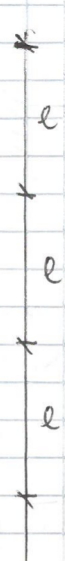
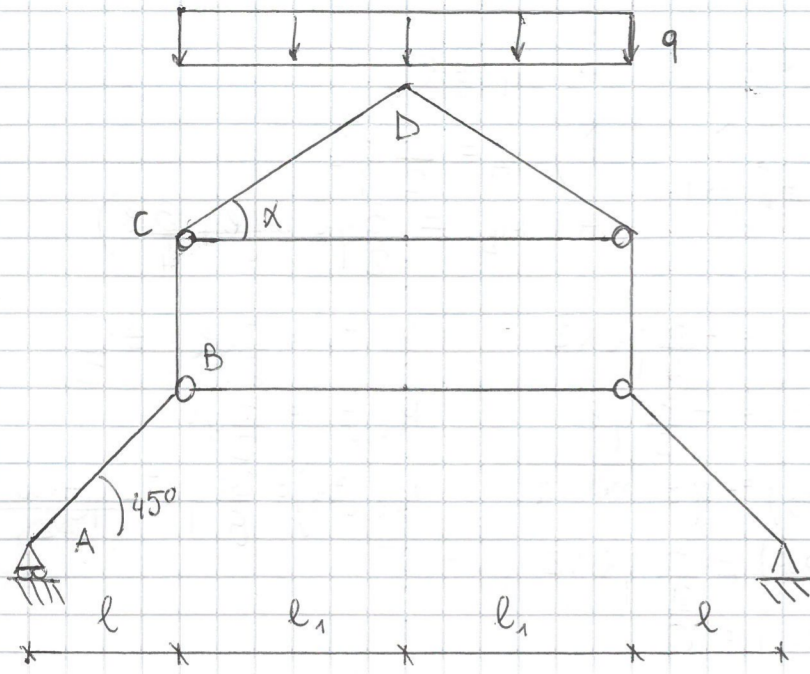


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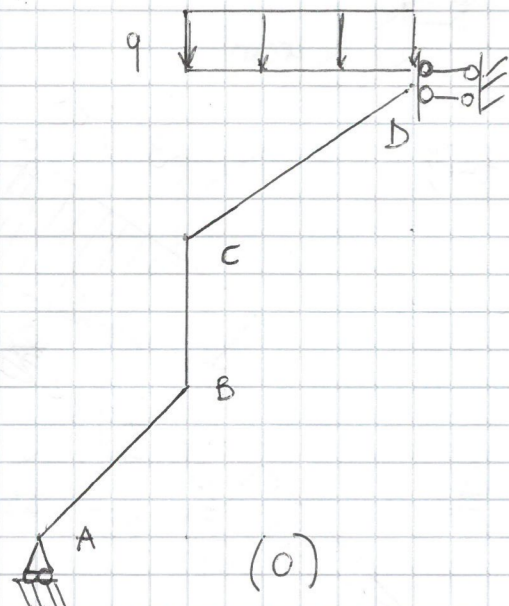


$q = 3000 \text{ N/m}$

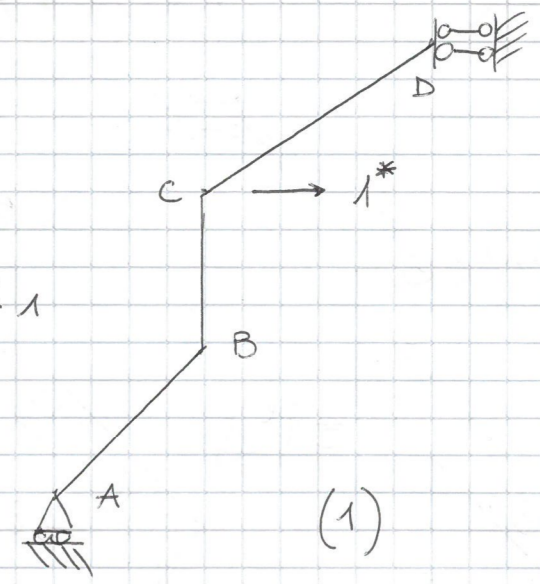
$l = 2 \text{ m}$

$l_1 = 3 \text{ m} = \frac{3}{2} l$

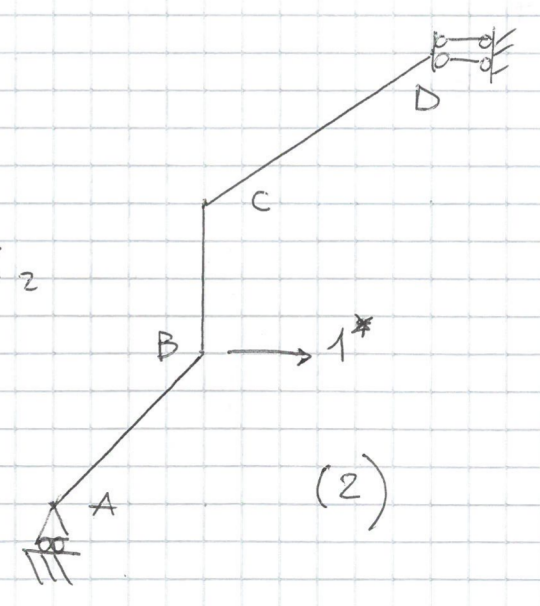
$\alpha = \arctan\left(\frac{4}{6}\right) \approx 33,7^\circ$



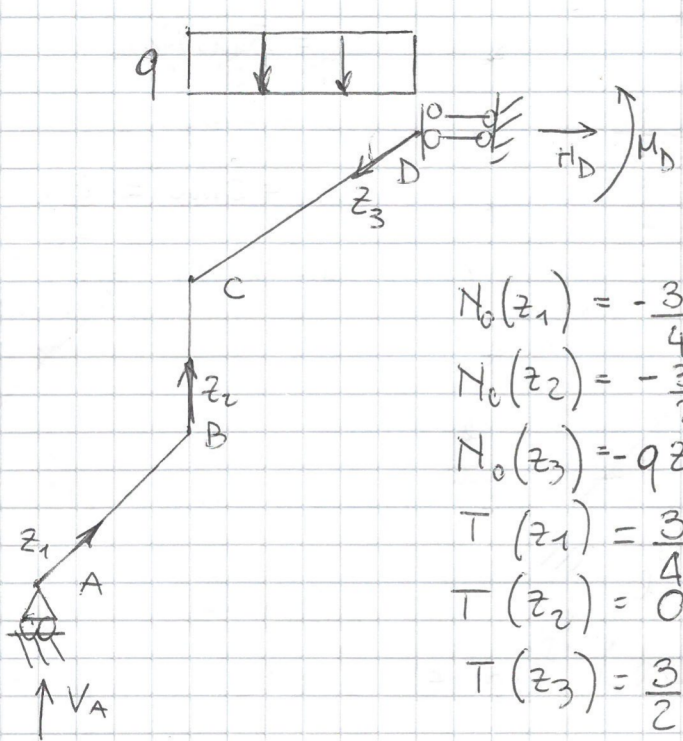
+  $X_1$



+  $X_2$



# 1) SISTEMA (c)



$$\rightarrow) H_D = 0$$

$$\uparrow) V_A = \frac{3}{2} ql$$

$$A) M_D = \frac{3}{2} ql \cdot \left( l + \frac{3}{4} l \right)$$

$$N_0(z_1) = -\frac{3}{4} ql \sqrt{2}$$

$$M_0(z_1) = \frac{3}{2} ql \cdot \frac{z \sqrt{2}}{2}$$

$$N_0(z_2) = -\frac{3}{2} ql$$

$$M_0(z_2) = \frac{3}{2} ql^2$$

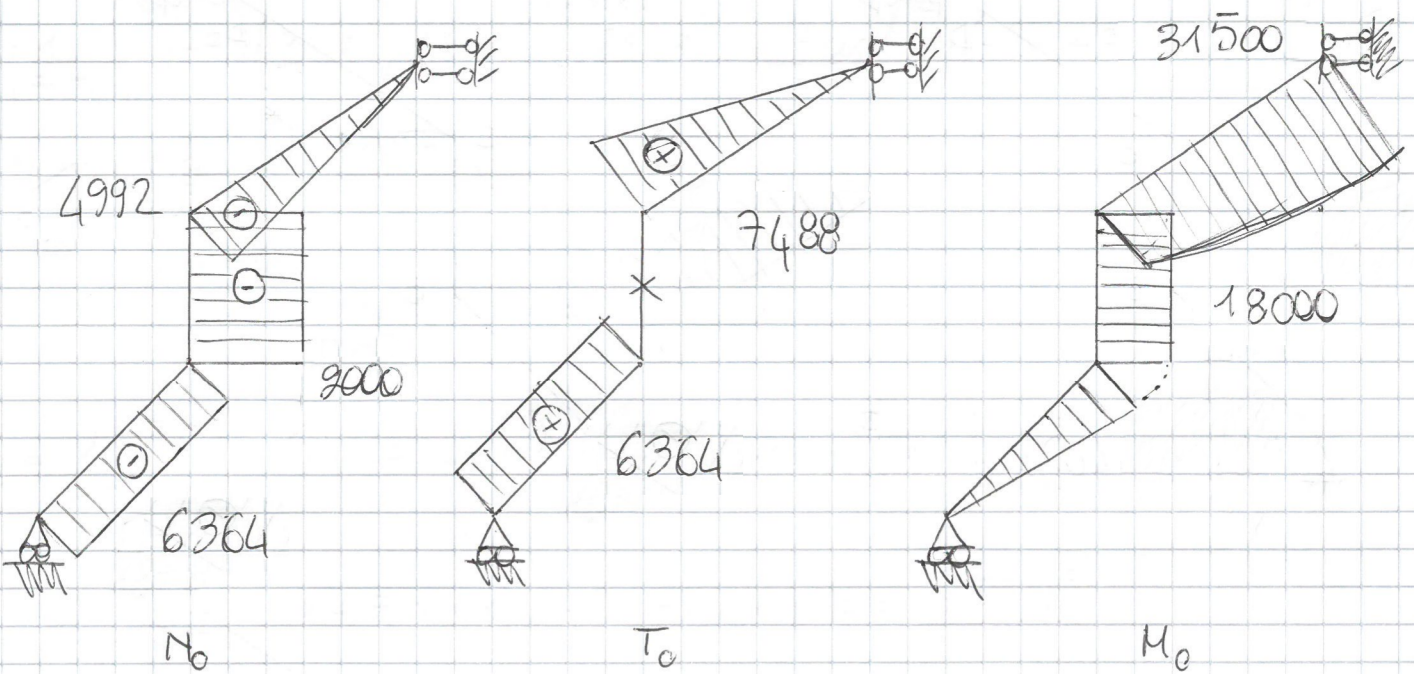
$$N_0(z_3) = -qz \cdot \cos \alpha$$

$$M_0(z_3) = \frac{z^2}{8} ql^2 - \frac{q(z \cdot \cos \alpha)^2}{2}$$

$$T(z_1) = \frac{3}{4} ql \sqrt{2}$$

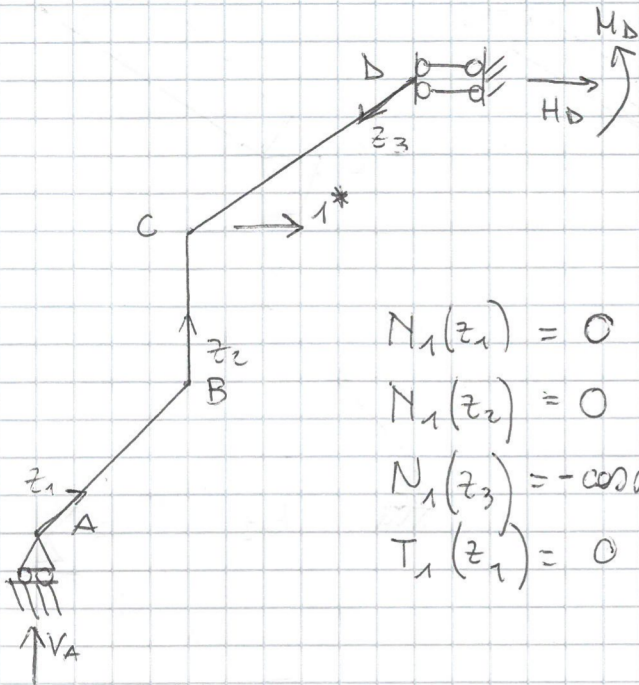
$$T(z_2) = 0$$

$$T(z_3) = \frac{3}{2} ql \cos \alpha$$



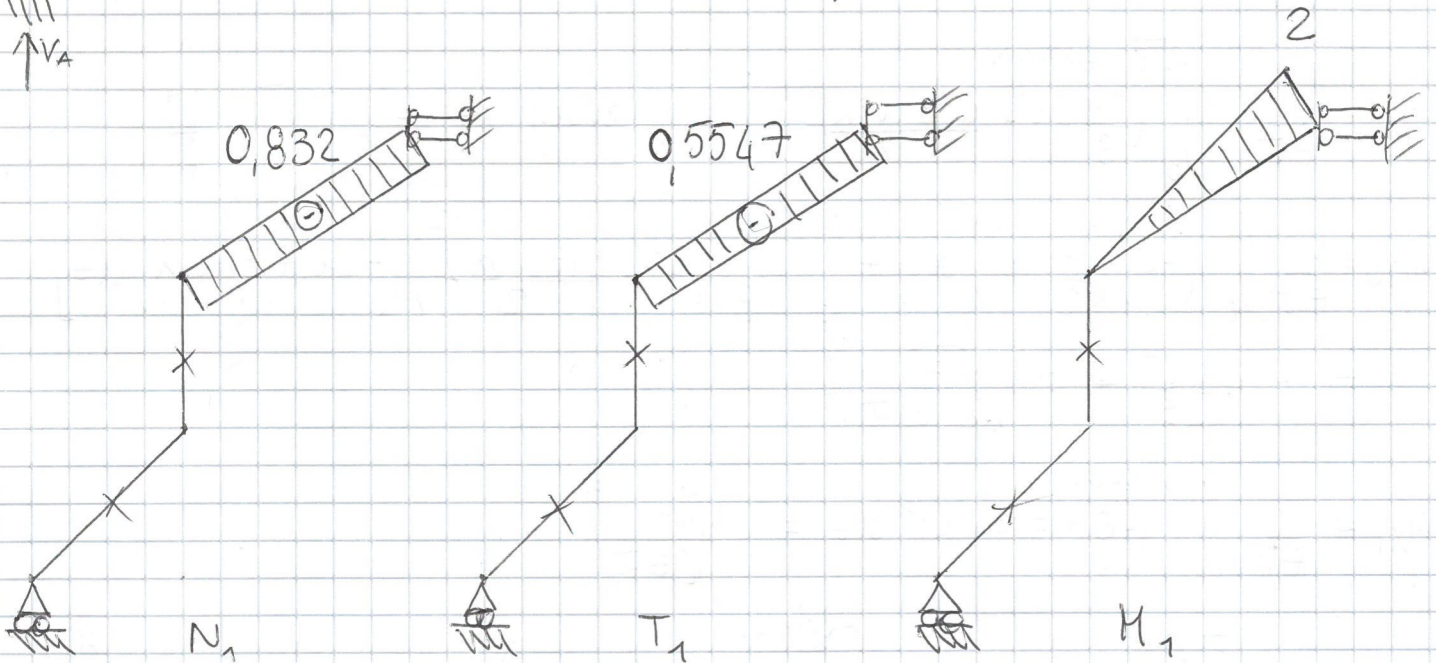


# SISTEMA (1)

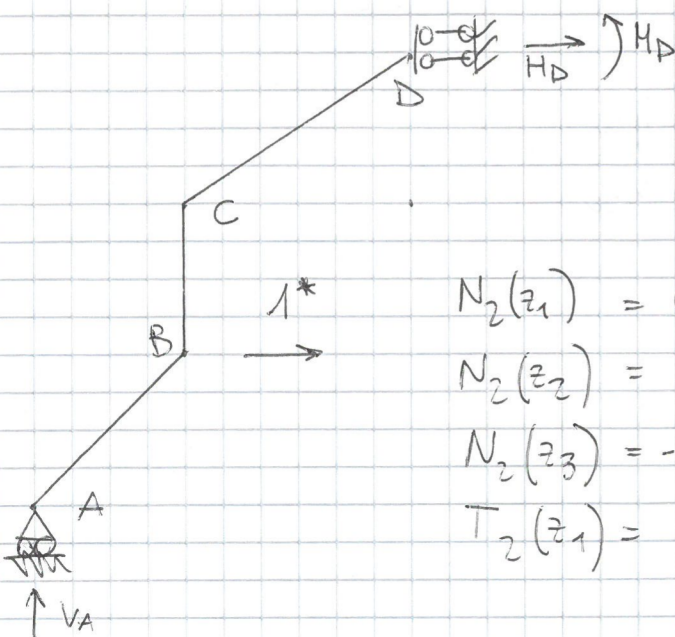


$$\begin{aligned} \rightarrow) H_D &= -1 \\ \uparrow) V_A &= 0 \\ \curvearrowright) M_D &= -l \end{aligned}$$

$$\begin{aligned} N_1(z_1) &= 0 & T_1(z_2) &= 0 & M_1(z_3) &= -l + z \cos \alpha \\ N_1(z_2) &= 0 & T_1(z_3) &= -\sin \alpha & & -l + z \sin \alpha \\ N_1(z_3) &= -\cos \alpha & M_1(z_1) &= 0 & & \\ T_1(z_1) &= 0 & M_1(z_2) &= 0 & & \end{aligned}$$



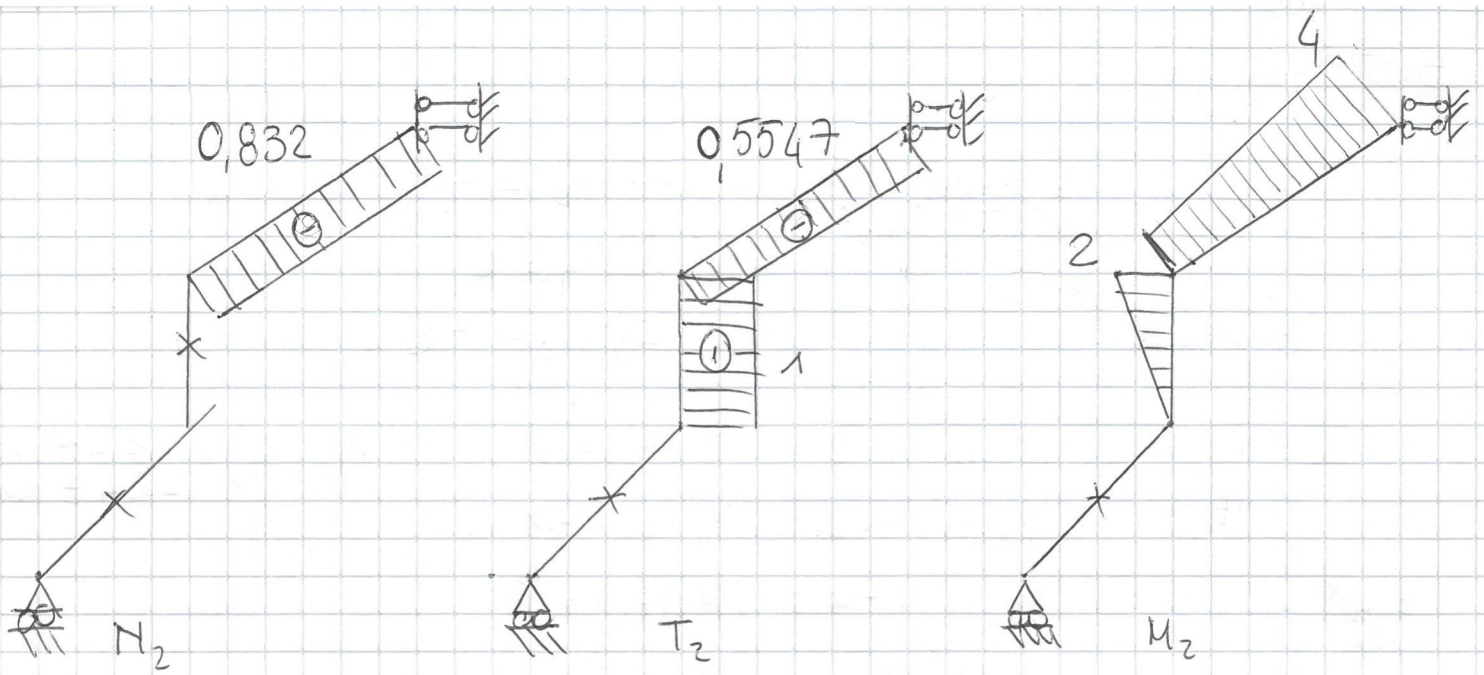
# SISTEMA (2)



$$\begin{aligned} \rightarrow) H_D &= -1 \\ \uparrow) V_A &= 0 \\ \curvearrowright) M_D &= -2l \end{aligned}$$

$$\begin{aligned} N_2(z_1) &= 0 & T_2(z_2) &= -1 & M_2(z_3) &= 2l + z \sin \alpha \\ N_2(z_2) &= 0 & T_2(z_3) &= -\sin \alpha & & \\ N_2(z_3) &= -\cos \alpha & M_2(z_1) &= 0 & & \\ T_2(z_1) &= 0 & M_2(z_2) &= -z & & \end{aligned}$$





$$M_{10} = \frac{1}{EJ} \int_0^{\frac{\sqrt{13} l}{\sin \alpha}} \left( \frac{21}{8} ql^2 - q \frac{(z \cos \alpha)^2}{2} \right) (-l + z \sin \alpha) dz = -\frac{39\sqrt{13} ql^4}{64 EJ}$$

$$M_{20} = \frac{1}{EJ} \left[ \int_0^l (-z) \left( \frac{3}{2} ql^2 \right) dz + \int_0^{\frac{l}{\sin \alpha}} \left( \frac{21}{8} ql^2 - q \frac{(z \cos \alpha)^2}{2} \right) (-2l + z \sin \alpha) dz \right]$$

$$= -\frac{3ql^4}{4 EJ} - \frac{111\sqrt{13} ql^4}{64 EJ}$$

$$M_{11} = \frac{1}{EJ} \int_0^{\frac{l}{\sin \alpha}} (-l + z \sin \alpha)^2 dz = \frac{\sqrt{13} l^3}{6 EJ}$$

$$M_{22} = \frac{1}{EJ} \left[ \int_0^l z^2 dz + \int_0^{\frac{l}{\sin \alpha}} (-2l + z \sin \alpha)^2 dz \right] = \frac{l^3}{3 EJ} + \frac{7\sqrt{13} l^3}{6}$$

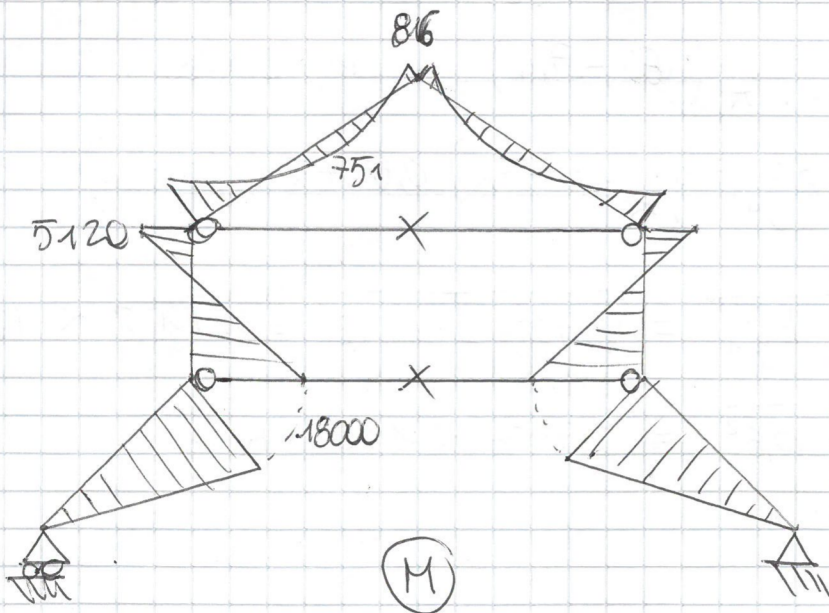
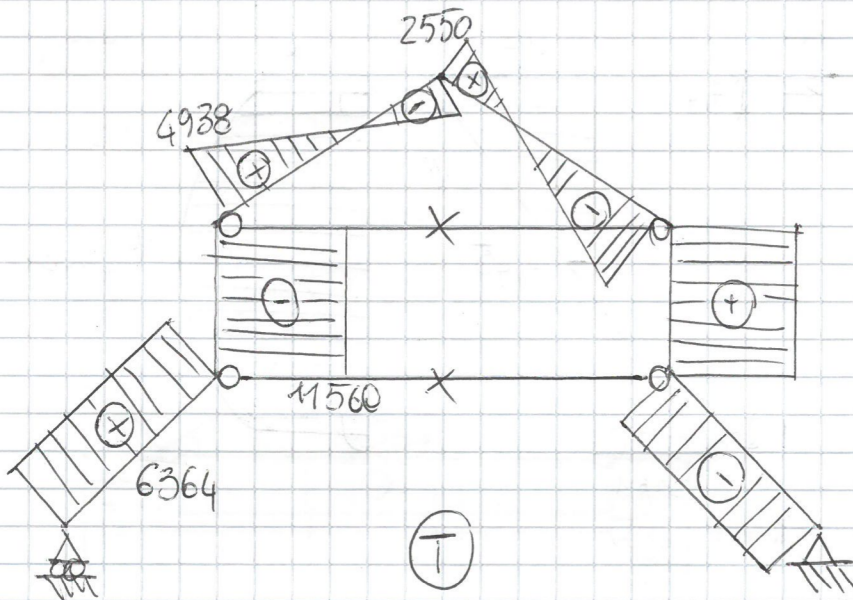
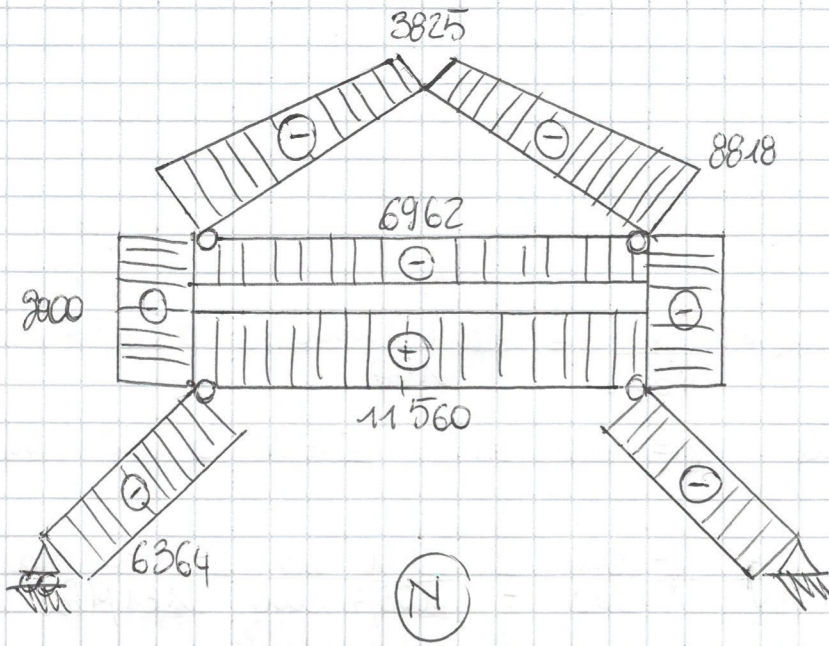
$$M_{12} = \frac{1}{EJ} \int_0^{\frac{l}{\sin \alpha}} (-2l + z \sin \alpha)(-l + z \sin \alpha) dz = \frac{5\sqrt{13} l^3}{12}$$

$$(1) \rightarrow \begin{cases} M_{11} \cdot X_1 + M_{12} \cdot X_2 = -M_{10} \\ M_{12} \cdot X_1 + M_{22} \cdot X_2 = -M_{20} \end{cases}$$

$$X_1 = -6962 \text{ N}$$

$$X_2 = 11560 \text{ N}$$







$$2) \quad M_B = 18000 \text{ Nm}$$

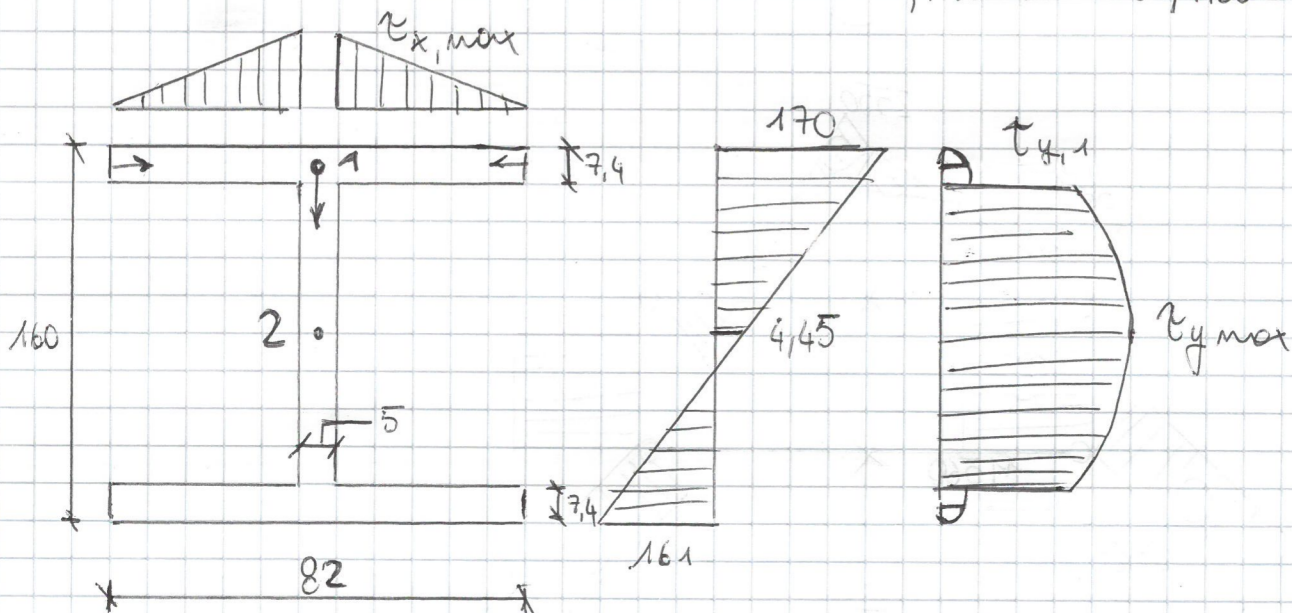
$$N_B = -9000 \text{ N}$$

$$T_B = -11560 \text{ N}$$

Progetto  $W_{\min} = \frac{M_B}{\sigma_{\text{amm}}} = \frac{18000 \cdot 1000}{190} = 94737 \text{ mm}^3$

Adatto IPE 160  $A = 20,09 \text{ cm}^2$   $I = 869,3 \text{ cm}^4$   $W = 108,7 \text{ cm}^3$

$$\sigma_{\text{max}} = \frac{N_B}{A} + \frac{M_B}{W} = \frac{-9000}{2009} \pm \frac{18000 \cdot 1000}{108,7 \cdot 1000} = -170 \text{ MPa} \quad \left\{ \begin{array}{l} 161 \text{ MPa} \end{array} \right.$$



$$\tau_{x,\text{max}} = -\frac{T \cdot S_x^*}{I \cdot b} = \frac{11560 \cdot 7,4 \cdot (82-5) \cdot (160-7,4)}{4 \cdot 869,3 \cdot 10^4 \cdot 7,4} = 3,90 \text{ MPa}$$

$$\tau_{y,1} = \frac{11560 \cdot 82 \cdot 7,4 \cdot (80-7,4)}{869,3 \cdot 10^4 \cdot 5} = 11,72 \text{ MPa}$$

$$\tau_{y,\text{max}} = \frac{11560 \cdot (82 \cdot 7,4 \cdot (160-7,4) \cdot 0,5 + 5 \cdot (80-7,4)^2 \cdot 0,5)}{869,3 \cdot 10^4 \cdot 5} = 15,8 \text{ MPa}$$

$$\sigma_{\text{id},1} = \sqrt{\sigma_{z,1}^2 + 3\tau_{y,1}^2} = \sqrt{170^2 + 3 \cdot 11,72^2} = 171,2 < 190 \text{ MPa}$$

$$\sigma_{\text{id},2} = \sqrt{4,45^2 + 3 \cdot 15,8^2} = 27,7 < 190 \text{ MPa}$$



3) IPE 80  $A_{80} = 7,64 \text{ cm}^2$

$$M_{11}^N = \frac{1}{EA_{80}} \int_0^{\frac{6l}{2}} 1 \, dz = \frac{6l}{2EA_{80}}$$

$$M_{22}^N = \frac{1}{EA_{80}} \frac{6l}{2}$$

$$M_{TOT}^{JK} = M_{JK} + M_{JK}^N$$

$$\begin{aligned} (1) &\rightarrow \begin{cases} M_{11}^{TOT} \cdot X_1 + M_{12}^{TOT} \cdot X_2 = -M_{10}^{TOT} \\ M_{12}^{TOT} \cdot X_1 + M_{22}^{TOT} \cdot X_2 = -M_{20}^{TOT} \end{cases} \\ (2) &\rightarrow \end{aligned}$$

$$X_1 = -6530 \text{ N}$$

$$X_2 = 11406 \text{ N}$$

