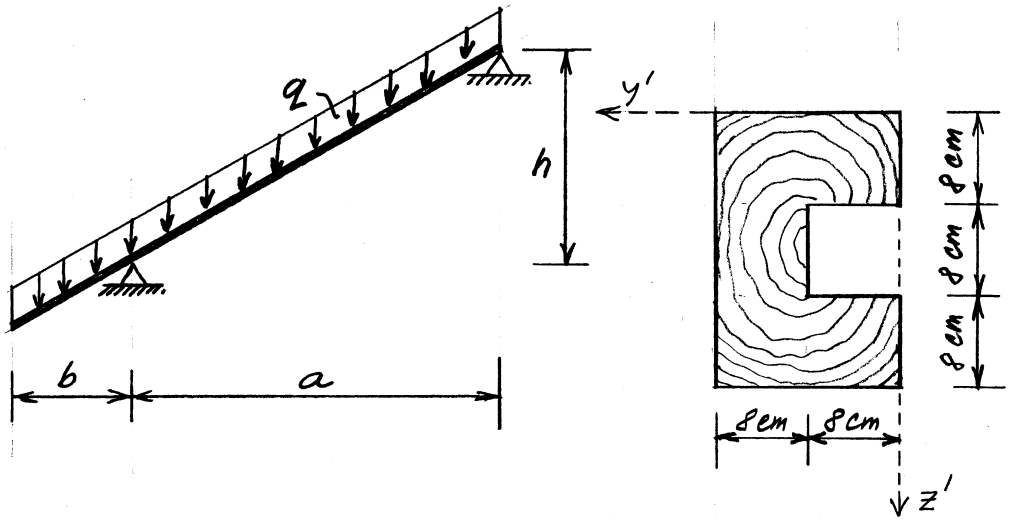
1. V lesen tram je bočno zarezan žleb dimenzij $8 \times 8\,cm$, kot kaže skica. V navpični enakomerni zvezni obtežbi q, ki je definirana na dolžinsko enoto nosilca, je že upoštevana tudi njegova lastna teža.
   a. Določi in skiciraj potek osnih in prečnih sil ter upogibnih momentov vzdolž nosilca ter označi prereza, v katerih nastopata največji upogibni moment in največja prečna sila!
   b. Določi in skiciraj potek normalnih napetosti v prerezu, kjer nastopa največji upogibni moment, ter potek strižnih napetosti v prerezu, kjer nastopa največja prečna sila !
   c. Določi in skiciraj jedro prečnega prereza nosilca!



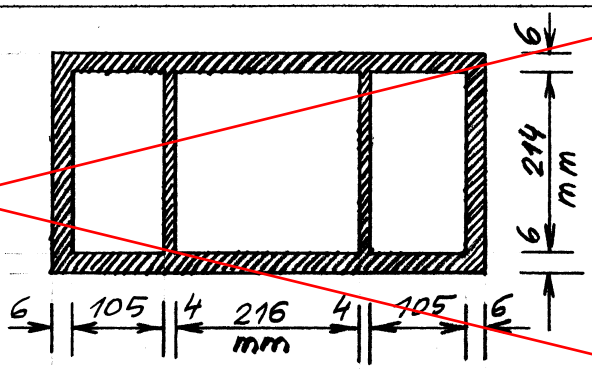
$q = 6\,kN/m$

$h = 2.31\,m$

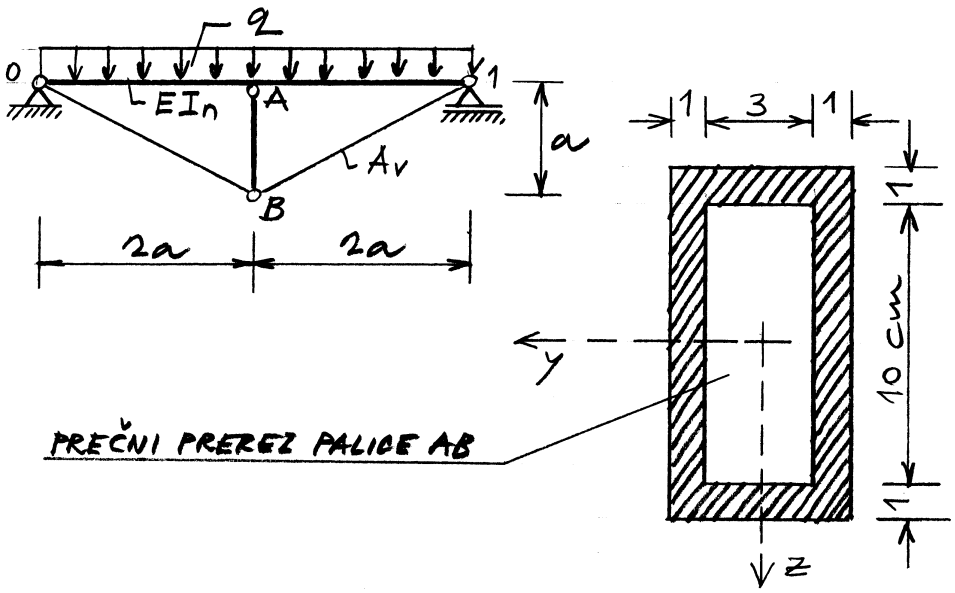
$a = 4\,m$

$b = 1.5\,m$

2. Dovoljena strižna napetost v jeklu je $[\tau] = 100\,MPa$. Določi dovoljeni torzijski moment, s katerim lahko obremenimo prikazani prečni prerez pri čisti torziji!



3. Določi kritično velikost obtežbe q glede na uklon palice AB!



$E = 2.1 \cdot 10^5\,MPa$

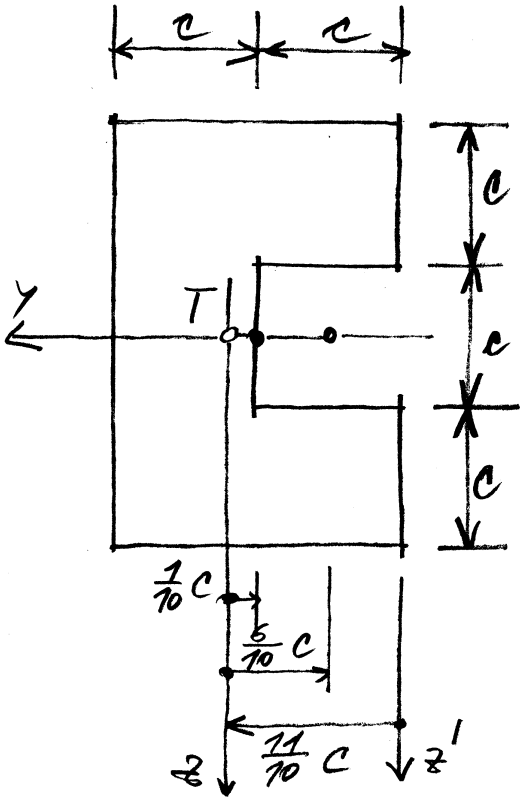
$A_v = 2\,cm^2$

$I_n = 4000\,cm^4$

$a = 2\,m$

TRDNOST IZPIT 19. 12. 94

Ad 1.) Geometrijske karakteristike prečnega prereza:



$$A_x = 6c^2 - c^2 \rightarrow \boxed{A_x = 5c^2}$$

$$y_T = \frac{1}{5c^2}\left(6c^2 \cdot c - c^2 \cdot \frac{c}{2}\right)$$

$$\boxed{y_T = \frac{11}{10}c}$$

$$I_y = \frac{1}{12}\left[2c \cdot (3c)^3 - c \cdot c^3\right]$$

$$\boxed{I_y = \frac{53}{12}c^4}$$

$$I_z = \frac{1}{12}\left[3c \cdot (2c)^3 - c \cdot c^3\right] + 6c^2 \cdot \left(\frac{1}{10}c\right)^2 - c^2 \cdot \left(\frac{6}{10}c\right)^2$$

$$\boxed{I_z = \frac{97}{60}c^4}$$

$$i_y^2 = \frac{I_y}{A_x} = \frac{53c^4}{12 \cdot 5c^2} \rightarrow \boxed{i_y^2 = \frac{53}{60}c^2}$$

$$i_z^2 = \frac{I_z}{A_x} = \frac{97c^4}{60 \cdot 5c^2} \rightarrow \boxed{i_z^2 = \frac{97}{300}c^2}$$

$c = 8$ cm:

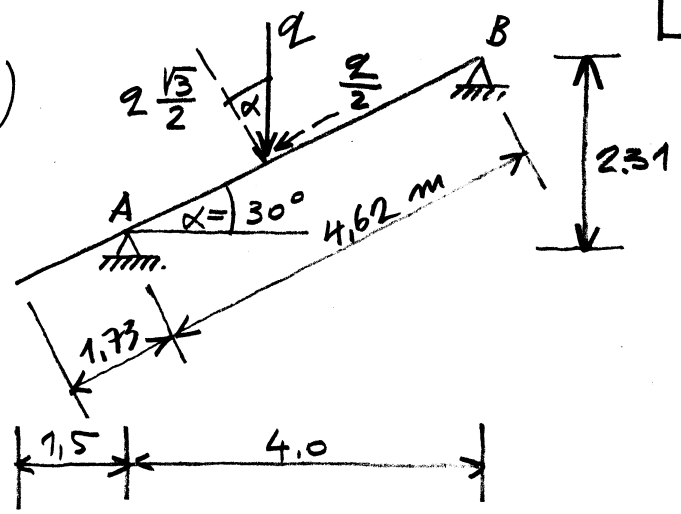
$$\boxed{\begin{array}{l} A_x = 320 \text{ cm}^2; \quad y_T = 8{,}8 \text{ cm} \\ I_y = 18091 \text{ cm}^4; \quad I_z = 6622 \text{ cm}^4 \\ i_y^2 = 56{,}53 \text{ cm}^2; \quad i_z^2 = 20{,}69 \text{ cm}^2 \end{array}}$$

$$S_y^*\left(z=-\frac{c}{2}\right) = -2c^3 \longrightarrow \boxed{S_y^*\left(z=-\frac{c}{2}\right) = -1024\ cm^3}$$

$$S_y^*(z=0) = -2c^3 - \frac{c^2}{2}\cdot\frac{c}{4} = -\frac{17}{8}c^3$$

$$\boxed{S_y^*(z=0) = -1088\ cm^3}$$

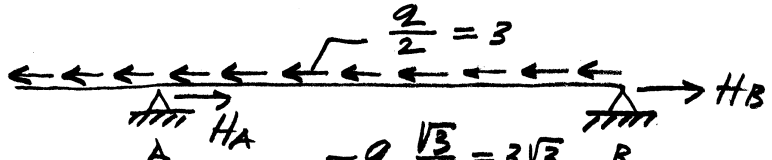
a)

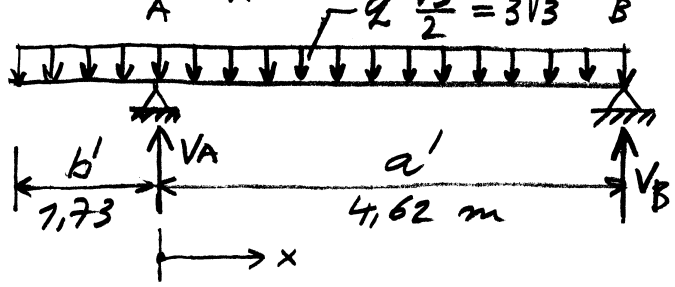


$$H_A = \frac{q}{2}\left(b' + \frac{a'}{2}\right)$$

$$H_A = \frac{6}{2}\left(1{,}73 + \frac{4{,}62}{2}\right)$$

$$\boxed{H_A = 12{,}12\ kN}$$





$$H_B = \frac{q}{2}\cdot\frac{a'}{2}$$

$$H_B = \frac{6}{2}\cdot\frac{4{,}62}{2}$$

$$\boxed{H_B = 6{,}93\ kN}$$

$$V_A = 3\sqrt{3}\left(1{,}73 + \frac{4{,}62}{2} + \frac{1{,}73^2}{2\cdot 4{,}62}\right) \longrightarrow \boxed{V_A = 22{,}68\ kN}$$

$$V_B = 3\sqrt{3}\left(\frac{4{,}62}{2} - \frac{1{,}73^2}{2\cdot 4{,}62}\right) \longrightarrow \boxed{V_B = 10{,}32\ kN}$$

$$M_A = -3\sqrt{3}\,\frac{1{,}73^2}{2} \longrightarrow \boxed{M_A = -7{,}79\ kNm}$$

$$M_y = -7{,}79 + \left(22{,}68 - 3\sqrt{3}\cdot 1{,}73\right)x - 3\sqrt{3}\,\frac{x^2}{2}$$

$$\frac{dM_y}{dx} = 13{,}68 - 3\sqrt{3}\,x_m = 0 \longrightarrow \boxed{x_m = 2{,}63\ m}$$

$$M_{y\,max}^{\oplus} = -7{,}79 + 13{,}68 \cdot 2{,}63 - 3\sqrt{3}\,\frac{2{,}63^2}{2}$$

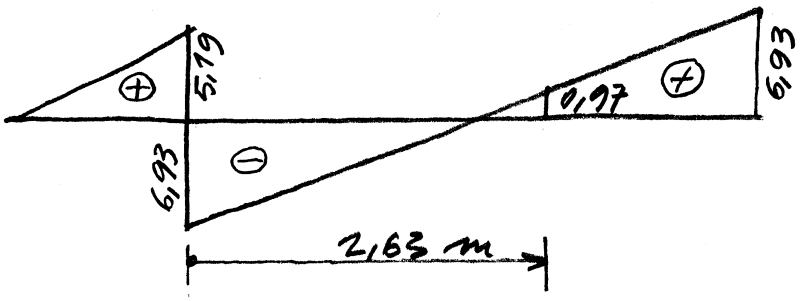
$$\boxed{M_{y\,max}^{\oplus} = 10{,}23\ kNm}$$

$$N_x(2{,}63\ m) = -12{,}12 + 3(1{,}73 + 2{,}63)$$

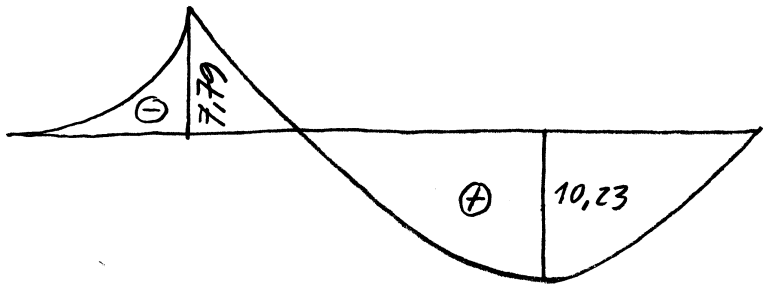
$$\boxed{N_x(2{,}63) = 0{,}97\ kN}$$

$$\boxed{\begin{aligned} N_z(A^L) &= -9\ kN \\ N_z(A^D) &= 13{,}69\ kN = N_{z\,max} \\ N_z(B^L) &= -10{,}31\ kN \end{aligned}}$$

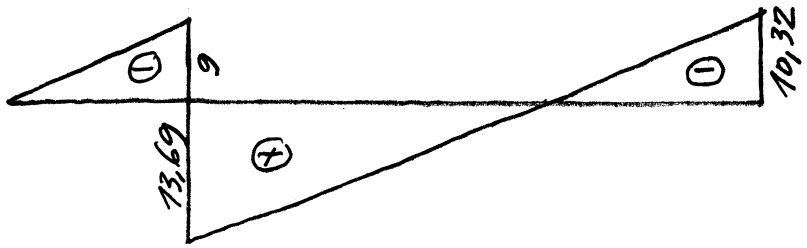
b)



[N_x]



[M_y]



[N_z]

$x = 2{,}63\ m \longrightarrow N_x = 0{,}97\ kN$

$M_y = 10{,}23\ kNm$

$$\sigma_{xx} = \frac{N_x}{A_x} + \frac{M_y}{I_y} \cdot z = \frac{0{,}97}{320} + \frac{1023}{18091}\,z$$

$$\boxed{\begin{aligned} \sigma_{xx}^{z} &= \sigma_{xx}(z=-12) = -0{,}676 \ kN/cm^2 = -6{,}76 \ MPa \\ \sigma_{xx}^{s} &= \sigma_{xx}(z=12) = 0{,}682 \ kN/cm^2 = 6{,}82 \ MPa \end{aligned}}$$

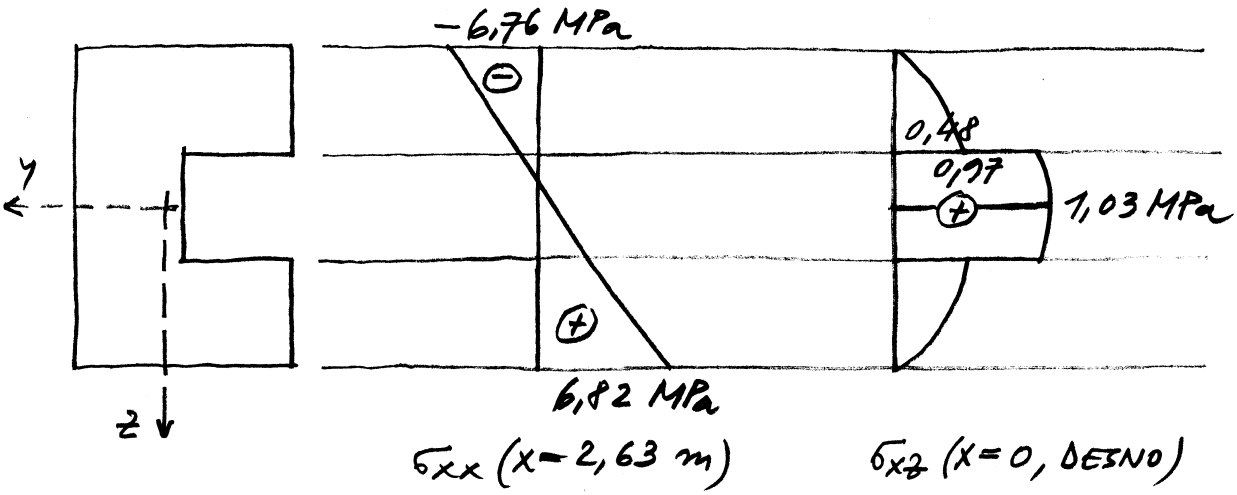
$x = 0 \ (D) \rightarrow N_z = 13{,}69 \ kN$

$$\sigma_{xz} = -N_z \frac{S_y^*}{b^* I_y} \rightarrow \sigma_{xz} = -0{,}000757 \frac{S_y^*}{b^*}$$

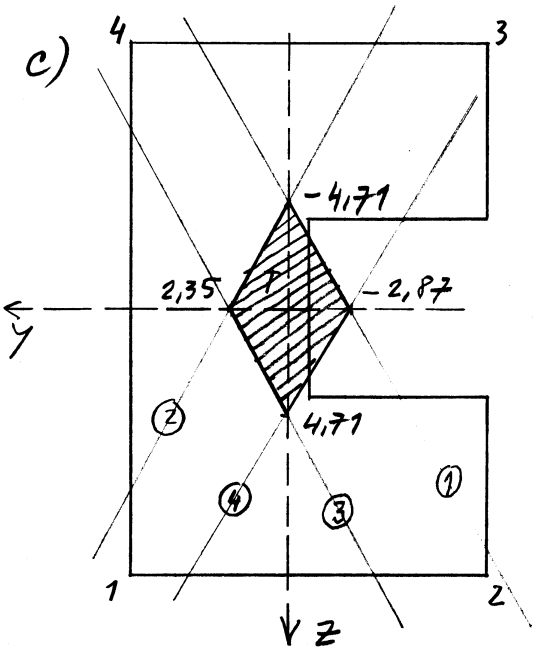
$$z = -4 \ cm \rightarrow \sigma_{xz}^{z} = 0{,}000757 \frac{1024}{16} = 0{,}048 \ kN/cm^2$$

$$\sigma_{xz}^{s} = 0{,}000757 \frac{1024}{8} = 0{,}097 \ kN/cm^2$$

$$z = 0 \rightarrow \sigma_{xz} = 0{,}000757 \frac{1088}{8} = 0{,}103 \ kN/cm^2$$

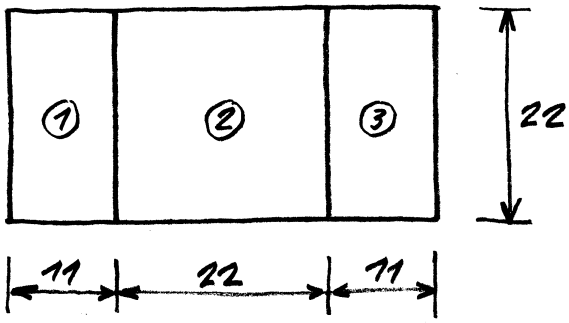


c)



tč	y_0	z_0	$m = -\frac{i_z^2}{y_0}$	$n = -\frac{i_y^2}{z_0}$
1	7,2	12	−2,87	−4,71
2	−8,8	12	2,35	−4,71
3	−8,8	−12	2,35	4,71
4	7,2	−12	−2,87	4,71

Ad 2.)



$$\boxed{\varphi_1 = \varphi_3}$$

$$A_1 = A_3 = 11 \cdot 22 = 242 \text{ cm}^2$$

$$A_2 = 22 \cdot 22 = 484 \text{ cm}^2$$

$$a_{11} = \frac{1}{6}(2 \cdot 11 + 22) + \frac{1}{4} \cdot 22 = 12{,}83$$

$$a_{22} = \frac{1}{6} \cdot 2 \cdot 22 + \frac{1}{4} \cdot 2 \cdot 22 = 18{,}33$$

$$a_{33} = a_{11} = 12{,}83$$

$$a_{12} = a_{21} = -\frac{1}{4} \cdot 22 = -5{,}5$$

$$a_{23} = a_{32} = -\frac{1}{4} \cdot 22 = -5{,}5$$

???

$$\begin{bmatrix} 12{,}83 & -5{,}5 \\ -5{,}5 & 18{,}33 \end{bmatrix} \begin{Bmatrix} \varphi_1 \\ \varphi_2 \end{Bmatrix} = 2 \begin{Bmatrix} 242 \\ 484 \end{Bmatrix} \rightarrow \boxed{\begin{matrix} \varphi_1 = \varphi_3 = 81{,}24 \\ \varphi_2 = 101{,}54 \end{matrix}}$$

$-11{,}0$

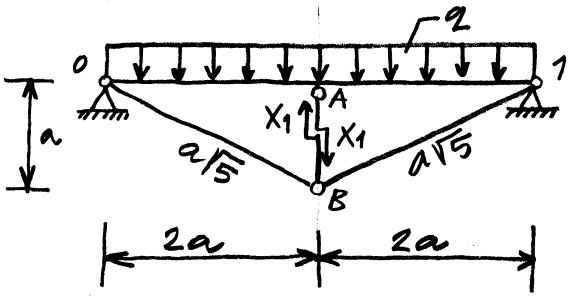
$$I_x = 2 \cdot (2 \cdot 81{,}24 + 101{,}54) \rightarrow \boxed{I_x = 176\,930 \text{ cm}^4}$$

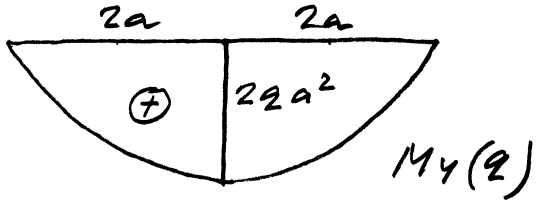
$$\tau = \frac{M_x}{I_x} \cdot \frac{\Delta\varphi}{\delta} \longrightarrow [M_x] = [\tau] \frac{\delta I_x}{\Delta\varphi}$$

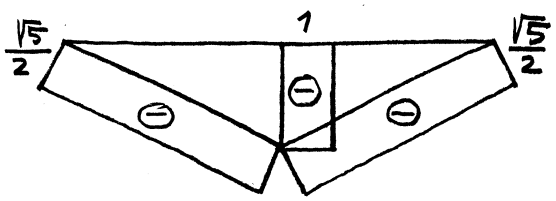
a) $$[M_x] = 10 \frac{0{,}4 \cdot 176\,930}{101{,}54 - 81{,}24} \longrightarrow [M_x] = 34.863 \text{ kNcm}$$

b) $$[M_x] = 10 \frac{0{,}6 \cdot 176\,930}{101{,}54 - 0} \longrightarrow \boxed{[M_x] = 10\,455 \text{ kNcm}}$$

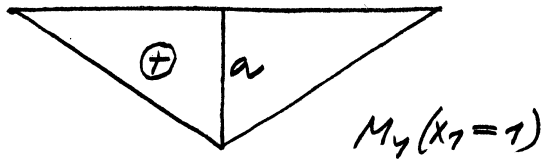
Ad 3.)







$N_x(X_1 = 1)$



$$A_p = 12 \cdot 5 - 10 \cdot 3 \quad \rightarrow \quad \boxed{A_p = 30 \text{ cm}^2}$$

$$I_{min} = I_z = \frac{1}{12}\left(12 \cdot 5^3 - 10 \cdot 3^3\right) \rightarrow \boxed{I_{min} = 102{,}5 \text{ cm}^4}$$

$$a_{11} = \frac{4a^3}{3EI_n} + \frac{5a\sqrt{5}}{2EA_v} + \frac{a}{EA_p} \quad \rightarrow \quad a_{11} = 0{,}1539$$

$$b_1 = \frac{10qa^3}{3EI_n} \quad \rightarrow \quad b_1 = 0{,}3175\, q$$

$$a_{11} X_1 + b_1 = 0 \quad \rightarrow \boxed{X_1 = -2{,}06\, q} \quad \boxed{l_u = 200 \text{ cm}}$$

$$N_{kr} = \frac{\pi^2 E I_{min}}{l_u^2} \quad \rightarrow \boxed{N_{kr} = 531 \text{ kN}}$$

$$N_{kr} = 531 \text{ kN} = 2{,}06\, q_{kr}$$

$$\boxed{q_{kr} = 257{,}8 \text{ kN/cm}}$$