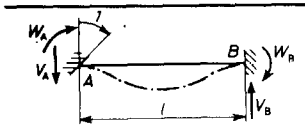
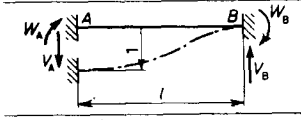
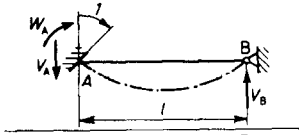
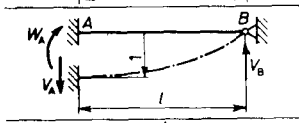
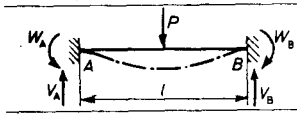
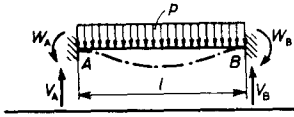
Tab. 8.9 – Reazioni dovute a cedimenti unitari e a carichi esterni assegnati

	$W_A = \frac{4EJ}{l}$; $W_B = \frac{2EJ}{l}$ $V_A = V_B = \frac{6EJ}{l^2}$
	$W_A = W_B = \frac{6EJ}{l^2}$ $V_A = V_B = \frac{12EJ}{l^3}$
	$W_A = \frac{3EJ}{l}$ $V_A = V_B = \frac{3EJ}{l^2}$
	$W_A = \frac{3EJ}{l^2}$ $V_A = V_B = \frac{3EJ}{l^3}$
	$W_A = W_B = \frac{Pl}{8}$ $V_A = V_B = \frac{P}{2}$
	$W_A = W_B = \frac{pl^2}{12}$ $V_A = V_B = \frac{pl}{2}$

Le (98) esprimono le condizioni di equilibrio, rispettivamente alla traslazione orizzontale, a quella verticale e alla rotazione, del nodo 2. I risultati che precedono si possono estendere a una struttura generica con m gradi di vincolo in più. In tal caso il metodo degli spostamenti conduce a scrivere:

$$\begin{aligned} K_{11}x_1 + K_{12}x_2 + \ldots + K_{1m}x_m &= K_{10} \\ &\vdots \\ K_{m1}x_1 + K_{m2}x_2 + \ldots + K_{mm}x_m &= K_{m0} \end{aligned} \qquad (99)$$

Le (99) in forma matriciale diventano: $[K]\{x\} = \{K_0\}$ (100)

dove il generico elemento K_{ij} della matrice $[K]$, detta «matrice delle rigidezze», si scrive:

$$K_{ij} = \int \left(\frac{M_i M_j}{EJ} + \frac{N_i N_j}{EA} + \chi \frac{T_i T_j}{GA} \right) dx_3 \qquad (101)$$

e il generico elemento K_{i0} del vettore dei termini noti $\{K_0\}$

$$K_{i0} = \int \left(\frac{M_0 M_i}{EJ} + \frac{N_0 N_i}{EA} + \chi \frac{T_0 T_i}{GA} \right) dx_3 \qquad (102)$$

Nel caso dei telai, quando si possano trascurare gli efetti delle reazioni assiale e tagliante rispetto a quelli della reazione flettente, le (101) e (102) diventano rispettivamente:

$$K_{ij} = \int \frac{M_i M_j}{EJ} dx_3; \quad K_{i0} = \int \frac{M_0 M_i}{EJ} dx_3 \qquad (103)$$

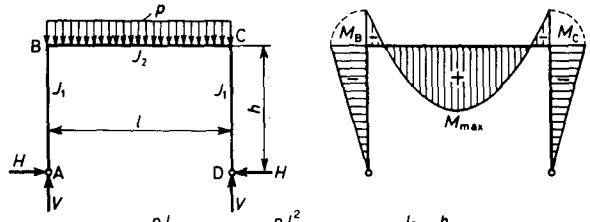
Nel caso di travature reticolari caricate ai nodi, le (101) e (102) diventano invece:

$$K_{ij} = \int \frac{N_i N_j}{EA} dx_3; \quad K_{i0} = \int \frac{N_0 N_i}{EA} dx_3. \qquad (104)$$

Nella tab. 8.9 sono riportate le reazioni dovute a cedimenti vincolari unitari e a forze esterne assegnate di alcuni casi strutturali semplici. Nella tab. 8.10 sono riportati diversi casi già risolti di telai.

Tab. 8.10 – Telai

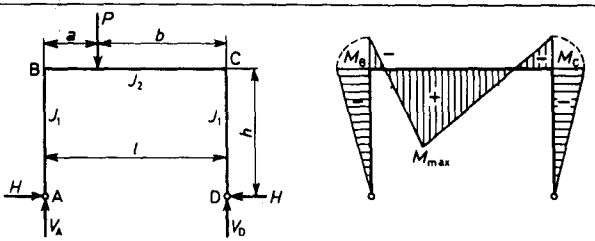
1.



$$V = \frac{pl}{2}; \quad H = \frac{pl^2}{4h(2k+3)}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l}$$

$$M_B = M_C = -Hh = -\frac{pl^2}{4(2k+3)}; \quad M_{max} = \frac{2k+1}{2k+3} \cdot \frac{pl^2}{8}$$

2.



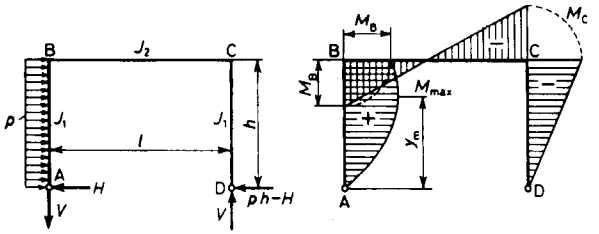
$$V_A = \frac{Pb}{l}; \quad V_D = \frac{Pa}{l}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l}; \quad H = \frac{3Pab}{2hl(2k+3)};$$

$$M_{max} = \frac{4k+3}{2k+3} \cdot \frac{Pab}{2l}; \quad M_B = M_C = -Hh = -\frac{3ab}{2l(2k+3)} \cdot P$$

segue

seguito tab. 8.10

3.



$$V=\frac{p\,h^2}{2\,l};\quad H=\frac{p\,h}{8}\cdot\frac{11\,k+18}{2\,k+3};\quad k=\frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$M_C=-\frac{p\,h^2}{8}\cdot\frac{5\,k+6}{2\,k+3};\quad M_B=\frac{3}{8}\,p\,h^2\cdot\frac{k+2}{2\,k+3}$$

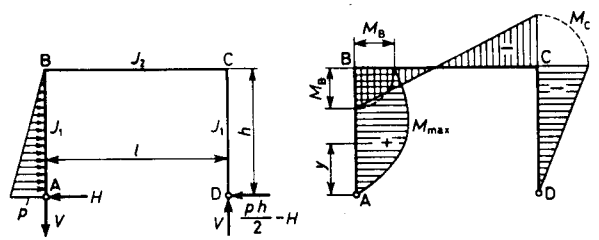
Per

$$y_m=\frac{h}{8}\cdot\frac{11\,k+18}{2\,k+3}$$

si ha:

$$M_{max}=\frac{p\,h^2}{128}\left(\frac{11\,k+18}{2\,k+3}\right)^2$$

4.



$$V=\frac{p\,h^2}{6\,l};\quad H=\frac{p\,h}{40}\cdot\frac{31\,k+50}{2\,k+3};\quad k=\frac{J_2}{J_1}\cdot\frac{h}{l};$$

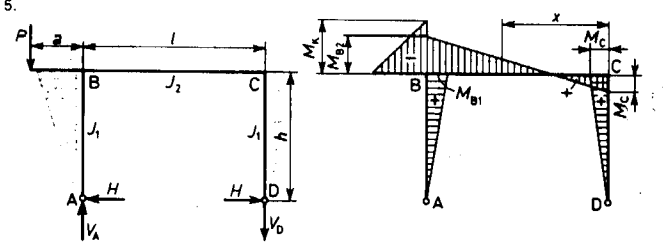
$$M_C=-\frac{p\,h^2}{40}\cdot\frac{9\,k+10}{2\,k+3};\quad M_B=\frac{p\,h^2}{120}\cdot\frac{13\,k+30}{2\,k+3};$$

$$M_y=H\,y-\frac{p\,y^2}{6\,h}(3\,h-y)$$

segue

seguito tab. 8.10

5.



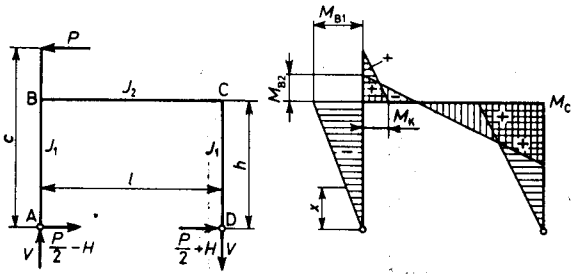
$$V_A=P\cdot\frac{a+l}{l};\quad V_D=P\cdot\frac{a}{l};\quad K=\frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$H=\frac{3\,P\cdot a}{2\,h\,(2\,k+3)};\quad M_{B_1}=M_C=H\cdot h;$$

$$M_{B_2}=H\cdot h-P\,a=-P\,a\cdot\frac{4\,k+3}{2\,(2\,k+3)};$$

$$M_x=H\cdot h-V_D\cdot x;\quad M_K=-P\cdot a$$

6.



$$V=\frac{P\cdot c}{l};\quad H=\frac{3\,P\,(c-h)}{2\,h\,(2\,k+3)};\quad k=\frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$M_x=-\left(\frac{P}{2}-H\right)\cdot x;\quad M_C=\left(\frac{P}{2}+H\right)h;$$

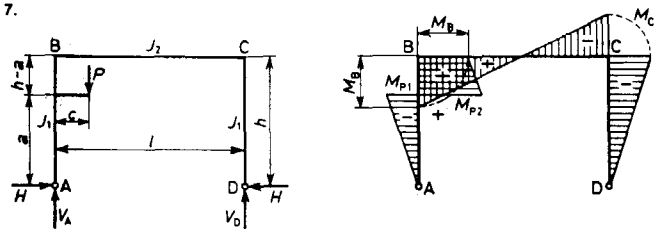
$$M_{B_1}=-\left(\frac{P}{2}-H\right)h;\quad M_{B_2}=-P\,c+\left(\frac{P}{2}+H\right)h;$$

$$M_K=P\,(c-h)$$

segue

seguito tab. 8.10

7.



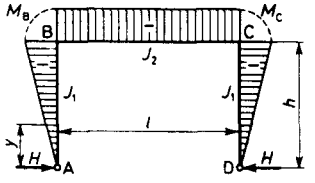
$$V_A = P\frac{l-c}{l}; \quad V_D = \frac{Pc}{l}; \quad k = \frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$H = \frac{3}{2}Pc\cdot\frac{k(h^2-a^2)+h^2}{h^3(2k+3)};$$

$$M_B = Pc - H\cdot h; \quad M_C = -H\cdot h$$

8.

Diagramma dei momenti per un aumento Δt della temperatura.



$$k = \frac{J_2}{J_1}\cdot\frac{h}{l}; \quad H = \frac{3\cdot\alpha\cdot E\cdot J_2\cdot\Delta t}{h^2(3+2k)};$$

$$M_y = -H\cdot y; \quad M_B = M_C = -H\cdot h$$

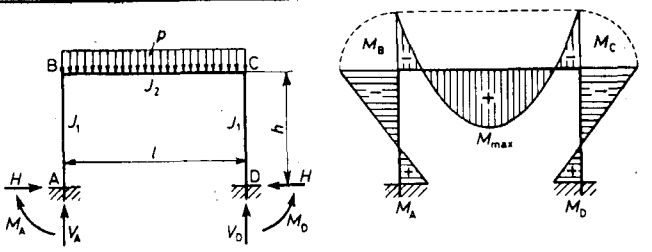
α = coefficiente di dilatazione lineare ($°C^{-1}$).

E = modulo di elasticità normale.

segue

seguito tab. 8.10

9.

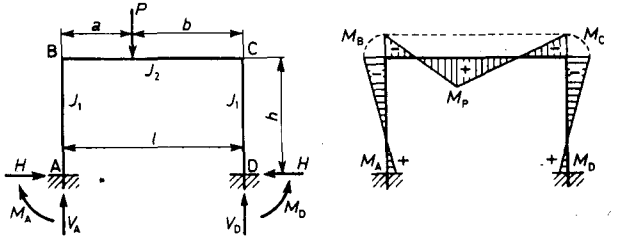


$$V_A = V_D = \frac{p\cdot l}{2}; \quad H = \frac{p\,l^2}{4h(k+2)}; \quad k = \frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$M_B = M_C = -\frac{p\,l^2}{6(k+2)}; \quad M_A = M_D = \frac{p\,l^2}{12(k+2)};$$

$$M_{max} = \frac{p\,l^2}{8} - \frac{p\,l^2}{6(k+2)} = \frac{p\,l^2}{24}\cdot\frac{2+3k}{k+2}$$

10.



$$k = \frac{J_2}{J}\cdot\frac{h}{l}; \quad \vartheta = \frac{a}{l}; \quad H = \frac{3P\cdot a\cdot b}{2h\cdot l(k+2)};$$

$$V_A = \frac{P\cdot b}{l}\cdot\frac{6k+1+\vartheta-2\vartheta^2}{6K+1}; \quad V_D = \frac{Pa}{l}\cdot\frac{6k+3\vartheta-2\vartheta^2}{6k+1};$$

$$M_A = \frac{Pab}{2l}\cdot\frac{5k-1+2\vartheta(k+2)}{(k+2)(6k+1)};$$

$$M_D = \frac{Pab}{2l}\cdot\frac{3+7k-2\vartheta(k+2)}{(k+2)(6k+1)};$$

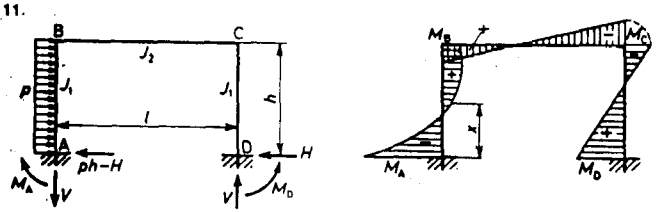
$$M_B = M_A - H\cdot h; \quad M_C = M_D - H\cdot h;$$

$$M_P = M_A - H\cdot h + V_A\cdot a$$

segue

seguito tab. 8.10

11.



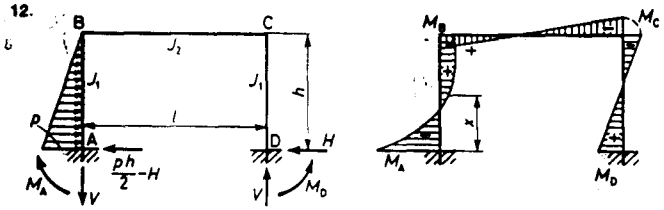
$$V = \frac{p\,h^2\,k}{l\,(6\,k+1)}; \quad H = \frac{p\,h}{8} \cdot \frac{2\,k+3}{k+2}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l};$$

$$M_A = -\frac{p\,h^2}{24}\left(12 - \frac{5\,k+9}{k+2} - \frac{12\,k}{6\,k+1}\right); \quad M_D = \frac{p\,h^2}{24}\left(\frac{5\,k+9}{k+2} - \frac{12\,k}{6\,k+1}\right);$$

$$M_x = M_A + (p \cdot h - H) \cdot x - \frac{p\,x^2}{2};$$

$$M_B = M_A - H \cdot h + \frac{p\,h^2}{2}; \quad M_C = M_D - H \cdot h$$

12.



$$V = \frac{p \cdot k \cdot h^2}{4\,l\,(6\,k+1)}; \quad H = \frac{p\,h}{40} \cdot \frac{3\,k+4}{k+2}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l};$$

$$M_A = -\frac{p\,h^2}{120}\left(20 - \frac{7\,k+12}{k+2} - \frac{15\,k}{6\,k+1}\right);$$

$$M_D = \frac{p\,h^2}{120}\left(\frac{7\,k+12}{k+2} - \frac{15\,k}{6\,k+1}\right);$$

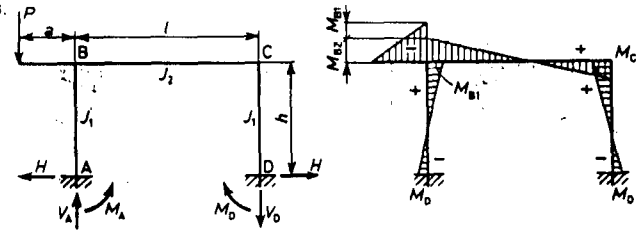
$$M_x = M_A + \left(\frac{p\,h}{2} - H\right) \cdot x - \frac{p\,x^2}{6\,h}(3\,h - x);$$

$$M_B = M_A - H \cdot h + \frac{p\,h^2}{6}; \quad M_C = M_D - H \cdot h$$

segue

seguito tab. 8.10

13.



$$k = \frac{J_2}{J_1} \cdot \frac{h}{l}; \quad H = \frac{p\,a}{2\,h} \cdot \frac{3}{k+2};$$

$$V_A = P \cdot \frac{a+l}{l} + \frac{M_D - M_A}{l}; \quad V_D = P \cdot \frac{a}{l} + \frac{M_A - M_D}{l};$$

$$M_A = -\frac{P\,a}{2} \cdot \frac{5\,k-1}{(6\,k+1)\,(k+2)};$$

$$M_D = -\frac{P\,a}{2} \cdot \frac{7\,k+3}{(6\,k+1)\,(k+2)};$$

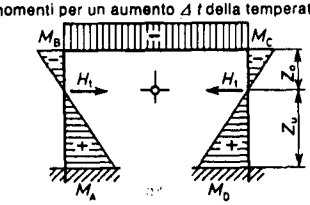
$$M_{B_1} = \frac{P\,a}{2} \cdot \frac{13\,k+4}{(6\,k+1)\,(k+2)};$$

$$M_{B_2} = -\frac{P\,a}{2} \cdot \frac{k\,(12\,k+13)}{(6\,k+1)\,(k+2)};$$

$$M_C = \frac{P\,a}{2} \cdot \frac{11\,k}{(6\,k+1)\,(k+2)}$$

14.

Diagramma dei momenti per un aumento Δt della temperatura.



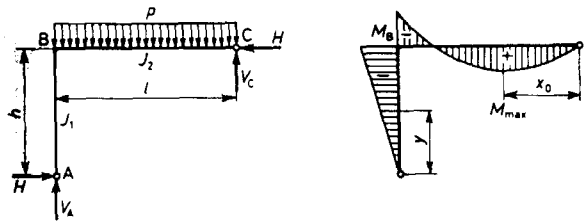
$$Z_0 = \frac{h\,k}{2\,k+1}; \quad Z_u = \frac{h\,(k+1)}{2\,k+1}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l};$$

$$H_1 = \frac{3\,E \cdot \alpha \cdot \Delta t \cdot J_2\,(2\,k+1)}{h^2 \cdot k\,(k+2)}$$

segue

seguito tab. 8.10

15.



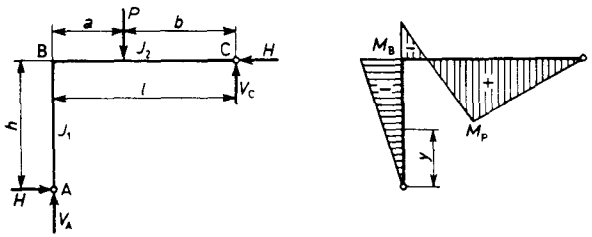
$$V_A = \frac{p\,l}{8}\cdot\frac{4k+5}{k+1};\quad k = \frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$V_C = \frac{p\,l}{8}\cdot\frac{4k+3}{k+1};\quad H = \frac{p\,l^2}{8\,h\,(k+1)};$$

$$M_B = -H\,h = -\frac{p\,l^2}{8\,(k+1)};\quad M_y = -H\,y;$$

$$x_0 = \frac{l}{8}\cdot\frac{4k+3}{k+1};\quad M_{max} = \frac{p\,l^2}{128}\left(\frac{4k+3}{k+1}\right)^2$$

16.



$$H = \frac{P\cdot a\cdot b\,(l+b)}{2\,h\,l^2\,(k+1)};\quad k = \frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$V_A = \frac{P\,b + H\,h}{l};\quad V_C = \frac{P\,a - H\,h}{l};$$

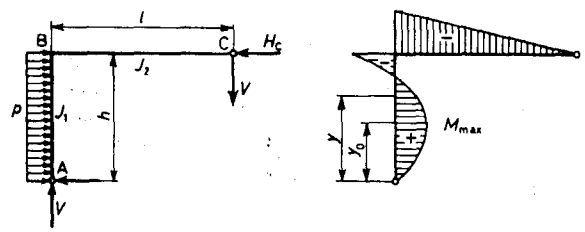
$$M_y = -Hy;\quad M_B = -H\,h;$$

$$M_P = \frac{P\,a\,b}{2\,l^3}\cdot\frac{2\,k\,l^2 + 3\,a\,l - a^2}{k+1}$$

segue

seguito tab. 8.10

17.



$$V = \frac{p\,h^2\,k}{8\,l\,(k+1)};\quad k = \frac{J_2}{J_1}\cdot\frac{h}{l};$$

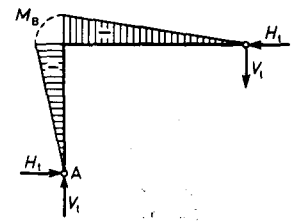
$$H_A = \frac{p\,h}{8}\cdot\frac{3k+4}{k+1};\quad H_C = \frac{p\,h}{8}\cdot\frac{5k+4}{k+1};$$

$$M_B = -V\,l;\quad M_y = \frac{p\,y}{8}\cdot\frac{4\,(h-y) + k\,(3\,h - 4\,y)}{k+1};$$

$$y_0 = \frac{3k+4}{k+1}\cdot\frac{h}{8};\quad M_{max} = \frac{p\,h^2}{128}\left(\frac{3k+4}{k+1}\right)^2$$

18.

Diagramma dei momenti per un aumento $\Delta\,t$ della temperatura.

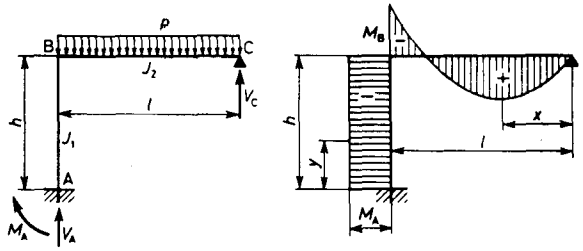


$$H_1 = \frac{2\,E\,\alpha\,\Delta\,t\,J_2}{h^2\,(k+1)};\quad V_1 = \frac{H_1\,h}{l};\quad k = \frac{J_2}{J_1}\cdot\frac{h}{l}$$

segue

seguito tab. 8.10

19.



$$V_C = \frac{3}{8} \cdot p\,l \cdot \frac{4k+1}{3k+1}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l};$$

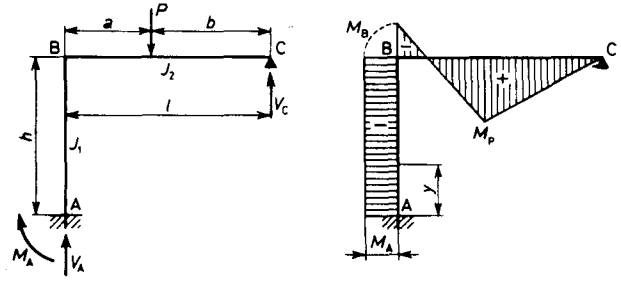
$$V_A = p\,l - V_C;$$

$$M_A = M_B = -\frac{p\,l^2}{8\,(3k+1)};$$

$$M_y = M_A - M_B - V_C\,l - \frac{p\,l^2}{2};$$

$$M_x = V_C \cdot x - \frac{p\,x^2}{2}$$

20.



$$V_C = P\,a \cdot \frac{a\,(3\,l - a) + 6\,k\,l^2}{2\,l^3\,(3k+1)}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l};$$

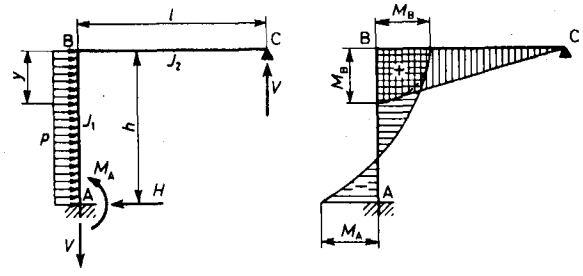
$$V_A = P - V_C; \quad My = M_A - M_B - V_C\,l - P\,a;$$

$$M_P = V_C \cdot b$$

segue

seguito tab. 8.10

21.



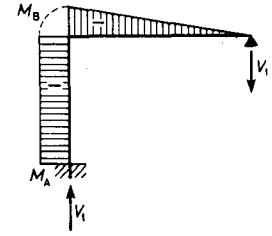
$$V = \frac{p\,h^2\,k}{2\,l\,(3k+1)}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l};$$

$$H = p\,h; \quad M_A = V\,l - \frac{p\,h^2}{2};$$

$$M_B = V\,l$$

22.

Diagramma dei momenti per un aumento $\Delta\,t$ della temperatura.

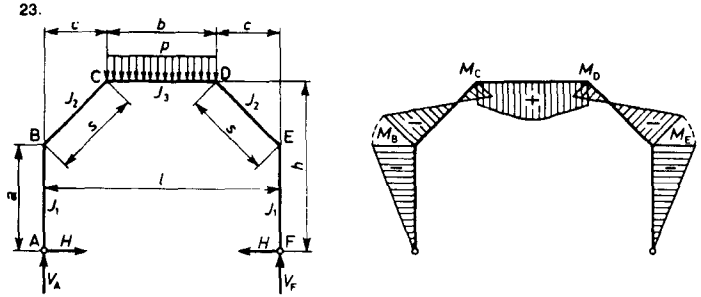


$$V_1 = \frac{3\,E\,\alpha\,\Delta\,t\,J_1\,k}{l^2\,(3k+1)}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{l}$$

segue

seguito tab. 8.10

23.



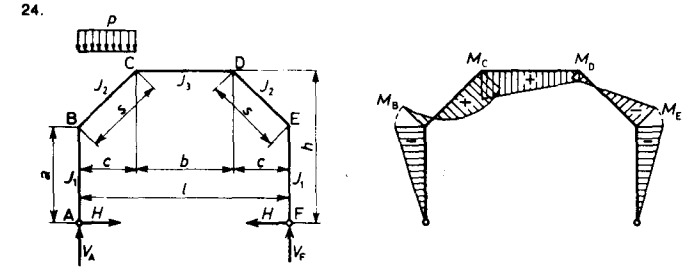
$$V_A = V_F = \frac{p\,b}{2}; \quad k_1 = \frac{J_2}{J_1}\cdot\frac{a}{s}; \quad k_2 = \frac{J_2}{J_3}\cdot\frac{b}{s};$$

$$H = \frac{p\,b}{4}\cdot\frac{2\,c\,(a+2\,h)+h\,k_2\,(l+4\,c)}{2\,a^2\,(k_1+1)+2\,h\,a+h^2\,(2+3\,k_2)};$$

$$M_B = M_E = -H\cdot a;$$

$$M_C = M_D = -H\cdot h+\frac{p\cdot b}{2}\cdot c; \quad M_{max} = -H\cdot h+\frac{p\,b}{4}\cdot\left(l-\frac{b}{2}\right)$$

24.



$$k_1 = \frac{J_2}{J_1}\cdot\frac{a}{s}; \quad k_2 = \frac{J_2}{J_3}\cdot\frac{b}{s}; \quad V_A = \frac{p\,c\,(l-c/2)}{l}; \quad V_F = \frac{p\,c^2}{2\,l};$$

$$H = \frac{p\,c^2}{8}\cdot\frac{6\,h\,k_2+5\,h+3\,a}{2\,a^2\,(k_1+1)+2\,h\,a+h^2\,(2+3\,k_2)};$$

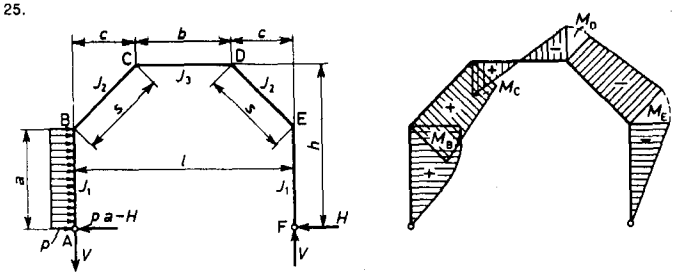
$$M_B = M_E = -H\,a;$$

$$M_C = -H\cdot h-\frac{p\,c^2}{2}+V_A\cdot c; \quad M_D = -H\cdot h+\frac{p\,c^2}{2\,l}$$

segue

seguito tab. 8.10

25.



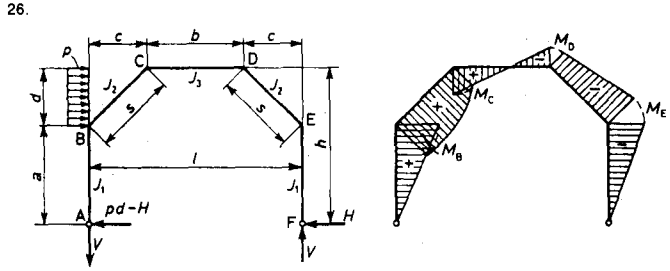
$$V = \frac{p\,a^2}{2\,l}; \quad k_1 = \frac{J_2}{J_1}\cdot\frac{a}{s}; \quad k_2 = \frac{J_2}{J_3}\cdot\frac{b}{s};$$

$$H = \frac{p\,a^2}{8}\cdot\frac{6\,h\,(k_2+1)+a\,(5\,k_1+6)}{2\,a^2\,(k_1+1)+2\,h\,a+h^2\,(2+3\,k_2)};$$

$$M_B = (p\,a-H)\,a-\frac{p\,a^2}{2}; \quad M_C = V\,(l-c)-H\cdot h;$$

$$M_D = -H\cdot h+V\cdot c; \quad M_E = -H\cdot a$$

26.



$$V = \frac{p\,d\,(h-d/2)}{l}; \quad k_1 = \frac{J_2}{J_1}; \quad k_2 = \frac{J_2}{J_3}\cdot\frac{b}{s};$$

$$H = \frac{p\,d}{8}\cdot\frac{a^2\,(8\,k_1+9)+h\,[2\,a\,(5+3\,k_2)+h\,(5+6\,k_2)]}{2\,a^2\,(k_1+1)+2\,h\,a+h^2\,(2+3\,k_2)};$$

$$M_B = (p\,d-H)\,a; \quad M_C = V\,(l-c)-H\cdot h;$$

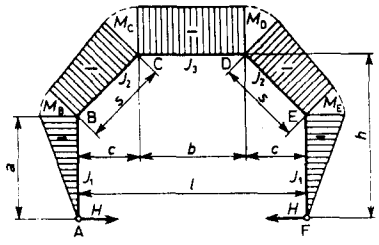
$$M_D = -H\cdot h+V\cdot c; \quad M_E = -H\cdot a$$

segue

seguito tab. 8.10

27.

Diagramma dei momenti per aumento Δt della temperatura.



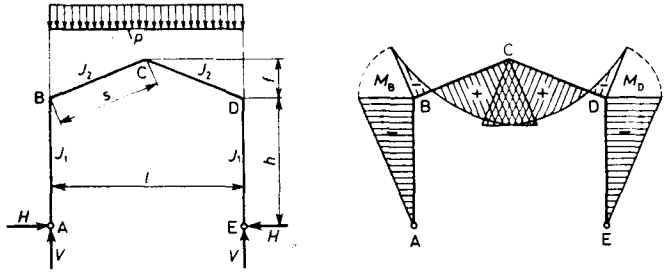
$$k_1 = \frac{J_2}{J_1} \cdot \frac{a}{s}; \quad k_2 = \frac{J_2}{J_3} \cdot \frac{b}{s};$$

$$H = \frac{3\, l\, \alpha\, \Delta t\, E\, J_2}{s\,[2\, a^2 (k_1 + 1) + 2\, h\, a + h^2 (2 + 3\, k_2)]};$$

$$M_C = -H \cdot h$$

$$M_B = -H \cdot a$$

28.



$$V = \frac{p\, l}{2}; \quad H = \frac{p\, l^2}{32} \cdot \frac{8\, h + 5\, f}{h^2 (k + 3) + f (3\, h + f)};$$

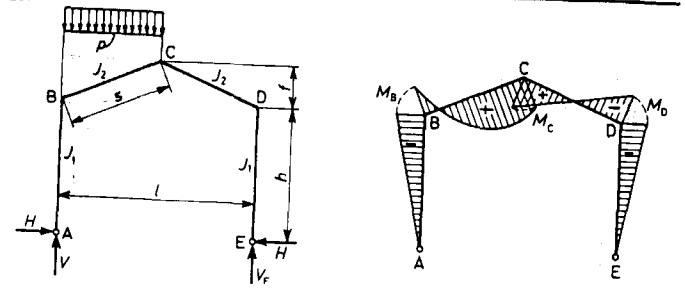
$$k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$M_B = -H \cdot h; \quad M_C = \frac{p\, l^2}{8} - H (h + f)$$

segue

seguito tab. 8.10

29.

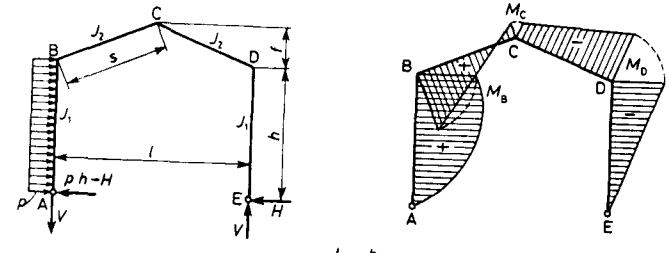


$$V_A = \frac{3\, p\, l}{8}; \quad V_E = \frac{p\, l}{8}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$H = \frac{p\, l^2}{64} \cdot \frac{8\, h + 5\, f}{h^2 (k + 3) + f (3\, h + f)};$$

$$M_B = M_D = -H \cdot h; \quad M_C = V_E \cdot l/2 - H (h + f)$$

30.



$$k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$V = \frac{q\, h^2}{2\, l}; \quad H = \frac{p\, h^2}{16} \cdot \frac{5\, h\, k + 6\, (2\, h + f)}{h^2 (k + 3) + f (3\, h + f)};$$

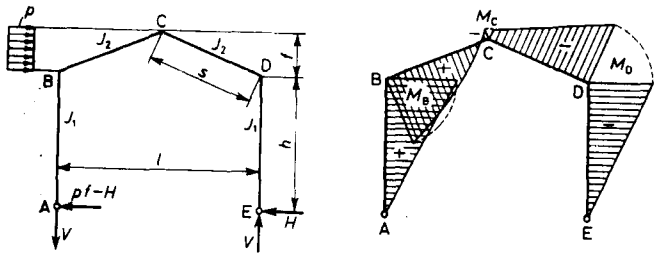
$$M_C = \frac{p\, h^2}{4} - H (h + f);$$

$$M_D = -H \cdot h; \quad M_B = \frac{p\, h^2}{2} - H \cdot h$$

segue

seguito tab. 8.10

31.



$$k = \frac{J_2}{J_1} \cdot \frac{h}{s}; \quad V = \frac{p\,f\,(2\,h + f)}{2\,l};$$

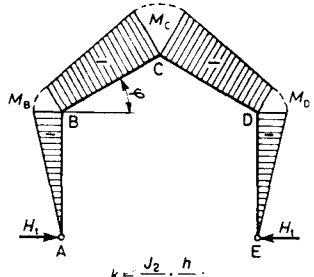
$$H = \frac{p\,f}{16} \cdot \frac{8\,h^2\,(k+3) + 5\,f\,(4\,h+f)}{h^2\,(k+3) + f\,(3\,h+f)};$$

$$M_B = (p\,f - H)\,h; \quad M_D = -H \cdot h;$$

$$M_C = V \cdot \frac{l}{2} - H\,(h+f)$$

32.

Diagramma dei momenti per un aumento Δt della temperatura.



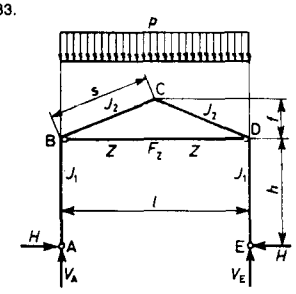
$$k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$H_1 = \frac{3\,E \cdot \alpha \cdot \Delta t \cdot J_2 \cos\varphi}{h^2\,(k+3) + f\,(3\,h+f)}$$

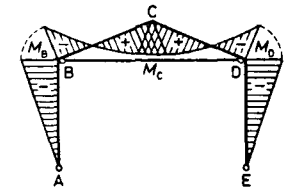
segue

seguito tab. 8.10

33.



E_z = modulo di elasticità normale della catena;
F_z = area della sezione della catena



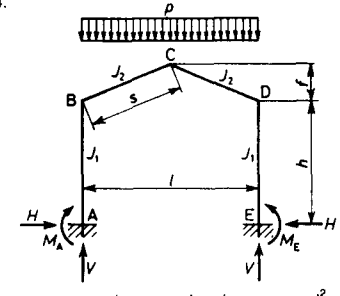
$$k = \frac{J_2}{J_1} \cdot \frac{h}{s}; \quad m = \frac{E\,J_2}{E_z\,F_z}; \quad \gamma = \frac{1}{1 + \dfrac{3\,m\,l}{2\,f^2\,s}}; \quad V = \frac{p\,l}{2};$$

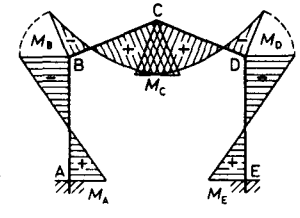
$$H = \frac{p\,l^2}{16} \cdot \frac{h\,(16 - 15\,\gamma) + 10\,f\,(1-\gamma)}{h^2\,(4\,k + 2 - 9\,\gamma) + 12\,h\,f\,(1-\gamma) + 4\,f^2\,(1-\gamma)};$$

Tensione nella catena $Z = (Z_0 - Z_a \cdot H)$, con $Z_0 = \dfrac{5\,p\,l^2}{32\,f} \cdot \gamma$; $\quad Z_a = \left(\dfrac{3\,h}{2\,f} + 1\right) \cdot \gamma$

Per catene rigide $\gamma = 1$. $\quad M_B = M_B = -H \cdot h$; $\quad M_C = \dfrac{p\,l^2}{8} - H\,(h+f) - Z_f$

34.





$$V = \frac{q\,l}{2}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{s}; \quad H = \frac{p\,l^2}{8} \cdot \frac{k\,(4\,h + 5\,f) + f}{(h\,k+f)^2 + 4\,k\,(h^2 + h\,f + f^2)};$$

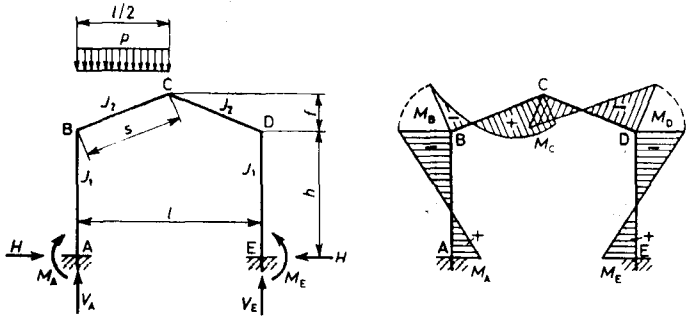
$$M_A = M_E = \frac{p\,l^2}{48} \cdot \frac{k\,h\,(8\,h + 15\,f) + f\,(6\,h - f)}{(k\,h+f)^2 + 4\,k\,(h^2 + h\,f + f^2)};$$

$$M_B = M_D = -H \cdot h + M_A; \quad M_C = -H\,(h+f) + M_A + \frac{p\,l^2}{8}$$

segue

seguito tab. 8.10

35.



$$V_A = \frac{3\,p\,l}{8} + \frac{M_E - M_A}{l};$$

$$V_E = \frac{p\,l}{8} - \frac{M_E - M_A}{l}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$H = \frac{p\,l^2}{16} \cdot \frac{k(4\,h + 5\,f) + f}{(h\,k + f)^2 + 4\,k(h^2 + h\,f + f^2)};$$

$$M_A = \frac{p\,l^2}{96}\left[\frac{k\,h(8\,h + 15\,f) + f(6\,h - f)}{(k\,h + f)^2 + 4\,k(h^2 + h\,f + f^2)} - \frac{3}{2(3\,k + 1)}\right];$$

$$M_E = \frac{p\,l^2}{96}\left[\frac{k\,h(8\,h + 15\,f) + f(6\,h - f)}{(k\,h + f)^2 + 4\,k(h^2 + h\,f + f^2)} + \frac{3}{2(3\,k + 1)}\right];$$

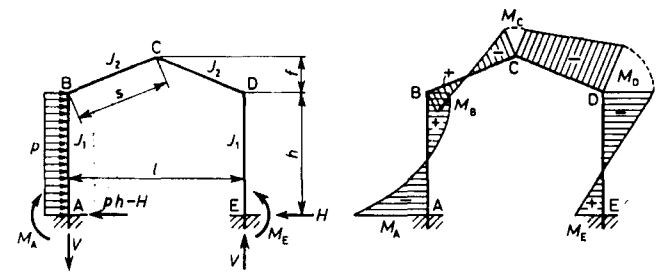
$$M_B = -H\,h + M_A; \qquad M_D = -H\,h + M_E;$$

$$M_C = -H(h + f) + M_E + V_E\,\frac{l}{2}$$

segue

seguito tab. 8.10

36.



$$V = \frac{p\,h^2}{2\,l} + \frac{M_A - M_E}{l}; \qquad k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$H = \frac{p\,h^2}{4} \cdot \frac{k^2\,h + k(3\,h + 2\,f)}{(h\,k + f)^2 + 4\,k(h^2 + h\,f + f^2)};$$

$$M_A = -\frac{p\,h^2}{24}\left[\frac{h^2\,k(k+6) + k\,f(15\,h + 16\,f) + 6\,f^2}{(h\,k + f)^2 + 4\,k(h^2 + h\,f + f^2)} + \frac{12\,k + 6}{3\,k + 1}\right];$$

$$M_E = \frac{h^2}{24}\left[-\frac{k^2\,k(k+6) + k\,f(15\,h + 16\,f) + 6\,f^2}{(h\,k + f)^2 + 4\,k(h^2 + h\,f + f^2)} + \frac{12\,k + 6}{3\,k + 1}\right];$$

$$M_D = -H \cdot h + M_E;$$

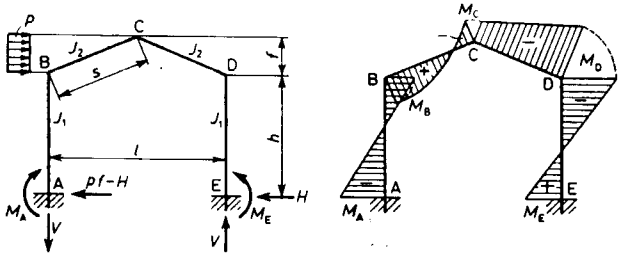
$$M_B = (p\,h - H)\,h + M_A - \frac{p\,h^2}{2};$$

$$M_C = -H(h + f) + M_E + \frac{p\,h^2}{4} \cdot \frac{k}{3\,k + 1}$$

segue

seguito tab. 8.10

37.



$$V = \frac{p\,f\,(h + f/2)}{l} + \frac{M_A - M_E}{l}; \quad k = \frac{J_2}{J_1} \cdot \frac{h}{s};$$

$$H = \frac{p\,f}{4} \cdot \frac{5\,f\,k\,(2\,h + f) + 2\,h^2\,k\,(k+4) + f^2}{(h\,k + f)^2 + 4\,k\,(h^2 + h\,f + f^2)};$$

$$M_A = -\frac{p\,f}{24}\left[\frac{f\,[h\,k\,(4\,h + 9\,f) + f\,(6\,h + f)]}{(h\,k + f)^2 + 4\,k\,(h^2 + h\,f + f^2)} + \frac{12\,h\,(3\,k + 2) + 3\,f}{6\,k + 2}\right];$$

$$M_E = \frac{p\,f}{24}\left[-\frac{f\,[h\,k\,(4\,h + 9\,f) + f\,(6\,h + f)]}{(h\,k + f)^2 + 4\,k\,(h^2 + h\,f + f^2)} + \frac{12\,h\,(3\,k + 2) + 3\,f}{6\,k + 2}\right];$$

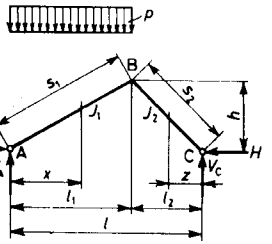
$$M_D = -H \cdot h + M_E; \qquad M_B = (p\,f - H)\,h + M_A;$$

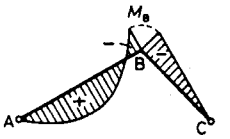
$$M_C = -H\,(h + f) + M_E + V_E \cdot \frac{l}{2}$$

segue

seguito tab. 8.10

38.





$N < 0$ se di compressione

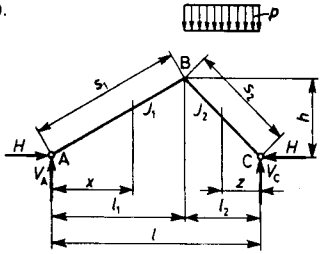
$$V_A = \frac{p\,l_1}{2\,l}\,(l + l_2); \quad V_C = \frac{p\,l_1^2}{2\,l}; \quad k = \frac{J_2}{J_1} \cdot \frac{s_1}{s_2};$$

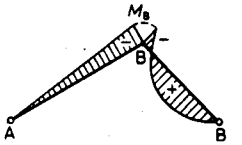
$$H = \frac{p\,l_1^2}{8\,h\,l} \cdot \frac{4\,l_2 + (l + 4\,l_2)\,k}{k+1}; \quad M_B = V_C \cdot l_2 - H \cdot h;$$

$$M_x = V_A \cdot x - H \cdot \frac{h\,x}{l_1} - \frac{p\,x^2}{2}; \quad N_x = -\,(V_A - p\,x)\,\frac{h}{s_1} - H \cdot \frac{l_1}{s_1};$$

$$M_Z = V_C \cdot z - H \cdot \frac{h \cdot z}{l_2}; \quad N_{BC} = -\,V_C \cdot \frac{h}{s_2} - H \cdot \frac{l_2}{s_2}$$

39.





$$V_A = \frac{p\,l_2^2}{2\,l}; \quad V_C = \frac{p\,l_2}{2\,l} \cdot (l + l_1); \quad k = \frac{J_2}{J_1} \cdot \frac{s_1}{s_2};$$

$$H = \frac{p\,l_2^2}{8\,h\,l} \cdot \frac{l + 4\,l_1\,(k+1)}{(k+1)};$$

$$M_x = V_A \cdot x - H \cdot \frac{h\,x}{l_1}; \quad M_B = V_A \cdot l_1 - H \cdot h;$$

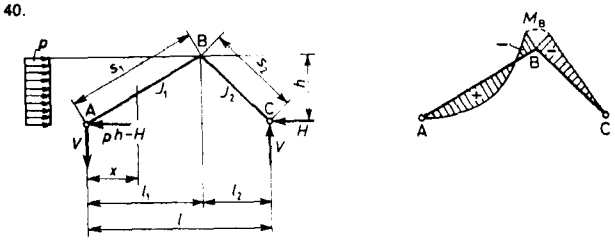
$$M_Z = V_C \cdot z - H \cdot \frac{h\,z}{l_2} - \frac{p\,z^2}{2};$$

$$N_{AB} = -\,V_A \cdot \frac{h}{s_1} - H \cdot \frac{l_1}{s_1}; \quad N_Z = -\,(V_C - p\,z)\,\frac{h}{s_2} - H \cdot \frac{l_2}{s_2}$$

segue

seguito tab. 8.10

40.



$$V = \frac{p\,h^2}{2\,l}\,;\quad k = \frac{J_2}{J_1}\cdot\frac{s_1}{s_2}\,;$$

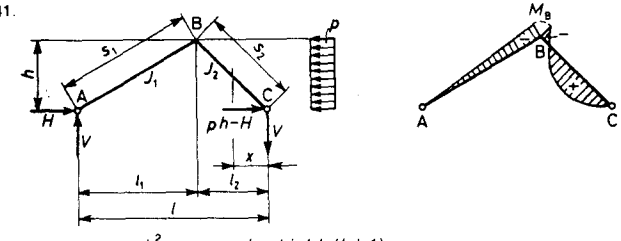
$$H = \frac{p\,h}{8\,l}\cdot\frac{4\,l_2 + (l + 4\,l_2)\,k}{k+1}\,;$$

$$M_x = (p\,h - H)\,\frac{h\,x}{l_1} - V\cdot x - \frac{p\,h^2\,x^2}{2\,l_1^2}\,;\quad M_B = V\,l_2^2 - H\cdot h\,;$$

$$N_x = V\cdot\frac{h}{s_1} + \left(p\,h - H - \frac{p\,h\,x}{l_1}\right)\frac{l_1}{s_1}\,;$$

$$N_{BC} = -\,V\cdot\frac{h}{s_2} - H\cdot\frac{l_2}{s_2}$$

41.



$$V = \frac{p\,h^2}{2\,l}\,;\quad H = \frac{p\,h}{8\,l}\cdot\frac{l + 4\,l_1\,(k+1)}{k+1}\,;\quad M_B = +\,V\cdot l_1 - H\cdot h\,;$$

$$k = \frac{J_2}{J_1}\cdot\frac{s_1}{s_2}\,;\quad M_x = (p\,h - H)\,\frac{h\,x}{l_2} - V\cdot x - \frac{p\,h^2\,x^2}{2\,l_2^2}\,;$$

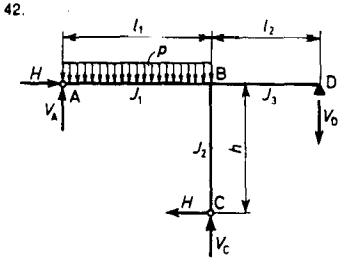
$$N_{AB} = -\,V\cdot\frac{h}{s_1} - H\cdot\frac{l_1}{s_1}\,;$$

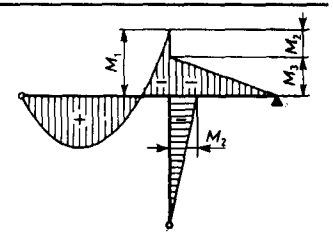
$$N_x = +\,V\cdot\frac{h}{s_2} + \left(p\,h - H - \frac{p\,h\,x}{l_2}\right)\frac{l_2}{s_2}$$

segue

seguito tab. 8.10

42.





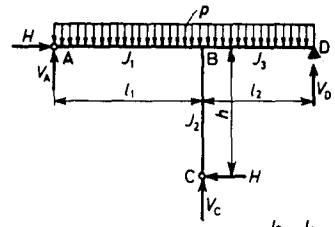
$$V_A = \frac{p\,l_1}{2} + \frac{M_1}{l}\,;\quad V_C = \frac{p\,l_1}{2} - \frac{M_1}{l_1} - \frac{M_3}{l_2}\,;$$

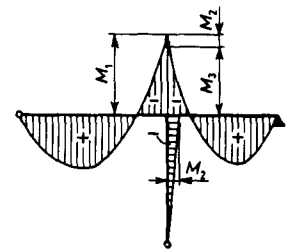
$$V_D = -\,\frac{M_3}{l_2}\,;\quad k_1 = \frac{J_2}{J_1}\cdot\frac{l_1}{h}\,;\quad k_2 = \frac{J_2}{J_3}\cdot\frac{l_2}{h}\,;$$

$$M_1 = -\,\frac{p\,l_1^2}{8}\cdot\frac{k_1\,(k_2+1)}{k_1 + k_1\,k_2 + k_2}\,;\quad M_3 = -\,\frac{p\,l_1^2}{8}\cdot\frac{k_1}{k_1 + k_1\,k_2 + k_2}\,;$$

$$M_2 = M_1 - M_3\,;\quad H = -\,\frac{M_2}{h}$$

43.





$$k_1 = \frac{J_2}{J_1}\cdot\frac{l_1}{h}\,;\quad k_2 = \frac{J_2}{J_3}\cdot\frac{l_2}{h}\,;\quad n = \frac{l_2}{l_1}$$

$$V_A = \frac{p\,l_1}{2} + \frac{M_1}{l_1}\,;\quad V_C = \frac{p\,(l_1 + l_2)}{2} - \frac{M_1}{l_1} - \frac{M_3}{l_2}\,;\quad V_D = \frac{p\,l_2}{2} + \frac{M_3}{l_2}\,;$$

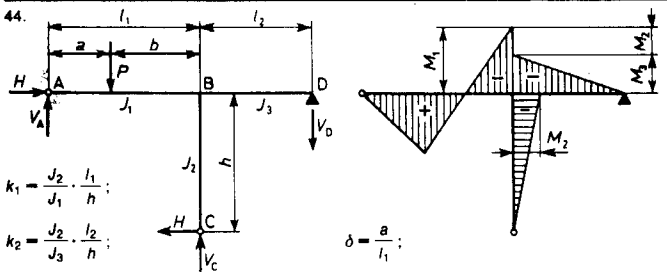
$$M_1 = -\,\frac{p\,l_1^2}{8}\cdot\frac{k_1\,(k_2+1) + n^2\,k_2}{k_1 + k_1\,k_2 + k_2}\,;\quad M_3 = -\,\frac{p\,l_1^2}{8}\cdot\frac{k_1 + n^2\,k_2\,(k_1+1)}{k_1 + k_1\,k_2 + k_2}\,;$$

$$M_2 = M_1 - M_3\,;\quad H = -\,\frac{M_2}{h}$$

segue

seguito tab. 8.10

44.



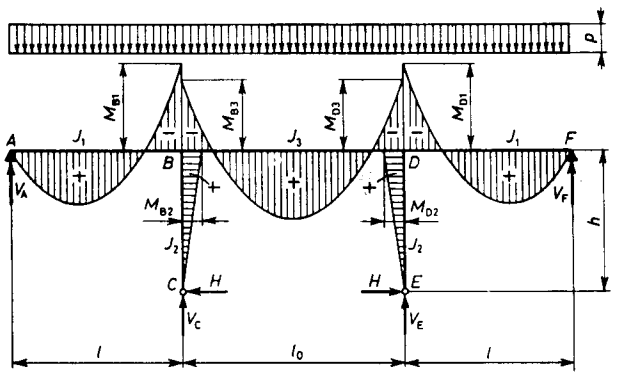
$$k_1 = \frac{J_2}{J_1} \cdot \frac{l_1}{h}\,; \qquad k_2 = \frac{J_2}{J_3} \cdot \frac{l_2}{h}\,; \qquad \delta = \frac{a}{l_1}\,;$$

$$H = -\frac{M_2}{h}\,; \quad V_A = \frac{P\,b}{l_1} + \frac{M_1}{l_1}\,; \quad V_C = \frac{P\,a}{l_1} - \frac{M_1}{l_1} - \frac{M_3}{l_2}\,; \quad V_D = -\frac{M_3}{l_2}\,;$$

$$M_1 = -\frac{P\,a\,(1-\delta^2)}{2} \cdot \frac{k_1\,(k_2+1)}{k_1 + k_1\,k_2 + k_2}\,;$$

$$M_3 = -\frac{P\,a\,(1-\delta^2)}{2} \cdot \frac{k_1}{k_1 + k_1\,k_2 + k_2}\,; \quad M_2 = M_1 - M_3$$

45.



$$n = \frac{l_0}{l}\,; \quad k_1 = \frac{J_3}{J_2} \cdot \frac{h}{l_0}\,; \quad k_2 = \frac{J_1}{J_2} \cdot \frac{h}{l}\,; \quad \mathcal{N}_1 = 3 + 3\,k_1 + 3\,k_2$$

$$H = -\frac{M_{B2}}{h}\,; \quad V_A = V_F = \frac{p\,l}{2} + \frac{M_{B1}}{l}\,; \quad V_C = V_E = \frac{p\,(l+l_0)}{2} - \frac{M_{B1}}{l}$$

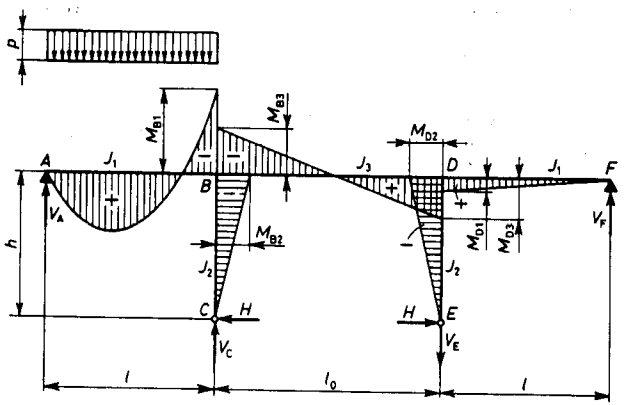
$$M_{B1} = M_{D1} = -\frac{p\,l^2}{8} \cdot \frac{2\,k_1 + 3 + 2\,n^2\,k_2}{\mathcal{N}_1}\,; \quad M_{B2} = M_{D2} = M_{B1} - M_{B3}$$

$$M_{B3} = M_{D3} = -\frac{p\,l^2}{4} \cdot \frac{k_1 + n^2\,(k_2+1)}{\mathcal{N}_1}$$

segue

seguito tab. 8.10

46.



$$k_1 = \frac{J_3}{J_2} \cdot \frac{h}{l_0}\,; \quad k_2 = \frac{J_1}{J_2} \cdot \frac{h}{l}\,; \quad \mathcal{N}_1 = 3 + 2\,k_1 + 3\,k_2\,;$$

$$\mathcal{N}_2 = 1 + 2\,k_1 + k_2\,;$$

$$H_C = \frac{M_{B2}}{h}\,; \quad H_E = -\frac{M_{D2}}{h}\,;$$

$$V_A = \frac{p\,l}{2} + \frac{M_{B1}}{l}\,; \quad V_F = \frac{M_{D1}}{l}\,;$$

$$V_C = \frac{p\,l}{2} - \frac{M_{B1}}{l} + \frac{M_{D3} - M_{B3}}{l_0}\,;$$

$$V_E = -\frac{M_{D3} - M_{B3}}{l_0} - \frac{M_{D1}}{l}\,;$$

$$\left.\begin{matrix} M_{B1} \\ M_{D1} \end{matrix}\right\} = \mp\frac{p\,l^2}{16}\left(\frac{2\,k_1+1}{\mathcal{N}_2} \pm \frac{2\,k_1+3}{\mathcal{N}_1}\right);$$

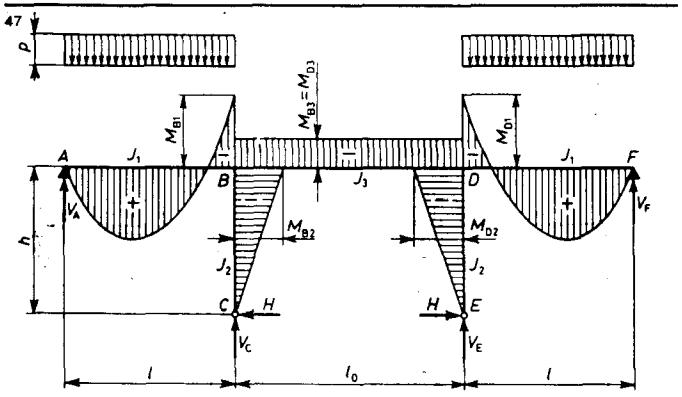
$$\left.\begin{matrix} M_{B3} \\ M_{D3} \end{matrix}\right\} = \mp\frac{p\,l^2\,k_1}{8}\left(\frac{1}{\mathcal{N}_2} \pm \frac{1}{\mathcal{N}_1}\right);$$

$$M_{B2} = M_{B1} - M_{B3}\,; \quad M_{D2} = M_{D1} - M_{D3}$$

segue

seguito tab. 8.10

47



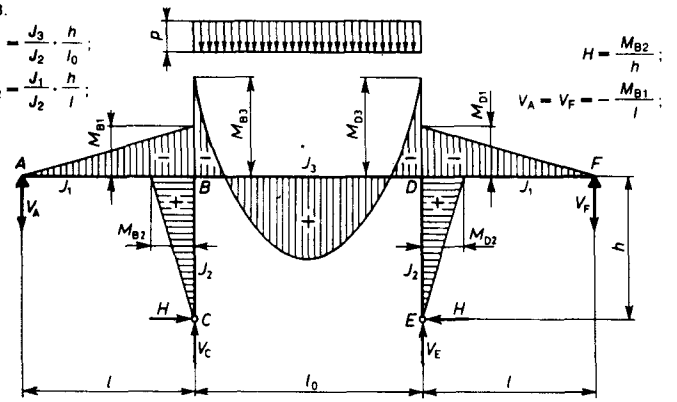
$$k_1 = \frac{J_3}{J_1}\cdot\frac{h}{l_0};\quad k_2 = \frac{J_1}{J_2}\cdot\frac{h}{l};\quad \mathcal{N}_1 = 3 + 2\,k_1 + 3\,k_2;\quad H = -\frac{M_{B2}}{h};$$

$$V_A = V_F = \frac{p\,l}{2} + \frac{M_{B1}}{l};\quad V_C = V_E = \frac{p\,l}{2} - \frac{M_{B1}}{l};\quad M_{B2} = M_{D2} = M_{B1} - M_{B3};$$

$$M_{B1} = M_{D1} = -\frac{p\,l^2}{8}\cdot\frac{2\,k_1 + 3}{\mathcal{N}_1};\quad M_{B3} = M_{D3} = -\frac{p\,l^2}{4}\cdot\frac{k_1}{\mathcal{N}_1}$$

48.

$$k_1 = \frac{J_3}{J_2}\cdot\frac{h}{l_0};\qquad k_2 = \frac{J_1}{J_2}\cdot\frac{h}{l};$$



$$H = \frac{M_{B2}}{h};\qquad V_A = V_F = -\frac{M_{B1}}{l};$$

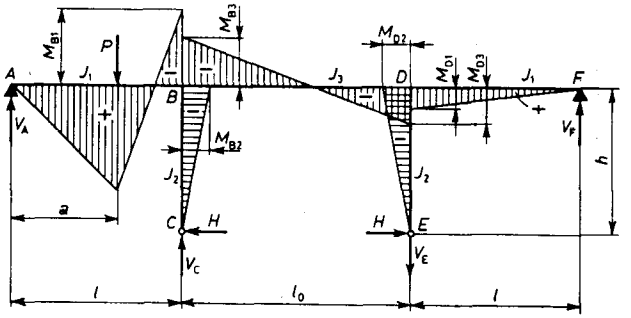
$$\mathcal{N}_1 = 3 + 2\,k_1 + 3\,k_2;\qquad V_C = V_E = \frac{p\,l_0}{2} - \frac{M_{B1}}{l};$$

$$M_{B1} = M_{D1} = -\frac{p\,{l_0}^2\,k_2}{4\,\mathcal{N}_1};\quad M_{B2} = M_{D2} = -\frac{p\,{l_0}^2}{4\,\mathcal{N}_1};\quad M_{B3} = M_{D3} = -\frac{p\,{l_0}^2\,(k_2+1)}{4\,\mathcal{N}_1}$$

segue

seguito tab. 8.10

49.



$$k_1 = \frac{J_3}{J_2}\cdot\frac{h}{l_0};\quad k_2 = \frac{J_1}{J_2}\cdot\frac{h}{l};\quad \mathcal{N}_1 = 3 + 2\,k_1 + 3\,k_2;$$

$$\mathcal{N}_2 = 1 + 2\,k_1 + k_2;\quad \delta = \frac{a}{l};$$

$$H_C = -\frac{M_{B2}}{h};\quad H_E = -\frac{M_{D2}}{h};$$

$$V_A = P\,(1-\delta) + \frac{M_{B1}}{l};\quad V_F = -\frac{M_{D1}}{l};$$

$$V_C = P\,\delta - \frac{M_{B1}}{l} + \frac{M_{D3} - M_{B3}}{l_0};$$

$$V_E = \frac{M_{D3} - M_{B3}}{l_0} + \frac{M_{D1}}{l};$$

$$\left.\begin{matrix} M_{B1} \\ M_{D1} \end{matrix}\right\} = \mp\frac{P\,a\,(1-\delta^2)}{4}\left(\frac{2\,k_1+1}{\mathcal{N}_2} \pm \frac{2\,k_1+3}{\mathcal{N}_1}\right);$$

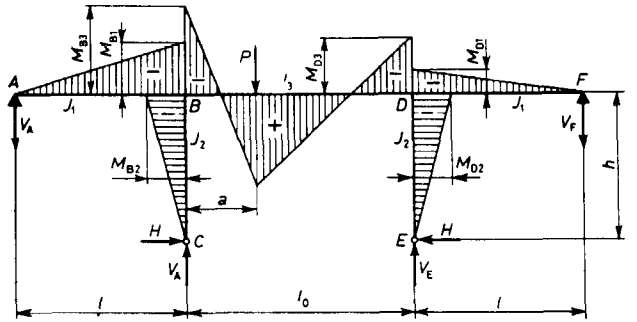
$$\left.\begin{matrix} M_{B3} \\ M_{D3} \end{matrix}\right\} = \mp\frac{P\,a\,(1-\delta^2)\,k_1}{2}\left(\frac{1}{\mathcal{N}_2} \pm \frac{1}{\mathcal{N}_1}\right);$$

$$M_{B2} = M_{B1} - M_{B3};\quad M_{D2} = M_{D1} - M_{D3}$$

segue

seguito tab. 8.10

50.



$$k_1 = \frac{J_3}{J_2}\cdot\frac{h}{l_0};\quad k_2 = \frac{J_1}{J_2}\cdot\frac{h}{l};\quad \mathcal{N}_1 = 3 + 2\,k_1 + 3\,k_2;\quad \mathcal{N}_2 = 1 + 2\,k_1 + k_2;$$

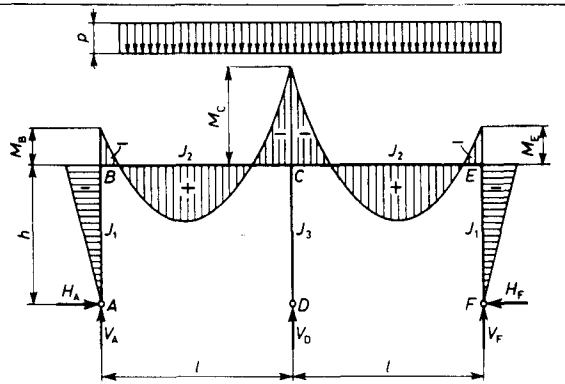
$$\delta = \frac{a}{l_0};\quad H_C = -\frac{M_{B2}}{h};\quad H_E = -\frac{M_{D2}}{h};\quad V_A = -\frac{M_{B1}}{l};$$

$$V_C = P(1-\delta) - \frac{M_{B1}}{l} + \frac{M_{D3} - M_{B3}}{l_0};\quad V_E = P\,\delta + \frac{M_{B3} - M_{D3}}{l_0} - \frac{M_{D1}}{l};\quad V_F = -\frac{M_{D1}}{l};$$

$$\left.\begin{matrix} M_{B1} \\ M_{D1} \end{matrix}\right\} = -\frac{P\,a\,(1-\delta)\,k_2}{2}\cdot\left(\frac{3}{\mathcal{N}_1} \pm \frac{1-2\,\delta}{\mathcal{N}_2}\right);\quad \left.\begin{matrix} M_{B3} \\ M_{D3} \end{matrix}\right\} = -\frac{P\,a\,(1-\delta)\cdot(k_2+1)}{2}\left(\frac{3}{\mathcal{N}_1} \pm \frac{1-2\,\delta}{\mathcal{N}_2}\right);$$

$$M_{B2} = M_{B3} - M_{B1};\quad M_{D2} = M_{D3} - M_{D1}.$$

51.



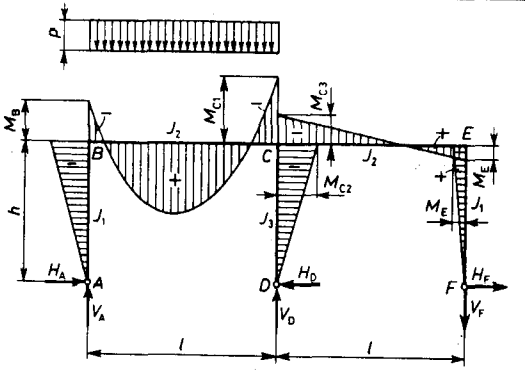
$$V_A = V_E = \frac{p\,l}{2} + \frac{M_C - M_B}{l};\quad V_F = p\,l - \frac{2\,(M_C - M_B)}{l};\quad k = \frac{J_2}{J_1}\cdot\frac{h}{l};$$

$$H = \frac{p\,l^2}{4\,(3+4\,k)\,h};\quad M_B = M_D = -H\,h;\quad M_C = -\frac{p\,l^2}{4}\cdot\frac{1+2\,k}{3+4\,k}.$$

segue

seguito tab. 8.10

52



$$V_A = \frac{p\,l}{2} + \frac{M_C^{\,s} - M_B}{l};\quad V_D = \frac{p\,l}{2} - \frac{M_C^{\,s} - M_B + M_C^{\,d} - M_E}{l};\quad V_F = \frac{-M_E + M_C^{\,d}}{l};$$

$$k_1 = \frac{J_2}{J_1}\cdot\frac{h}{l};\quad k_2 = \frac{J_2}{J_3}\cdot\frac{h}{l};\quad H_1 = \frac{p\,l^2}{8\,h}\left(\frac{1}{3+k_1+2\,k_2} + \frac{1}{3+4\,k_1}\right);$$

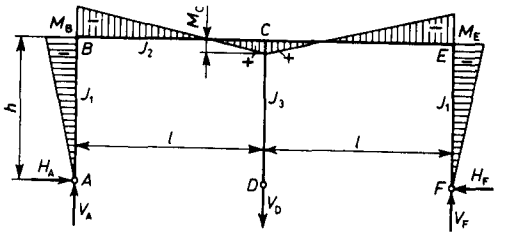
$$H_2 = \frac{p\,l^2}{8\,h}\cdot\frac{2}{3+k_1+2\,k_2};\quad H_3 = \frac{p\,l^2}{8\,h}\left(\frac{1}{3+k_1+2\,k_2} - \frac{1}{3+4\,k_1}\right);$$

$$M_B = -H_1\cdot h;\quad M_C = -H_2\cdot h;\quad M_E = +H_2\cdot h;$$

$$\left.\begin{matrix} M_C^{\,s} \\ M_C^{\,d} \end{matrix}\right\} = \frac{-p\,l^2}{8}\left(\pm\frac{1}{3+k_1+2\,k_2} + \frac{1+2\,k_1}{3+4\,k_1}\right)$$

53.

Diagramma dei momenti per un aumento $\Delta\,t$ della temperatura.

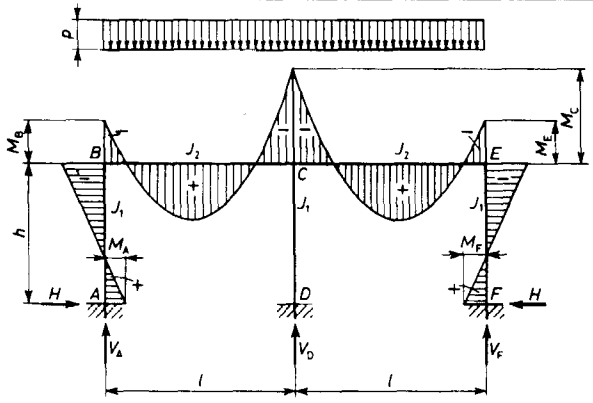


$$k = \frac{J_2}{J_1}\cdot\frac{h}{l};\quad H = \frac{12\cdot E\cdot\alpha\cdot\Delta\,t\cdot J_2}{h^2\,(3+4\,k)};\quad M_B = M_D = -H\cdot h;\quad M_C = +\frac{1}{2}\,M_B.$$

segue

seguito tab. 8.10

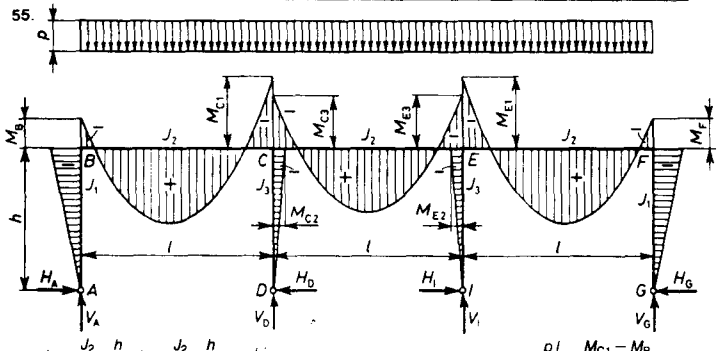
54.



$$V_A = V_E = \frac{p\,l}{2} + \frac{M_C - M_B}{l}\,; \quad V_F = p\,l - 2\,\frac{M_C - M_B}{l}\,; \quad H = \frac{M_A + M_B}{h}\,; \quad k = \frac{J_2}{J_1}\cdot\frac{h}{l}\,;$$

$$M_A = M_E = \frac{p\,l^2}{24\,(1+k)}\,; \quad M_B = M_D = -\,\frac{p\,l^2}{12\,(1+k)}\,; \quad M_C = -\,\frac{2+3\,k}{3\,(1+k)}\cdot\frac{p\,l^2}{8}$$

55.



$$k_1 = \frac{J_2}{J_1}\cdot\frac{h}{l}\,; \; k_2 = \frac{J_2}{J_3}\cdot\frac{h}{l}\,; \quad \mathcal{M} = 12\,k_1 + 20\,k_1\,k_2 + 18\,k_2\,; \quad V_A = V_G = \frac{p\,l}{2} + \frac{M_{C1} - M_B}{l}\,;$$

$$V_D = V_I = p\,l + \frac{M_B - M_{C1}}{l}\,; \quad H_A = H_G = -\,\frac{M_B}{h}\,; \quad H_D = H_I = -\,\frac{M_{C2}}{h}\,;$$

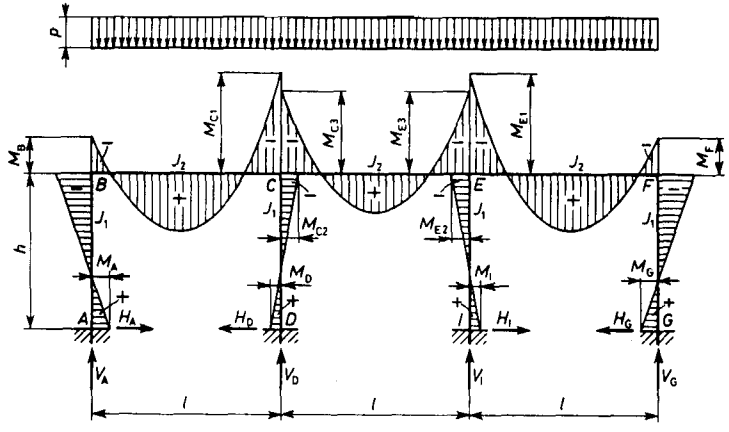
$$M_B = M_F = -\,\frac{p\,l^2}{4}\cdot\frac{6\,k_2 + 3}{\mathcal{M}}\,; \quad M_{C1} = M_{E1} = -\,\frac{p\,l^2}{4}\cdot\frac{6\,k_1 + 8\,k_1\,k_2 + 2\,k_2 + 7}{\mathcal{M}}\,;$$

$$M_{C3} = M_{E3} = -\,\frac{p\,l^2}{4}\cdot\frac{4\,k_1 + 8\,k_1\,k_2 + 6\,k_2 + 3}{\mathcal{M}}\,; \quad M_{C2} = M_{E2} = M_{C1} - M_{C3}$$

segue

seguito tab. 8.10

56.



$$k = \frac{J_2}{J_1}\cdot\frac{h}{l}\,; \quad \mathcal{M} = 3\,(4 + 10\,k^2 + k^2)\,;$$

$$V_A = V_G = \frac{p\,l}{2} + \frac{M_{C1} - M_B}{l}\,;$$

$$V_D = V_I = p\,l + \frac{M_B + M_{E2}}{l} - \frac{M_{C1} + M_{C3}}{l}\,;$$

$$H_A = H_G = \frac{M_A + M_B}{h}\,; \quad H_D = H_I = \frac{M_D + M_{C2}}{h}\,;$$

$$M_A = M_G = +\,\frac{p\,l^2}{2}\cdot\frac{2+3\,k}{\mathcal{M}}$$

$$M_B = M_F = -\,\frac{p\,l^2}{2}\cdot\frac{2+3\,k}{\mathcal{M}}\,;$$

$$M_{C1} = M_{E1} = -\,\frac{p\,l^2}{2}\cdot\frac{2 + 6\,k + 3\,k^2}{\mathcal{M}}\,;$$

$$M_{C3} = M_{E3} = -\,\frac{p\,l^2}{2}\cdot\frac{2 + 5\,k + 3\,k^2}{\mathcal{M}}\,;$$

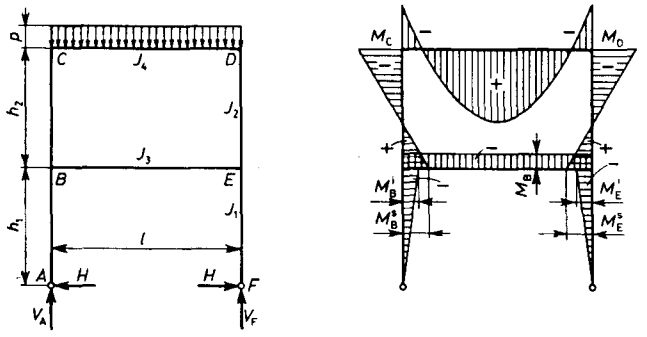
$$M_{C2} = M_{E2} = M_{C1} - M_{C3}\,;$$

$$M_D = M_I = \frac{M_{C2}}{2}$$

segue

seguito tab. 8.10

57.



$$V_A = V_F = \frac{p\,l}{2}; \quad k_1 = \frac{J_3}{J_1}\cdot\frac{h_1}{l}; \quad k_2 = \frac{J_4}{J_2}\cdot\frac{h_2}{l};$$

$$k_3 = \frac{J_3}{J_2}\cdot\frac{h_3}{l}; \quad H = \frac{M_B'}{h_1};$$

$$M_B' = M_E' = -\frac{p\,l^2}{4}\cdot\frac{k_3}{2\,k_1\,(3+2\,k_2)+k_3\,(2+k_2)\,(3+2\,k_1)};$$

$$M_B = M_E = -\frac{p\,l^2}{12}\cdot\frac{k_1\,k_3}{2\,k_1\,(3+2\,k_2)+k_3\,(2+k_2)\,(3+2\,k_1)};$$

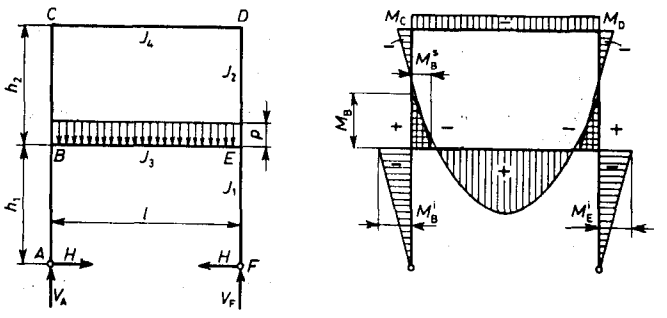
$$M_B^s = M_B^s = +\frac{p\,l^2}{12}\cdot\frac{k_3\,(3+2\,k_1)}{2\,k_1\,(3+2\,k_2)+k_3\,(2+k_2)\,(3+2\,k_1)};$$

$$M_C = M_D = -\frac{p\,l^2}{6}\cdot\frac{k_1\,(3+2\,k_3)+3\,k_2}{2\,k_1\,(3+2\,k_2)+k_2\,(2+k_2)\,(3+2\,k_1)}$$

segue

seguito tab. 8.10

58.



$$V_A = V_F = p\,\frac{l}{2}; \quad k_1 = \frac{J_2}{J_1}\cdot\frac{h_1}{l}; \quad k_2 = \frac{J_4}{J_2}\cdot\frac{h_2}{l};$$

$$k_3 = \frac{J_3}{J_2}\cdot\frac{h_2}{l}; \quad H = -\frac{M_B'}{h_1};$$

$$M_B' = M_B' = -\frac{p\,l^2}{4}\cdot\frac{k_3\,(2+k_2)}{2\,k_1\,(3+2\,k_2)+k_3\,(2+k_2)\,(3+2\,k_1)};$$

$$M_B = M_E = -\frac{p\,l^2}{6}\cdot\frac{k_1\,k_3}{2\,k_1\,(3+2\,k_2)+k_2\,(2+k_2)\,(3+2\,k_1)};$$

$$M_B^s = M_E^s = \frac{p\,l^2}{12}\cdot\frac{k_3\,(3+2\,k_1)}{2\,k_1\,(3+2\,k_2)+k_3\,(2+k_2)\,(3+2\,k_1)};$$

$$M_C = M_D = -\frac{p\,l^2}{6}\cdot\frac{k_1\,(3+2\,k_3)+3\,k_2}{2\,k_1\,(3+2\,k_2)+k_3\,(2+k_2)\,(3+2\,k_1)}$$