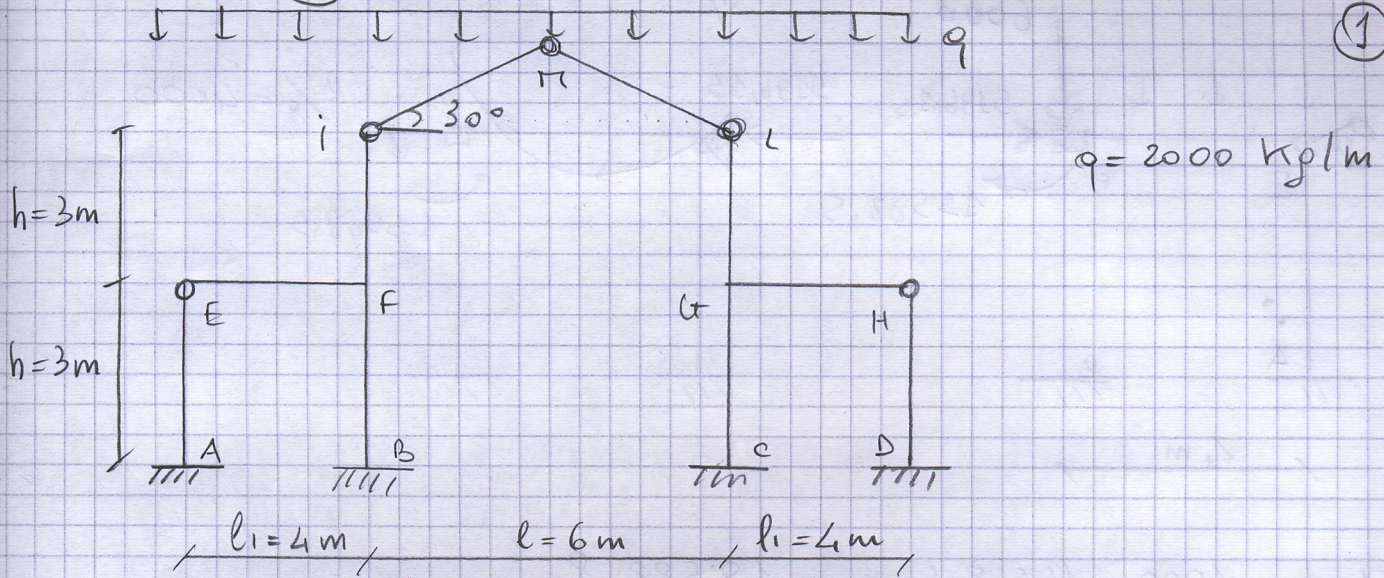
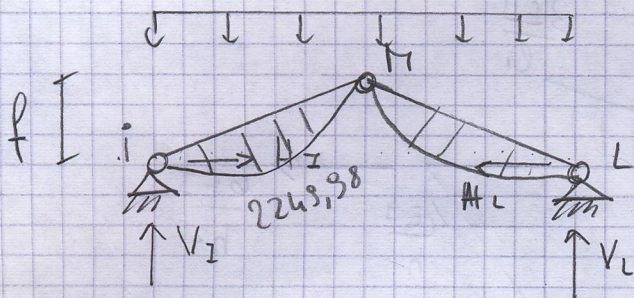




A) La struttura è isostatica

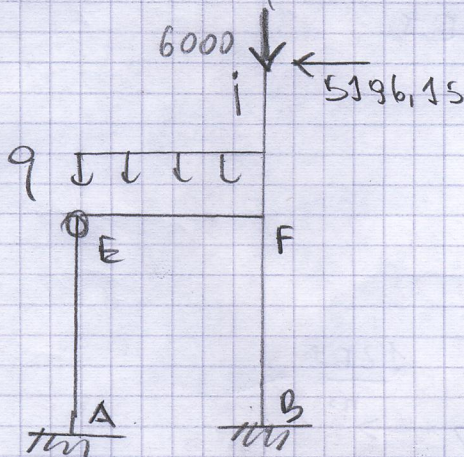


$$V_I = V_L = \frac{2000 \cdot 6}{2} = 6000 \text{ kg}$$

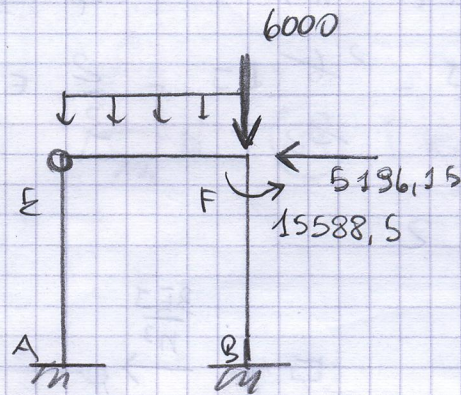
$$H_I = H_L = \left(\frac{q l^2}{8} \right) \cdot \frac{1}{f} = \frac{9000}{1,73205}$$

$$\Rightarrow H_I = H_L = 5196,15 \text{ kg}$$

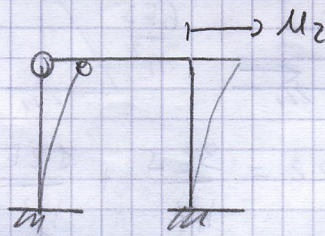
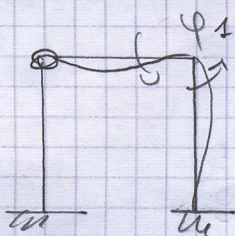
Riparto le reazioni ai nodi cambiando di segno sulla restante parte di struttura.



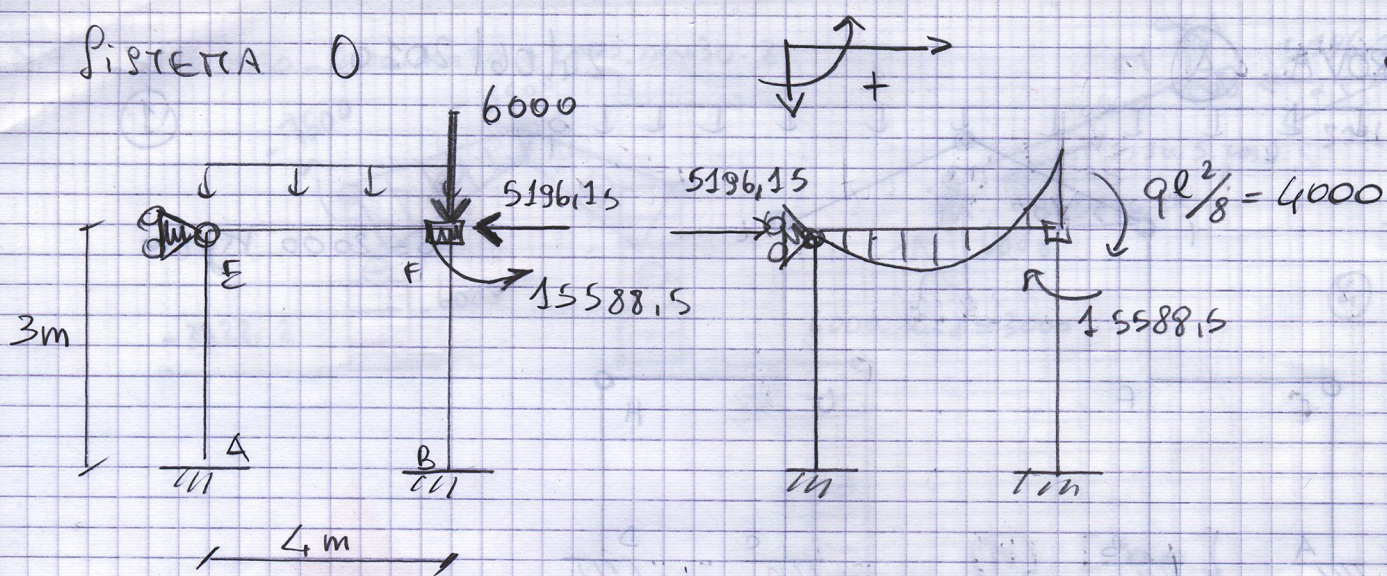
=



Risolvo con il metodo degli spostamenti $\Rightarrow$ 2 spostamenti



СИСТЕМА 0

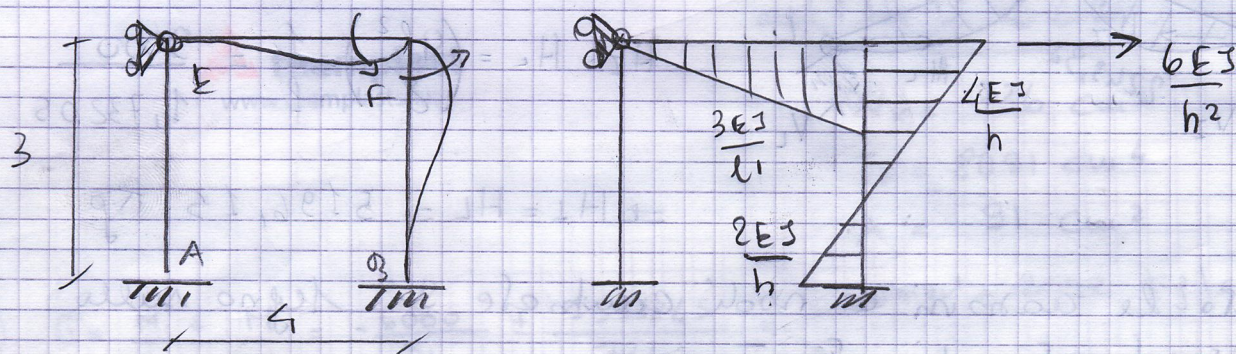


(2)

$$K_{10} = -4000 - 15588,5 = -19588,5$$

$$K_{20} = 5196,15$$

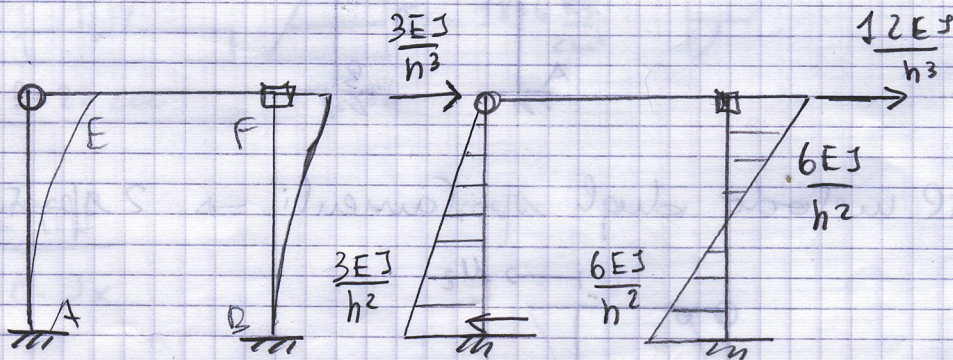
СИСТЕМА 1



$$K_{11} = EJ \left(\frac{3}{l_1} + \frac{4}{h} \right) = EJ \left(\frac{3}{4} + \frac{4}{3} \right) = \frac{25}{12} EJ$$

$$K_{12} = \frac{6EJ}{h^2} = \frac{26}{93} EJ = \frac{2}{3} EJ$$

СИСТЕМА 2



$$K_{21} = \frac{6EJ}{h^2} = \frac{2}{3} EJ ; K_{22} = \frac{3EJ}{h^2} + \frac{12EJ}{h^3} = EJ \cdot \frac{5}{9}$$

$$EJ \begin{pmatrix} 25/12 & 2/3 \\ 2/3 & 5/9 \end{pmatrix} \begin{pmatrix} \varphi_1 \\ \mu_2 \end{pmatrix} = \begin{pmatrix} 19588,8 \\ -5196,15 \end{pmatrix} \quad (3)$$

$$\begin{pmatrix} \varphi_1 \\ \mu_2 \end{pmatrix} = \frac{1}{EJ} \begin{pmatrix} 20122,7 \\ -33500,4 \end{pmatrix}$$

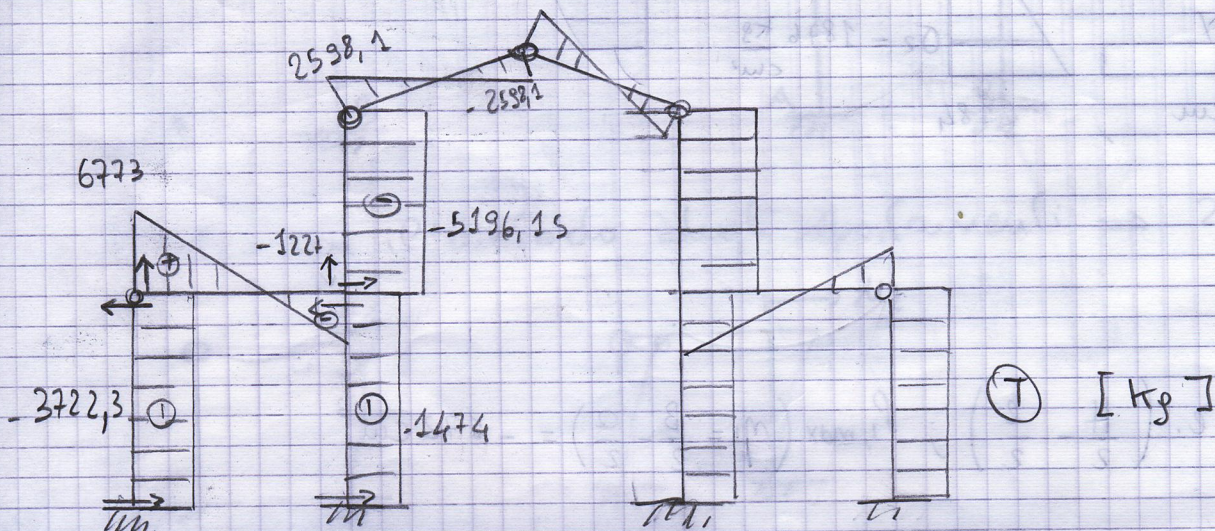
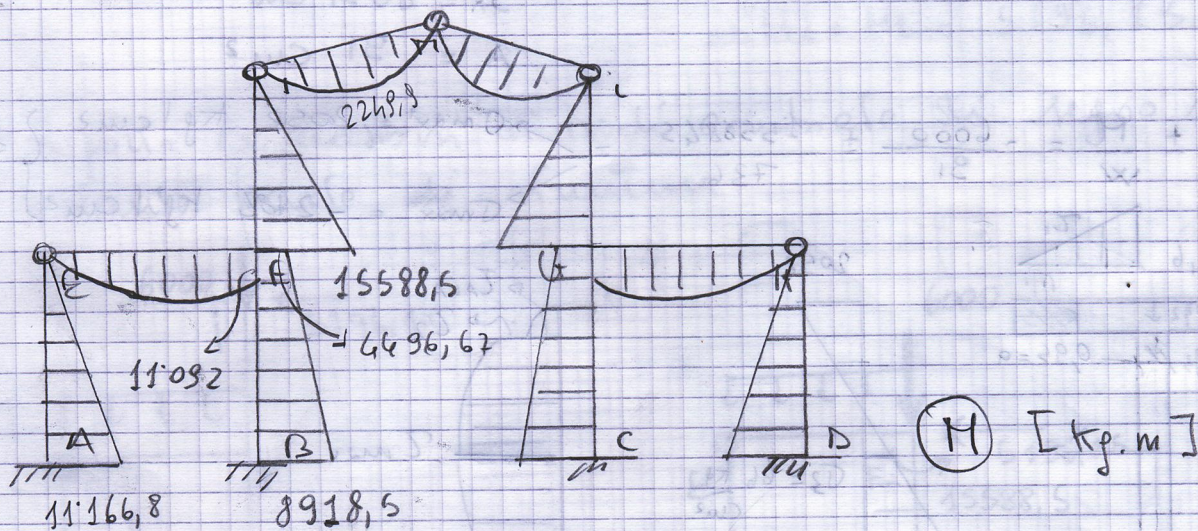
$$M_A = \frac{3EJ}{9} \left(-\frac{33500,4}{EJ} \right) = -11166,8$$

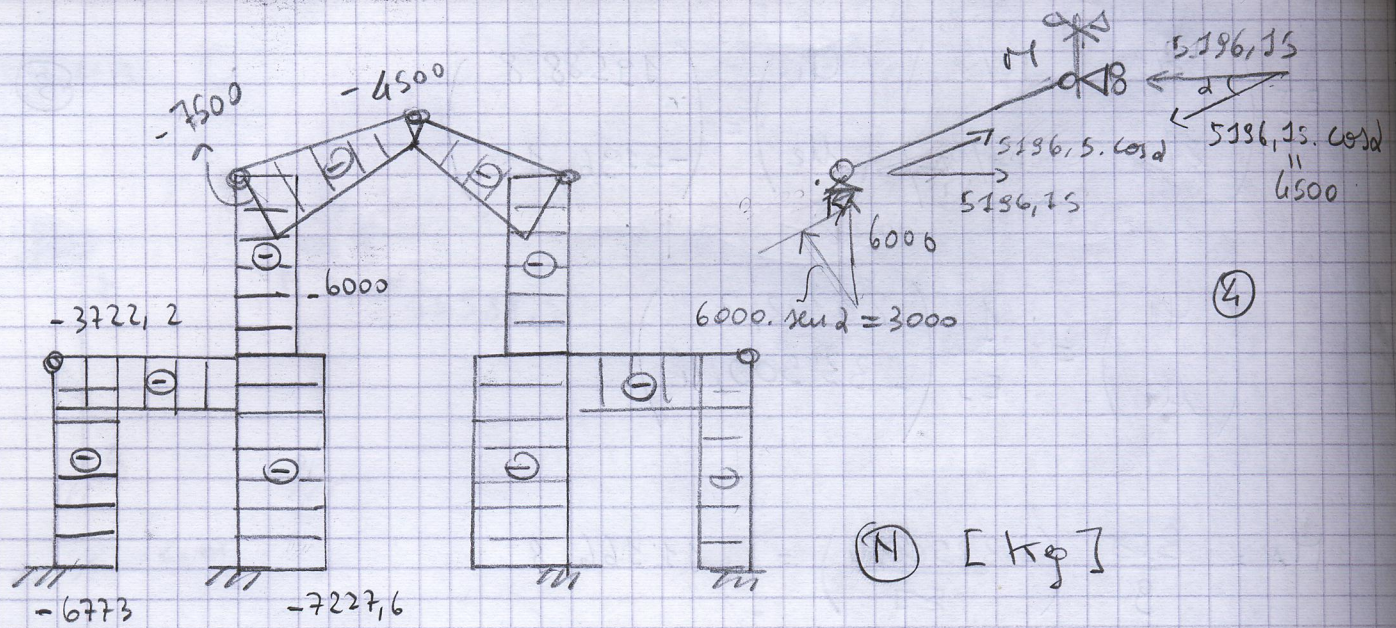
$$M_B = \frac{2}{3} EJ \left(\frac{20122,7}{EJ} \right) + \frac{6EJ}{9} \left(-\frac{33500,4}{EJ} \right) = -8918,5$$

$$M_{FB} = \frac{4EJ}{3} \left(\frac{20122,7}{EJ} \right) + \frac{6}{9} EJ \left(-\frac{33500,4}{EJ} \right) = 4496,67$$

$$M_{FE} = -4000 + \frac{3EJ}{4} \left(\frac{20122,7}{EJ} \right) = 11092$$

B)





C)

$$M_{max} = 15'588,45 \text{ kg.m}$$

$$T = 5196,15 \text{ kg}$$

$$N = -6000 \text{ kg}$$

Perfil HEB

$$W_{min} = \frac{15'588,45}{2'600} = 599,55$$

HEB 220

$$W_x = 736 \text{ cm}^3$$

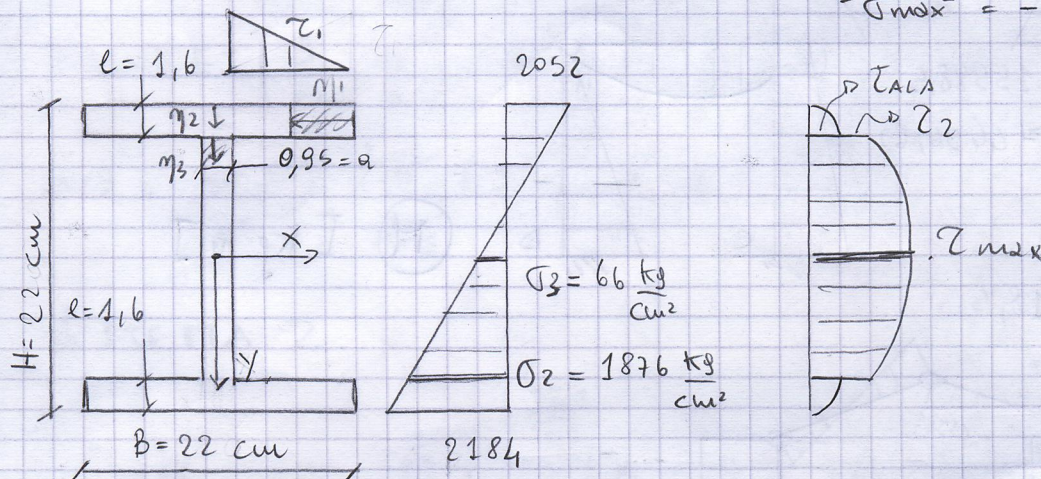
$$J_x = 8091 \text{ cm}^4$$

$$A = 91 \text{ cm}^2$$

D)

$$\sigma = \frac{N}{A} \pm \frac{M}{W} = -\frac{6000}{91} \pm \frac{15588,45}{736}$$

$$\left. \begin{aligned} \sigma_{max} &= 2052 \text{ kg/cm}^2 \\ \sigma_{max} &= -2184 \text{ kg/cm}^2 \end{aligned} \right\} < \sigma_{adm}$$



$$\tau = \frac{-T \cdot S}{C \cdot J_x}$$

$$S_1 = -\eta_1 \cdot e \cdot \left(\frac{H}{2} - \frac{e}{2} \right); S_{1,max} \left(\eta_1 = \frac{B}{2} - \frac{a}{2} \right) = -172 \text{ cm}^3$$

$$\tau_1 = \frac{-5196,15 \cdot (-172)}{1,6 \cdot 8091} = 69 \text{ kg/cm}^2$$

$$S_2 = -B \cdot \eta_2 \cdot \left(\frac{H}{2} - \frac{\eta_2}{2} \right); S_{2, \max} (\eta_2 = e) = -359 \text{ cm}^3$$

$$\tau_{AlA} = \frac{-T \cdot S}{B \cdot I_x} = \frac{-5196,15 \cdot (-359)}{22 \cdot 8091} = 10,5 \text{ kg/cm}^2$$

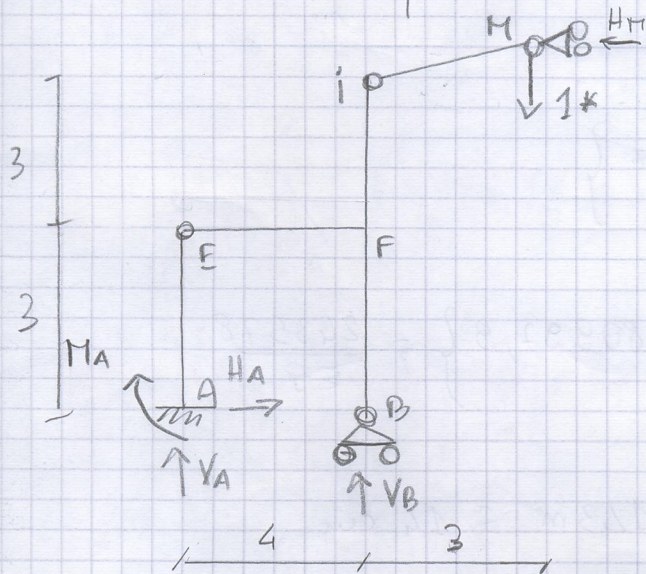
$$\tau_2 = \frac{-T \cdot S}{a \cdot I_x} = \frac{-5196,15 \cdot (-359)}{0,95 \cdot 8091} = 243 \text{ kg/cm}^2$$

$$S_3 = -a \cdot \eta_3 \cdot \left(\frac{H}{2} - e - \frac{\eta_3}{2} \right); S_{3, \max} (\eta_3 = \frac{H}{2} - e) = -42 \text{ cm}^3$$

$$\tau_{\max} = \tau_2 + \frac{T \cdot S}{e \cdot I_x} = \frac{-5196,15 \cdot (-42)}{0,95 \cdot 8091} + 243 = 271 \text{ kg/cm}^2$$

$$\begin{aligned} \sigma_{id}^{(1)} &= \sqrt{\sigma_{\max}^2 + 3 \cdot \tau_1^2} = 2187,3 \text{ kg/cm}^2 \\ \sigma_{id}^{(2)} &= \sqrt{\sigma_e^2 + 3 \cdot \tau_2^2} = 1922,6 \text{ kg/cm}^2 \\ \sigma_{id}^{(3)} &= \sqrt{\sigma_3^2 + 3 \cdot \tau_{\max}^2} = 674 \text{ "} \end{aligned} \left. \vphantom{\begin{aligned} \sigma_{id}^{(1)} \\ \sigma_{id}^{(2)} \\ \sigma_{id}^{(3)} \end{aligned}} \right\} < 2600 \frac{\text{kg}}{\text{cm}^2}$$

E) Calcolo dello spostamento verticale del nodo M



$$\uparrow) V_A + V_B = 1$$

$$\rightarrow) H_A - H_M = 0$$

$$i) -1 \cdot 3 + H_M \cdot 1,73205 = 0$$

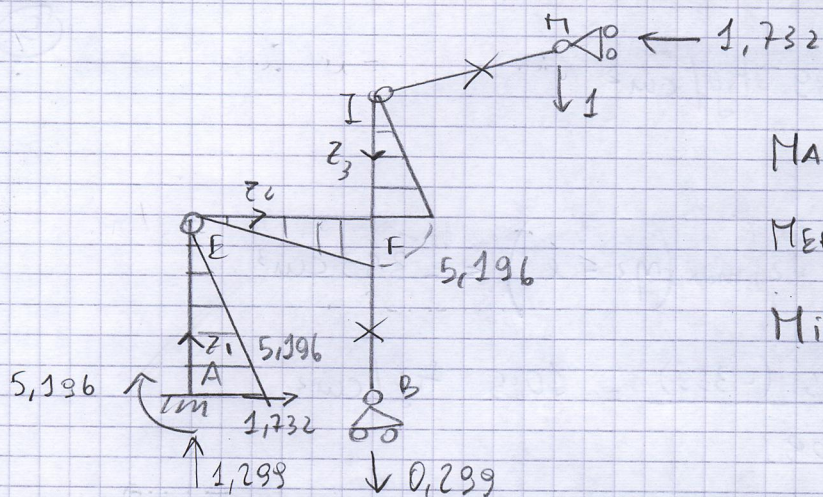
$$H_M = 1,732$$

$$\Rightarrow H_A = 1,732$$

$$\sum_{EA} 1,732 \cdot 3 - M_A = 0 \Rightarrow M_A = 5,196$$

$$\sum 5,196 + V_B \cdot 4 - 1 \cdot 7 + 1,732 \cdot 7,732 = 0$$

$$V_B = -0,299 \Rightarrow V_A = 1,299$$

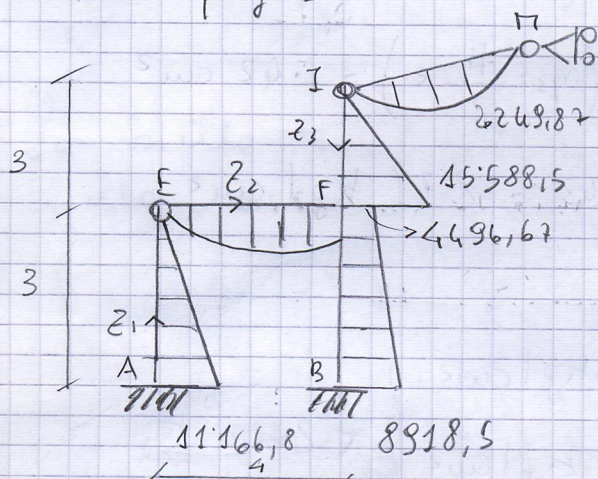


$$M_{AE}(z_1) = -1,732 \cdot z_1 + 5,196$$

$$M_{EF}(z_2) = 1,299 \cdot z_2$$

$$M_{IF}(z_3) = 1,732 \cdot z_3$$

Il diagramma del momento equilibrato è il seguente (vedi pag. 3)



$$M_{AE}(z_1) = 11166,8 - 3722,27 \cdot z_1$$

$$M_{EF}(z_2) = 6773 \cdot z_2 - 1000 \cdot z_2^2$$

$$M_{IF}(z_3) = 5196,17 \cdot z_3$$

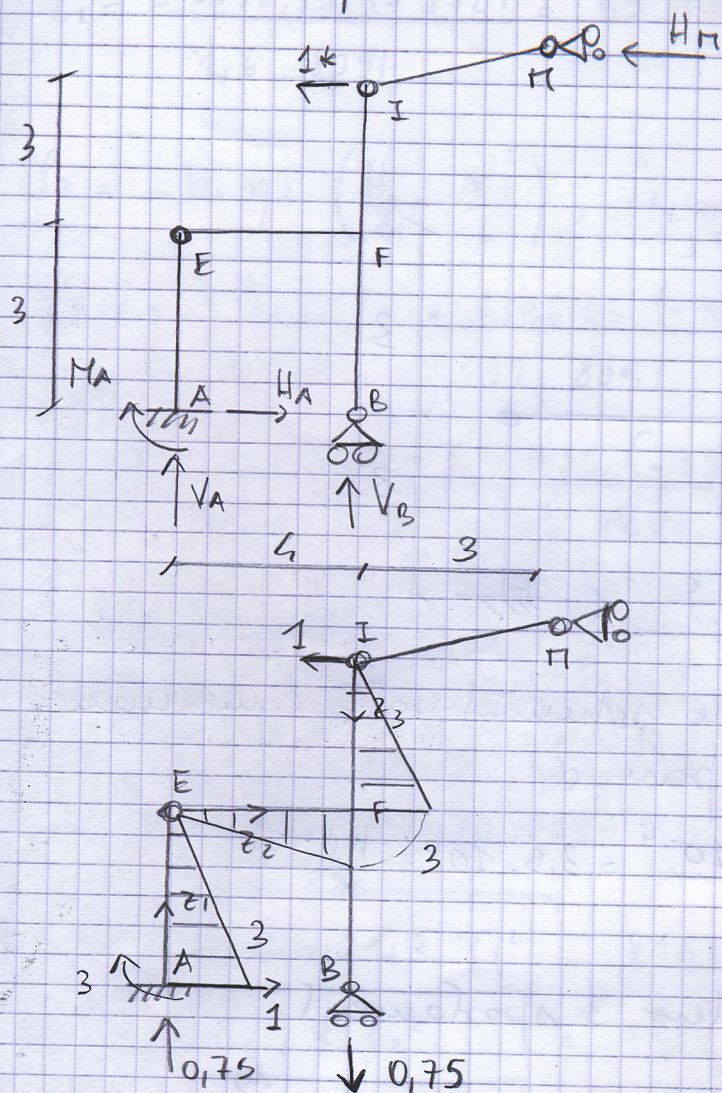
$$\begin{aligned} 1^* \Delta \pi = & \frac{1}{EI} \left\{ \int_0^3 (-1,732 \cdot z + 5,196)(11166,8 - 3722,27 \cdot z) dz + \right. \\ & + \int_0^4 (1,299 \cdot z)(6773 \cdot z - 1000 \cdot z^2) dz \\ & \left. + \int_0^3 (1,732 \cdot z)(5196,17 \cdot z) dz \right\} \end{aligned}$$

$$1^* \Delta \pi = \frac{1}{EI} \left\{ 58022,7 + 104557 + 80997,9 \right\} = \frac{243578}{EI}$$

$$\Rightarrow \Delta \pi = \frac{243578}{2,1 \cdot 10^{10} \cdot 8,1 \cdot 10^{-5}} = 0,143 \text{ m} \approx 14 \text{ cm}$$

Calcolo dello spostamento orizzontale del nodo I.

(7)



$$\uparrow) V_A + V_B = 0$$

$$\rightarrow) H_A - H_M = 1$$

$$\sum_{IM} H_M \cdot 1,732 = 0 \Rightarrow H_M = 0$$

$$\Rightarrow H_A = 1$$

$$\sum_{EA} 1 \cdot 3 - M_A = 0 \Rightarrow M_A = 3$$

$$\sum V_B \cdot 4 - 3 + 1 \cdot 6 = 0$$

$$V_B = -0,75$$

$$V_A = 0,75$$

$$M_{AE}(z_1) = 3 - 1 \cdot z_1$$

$$M_{EF}(z_2) = 0,75 \cdot z_2$$

$$M_{IF}(z_3) = 1 \cdot z_3$$

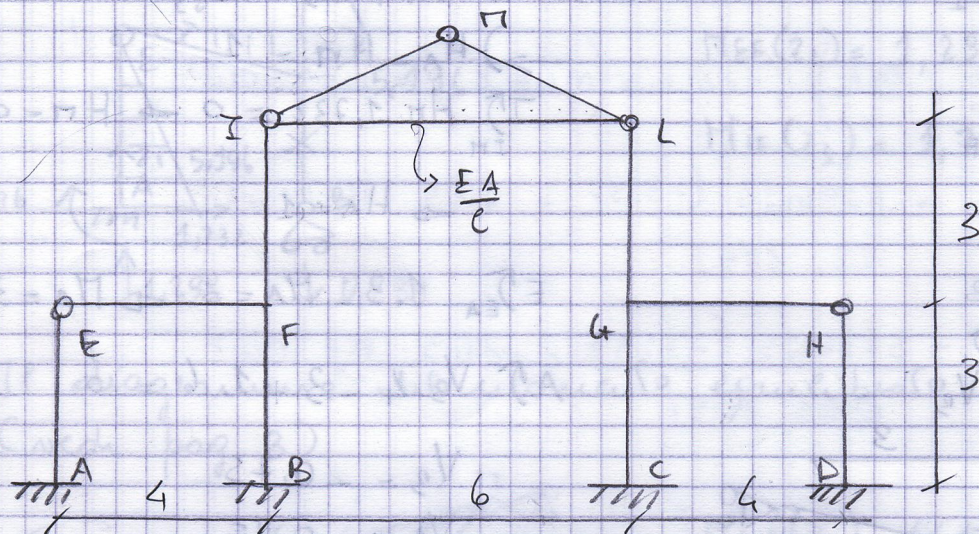
$$\begin{aligned} 1^* \cdot h_I = \frac{1}{EJ} & \left\{ \int_0^3 (11166,8 - 3722,27 \cdot z)(3 - z) dz + \right. \\ & + \int_0^4 (6773 \cdot z - 1000 \cdot z^2)(0,75 \cdot z) dz + \\ & \left. + \int_0^3 (5196,17 \cdot z)(z) dz \right\} \end{aligned}$$

$$1^* \cdot h_I = \frac{1}{EJ} \left\{ 33500,4 + 60368 + 46765,5 \right\} = \frac{140634}{EJ}$$

$$\Rightarrow h_I = 0,083 \text{ m} \approx 8,3 \text{ cm}$$

F) $A_{\text{colonna}} = 5 \text{ cm}^2$

8

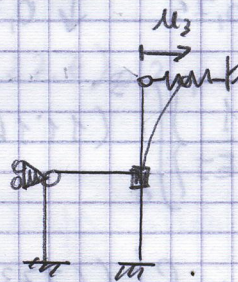
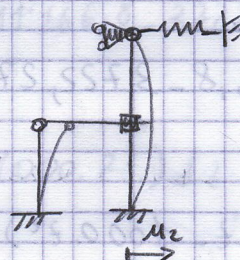
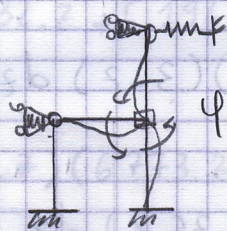
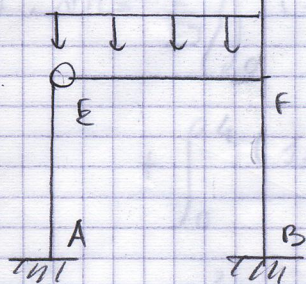


La trave I-L, può essere schematizzata come una molla, avente rigidezza pari a:

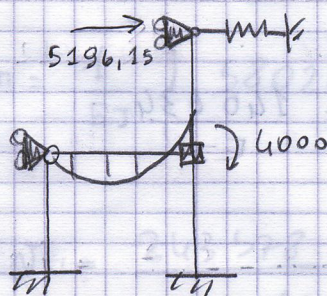
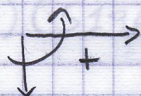
$$K = \frac{EA}{L/2} = \frac{2,1 \cdot 10^{10} \cdot 5 \cdot 10^{-4}}{3} = 3,5 \cdot 10^6 \frac{\text{kg}}{\text{m}}$$

6000
5196,15
 $K = EA/L/2$

Considero 3 spostamenti:



SISTEMA 0

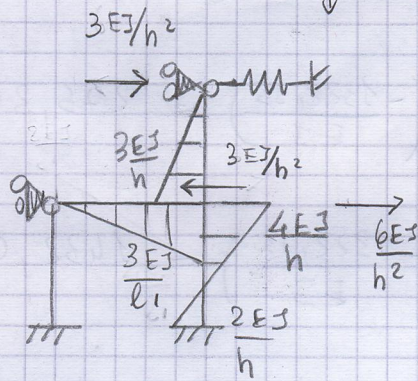
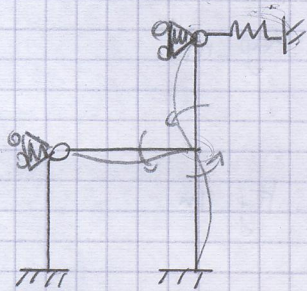


$$K_{10} = -4000$$

$$K_{20} = 0$$

$$K_{30} = 5196,15$$

SISTEMA 1

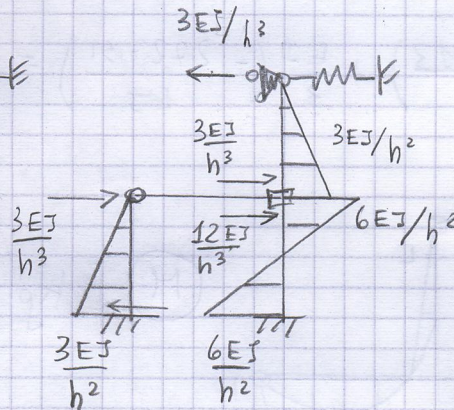
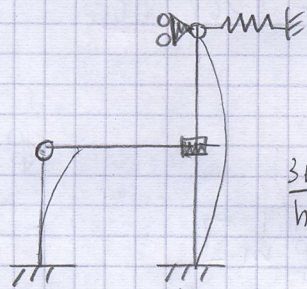


$$K_{11} = EJ \left(\frac{4}{h} + \frac{3}{h} + \frac{3}{l_1} \right) = \frac{37}{12} EJ$$

$$K_{12} = EJ \left(\frac{6}{h^2} - \frac{3}{h^2} \right) = \frac{EJ}{3}$$

$$K_{13} = \frac{3EJ}{h^2} = \frac{EJ}{3}$$

SISTEMA 2

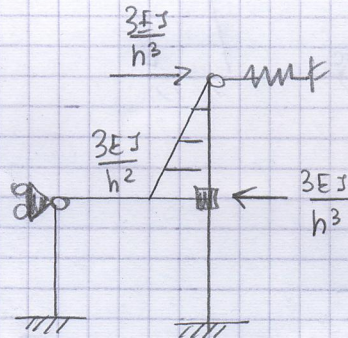
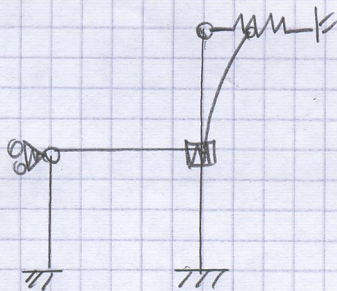


$$K_{21} = EJ \left(\frac{6}{h^2} - \frac{3}{h^2} \right) = \frac{3EJ}{h^2} = \frac{EJ}{3}$$

$$K_{22} = EJ \left(\frac{3}{h^3} + \frac{3}{h^3} + \frac{12}{h^3} \right) = \frac{2EJ}{3}$$

$$K_{23} = \frac{3EJ}{h^3} = -\frac{EJ}{9}$$

SISTEMA 3



$$K_{31} = \frac{3EJ}{h^2} = \frac{EJ}{3}$$

$$K_{32} = -\frac{EJ}{9}$$

$$K_{33} = \frac{3EJ}{h^3} + k = \frac{EJ}{9} + k$$

$$EJ \begin{pmatrix} 37/12 & 1/3 & 1/3 \\ 1/3 & 2/3 & -1/9 \\ 1/3 & -1/9 & \frac{1}{9} + \frac{k}{EJ} \end{pmatrix} \begin{pmatrix} \varphi_1 \\ u_2 \\ u_3 \end{pmatrix} = \begin{pmatrix} 4000 \\ 0 \\ -5196,15 \end{pmatrix}$$

$\hookrightarrow 2,171$

$$\begin{pmatrix} \varphi_1 \\ u_2 \\ u_3 \end{pmatrix} = \frac{1}{EJ} \begin{pmatrix} 1735,1 \\ -1322,13 \\ -2727,51 \end{pmatrix}$$

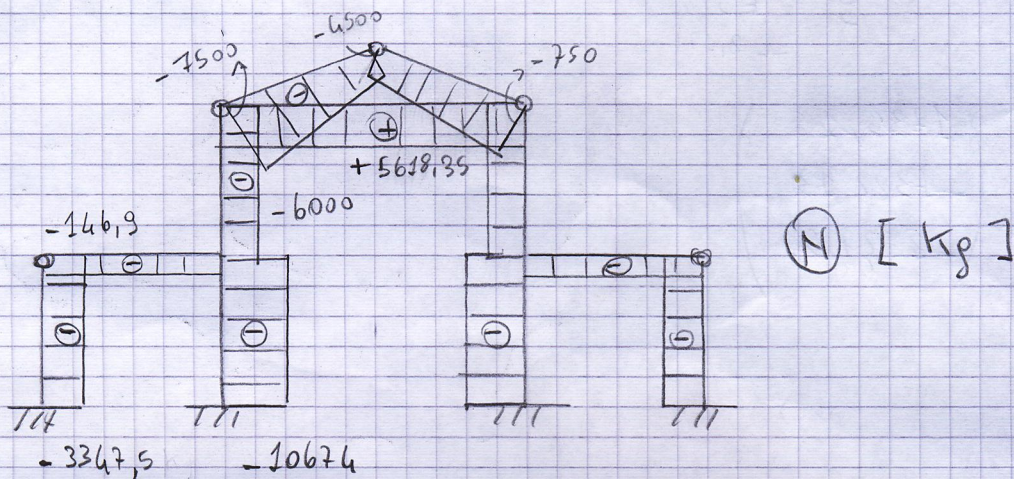
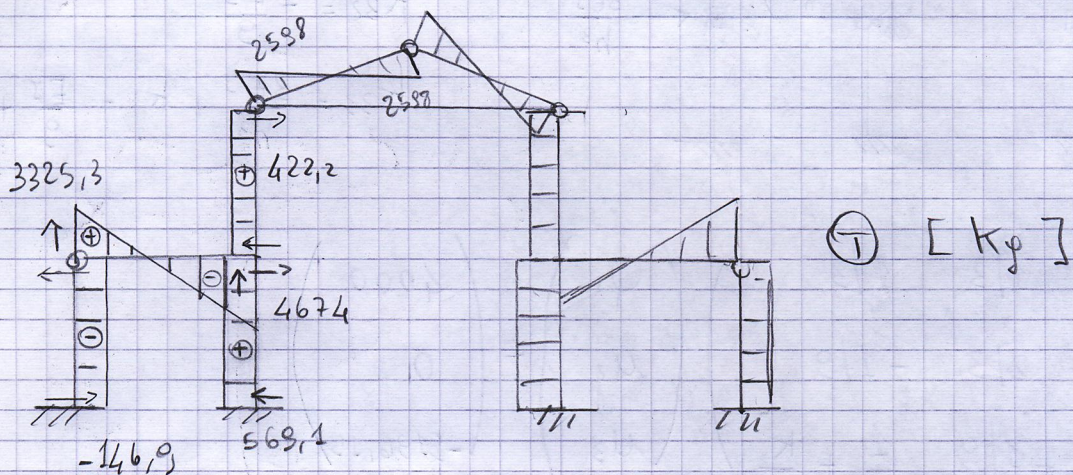
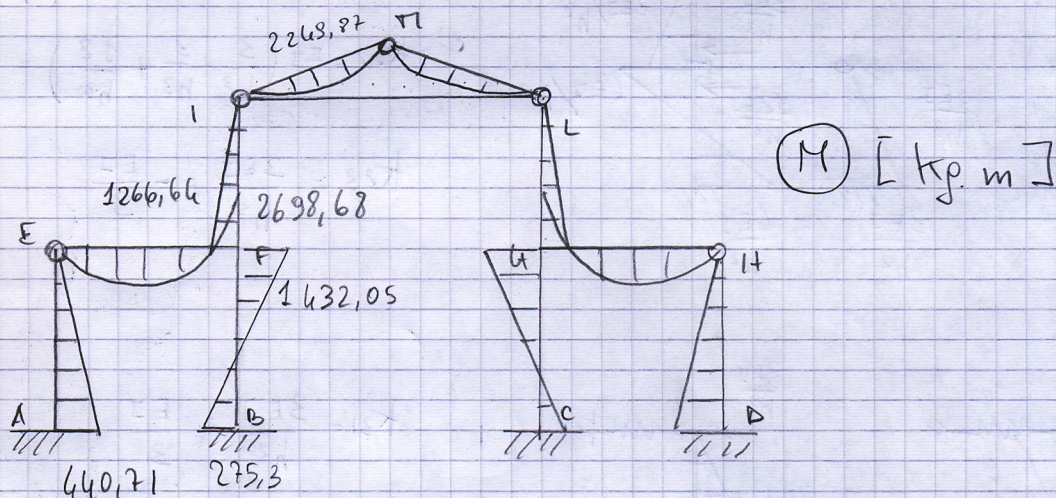
$$M_A = \frac{3}{9} EJ \left(-\frac{1322,13}{EJ} \right) = -440,71 \text{ kg.m}$$

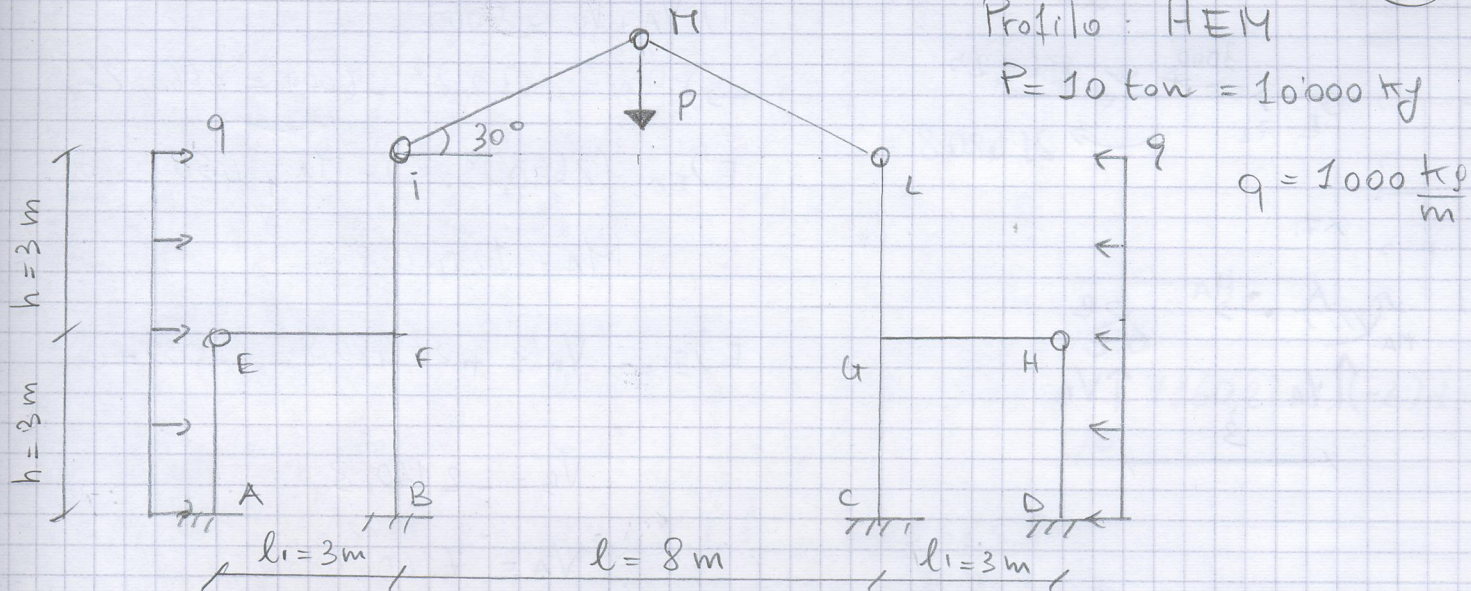
$$M_B = \frac{2}{3} EJ \left(\frac{1735,1}{EJ} \right) + \frac{6}{9} EJ \left(-\frac{1322,13}{EJ} \right) = 275,31 \text{ kg.m}$$

$$M_{FB} = \frac{4}{3} EJ \left(\frac{1735,1}{EJ} \right) + \frac{6}{9} EJ \left(-\frac{1322,13}{EJ} \right) = 1432,05 \text{ kg.m}$$

$$M_{FE} = -4000 + \frac{2}{3} EJ \left(\frac{1735,1}{EJ} \right) = -2698,68 \text{ kg.m}$$

$$M_{FJ} = EJ \left(\frac{1735,1}{EJ} \right) - \frac{EJ}{3} \left(-\frac{1322,13}{EJ} \right) + \frac{EJ}{3} \left(-\frac{2727,51}{EJ} \right) = 1266,64$$



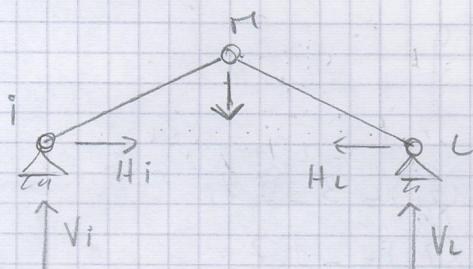


Profilo: HEM

$$P = 10 \text{ ton} = 10'000 \text{ kg}$$

$$q = 1000 \frac{\text{kg}}{\text{m}}$$

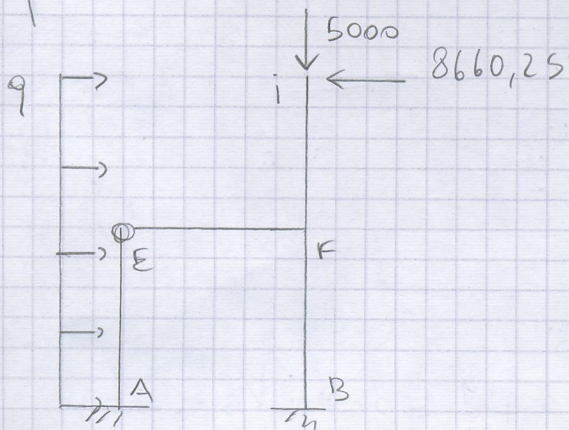
A) ILT irreflexe



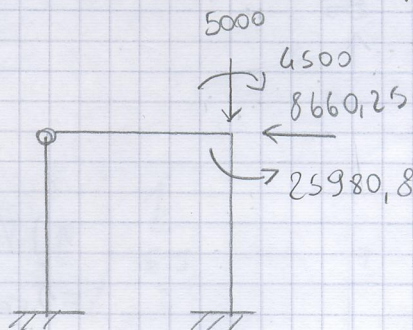
$$\uparrow) V_i = V_L = 5000 \text{ kg}$$

$$H_i = H_L = \frac{(V_i \cdot l/2)}{(l/2 \cdot \tan 30^\circ)} = 8660,25$$

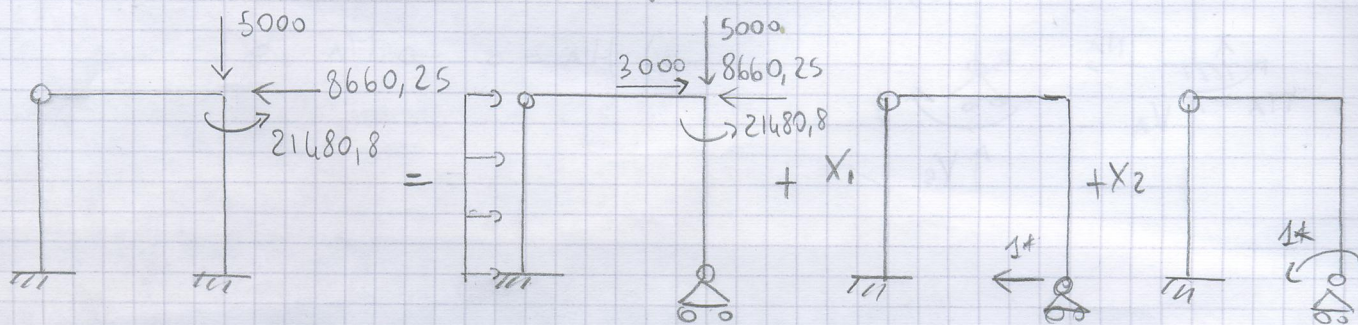
Riparto le reazioni ai nodi considerando il peso sulle verticali
parte di struttura.



=

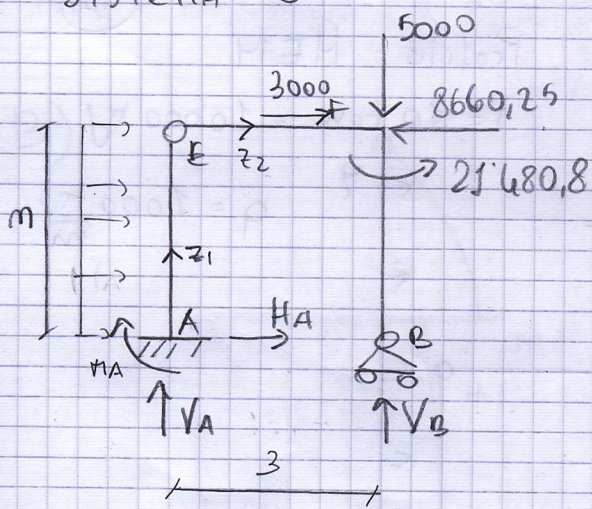


soluzione con il metodo delle forze



SISTEMA 0

(12)



$$\uparrow) V_A + V_B = 5000$$

$$\rightarrow) H_A = 8660,25 - 6000 = 2660,25$$

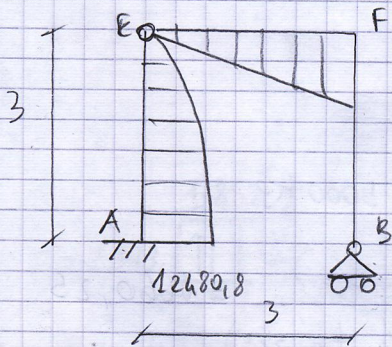
$$\overset{E}{\curvearrowleft} \sum M_{EA} (2660,25 \cdot 3) - M_A + 4500 = 0$$

$$M_A = 12480,8$$

$$\overset{E}{\curvearrowleft} \sum M_{EFB} V_B \cdot 3 + 21480,8 - 15000 = 0$$

$$V_B = -2160,3$$

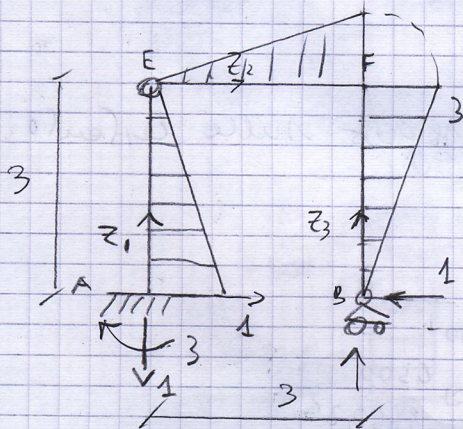
$$V_A = 7160,27$$



$$M_{AE}(z_1) = 12480,8 - 2660 \cdot z_1 - 500 \cdot z_1^2$$

$$M_{EF}(z_2) = 7160,27 \cdot z$$

SISTEMA 1

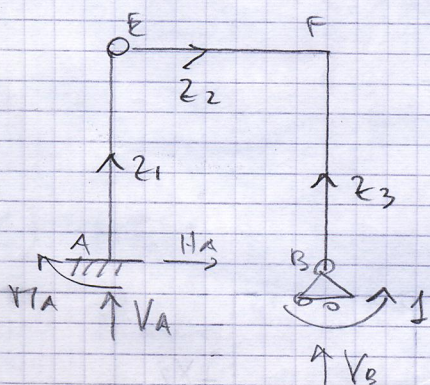


$$M_{AE}(z_1) = 3 - 1 \cdot z_1$$

$$M_{EF}(z_2) = -1 \cdot z$$

$$M_{BF}(z_3) = 1 \cdot z$$

SISTEMA 2

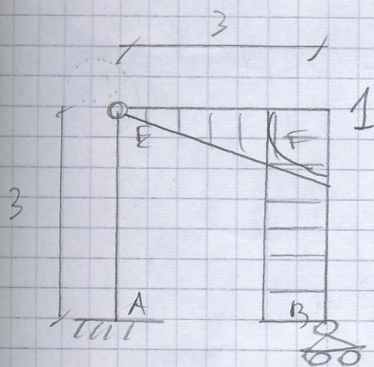


$$\uparrow) V_A + V_B = 0$$

$$\overset{E}{\curvearrowleft} \sum M_{EFB} V_B \cdot 3 + 1 = 0 \Rightarrow V_B = -\frac{1}{3}$$

$$\Rightarrow V_A = \frac{1}{3}$$

$$\rightarrow) H_A = 0 \Rightarrow M_A = 0$$



$$M_{AE}(z_1) = 0$$

$$M_{EF}(z_2) = \frac{1}{3} \cdot z_2$$

$$M_{BF}(z_3) = -1$$

$$\eta_{10} = \frac{1}{EI} \left\{ \int_0^3 (12480,8 - 2660 \cdot z - 500 \cdot z^2)(3-z) dz + \int_0^3 (7160,27 \cdot z)(-z) dz \right\}$$

$$= \frac{1}{EI} \left\{ 40818,6 - 64662 \cdot 4 \right\} = -\frac{23623,8}{EI}$$

$$\eta_{20} = \frac{1}{EI} \left\{ \int_0^3 (7160,27 \cdot z) \left(\frac{z}{3} \right) dz \right\} = \frac{21680,8}{EI}$$

$$\eta_{11} = \frac{1}{EI} \left\{ \int_0^3 (3-z)^2 dz + \int_0^3 z^2 dz + \int_0^3 z^2 dz \right\}$$

$$= \frac{1}{EI} \left\{ 9 + 9 + 9 \right\} = \frac{27}{EI}$$

$$\eta_{22} = \frac{1}{EI} \left\{ \int_0^3 \left(\frac{z}{3} \right)^2 dz + \int_0^3 1 dz \right\} = \frac{1}{EI} \left\{ 1 + 3 \right\} = \frac{4}{EI}$$

$$\eta_{12} = \frac{1}{EI} \left\{ \int_0^3 (-z) \left(\frac{z}{3} \right) dz + \int_0^3 (z)(-1) dz \right\} = \frac{1}{EI} \left\{ -3 - 4,5 \right\} = -\frac{7,5}{EI}$$

$$\frac{1}{EI} \begin{pmatrix} 27 & -7,5 \\ -7,5 & 4 \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} = \begin{pmatrix} 23623,8 \\ -21680,8 \end{pmatrix} \cdot \frac{1}{EI}$$

$$\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} = \begin{pmatrix} -1287,17 \\ -7783,63 \end{pmatrix}$$

$$M_A = 12480,8 + 3(-1287,17) = 8619,29$$

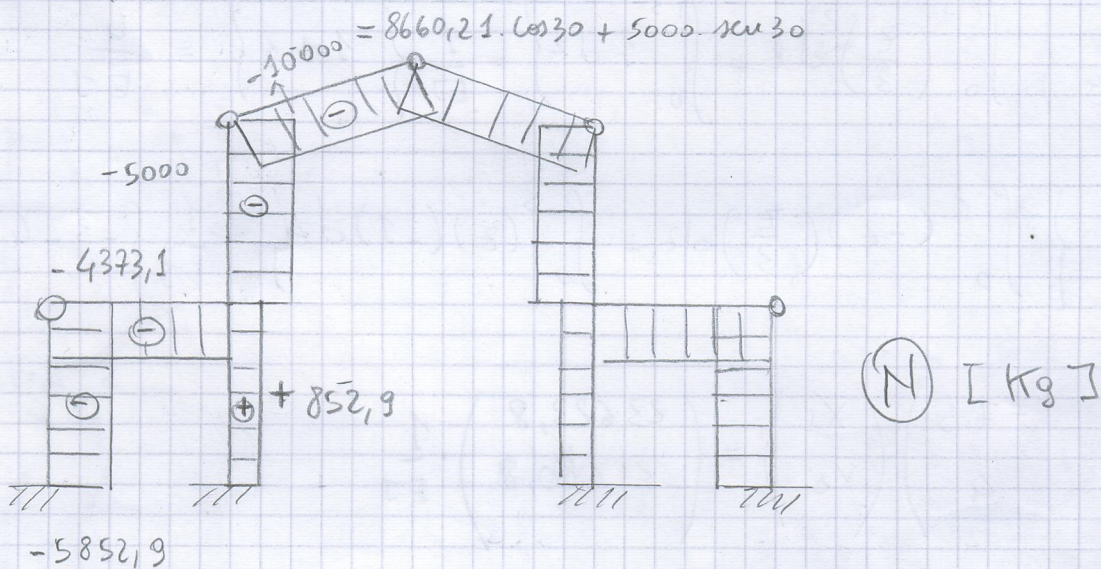
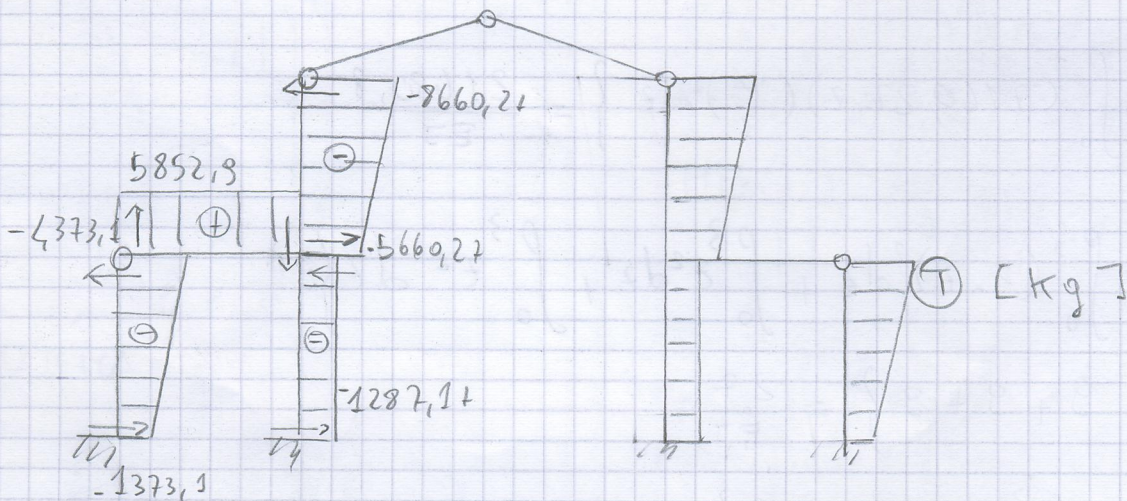
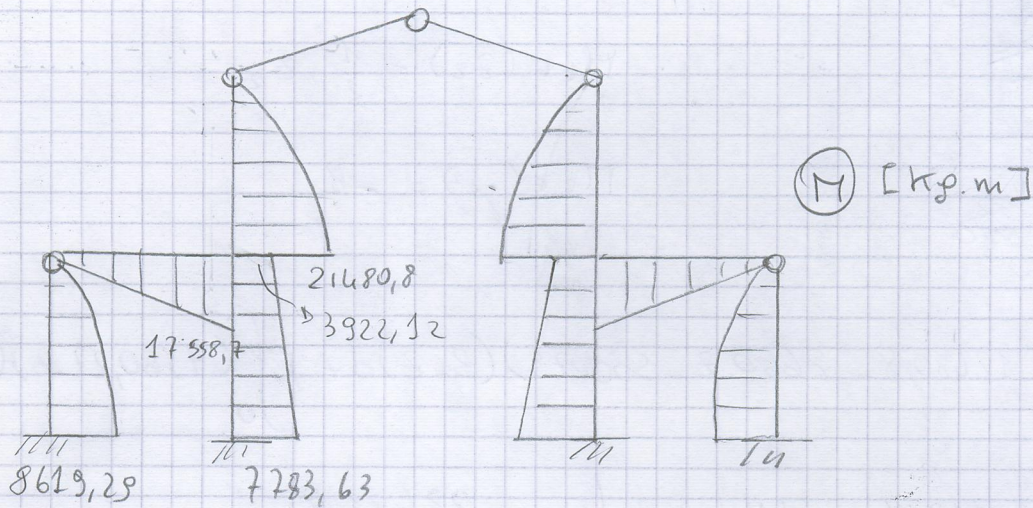
$$M_B = -1 \cdot (-7783,63) = 7783,63$$

$$M_{FB} = 3(-1287,17) - 1(-7783,63) = 3922,12$$

$$M_{FE} = 21'480,8 - 3(-1287,17) + 1(-7283,63) = 17'558,7$$

(14)

B)



C) HEM

$$M_{max} = 21'480,8$$

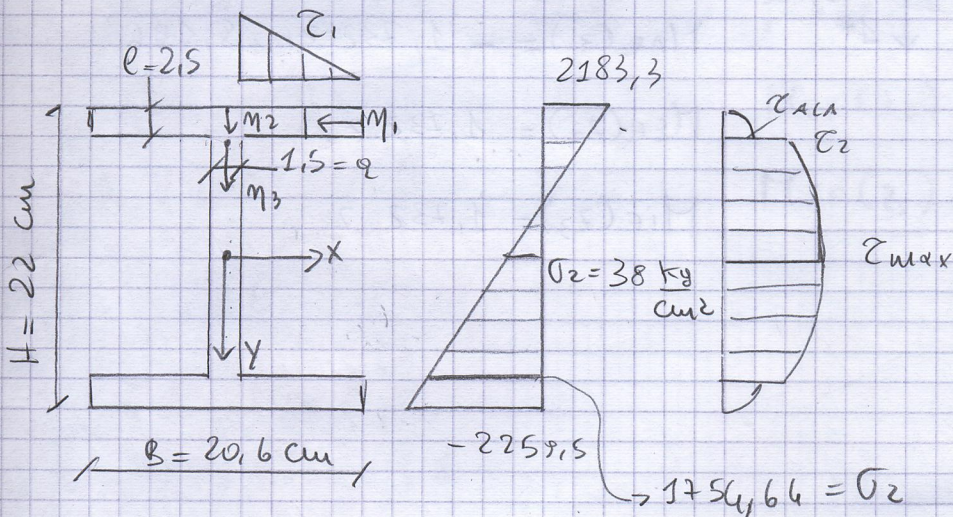
$$T = 5660,27$$

$$N = -5000$$

$$W_{min} = \frac{21'48080}{2600} = 826,2$$

$$\Rightarrow \text{HEM } 200 \left\{ \begin{array}{l} W_x = 967 \text{ cm}^3 \\ J_x = 10'662 \text{ cm}^4 \\ A = 131,3 \text{ cm}^2 \end{array} \right.$$

D)
$$\sigma = \frac{N}{A} + \frac{M}{W} = \frac{-5000}{131,3} + \frac{2148080}{967} = \begin{cases} \sigma_{\max}^+ = 2183,3 \\ \sigma_{\max}^- = -2259,5 \end{cases} \quad (95)$$



$$\tau = -\frac{T \cdot S}{C \cdot J_x}$$

$$S_1 = -e \cdot M_1 \cdot \left(\frac{H}{2} - \frac{e}{2} \right); \quad S_{1, \max} \left(M_1 = \frac{B}{2} - \frac{e}{2} \right) = -233 \text{ cm}^3$$

$$\tau_1 = -\frac{5660,27 \cdot (-233)}{2,5 \cdot 10662} = 49,57 \text{ kg/cm}^2$$

$$S_2 = -M_2 \cdot B \cdot \left(\frac{H}{2} - \frac{M_2}{2} \right); \quad S_{2, \max} (M_2 = e) = -502,12 \text{ cm}^3$$

$$\tau_{ALA} = -\frac{5660,27 \cdot (-502,12)}{20,6 \cdot 10662} = 12,96 \text{ kg/cm}^2$$

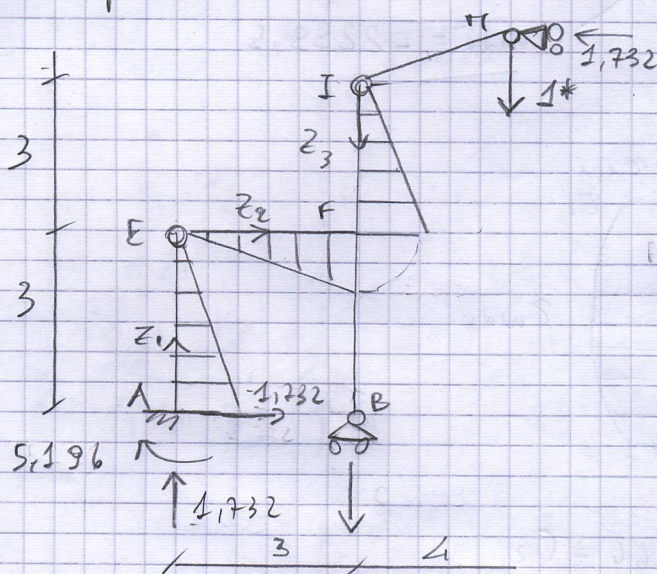
$$\tau_2 = -\frac{5660,27 \cdot (-502,12)}{1,5 \cdot 10662} = 178 \text{ kg/cm}^2$$

$$S_3 = -a \cdot M_3 \cdot \left(\frac{H}{2} - e - \frac{M_3}{2} \right); \quad S_{3, \max} \left(M_3 = \frac{H}{2} - e \right) = 54,19 \text{ cm}^3$$

$$\tau_{\max} = \tau_2 + \frac{5660,27 \cdot (54,19)}{1,5 \cdot 10662} = 197,2 \text{ kg/cm}^2$$

$$\begin{aligned} \sigma_{id}^{(1)} &= \sqrt{\sigma_{\max}^2 + 3 \cdot \tau_1^2} = 2261,13 \text{ kg/cm}^2 \\ \sigma_{id}^{(2)} &= \sqrt{\sigma_2^2 + 3 \cdot \tau_2^2} = 1781,52 \text{ " } \\ \sigma_{id}^{(3)} &= \sqrt{\sigma_3^2 + 3 \cdot \tau_{\max}^2} = 343,6 \text{ " } \end{aligned} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} < 2600 \text{ kg/cm}^2$$

E) spostamento verticale Δ

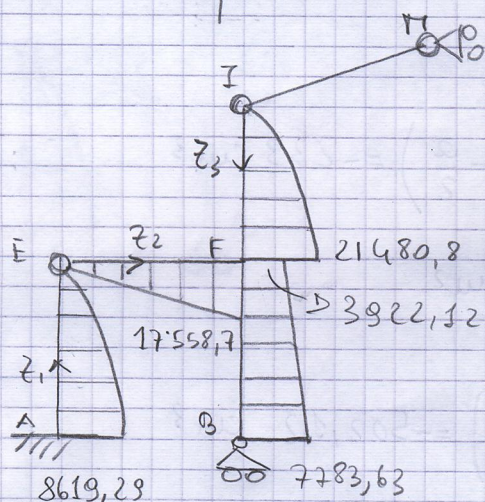


$$M_{AE}(z_1) = -1,732 \cdot z_1 + 5,196$$

$$M_{EF}(z_2) = 1,732 \cdot z_2$$

$$M_{IF}(z_3) = 1,732 \cdot z$$

Momento equibrio



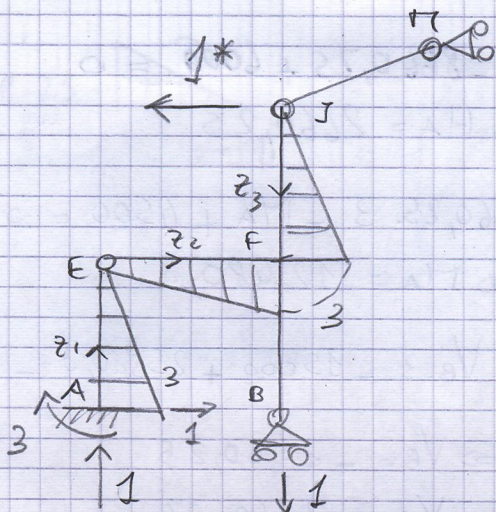
$$M_{AE}(z_1) = 8619,29 - 500z_1^2 - 1373,1 \cdot z_1$$

$$M_{EF}(z_2) = 5852,9 \cdot z_2$$

$$M_{IF}(z_3) = 8660,21 \cdot z - 500 \cdot z^2$$

$$\begin{aligned} \Delta^* \cdot \Delta = \frac{1}{EI} & \left\{ \int_0^3 (-1,732 \cdot z + 5,196)(8619,29 - 500 \cdot z^2 - 1373,1 \cdot z) dz + \right. \\ & + \int_0^3 (1,732 \cdot z)(5852,9 \cdot z) dz + \int_0^3 (1,732 \cdot z)(8660,21 \cdot z - 500 \cdot z^2) dz \Big\} \\ & = \frac{1}{EI} \left\{ 50631,3 + 91235 + 117459 \right\} = \frac{259325}{EI} \end{aligned}$$

$$\rightarrow \Delta = \frac{259325}{2,1 \cdot 10^{10} \cdot 10642 \cdot 10^{-8}} = 0,116$$



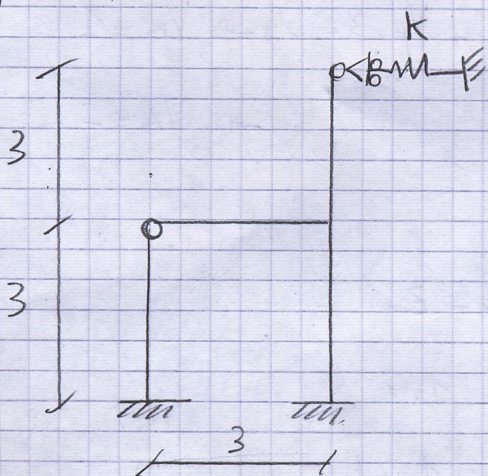
$$M_{EF}(z_2) = 1.7$$

$$M_{IF}(z_3) = 1.2$$

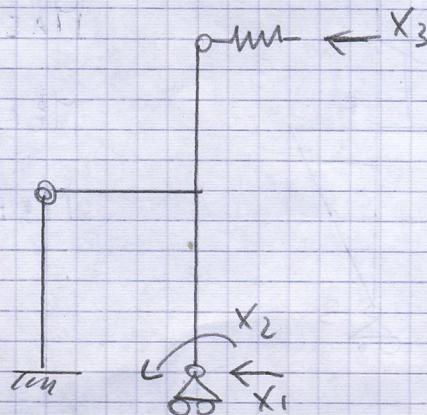
$$1^*. h_I = \frac{1}{EJ} \left\{ \int_0^3 (3-z)(8619,29 - 500 \cdot z^2 - 1373,1 \cdot z) dz + \right. \\ \left. + \int_0^3 (z)(5852,9 \cdot z) dz + \int_0^3 (z)(8660,21 \cdot z - 500 \cdot z^2) dz \right\} \\ = \frac{1}{EJ} \left\{ 29232,9 + 52676,1 + 67816,9 \right\} = \frac{149726}{EJ}$$

$$\Rightarrow h_I = 0,067 \text{ m} \approx 6,7 \text{ cm}$$

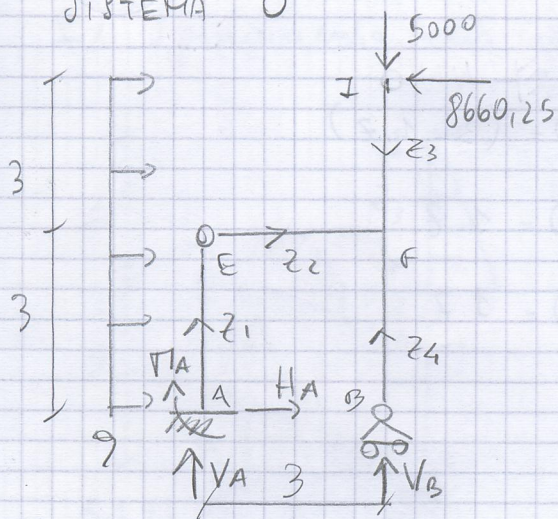
F)



$$K = \frac{EA}{L/2} = \frac{21 \cdot 10^{10} \cdot 5 \cdot 10^{-4}}{4} = 2,625 \cdot 10^6 \frac{\text{kg}}{\text{m}}$$



SISTEMA 0



$$\uparrow) V_A + V_B = 5000$$

$$\rightarrow) H_A - 8660,25 + 6000 = 0$$

$$\Rightarrow H_A = 2660,25$$

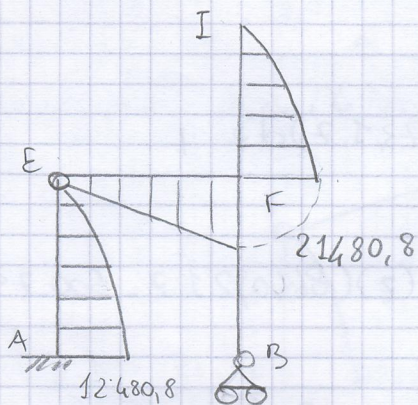
$$E \curvearrowright_{EA} 2660,25 \cdot 3 - M_A + 4500 = 0$$

$$\Rightarrow M_A = 12480,8$$

$$E \curvearrowright_{EFB} V_B \cdot 3 - 15000 + 25580,8 - 4500 = 0$$

$$\Rightarrow V_B = -2160,25$$

$$\Rightarrow V_A = 7160,25$$

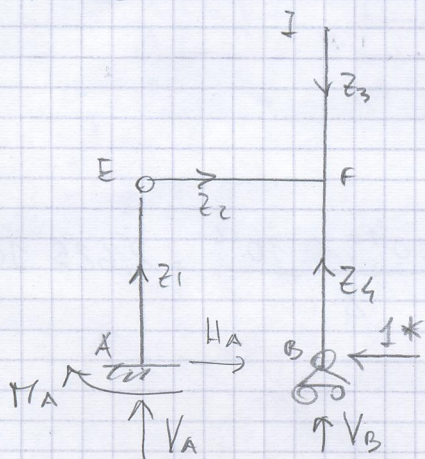


$$M_{AE}(z_1) = -2660,25 \cdot z_1 + 12480,8 - 500 \cdot z_1^2$$

$$M_{EF}(z_2) = 7160,25 \cdot z_2$$

$$M_{BF}(z_3) = 8660,25 \cdot z_3 - 500 \cdot z_3^2$$

SISTEMA 1



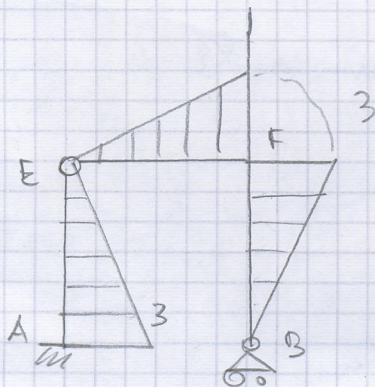
$$\rightarrow) H_A = 1$$

$$\uparrow) V_A + V_B = 0$$

$$E \curvearrowright_{EA} 1 \cdot 3 - M_A = 0 \Rightarrow M_A = 3$$

$$E \curvearrowright_{EFB} -1 \cdot 3 + V_B \cdot 3 = 0 \Rightarrow V_B = 1$$

$$\Rightarrow V_A = -1$$

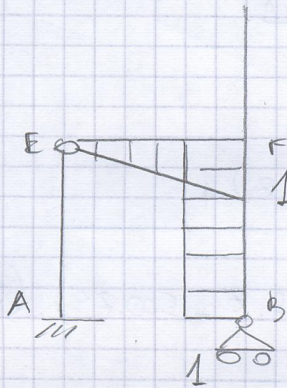
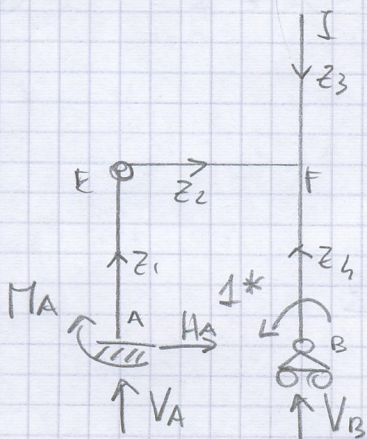


$$M_{AE}(z_1) = 3 - z$$

$$M_{EF}(z_2) = -1 \cdot z$$

$$M_{BF}(z_4) = 1 \cdot z$$

СИСТЕМА 2



$$\uparrow) V_A + V_B = 0$$

$$\rightarrow) H_A = 0 \Rightarrow \Pi_A = 0$$

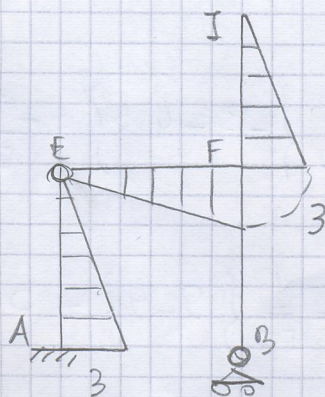
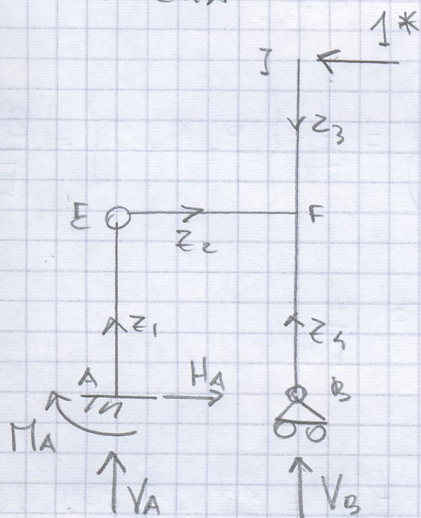
$$E \curvearrowright EFB \quad 1 + V_B \cdot 3 = 0 \Rightarrow V_B = -\frac{1}{3}$$

$$V_A = \frac{1}{3}$$

$$M_{EF}(z_2) = \frac{1}{2} \cdot z$$

$$M_{BF}(z_4) = -1$$

СИСТЕМА 3



$$\uparrow) V_A + V_B = 0$$

$$\rightarrow) H_A = 1$$

$$E \curvearrowright EA \quad 1 \cdot 3 - M_A = 0 \Rightarrow M_A = 3$$

$$E \curvearrowright EFB \quad V_B \cdot 3 + 3 = 0 \Rightarrow V_B = -1$$

$$V_A = 1$$

$$M_{AE}(z_1) = 3 - z$$

$$M_{EF}(z_2) = 1 \cdot z$$

$$M_{IF}(z_3) = 1 \cdot z$$

$$\eta_{10} = \frac{1}{EJ} \left\{ \int_0^3 (-2660,25 \cdot z_1 + 12'680,8 - 500 \cdot z^2)(3-z) dz + \right.$$

(20)

$$+ \int_0^3 (7160,25 \cdot z)(-z) dz \Big\} = \frac{-23'624,7}{EJ}$$

$$\eta_{20} = \frac{1}{EJ} \left\{ \int_0^3 (7160,25 \cdot z) \left(\frac{z}{3} \right) dz \right\} = \frac{21'480,8}{EJ}$$

$$\eta_{30} = \frac{1}{EJ} \left\{ \int_0^3 (-2660,25 \cdot z + 12'680,8 - 500 \cdot z^2)(3-z) + \right.$$

$$+ \int_0^3 (7160,25 \cdot z)(z) dz + \int_0^3 (8660,25 \cdot z - 500 \cdot z^2)(z) dz \Big\}$$

$$= \frac{1}{EJ} \left\{ 40817,5 + 64'642,2 + 67817,3 \right\} = \frac{173'077}{EJ}$$

$$\eta_{11} = \frac{1}{EJ} \left\{ \int_0^3 (3-z)^2 dz + \int_0^3 z^2 dz + \int_0^3 z^2 dz \right\} = \frac{1}{EJ} \left\{ 9 + 9 + 9 \right\} = \frac{27}{EJ}$$

$$\eta_{22} = \frac{1}{EJ} \left\{ \int_0^3 \frac{z^2}{9} dz + \int_0^3 1 dz \right\} = \frac{1}{EJ} \left\{ 1 + 3 \right\} = \frac{4}{EJ}$$

$$\eta_{33} = \frac{1}{EJ} \left\{ \int_0^3 (3-z)^2 dz + \int_0^3 z^2 dz + \int_0^3 z^2 dz \right\} + \frac{1}{K} \cdot 1^* = \frac{27}{EJ} + 3,809 \cdot 10^{-7}$$

$$\eta_{12} = \frac{1}{EJ} \left\{ \int_0^3 (-z) \left(\frac{z}{3} \right) dz + \int_0^3 (z)(-1) dz \right\} = \frac{1}{EJ} \left\{ -3 - 4,5 \right\} = \frac{-7,5}{EJ}$$

$$\eta_{13} = \frac{1}{EJ} \left\{ \int_0^3 (3-z)(3-z) dz + \int_0^3 (-z)(z) dz \right\} = \frac{1}{EJ} \left\{ 9 - 9 \right\} = 0$$

$$\eta_{23} = \frac{1}{EI} \left\{ \int_0^3 \left(\frac{z}{3} \right) (z) dz \right\} = \frac{3}{EI}$$

(21)

$$\frac{1}{EI} \begin{pmatrix} 27 & -7,5 & 0 \\ -7,5 & 4 & 3 \\ 0 & 3 & 27 + (3,809 \cdot 10^{-2} \cdot EI) \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix} = \frac{1}{EI} \begin{pmatrix} 23 \cdot 624,7 \\ -21 \cdot 480,8 \\ -173 \cdot 087 \end{pmatrix}$$

$\hookrightarrow 27,85$

$$\Rightarrow \begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix} = \begin{pmatrix} 1524,58 \\ 2338,58 \\ -6466,88 \end{pmatrix}$$

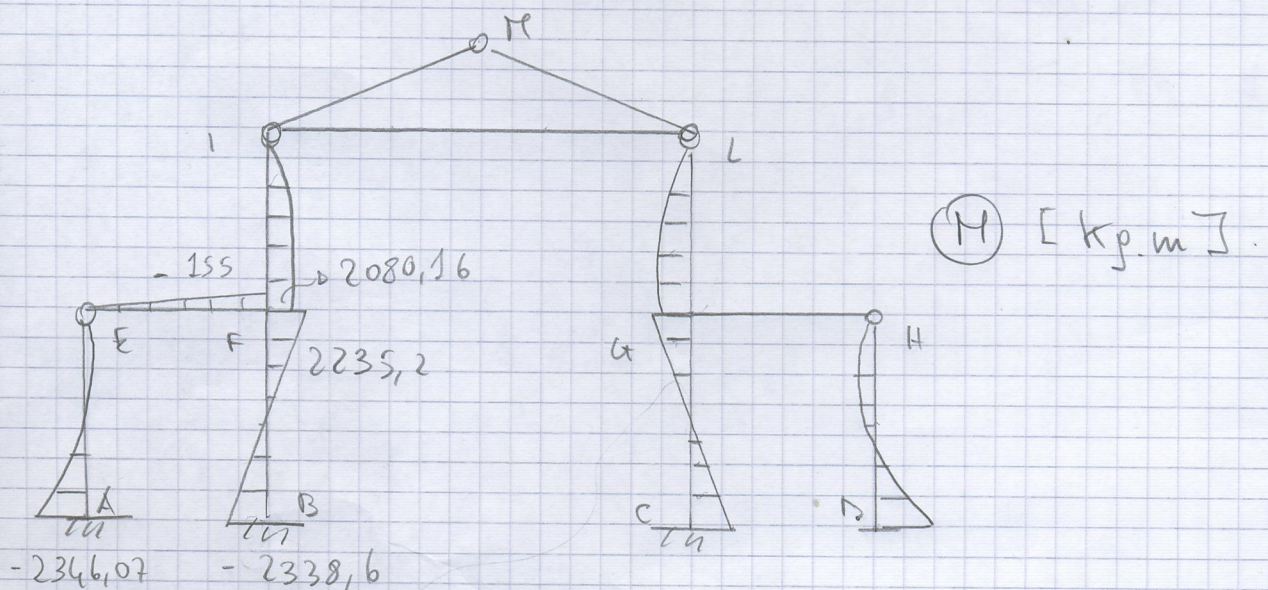
$$M_A = 12480,8 + 3(1524,58) + 3(-6466,88) = -2346,07 \text{ kg.m}$$

$$M_B = -2338,6 \text{ kg.m}$$

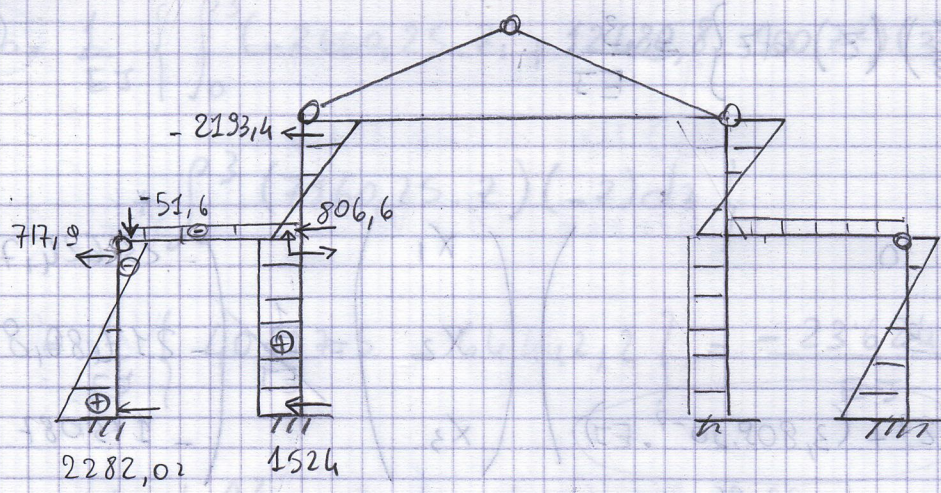
$$M_{FE} = 21480,8 - 3(1524,58) + 1(2338,58) + 3(-6466,88) = -155 \text{ kg.m}$$

$$M_{FB} = 3(1524,58) - 2338,58 = 2235,2$$

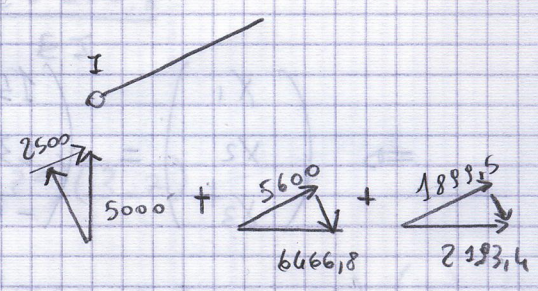
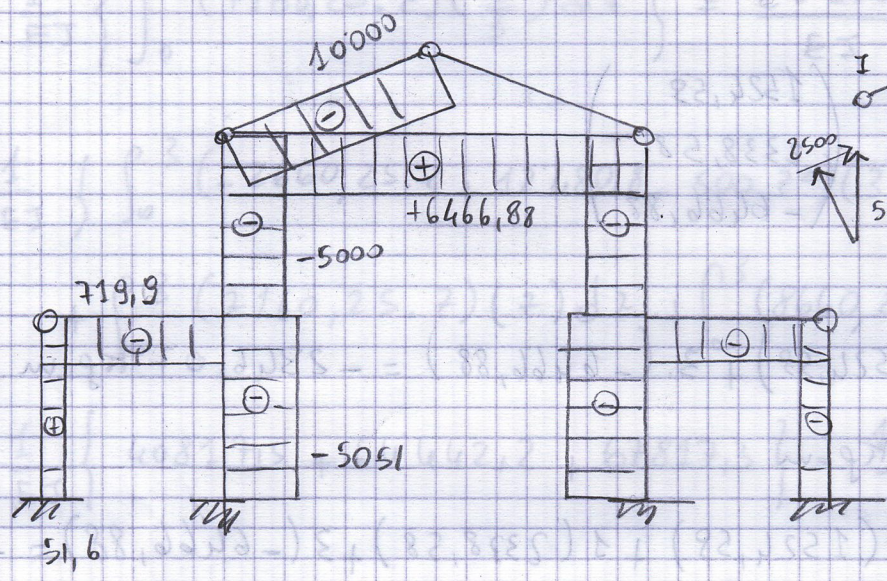
$$M_{FI} = 21480,8 + 3(-6466,88) = 2080,16$$



(22)



(T) [kp]



(H) [kp]