTABILI



eq. compattezza

$$\phi_{BA} = \phi_{BC} \quad \uparrow +$$

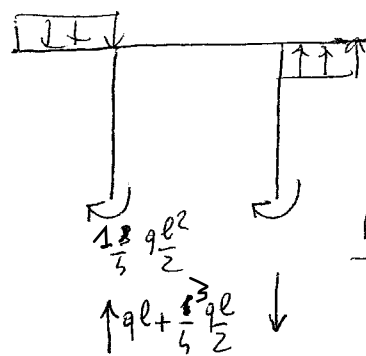
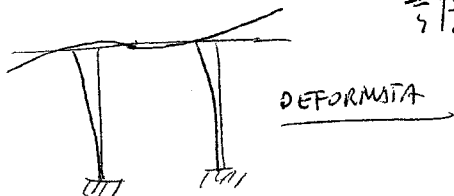
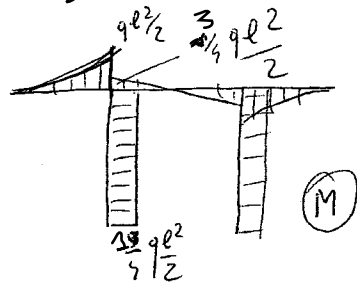
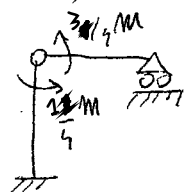


$$\phi_{BC} = \phi_{BA}$$

$$\frac{(M-X)l}{3EI} = \frac{Xl}{EI} \rightarrow \frac{M}{3} = \frac{4}{3}X \rightarrow X = \frac{1}{4}M$$

$$\phi_{BC} = \frac{(M-X)l}{3EI}$$

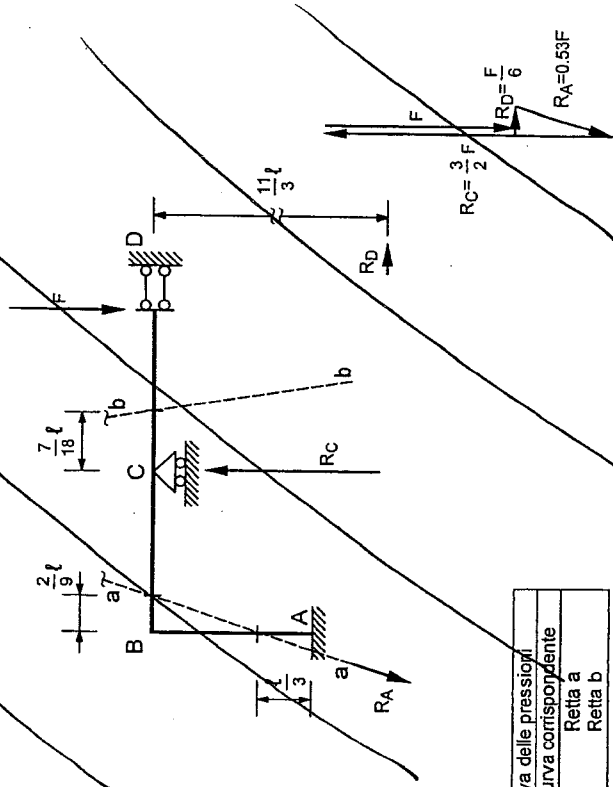
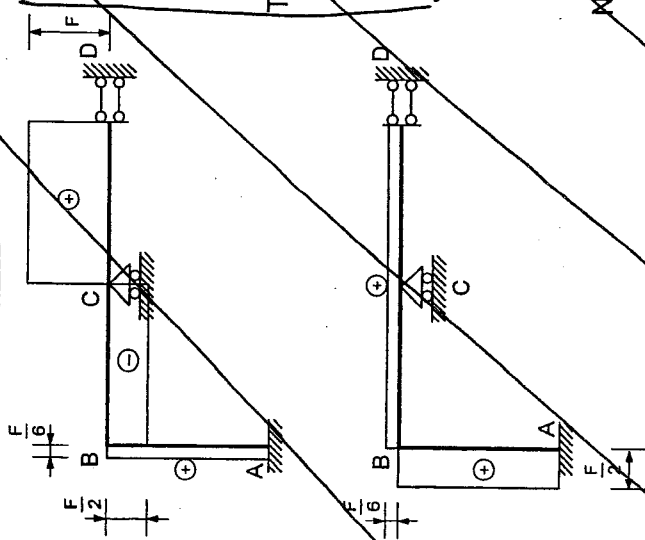
$$\phi_{BA} = -\frac{Xl}{EI}$$



REA2. ESTERNE

NEGLI ESERCIZI CHE SEGUONO NON È IN PROGRAMMA LA DETERMINAZIONE DELLA L.D.P. I CASI LIMITE DEI VINCOLI ELASTICI SONO UTILI PER

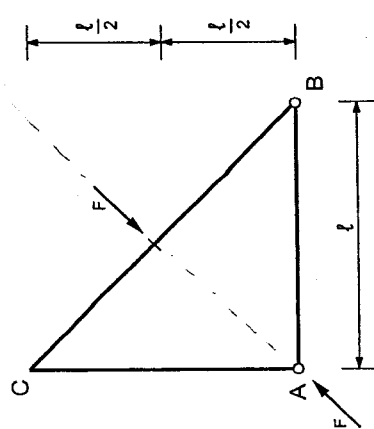
CAPIRE IL COMPORTAMENTO DELLA STRUTTURA IN UN TEMA D'ESAME K VERRÀ INDICATO NEL TESTO



Curva delle pressioni	
Tratto	Curva corrispondente
ABC	Retta a
CD	Retta b

1.3

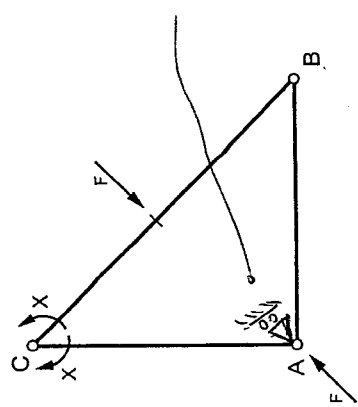
STRUTTURA AUTOEQUILIBRATA 1V. STAT. DET. (IPERSTATICA INTERNA)



Reticolare associata

S.P.

CARICATO INTRODOTTI PER BLOCCARE IL MOTO RIGIDO (NON REAGISCE, È SCARICATO)



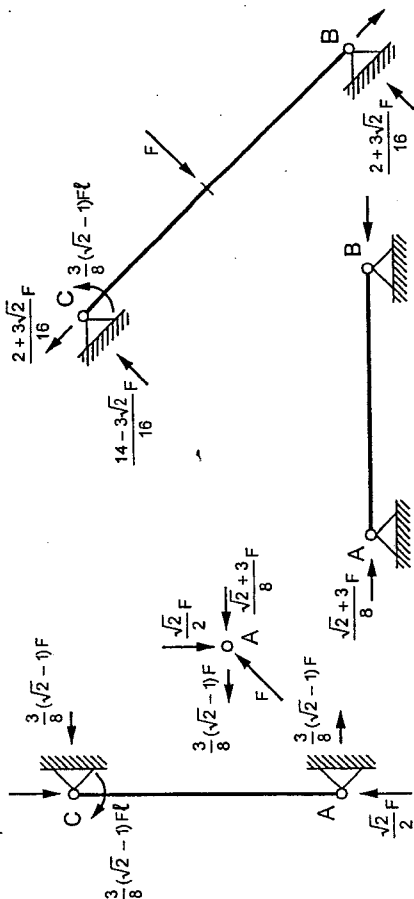
Telaio a nodi fissi.

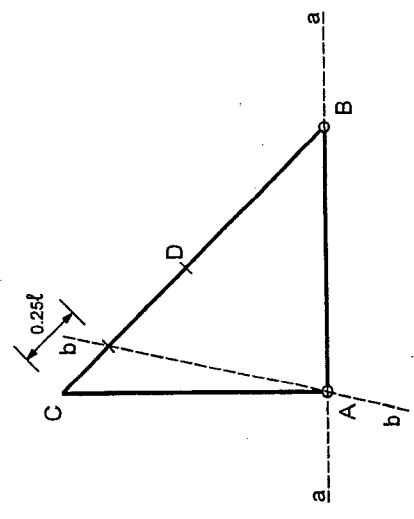
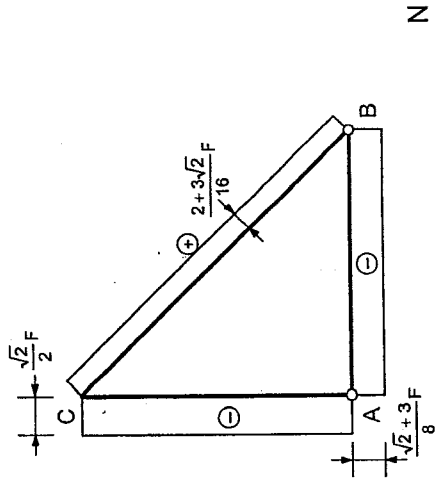
Equazione di congruenza angolare nel nodo C:

$$\varphi_{CA} = \varphi_{CB}, \quad -\frac{Xl}{3EI} = \frac{X\sqrt{2}l}{3EI} - \frac{F(\sqrt{2}l)^2}{16EI}$$

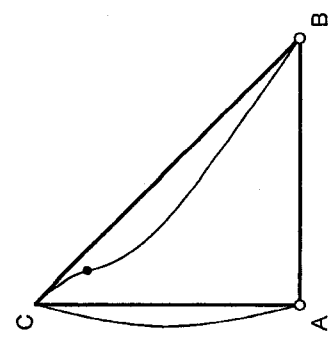
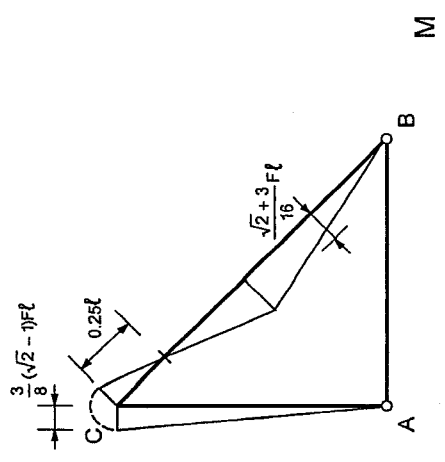
$$X = \frac{3}{8}(\sqrt{2} - 1)Fl$$

Schemi parziali

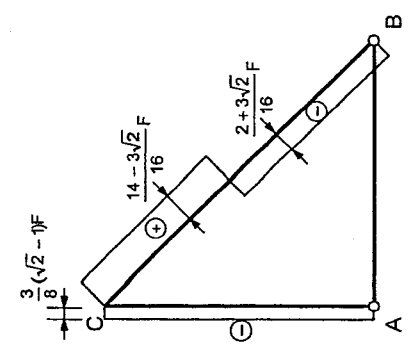




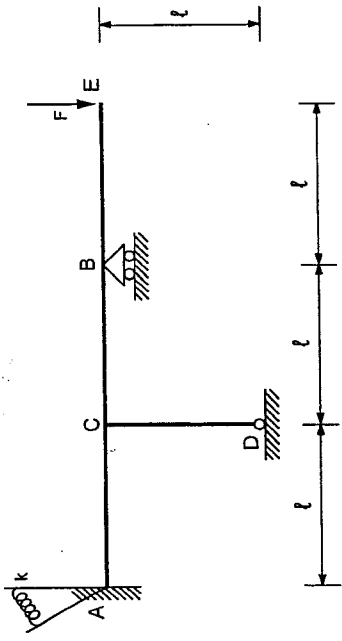
Curva delle pressioni		
Tratto	Curva corrispondente	
ABD	Retta a	
ACD	Retta b	



Deformata elastica

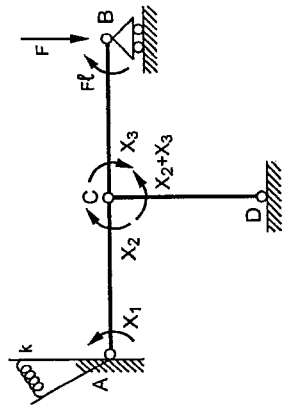


1.9



Reticolare associata

S.P.



Telaio a nodi fissi.

Equazioni di congruenza angolare nei nodi A e C:

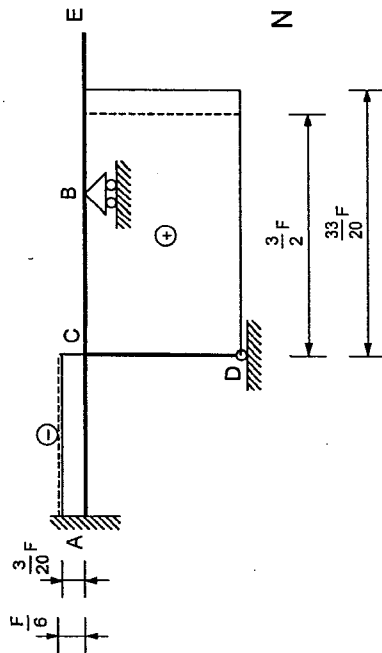
$$\begin{aligned} \varphi_{AC} &= -X_1/k, & \frac{X_1 l}{3EI} + \frac{X_2 l}{6EI} &= -\frac{X_1}{k}, & X_1 &= -\frac{F l}{2} \frac{k l + 18EI}{5k l + 18EI} \\ \varphi_{CA} &= \varphi_{CB}, & \frac{X_2 l}{3EI} - \frac{X_1 l}{6EI} &= -\frac{X_3 l}{3EI} + \frac{F l^2}{6EI}, & X_2 &= -F l \frac{k l + 3EI}{5k l + 18EI} \\ \varphi_{CA} &= \varphi_{CD}, & \frac{X_2 l}{3EI} - \frac{X_1 l}{6EI} &= \frac{(X_2 + X_3) l}{3EI}, & X_3 &= -\frac{F l}{4} \frac{7k l + 24EI}{5k l + 18EI} \end{aligned}$$

Quando la rigidezza k dell'incastro cedevoles angolarmente tende all'infinito si ottiene il seguente risultato:

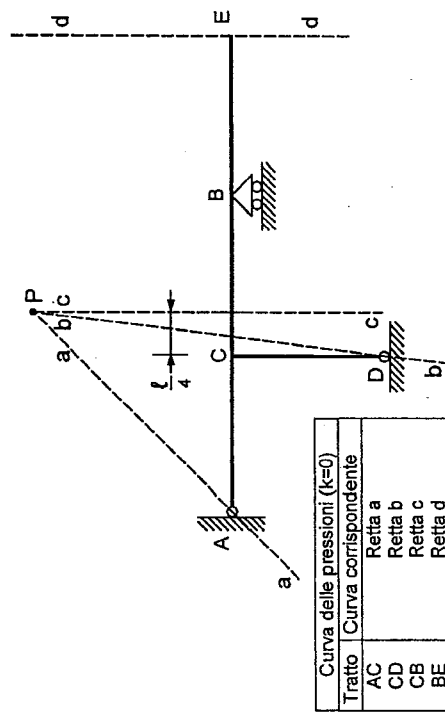
$$\lim_{k \rightarrow \infty} X_1 = -\frac{F l}{10}, \quad \lim_{k \rightarrow \infty} X_2 = -\frac{F l}{5}, \quad \lim_{k \rightarrow \infty} X_3 = \frac{7}{20} F l$$

Quando, invece, la rigidezza k dell'incastro tende a zero si ottiene il seguente risultato:

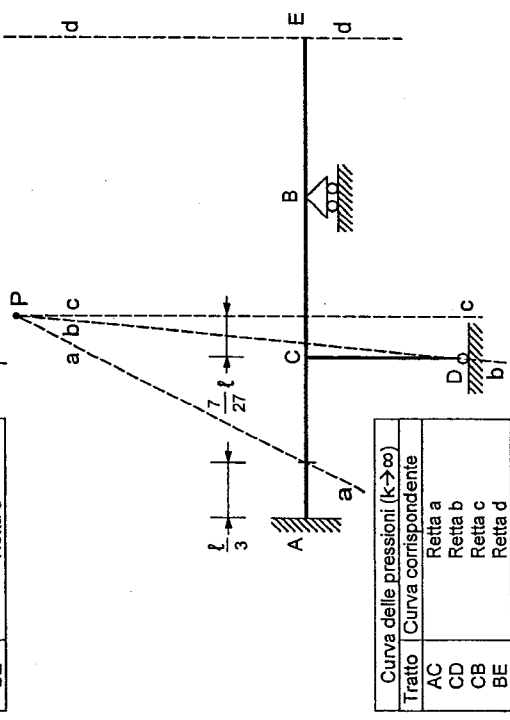
$$\lim_{k \rightarrow 0} X_1 = 0, \quad \lim_{k \rightarrow 0} X_2 = -\frac{F l}{6}, \quad \lim_{k \rightarrow 0} X_3 = \frac{F l}{3}$$



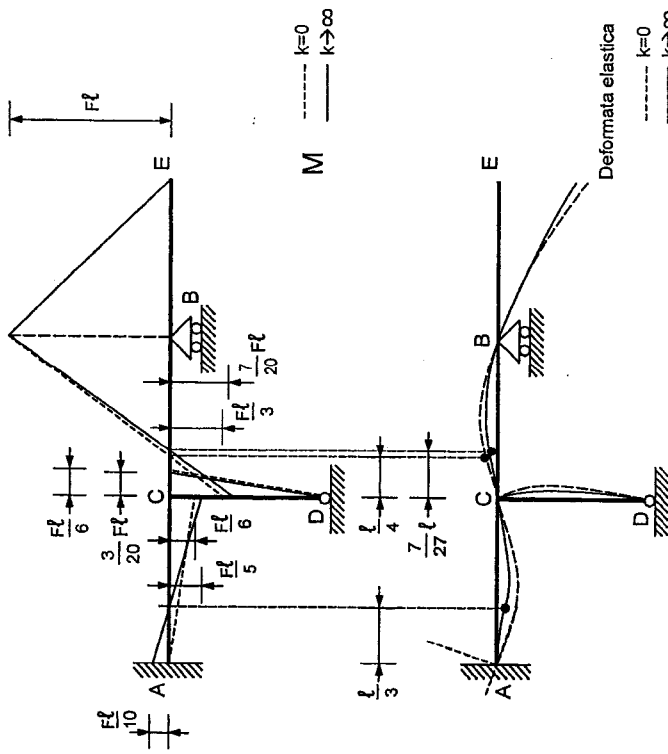
----- $k=0$
 ----- $k \rightarrow \infty$



Curva delle pressioni ($k=0$)	
Tratto	Curva corrispondente
AC	Retta a
CD	Retta b
CB	Retta c
BE	Retta d



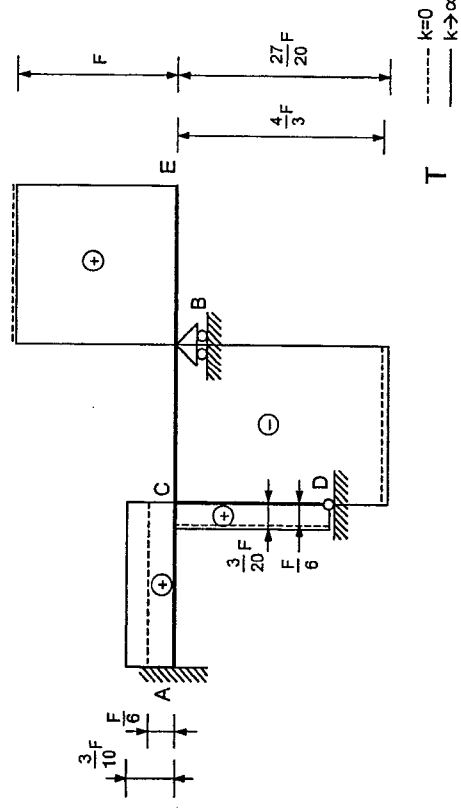
Curva delle pressioni ($k \rightarrow \infty$)	
Tratto	Curva corrispondente
AC	Retta a
CD	Retta b
CB	Retta c
BE	Retta d



M ----- $k=0$
 ----- $k \rightarrow \infty$

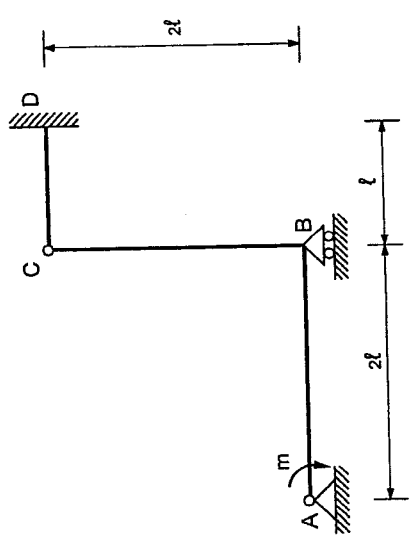
Deformata elastica

----- $k=0$
 ----- $k \rightarrow \infty$



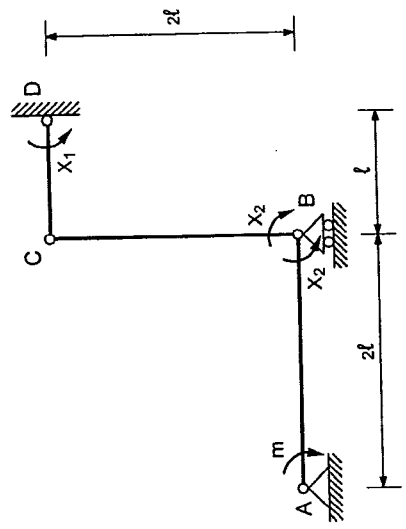
T ----- $k=0$
 ----- $k \rightarrow \infty$

1.10



Reticolare associata

S.P.

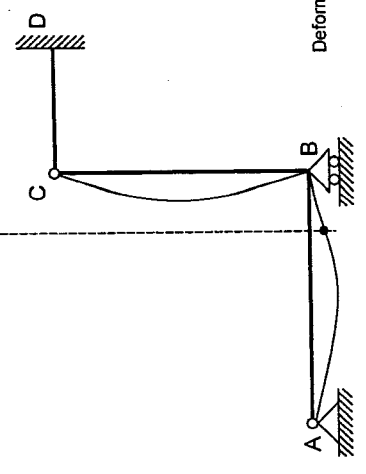
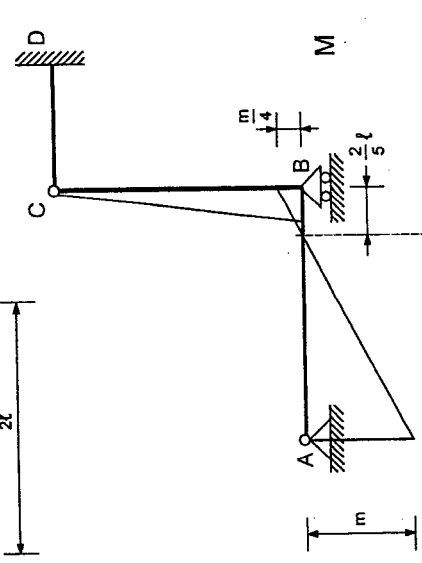
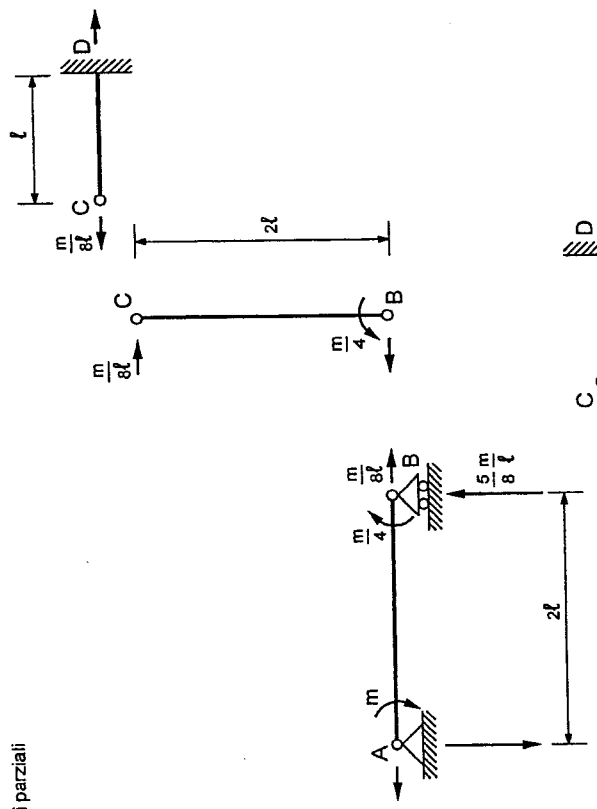


Telaio a nodi fissi.

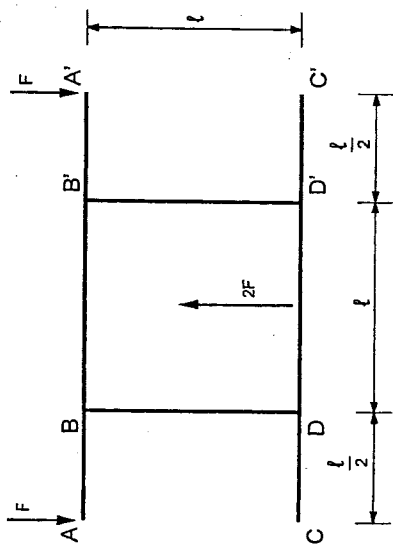
Equazioni di congruenza angolare nei nodi D e B:

$$\begin{aligned} \varphi_{DC} &= 0, & X_1 \frac{l}{3EI} &= 0, & X_1 &= 0 \\ \varphi_{BA} &= \varphi_{BC}, & X_2 \frac{2l}{3EI} + \frac{m2l}{6EI} &= -\frac{X_2 2l}{3EI}, & X_2 &= -\frac{m}{4} \end{aligned}$$

Schemi parziali



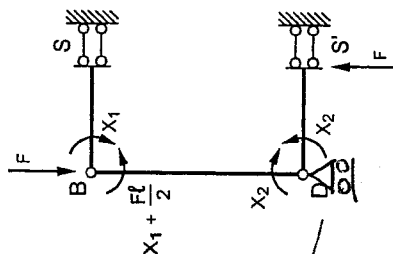
3.2



La struttura è simmetrica con carico simmetrico.

~~Retecolare associata~~

S.P.



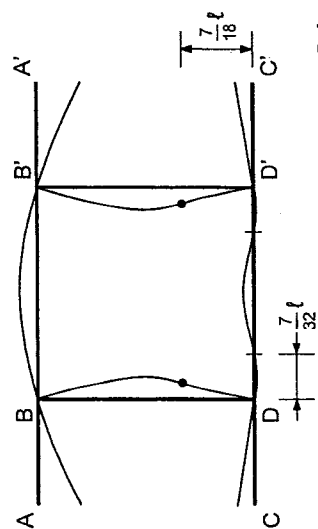
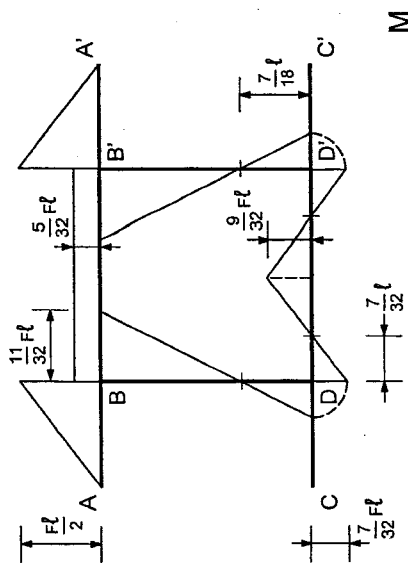
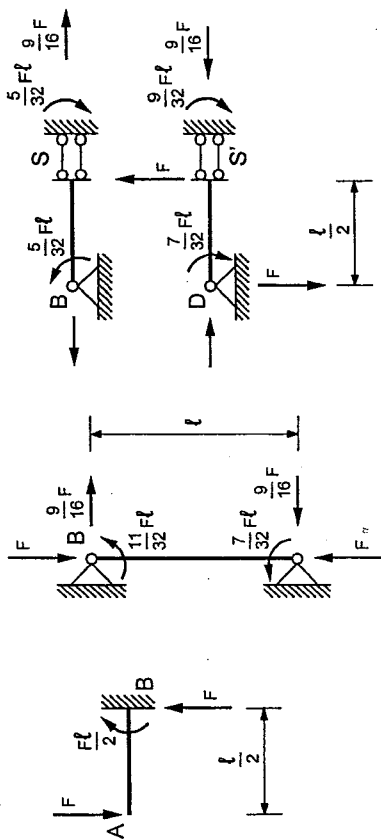
CARRELLINO INTRODOTTI
PER BILANCIARE
IL MOMENTO RIGIDO
(E' SCARICO)

Telaio a nodi fissi.

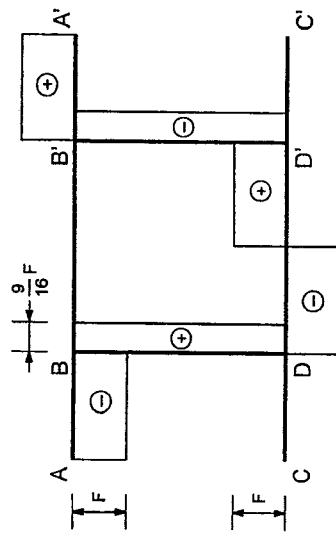
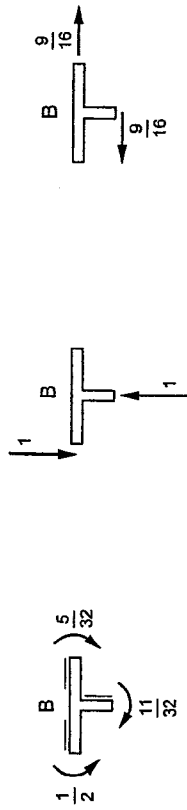
Equazioni di congruenza angolare nei nodi B e D:

$$\begin{aligned} \varphi_{BD} = \varphi_{BS} &= \frac{(X_1 + \frac{F}{2})l}{3EI} + \frac{X_2 l}{6EI} = -\frac{X_1 l}{2EI} & X_1 = -\frac{5 F l}{32} \\ \varphi_{DB} = \varphi_{DS} &= -\frac{(X_1 + \frac{F}{2})l}{6EI} - \frac{X_2 l}{3EI} = \frac{X_2 l}{2EI} + \frac{F l^2}{8EI} & X_2 = -\frac{7 F l}{32} \end{aligned}$$

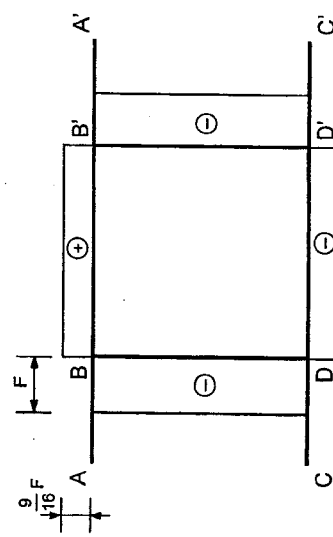
Schemi parziali



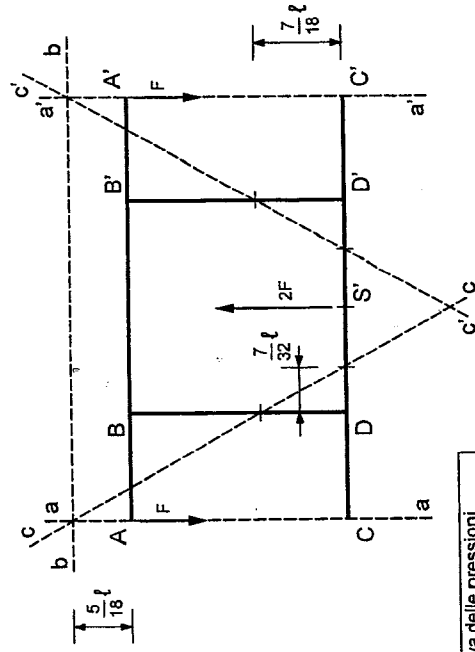
Deformata elastica



T

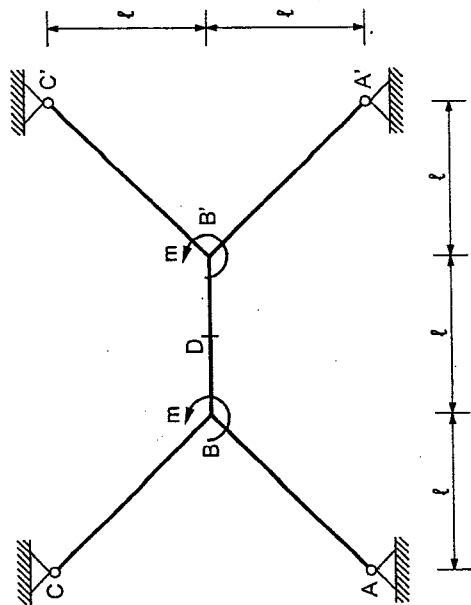


N



Curva delle pressioni	
Tratto	Curva corrispondente
AB	Retta a
BB'	Retta b
BDS'	Retta c
A'B'	Retta a'
B'D'S	Retta c'
CD-C'D'	Non definita

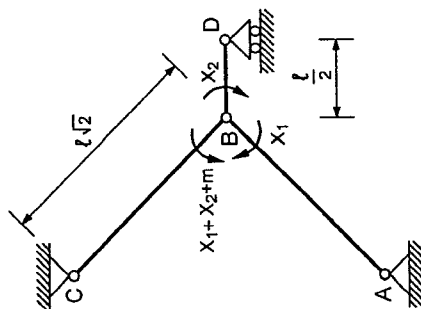
3.8



La struttura è a simmetria assiale con carico antisimmetrico ed a simmetria polare con carico simmetrico.

Reticolare associata

S.p.

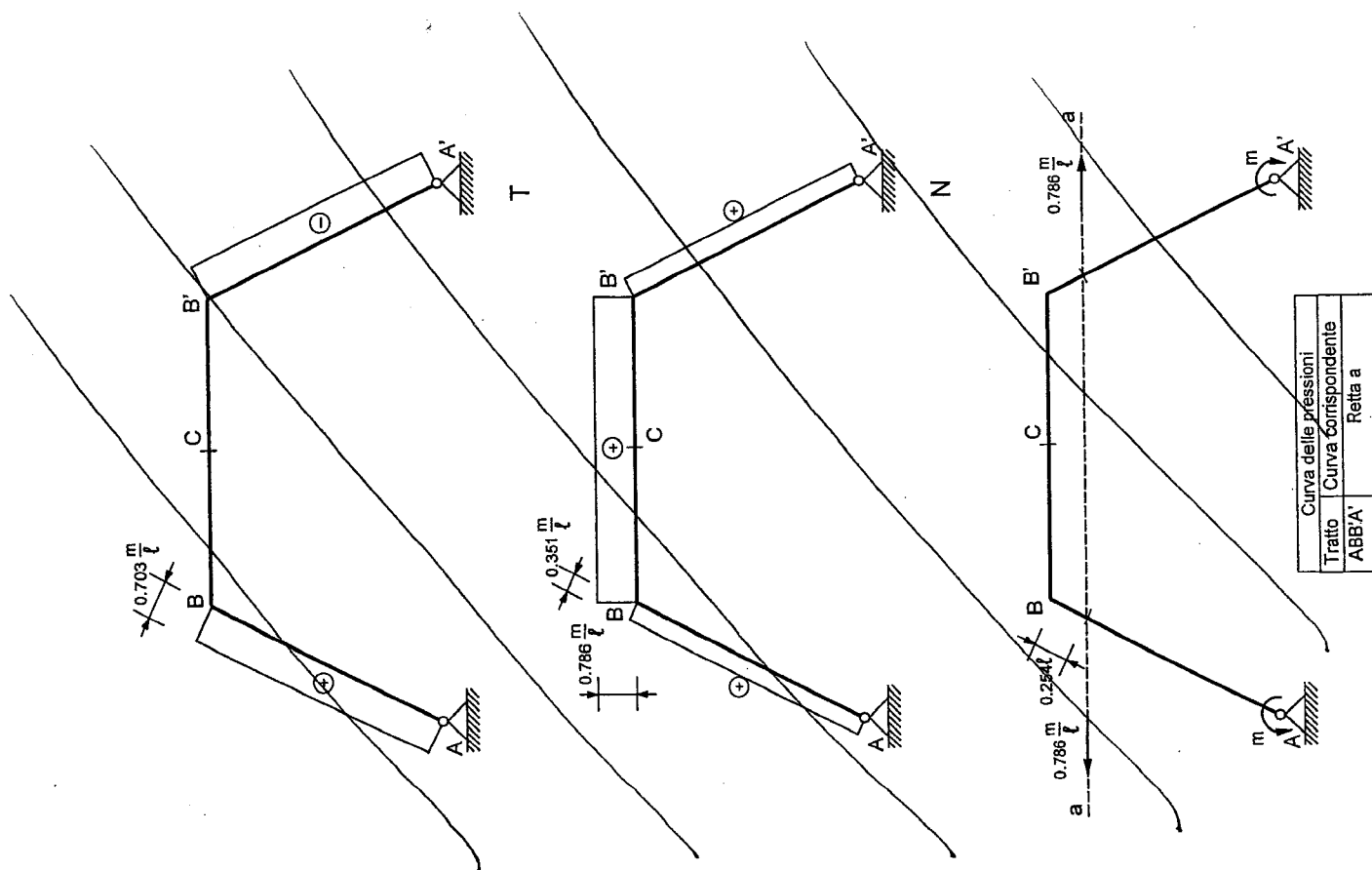


Telaio a nodi fissi.

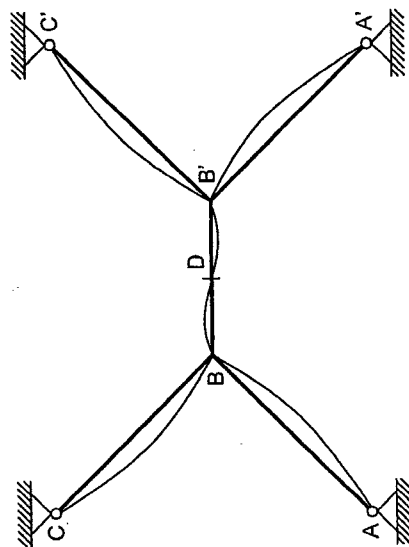
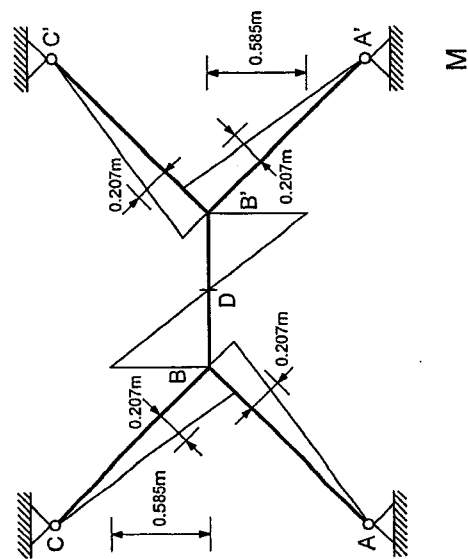
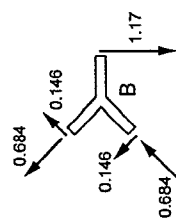
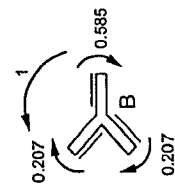
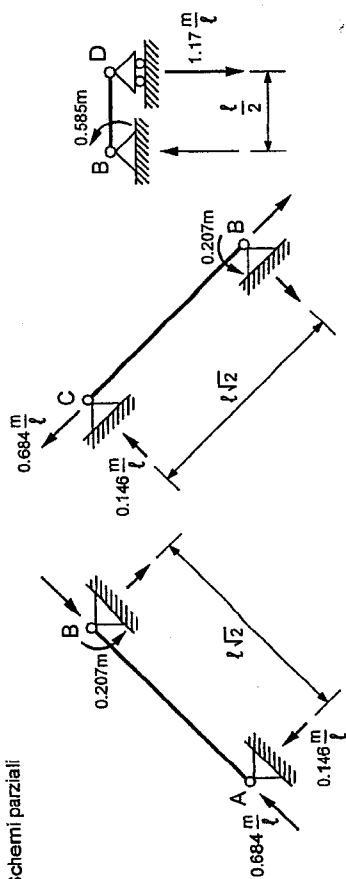
Equazioni di congruenza angolare nel nodo B:

$$\varphi_{BC} = \varphi_{BA}, \quad \frac{(X_1 + X_2 + m)\sqrt{2}l}{3EI} = -\frac{X_1\sqrt{2}l}{3EI}, \quad X_1 = -\frac{(\sqrt{2}-1)}{2}m = -0.207m$$

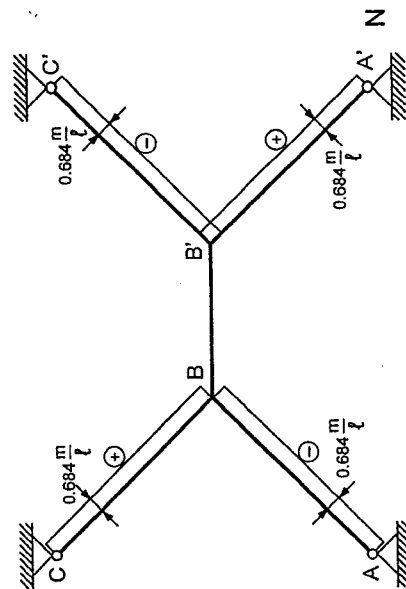
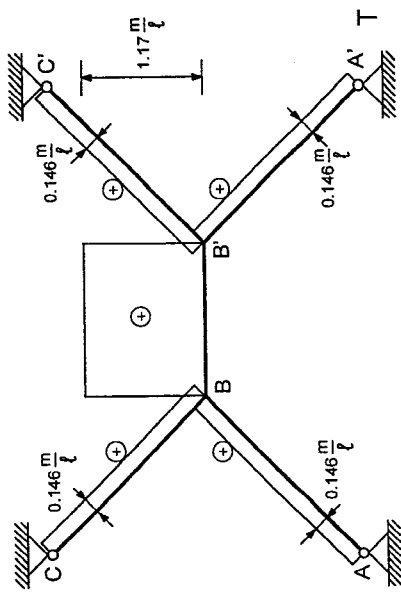
$$\varphi_{DC} = \varphi_{DB}, \quad \frac{(X_1 + X_2 + m)\sqrt{2}l}{3EI} = -\frac{X_2l}{6EI}, \quad X_2 = -(2-\sqrt{2})m = -0.585m$$



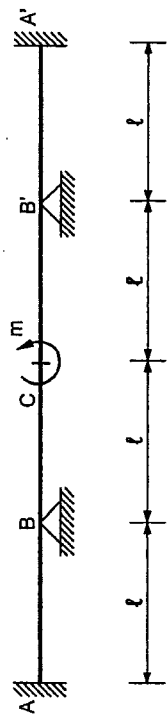
Schemi parziali



Deformata elastica



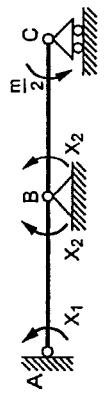
4.8



La struttura è simmetrica con carico antisimmetrico.

Reticolare associata

S.P.

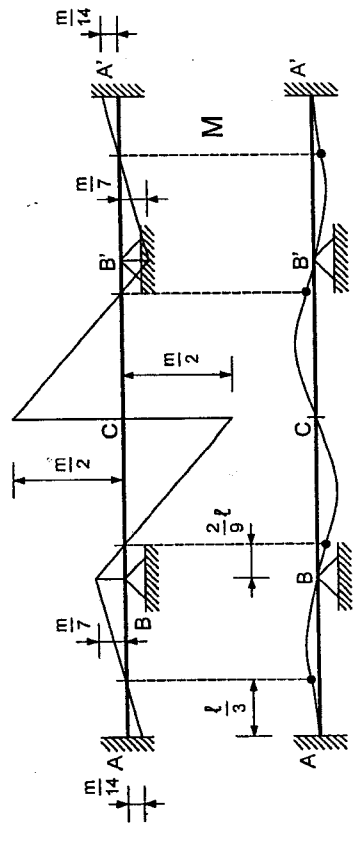
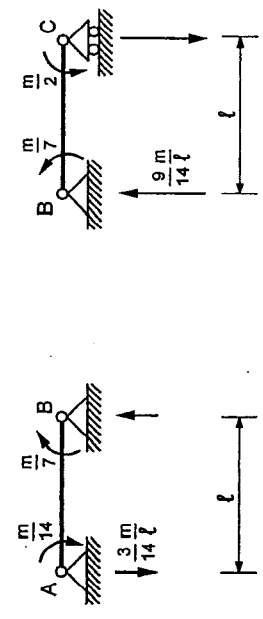


La trave è a nodi fissi e quindi le equazioni sono solo di congruenza.

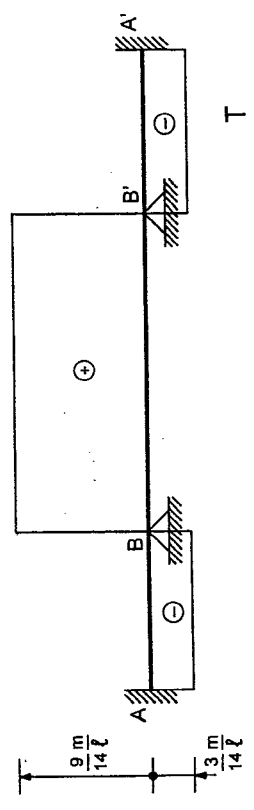
Equazioni di congruenza angolare nei nodi A e B:

$$\begin{aligned} \varphi_{AB} &= 0, & X_1 l + \frac{X_2 l}{6EI} &= 0, & X_1 &= -\frac{m}{14} \\ \varphi_{BA} &= \varphi_{BC}, & -\frac{X_1 l}{6EI} - \frac{X_2 l}{3EI} &= \frac{X_2 l}{3EI} - \frac{m}{12EI}, & X_2 &= \frac{m}{7} \end{aligned}$$

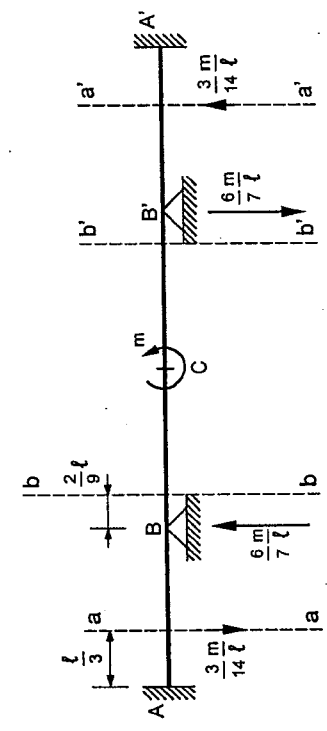
Schemi parziali



Deformata elastica

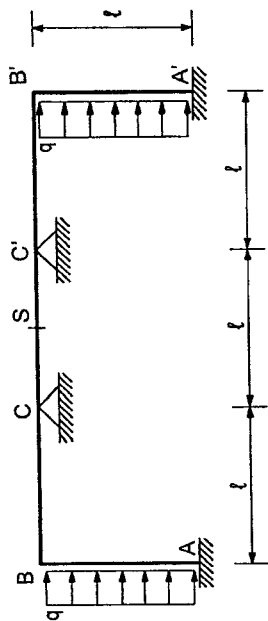


N=0



Curva delle pressioni	
Tratto	Curva corrispondente
AB	Retta a
BC	Retta b
CB'	Retta b'
B'A'	Retta a'

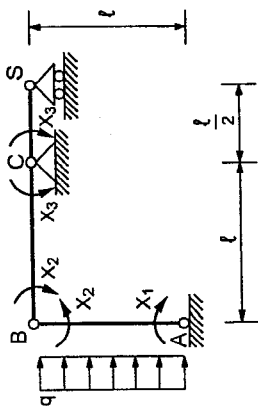
4.22



La struttura è simmetrica con carico antisimmetrico.

Releolare associata

S.P.

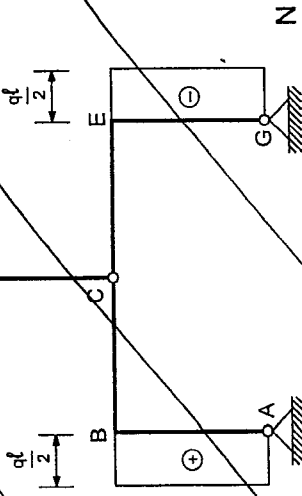
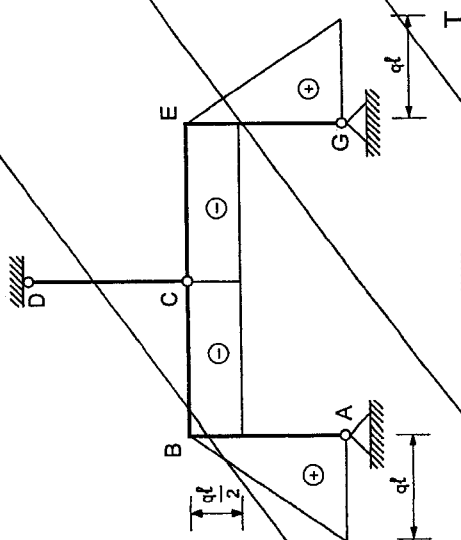
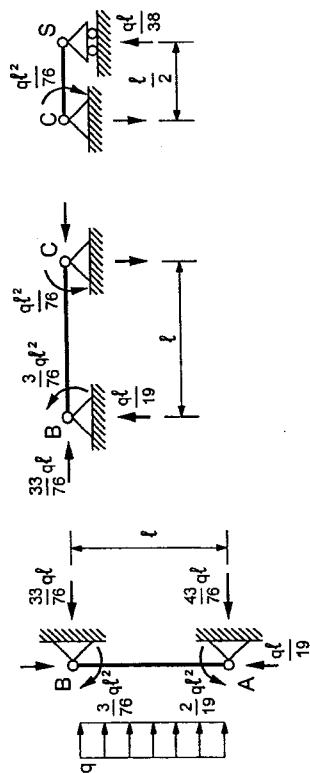


Telaio a nodi fissi.

Equazioni di congruenza angolare nei nodi A, B e C:

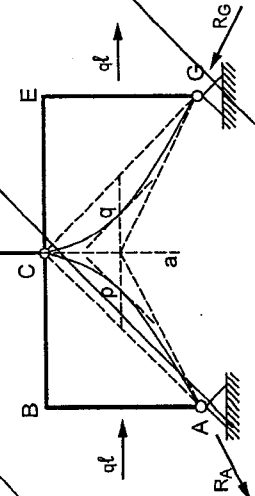
$$\begin{aligned} \varphi_{AB} &= 0, & -\frac{X_1 l}{3EI} - \frac{X_2 l}{6EI} - \frac{ql^3}{24EI} &= 0, & X_1 &= -\frac{2}{19} \frac{ql^2}{EI} \\ \varphi_{BA} &= \varphi_{BC}, & \frac{X_1 l}{6EI} + \frac{X_2 l}{3EI} + \frac{ql^3}{24EI} &= -\frac{X_2 l}{3EI} - \frac{X_3 l}{6EI}, & X_2 &= -\frac{3}{76} \frac{ql^2}{EI} \\ \varphi_{CB} &= \varphi_{CS}, & \frac{X_2 l}{6EI} + \frac{X_3 l}{3EI} &= -\frac{X_3 l}{6EI}, & X_3 &= \frac{ql^2}{76EI} \end{aligned}$$

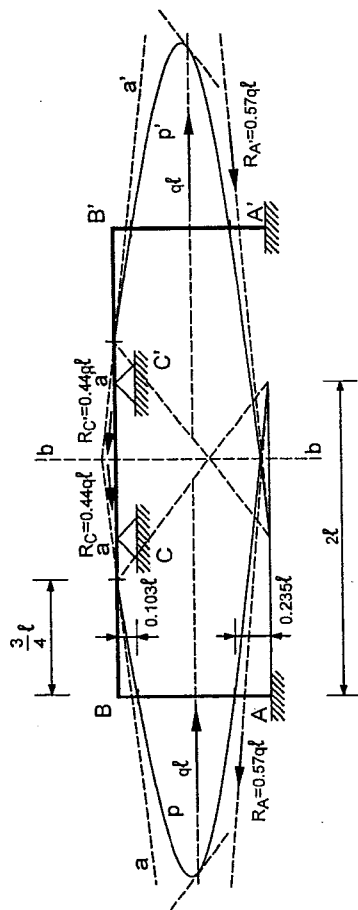
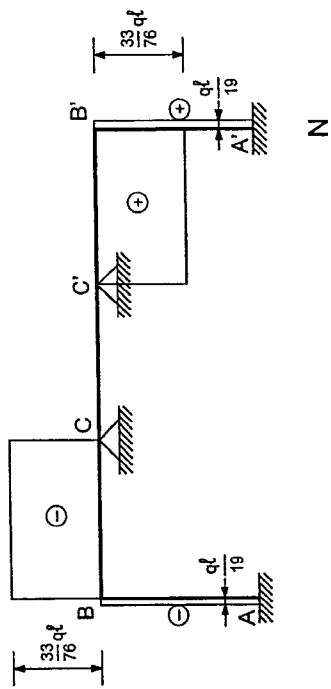
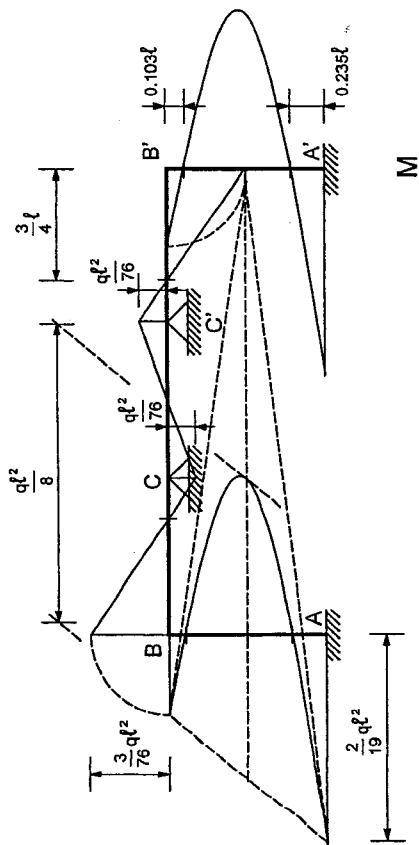
Schemi parziali



Tratto	Curva delle pressioni
AB	Parabola p
BCE	Retta a
EG	Parabola q
CD	Non definibile

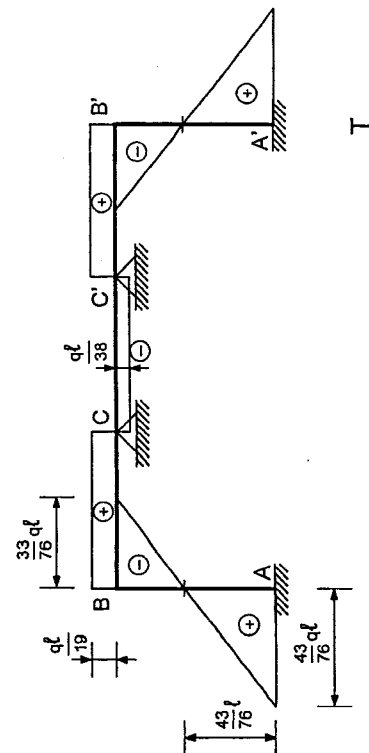
$$\begin{aligned} R_G &= \frac{\sqrt{5}}{2} ql \\ R_A &= \frac{\sqrt{5}}{2} ql \end{aligned}$$

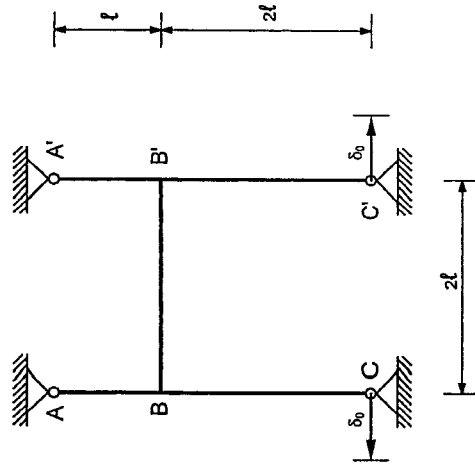




Tratto	Curva delle pressioni
AB	Parabola p
BC	Retta a
CC'	Retta b
C'B'	Retta a'
B'A'	Parabola p'

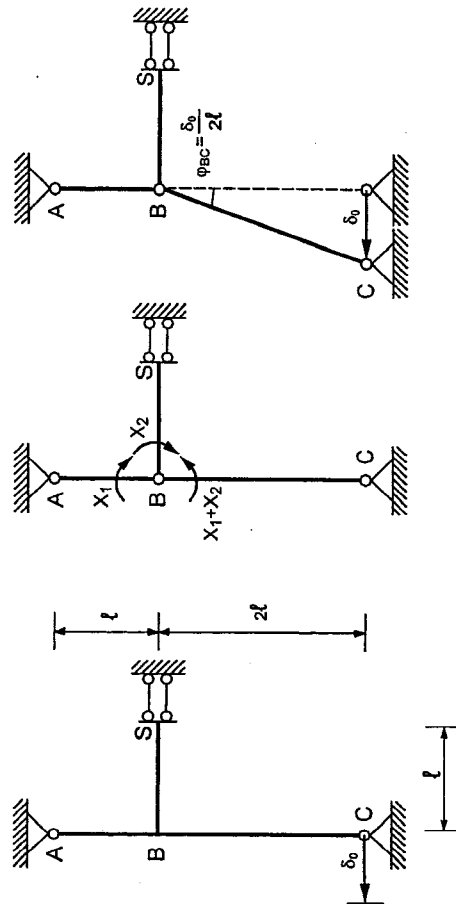
Deformata elastica





La struttura è simmetrica con carico simmetrico.

Reticolare associata S. f.

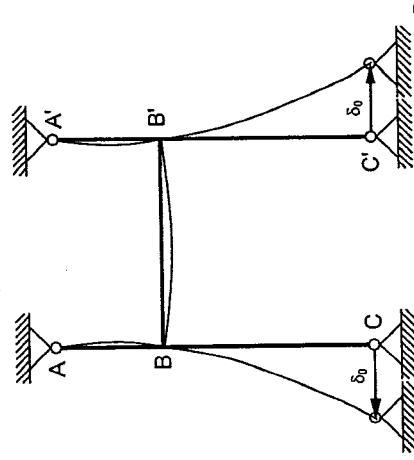
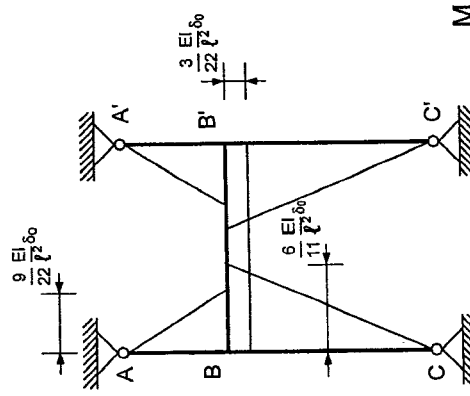
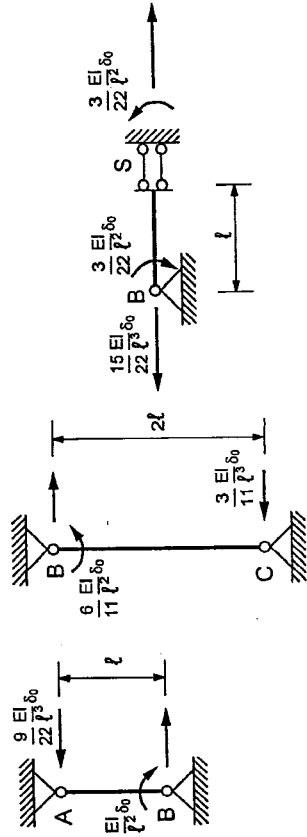


Telaio a nodi fissi.

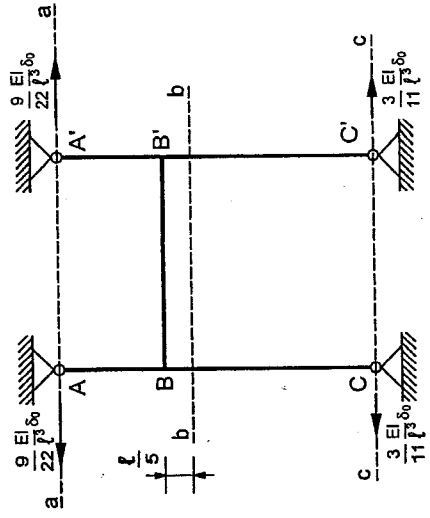
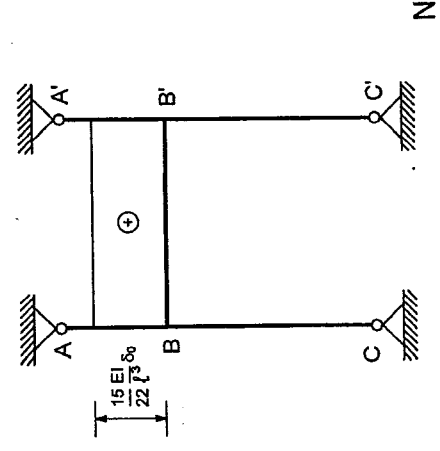
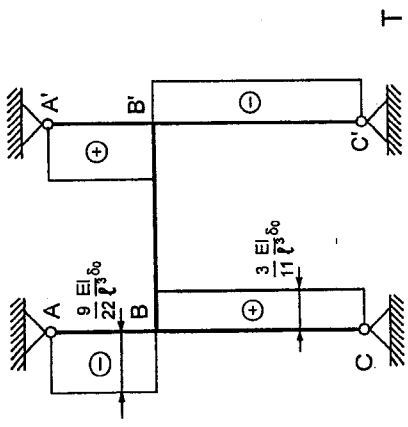
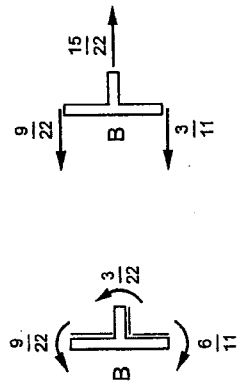
Equazioni di congruenza angolare nel nodo B:

$$\begin{aligned} \varphi_{BA} &= \varphi_{BC}, & X_1 &= \frac{9 \delta_0 EI}{22 l^2}, \\ -\frac{X_1 l}{3EI} - \frac{(X_1 + X_2) 2l}{3EI} - \frac{\delta_0}{2l}, & & X_2 &= -\frac{3 \delta_0 EI}{22 l^2}, \\ \varphi_{BA} &= \varphi_{BC}, & & \end{aligned}$$

Schemi parziali

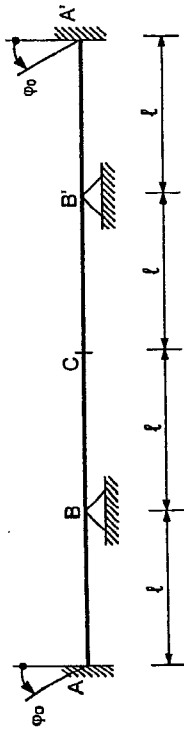


Deformata elastica



Curva delle pressioni	
Tratto	Curva corrispondente
AB	Retta a
A'B'	Retta a
BB'	Retta b
CB	Retta c
C'B'	Retta c

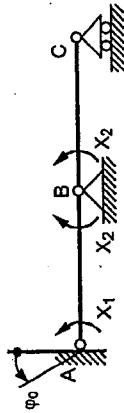
5.24



La struttura è simmetrica con carico antisimmetrico.

Retiela associata

S.p.

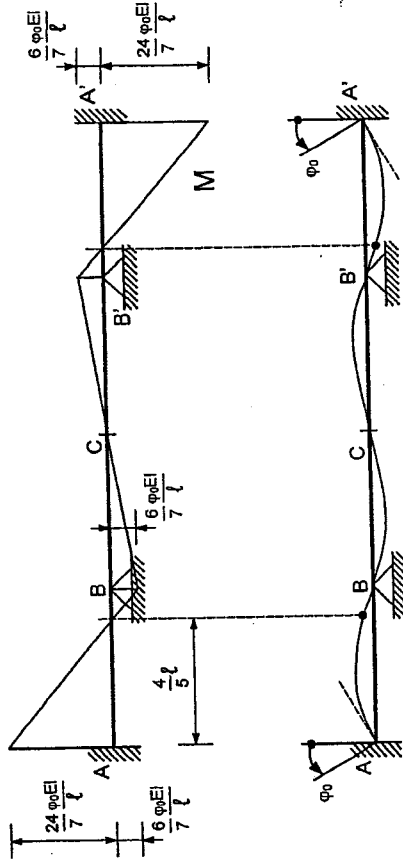
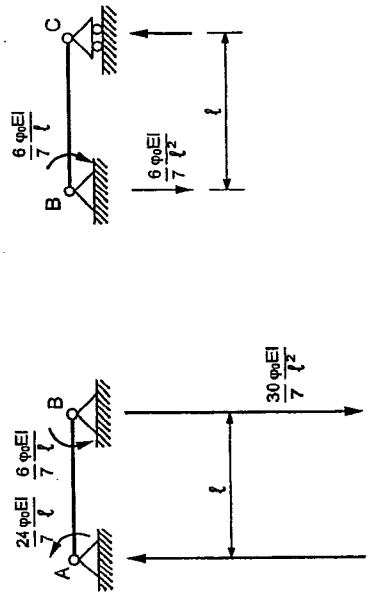


La trave è a nodi fissi e quindi le equazioni sono solo di congruenza.

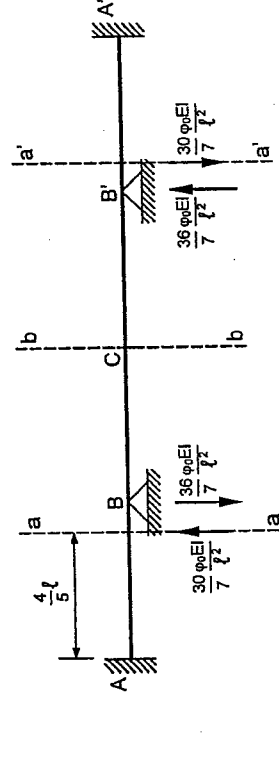
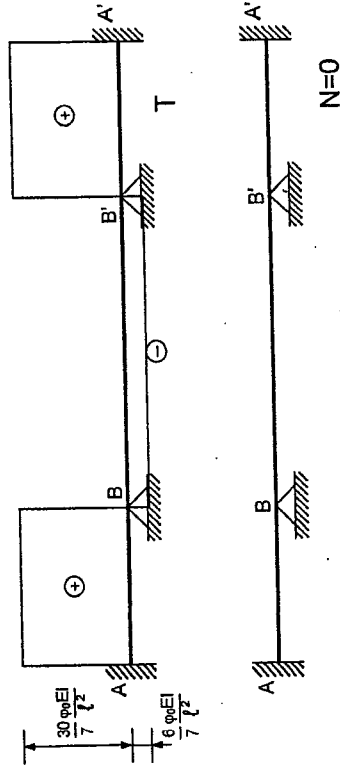
Equazioni di congruenza angolare nei nodi A e B:

$$\begin{aligned} \varphi_{AB} &= \varphi_0, & X_1 \frac{l}{3EI} + \frac{X_2 l}{6EI} &= \varphi_0, & X_1 &= \frac{24 \varphi_0 EI}{7 l} \\ \varphi_{BA} &= \varphi_{BC}, & \frac{X_1 l}{6EI} - \frac{X_2 l}{3EI} &= \frac{X_2 l}{3EI}, & X_2 &= -\frac{6 \varphi_0 EI}{7 l} \end{aligned}$$

Schemi parziali

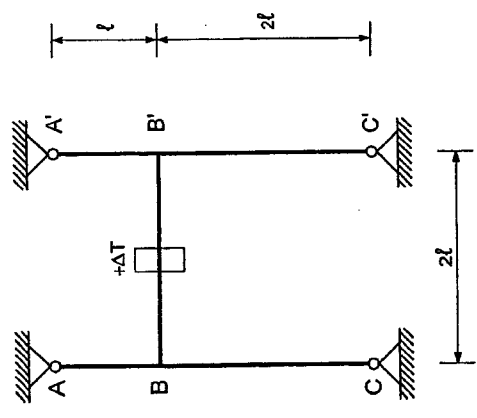


Deformata elastica

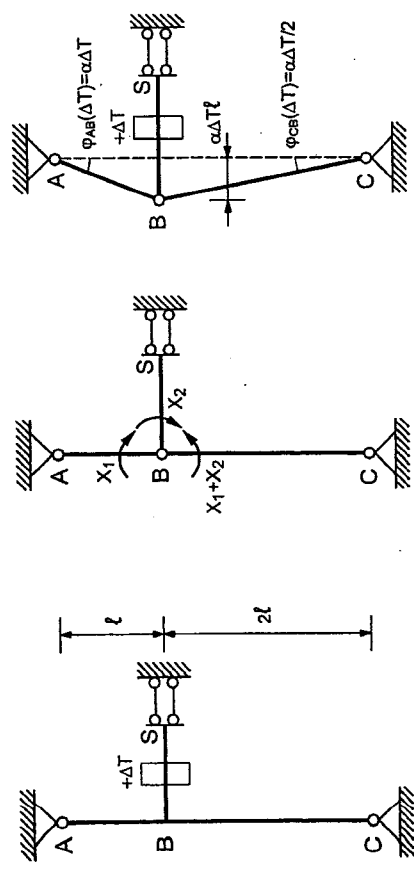


Curva delle pressioni	
Tratto	Curva corrispondente
AB	Retta a
BCB'	Retta b
B'A'	Retta a'

6.1



La struttura è simmetrica con carico simmetrico.
Reticolare associata

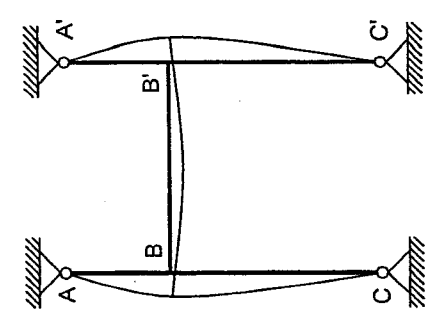
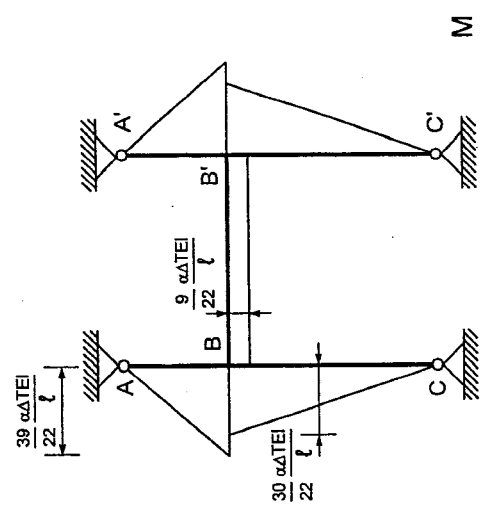
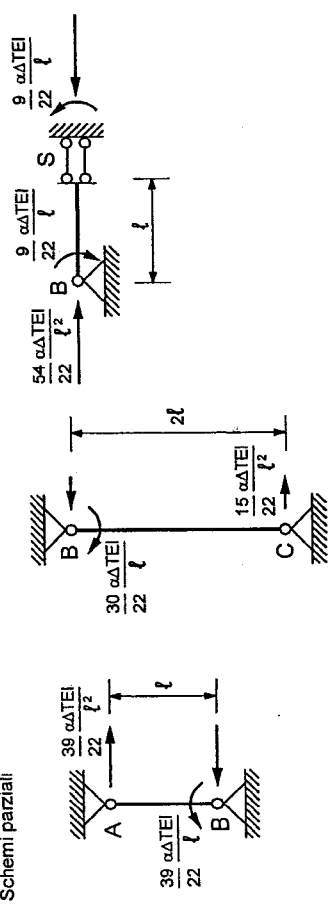


Telaio a nodi fissi.

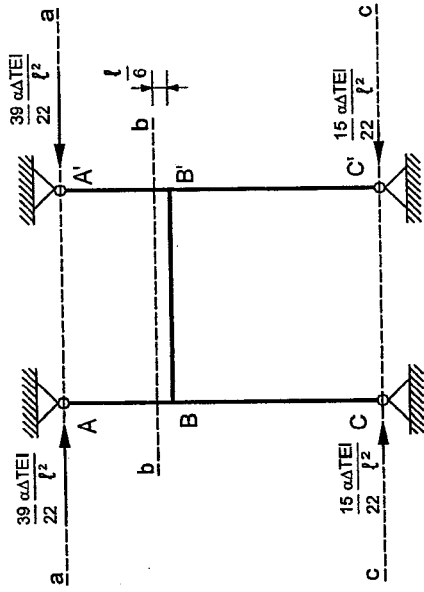
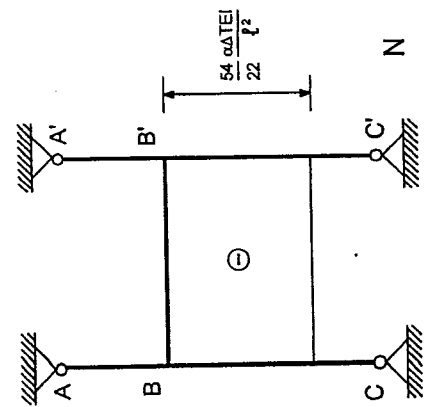
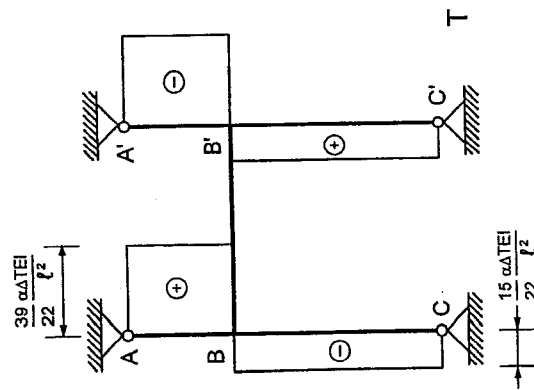
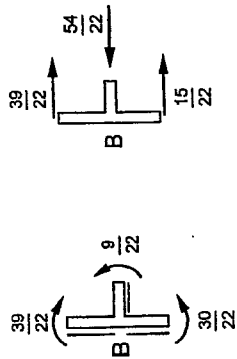
Equazioni di congruenza angolare nel nodo B:

$$\begin{aligned} \varphi_{BA} &= \varphi_{BC}, & -\frac{X_1 l}{3EI} - \alpha \Delta T &= \frac{(X_1 + X_2) 2l}{3EI} + \frac{\alpha \Delta T}{2}, & X_1 &= -\frac{39 \alpha \Delta T EI}{22 l} \\ \varphi_{BA} &= \varphi_{BS}, & -\frac{X_1 l}{3EI} - \alpha \Delta T &= -\frac{X_2 l}{EI}, & X_2 &= \frac{9 \alpha \Delta T EI}{22 l} \end{aligned}$$

Schemi parziali

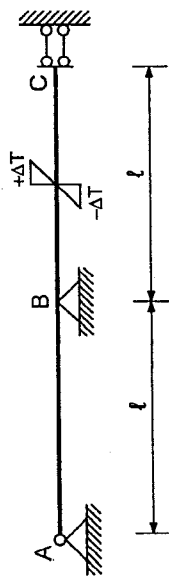


Deformata termoelastica

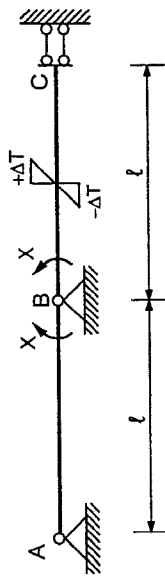


Curva delle pressioni	
Tratto	Curva corrispondente
AB	Retta a
A'B'	Retta a
BB'	Retta b
CB	Retta c
C'B'	Retta c

6.7



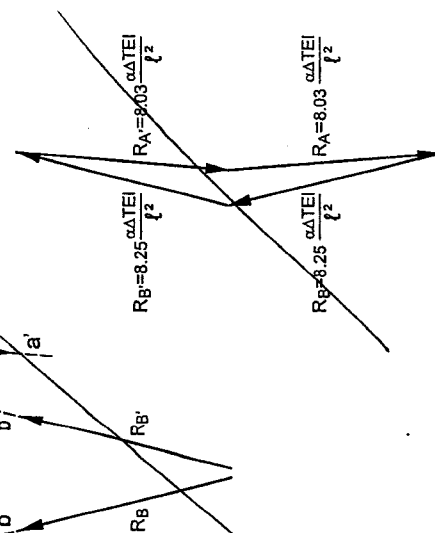
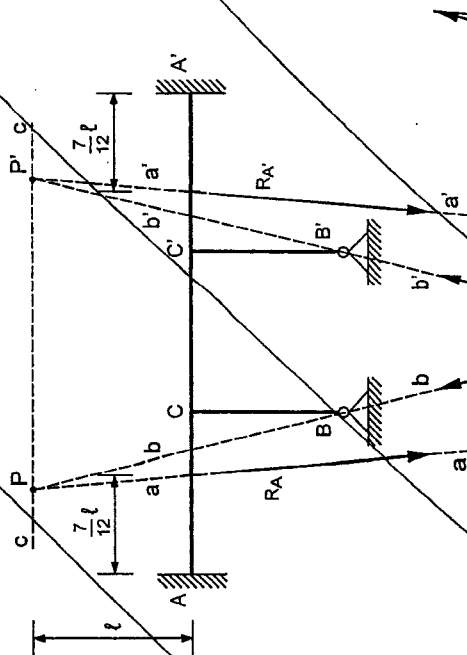
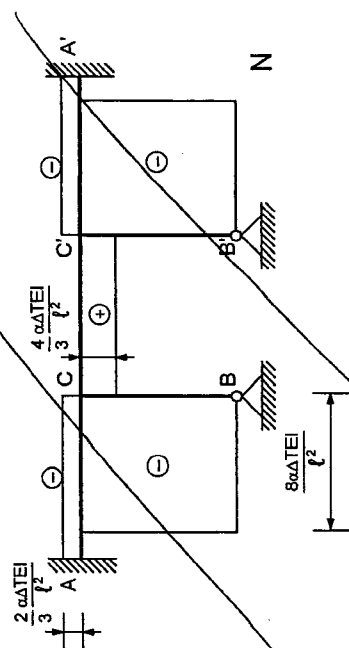
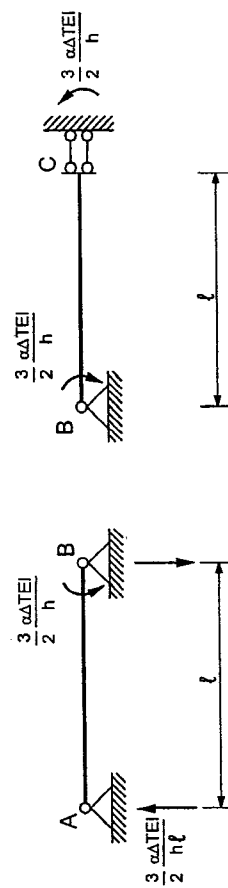
Reticolare associata



Equazione di congruenza angolare nel nodo B:

$$\varphi_{BA} = \varphi_{BC}, \quad -\frac{Xl}{3EI} = \frac{Xl}{EI} + \frac{2\alpha\Delta Tl}{h}, \quad X = -\frac{3\alpha\Delta Tl}{2h}$$

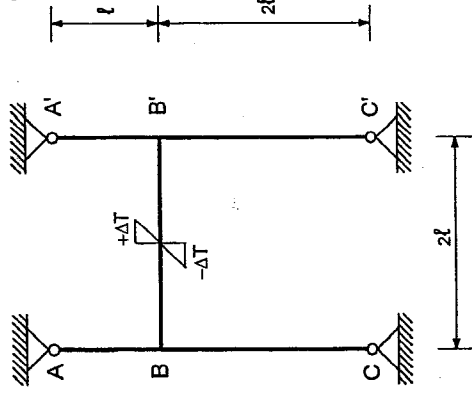
Schemi parziali



Curva delle pressioni	
Traito	Curva corrispondente
AC	Retta a
CB	Retta b
CC'	Retta c
C'B'	Retta b'
CA'	Retta a'

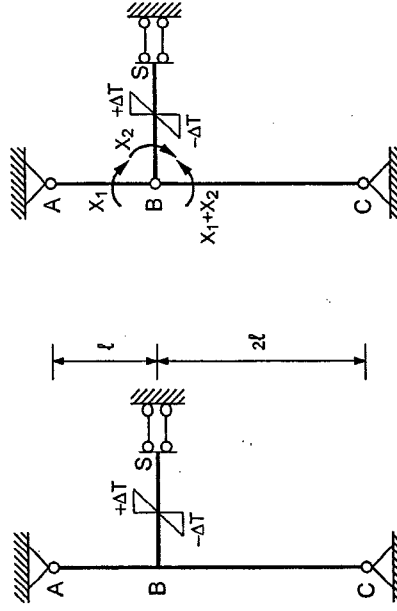
DI QUESTO ES.
C'E' SOLO QUESTA
PAGINA.

6.8



La struttura è simmetrica con carico simmetrico.

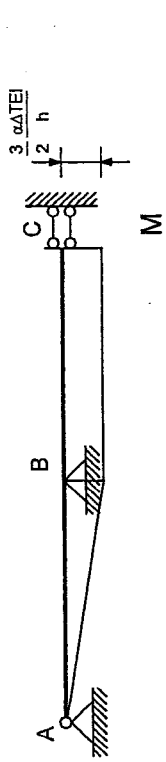
Reticolare associata



Telaio a nodi fissi.

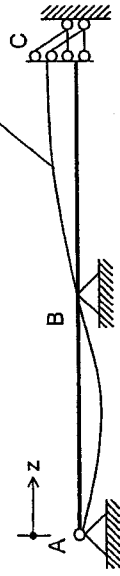
Equazioni di congruenza angolare nel nodo B:

$$\begin{aligned} \varphi_{BA} &= \varphi_{BC}, \\ \varphi_{BA} &= \varphi_{BS}, \\ X_1 l &= \frac{(X_1 + X_2) 2l}{3EI}, \\ X_1 l &= \frac{X_2 l}{3EI} + \frac{2\alpha \Delta T l}{EI}, \\ X_1 &= -\frac{12 \alpha \Delta T EI}{11 h}, \\ X_2 &= \frac{18 \alpha \Delta T EI}{11 h} \end{aligned}$$

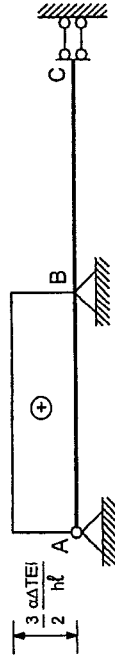


Curvatura termoelastica

$$\chi(z) = \frac{3 \alpha \Delta T}{2 h} - \frac{2 \alpha \Delta T}{h} - \frac{1 \alpha \Delta T}{2 h}$$



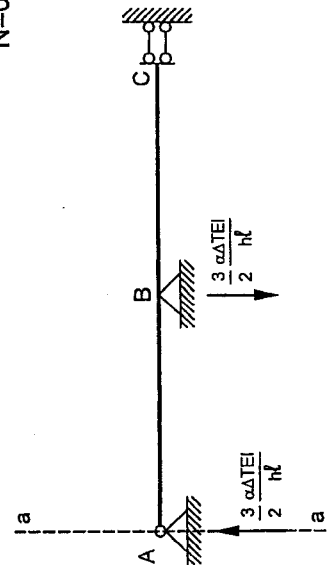
Deformata termoelastica



T

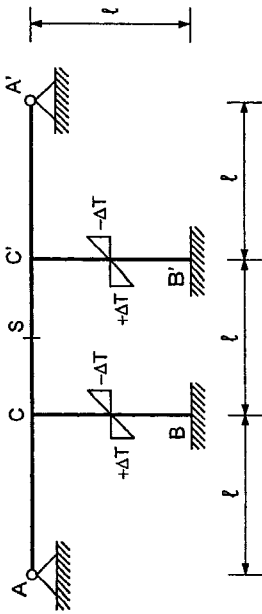


N=0



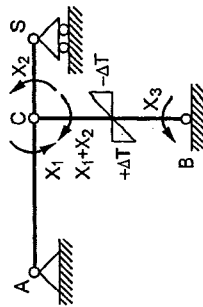
Curva delle pressioni	
Tratto	Curva corrispondente
AB	Retta a
BC	Retta impropria

6.20



La struttura è simmetrica con carico antisimmetrico.

Reticolare associata

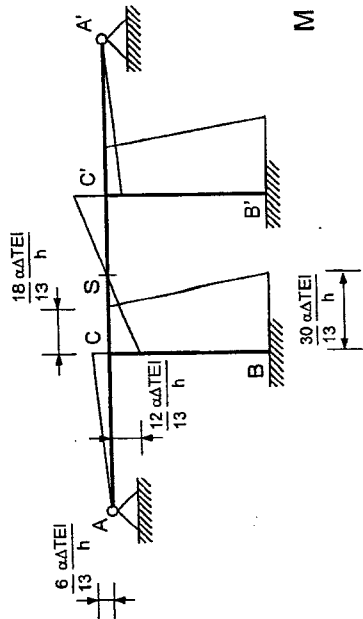
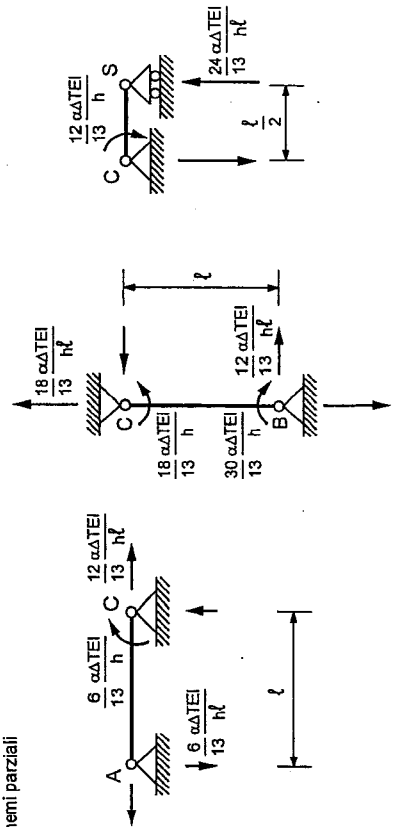


Telaio a nodi fissi.

Equazioni di congruenza angolare nei nodi B e C:

$$\begin{aligned} \varphi_{CA} &= \varphi_{CS}, & X_1 l &= \frac{X_2 l}{3EI}, & X_1 &= -\frac{6 \alpha \Delta T E I}{13 h} \\ \varphi_{CB} &= \varphi_{CS}, & \frac{X_1 l}{3EI} &= -\frac{(X_1 + X_2) l}{3EI} - \frac{X_3 l}{6EI} - \frac{\alpha \Delta T l}{h}, & X_2 &= -\frac{12 \alpha \Delta T E I}{13 h} \\ \varphi_{BC} &= 0, & \frac{(X_1 + X_2) l}{6EI} + \frac{X_3 l}{3EI} + \frac{\alpha \Delta T l}{h} &= 0, & X_3 &= -\frac{30 \alpha \Delta T E I}{13 h} \end{aligned}$$

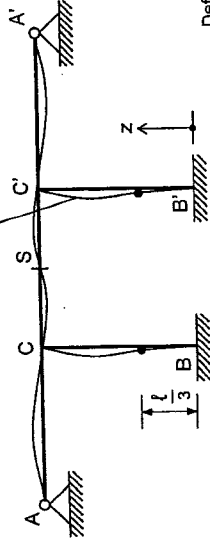
Schemi parziali



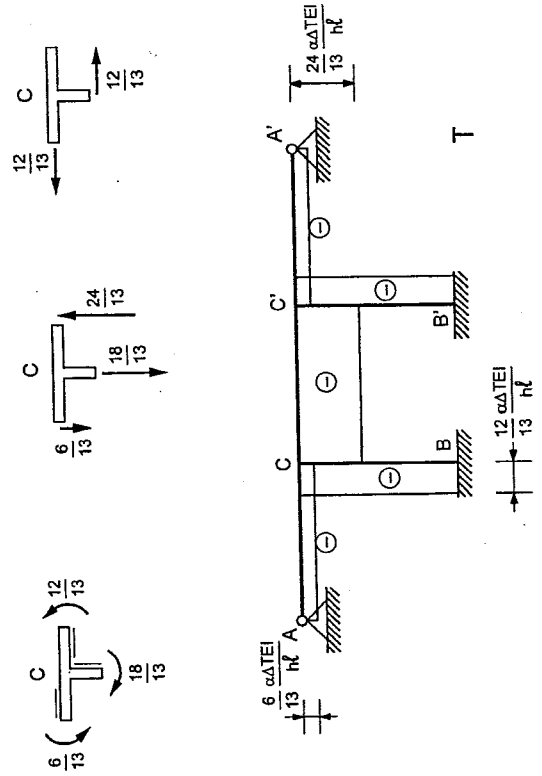
Curvatura termoelastica:

$$\chi(z) = -\frac{2\alpha\Delta T}{h} + \frac{30\alpha\Delta T}{13h} - \frac{12\alpha\Delta T}{13h} \frac{z}{l}, \quad 0 \leq z \leq l$$

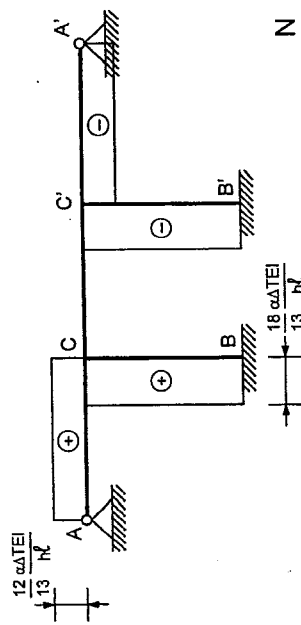
$$\chi\left(\frac{l}{3}\right) = 0 \quad (\text{Flesso termoelastico})$$



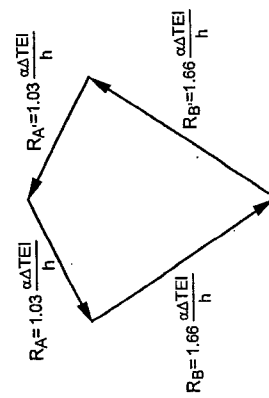
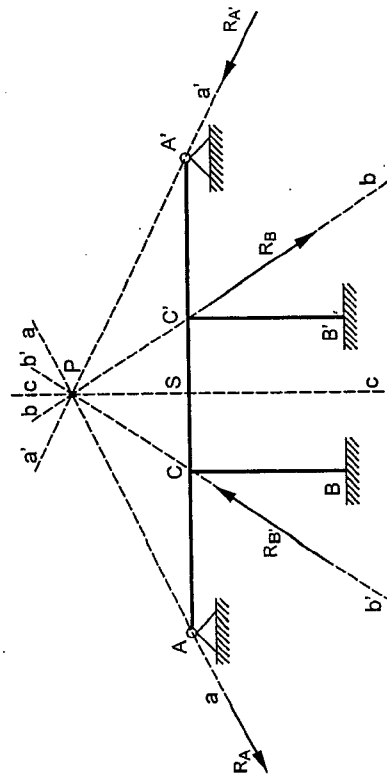
Deformata termoelastica



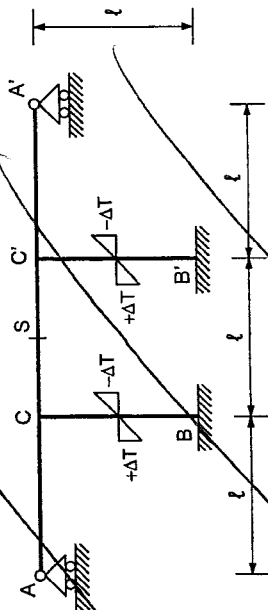
6.21



N

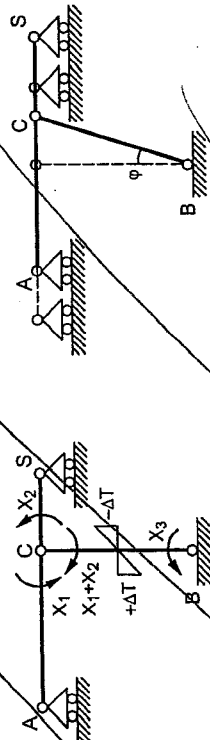


Curva delle pressioni	
Tratto	Curva corrispondente
AC	Retta a
CB	Retta b
CC'	Retta c
C'B'	Retta b'
C'A'	Retta a'



La struttura è simmetrica con carico antisimmetrico.

Reticolare associata

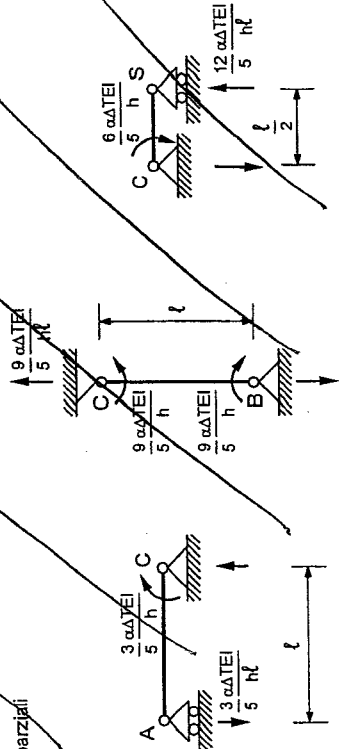


Telaio a nodi spostabili.

Equazioni di congruenza angolare nei nodi B e C, associate ad un'equazione di equilibrio espressa tramite il P.L.V.:

$$\begin{aligned} \varphi_{CA} &= \varphi_{CS}, & X_1 l &= \frac{X_2 l}{3EI}, & X_1 l &= -\frac{3 \alpha \Delta T EI}{5} \frac{h}{h}, \\ \varphi_{CA} &= \varphi_{CB}, & X_1 l &= -\frac{(X_1 + X_2) l}{3EI} - \frac{X_3 l}{6EI} - \frac{\alpha \Delta T l}{h}, & X_2 &= -\frac{6 \alpha \Delta T EI}{5} \frac{h}{h}, \\ \varphi_{BC} &= 0, & \frac{(X_1 + X_2) l}{6EI} + \frac{X_3 l}{3EI} + \frac{\alpha \Delta T l}{h} - \varphi &= 0, & X_3 &= -\frac{9 \alpha \Delta T EI}{5} \frac{h}{h}, \\ \text{P.L.V.,} & & (X_1 + X_2) \varphi - X_3 \varphi &= 0, & \varphi &= \frac{\alpha \Delta T l}{10h} \end{aligned}$$

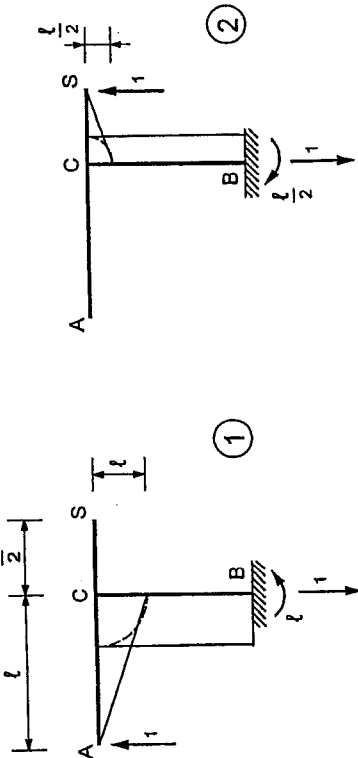
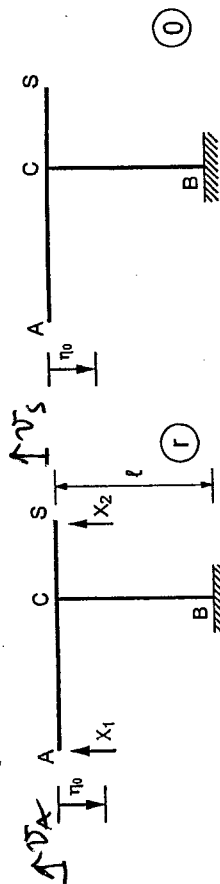
Schemi parziali



7.8 (v. 5.14)

STR. PRINCIPALE

eq di congruenza:
 $v_A = -\eta_0$, $v_S = 0$



Poiché il momento reale M_r è fornito dalla combinazione lineare dei momenti parziali M_i :

$$M_r = M_0 + \sum_i X_i M_i$$

nel caso considerato, essendo $M_0 = 0$, si ha:

$$M_r = X_1 M_1 + X_2 M_2$$

Dai diagrammi dei momenti si ricava la seguente tabella.

Tratto	$\int_s M_1^2 ds$	$\int_s M_2^2 ds$	$\int_s M_1 M_2 ds$
AC	$\frac{l^3}{3}$	0	0
CB	$\frac{l^3}{4}$	$\frac{l^3}{4}$	$-\frac{l^3}{2}$
CS	0	$\frac{l^3}{24}$	0
Totale	$\frac{4l^3}{3}$	$\frac{7l^3}{24}$	$-\frac{l^3}{2}$

Equazioni risolventi:

$$\int_s \frac{M_1 M_r}{EI} ds = \int_s \frac{M_1 M_0}{EI} ds + X_1 \int_s \frac{M_1^2}{EI} ds + X_2 \int_s \frac{M_1 M_2}{EI} ds = -\eta_0$$

$$\int_s \frac{M_2 M_r}{EI} ds = \int_s \frac{M_2 M_0}{EI} ds + X_1 \int_s \frac{M_1 M_2}{EI} ds + X_2 \int_s \frac{M_2^2}{EI} ds = 0$$

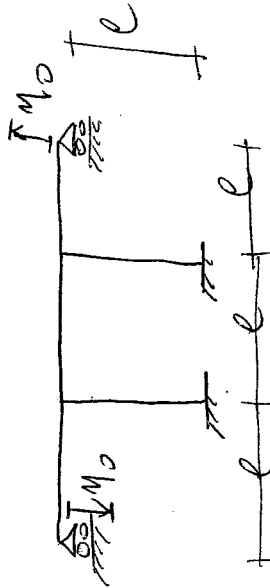
$$X_1 \frac{4}{3} l^3 - X_2 \frac{l^3}{2} = -\eta_0 EI$$

$$-X_1 \frac{l^3}{2} + X_2 \frac{7}{24} l^3 = 0$$

Dalla risoluzione del sistema si ottiene:

$$X_1 = \frac{21}{10} \frac{EI}{l^3} \eta_0, \quad X_2 = \frac{18}{5} \frac{EI}{l^3} \eta_0$$

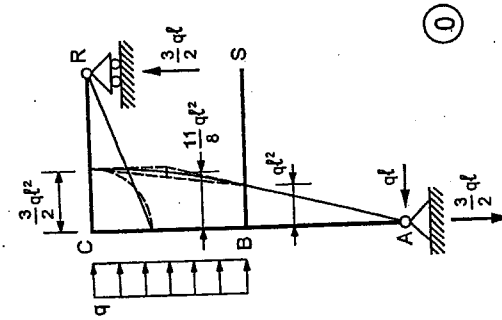
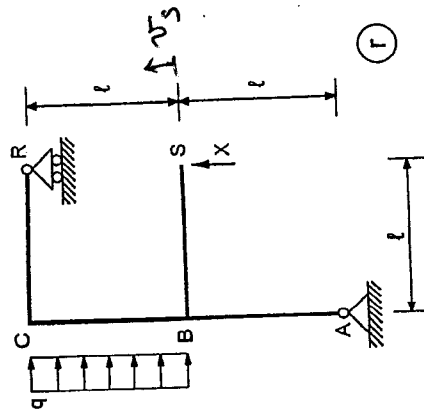
TESTO ESERCIZIO



RISOLUZIONE CON P.L.V.
 (SCHEMA ANTISIMMETRICO)

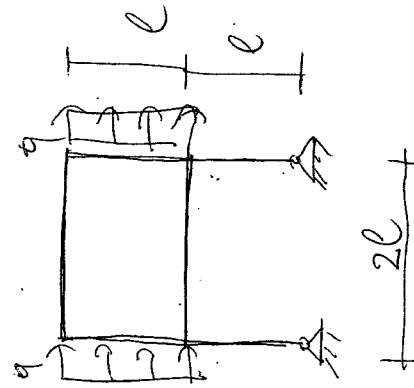
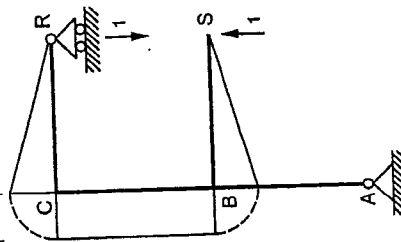
SOLUZIONE

7.9 (v. 4.25)



STRUTTURA PRINCIPALE
eq di congruenza: $\delta_3 = 0$

TESTO ESERCIZIO



RISOLVERE CON P.L.V.
(SCHEMA ANTISIMMETRICO)

Poiché il momento reale M_r è fornito dalla combinazione lineare dei momenti parziali M_i :

$$M_r = M_0 + \sum X_i M_i,$$

nel caso considerato si ha:

$$M_r = M_0 + X M_1.$$

Dai diagrammi dei momenti si ricava la seguente tabella.

Tratto	$\int_s M_1^2 ds$	$\int_s M_0 M_1 ds$
AB	0	0
SB	$\frac{l^3}{3}$	0
BC	$\frac{l^3}{3}$	$-\frac{4}{3} ql^4$
CR	$\frac{l^3}{3}$	$-\frac{ql^4}{2}$
Totale	$\frac{5l^3}{3}$	$-\frac{11}{6} ql^4$

Equazione risolvente:

$$\int_s \frac{M_r M_1}{EI} ds = \int_s \frac{M_r M_0}{EI} ds + X \int_s \frac{M_1^2}{EI} ds = -\frac{11 ql^4}{6 EI} + X \frac{5 l^3}{3 EI} = 0,$$

$$X = \frac{11}{10} ql$$