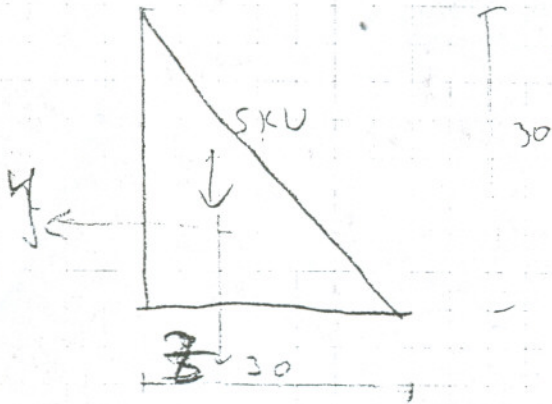


-1-

①



$$I_y = \frac{1}{36} \cdot 30^4 = 22500 \text{ cm}^4 = I_z$$

$$A = 15 \cdot 30 = 450$$

$$I_{yz} = -\frac{1}{72} \cdot 30^4 = -11250 \text{ cm}^4$$

$$I_{1,2} = \frac{22500 + 22500}{2} \pm \sqrt{0 + (-11250)^2}$$

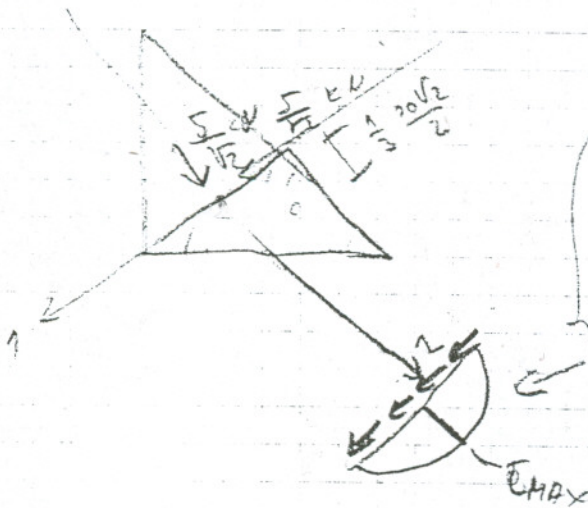
$$I_1 = 33750 \quad I_2 = 11250$$

$$\tan 2\alpha = \frac{-2(-11250)}{0} = \infty$$

$$\tan 2\alpha = \frac{-2 I_{yz}}{I_y - I_z}$$

$$2\alpha = \frac{\pi}{2} \quad \alpha = \frac{\pi}{4}$$

по направлению главных осей
разрушение по y-оси



$$\sigma_{\max} = \frac{3}{2} \cdot \frac{T}{A} =$$

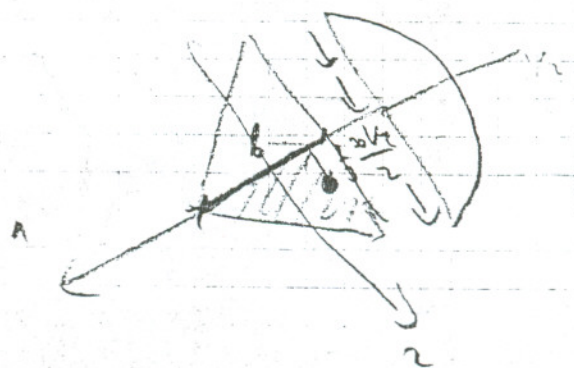
$$= \frac{3}{2} \cdot \frac{\frac{5}{\sqrt{2}} \cdot 1000 \cdot 10^{-3}}{450 \cdot 10^{-6}} = 0,1175 \text{ МПа}$$

$$I_{Tyz} = \frac{4}{5} \frac{T}{A}$$

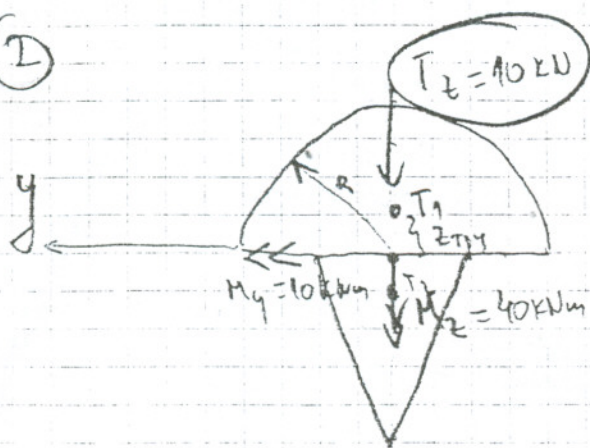
$$S_1 = 15 \cdot 15 \cdot \frac{1}{3} \frac{30\sqrt{2}}{2} = 159 \text{ cm}^2$$

$$T_{Tyz} = \frac{\frac{5}{\sqrt{2}} \cdot 1000 \cdot 159 \cdot 10^{-6}}{33750 \cdot 10^{-8} - \frac{30\sqrt{2}}{2} \cdot 10^{-2}} =$$

$$T_{\text{max}} = \frac{T_z \cdot S_y}{I_y \cdot b}$$



①



-2-

R=20

h

for y axis

$$A_1 \cdot z_{T1} = A_2 \cdot z_{T2}$$

$$\frac{20^2 \pi}{2} \cdot \frac{4}{3} \frac{20}{\pi} = 10h \cdot \frac{1}{3}$$

$$h = 40$$

S_y, I_y - сформулюємо огу ч.
« паралельно осі
зв'язку z (1)

$$S_y = \frac{20^2 \pi}{2} \cdot \frac{4}{3} \frac{20}{\pi} = 5333,33 \text{ cm}^3$$

$$S_{y1} = S_{y2}$$



$$I_y = 2 \cdot 0,05488 \cdot 20^4 +$$

$$+ \left(\frac{4}{3} \cdot \frac{10^3}{\pi} \right) \cdot \frac{20^2 \pi}{2}$$

$$+ \frac{1}{36} \cdot 40^3 \cdot 20 + \left(\frac{1}{3} \cdot 40 \right)^2 (10 \cdot 40) = 169488 \text{ cm}^4$$

$$I_{y \Delta} = 2 \cdot 0,05488$$

+ 1000000

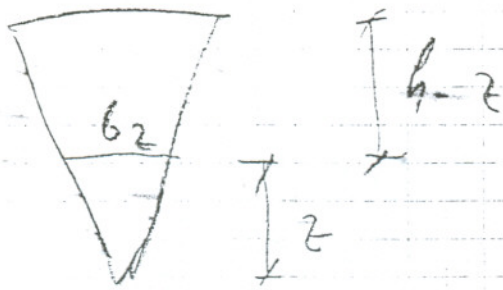
чотирикутник

$$T_{xz} =$$



$$T_{xz} = \frac{T_{z \text{ CORE}} \cdot S_y}{I_y \cdot b} = \frac{10000 \cdot 5333,33 \cdot 10^{-6}}{169488 \cdot 10^{-8} \cdot 40 \cdot 10^{-2}} = 0,0737 \text{ MPa}$$

$$T_{xz} = \frac{T_{z \text{ CORE}} \cdot S_y}{I_y \cdot b} = \frac{10000 \cdot 5333,33 \cdot 10^{-6}}{169488 \cdot 10^{-8} \cdot 20 \cdot 10^{-2}} = 0,1573 \text{ MPa}$$



$$S_{yc_z} = b_z \cdot z \cdot \frac{1}{2} \cdot \left(h-z + \frac{1}{3}z \right) =$$

$$\frac{S_y}{b} = \frac{z}{2} \left(40 - \frac{2}{3}z \right) = 20z - \frac{z^2}{3}$$

$$\left(\frac{S_y}{b} \right)' = 0 \quad \text{3.1} \quad \tau_{\max}$$

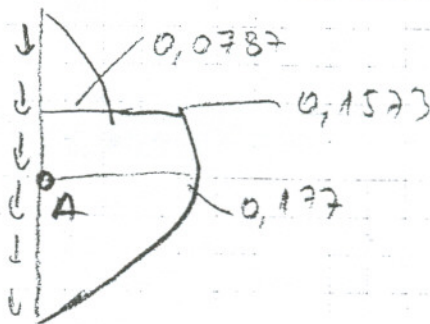
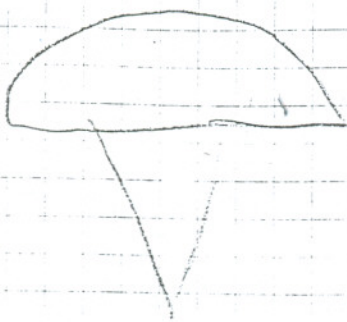
$$20 - \frac{2}{3}z = 0$$

$$z = 30 \text{ cm}$$

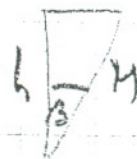
$$\frac{S_y}{b} = \frac{300 \cdot 10^{-4} \text{ m}^2}{6 \cdot 10^{-2} \text{ m}} = 5 \cdot 10^{-3} \text{ m}$$

$$\tau_{\max}^{\Delta} = \frac{10000}{169439 \cdot 10^{-3}} \cdot 300 \cdot 10^{-4} = 0,177 \text{ MPa}$$

гужайтам



$$c) \cos \beta = \frac{h}{M}$$



$$\cos \beta = \frac{40}{\sqrt{40^2 + 10^2}} = \frac{40}{41,27} = 0,97$$

$$\tau_{x, \max}^* = \frac{1}{\cos \beta} \cdot \tau_{x, \max} = 0,182 \text{ МПа}$$

* Круг ρ в максим. смеще $\tau = 0$

(Круг ρ τ_{\max} смеще в круг $\neq 0$)

$$I_z = \frac{1}{48} \cdot 20^3 \cdot 40 + \frac{20^4 \pi}{8} = 69498,52 \text{ см}^4$$

$$\sigma_x = \frac{M_y}{I_z} \cdot z - \frac{M_z}{I_y} \cdot y = \frac{10000}{169499 \cdot 10^{-8}} \cdot 10 \cdot 10^{-2} = 0,589 \text{ МПа}$$

$$S^* = \begin{bmatrix} 0,539 & 0 & 0,1825 \\ 0 & 0 & 0 \\ 0,1825 & 0 & 0,239 \end{bmatrix} \cdot 10^6$$

d) Кин. и стат. бремя раб. на
 неупр. стержень вращ. вокруг центра
 осей $I_x = 0$

$$G_x = \frac{M_1}{I_y} \cdot z - \frac{M_2}{I_z} \cdot y$$

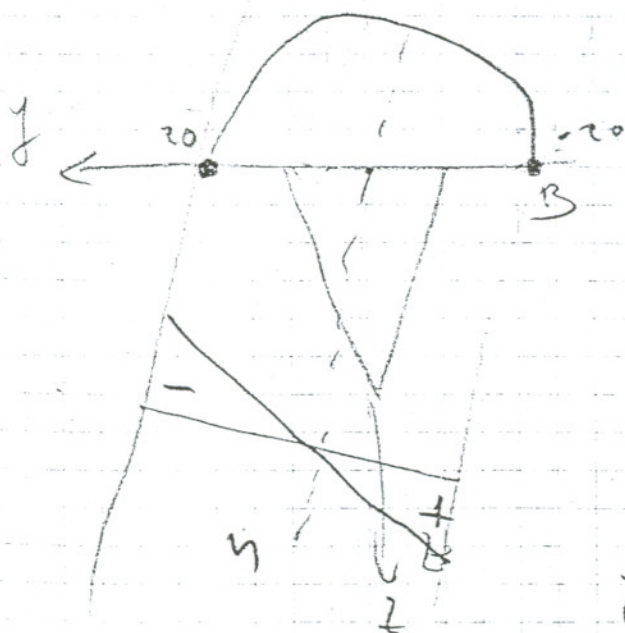
$$0 = \frac{10000}{169489} \cdot z - \frac{40000}{69489,52} \cdot y$$

$$0,525y = 0,059z$$

$$z = 9,746y$$

$$y = 1$$

$$z = 9,746$$



$$G_{x,max} = \frac{M_1}{I_y} \cdot z - \frac{M_2}{I_z} \cdot y$$

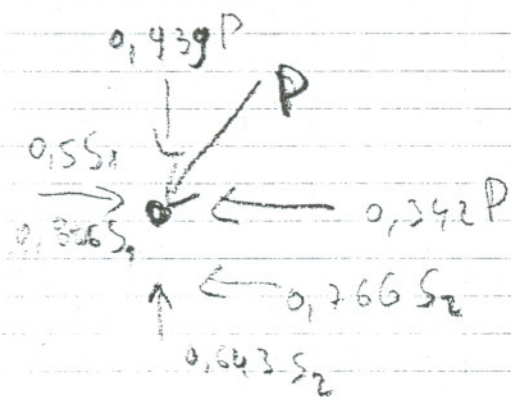
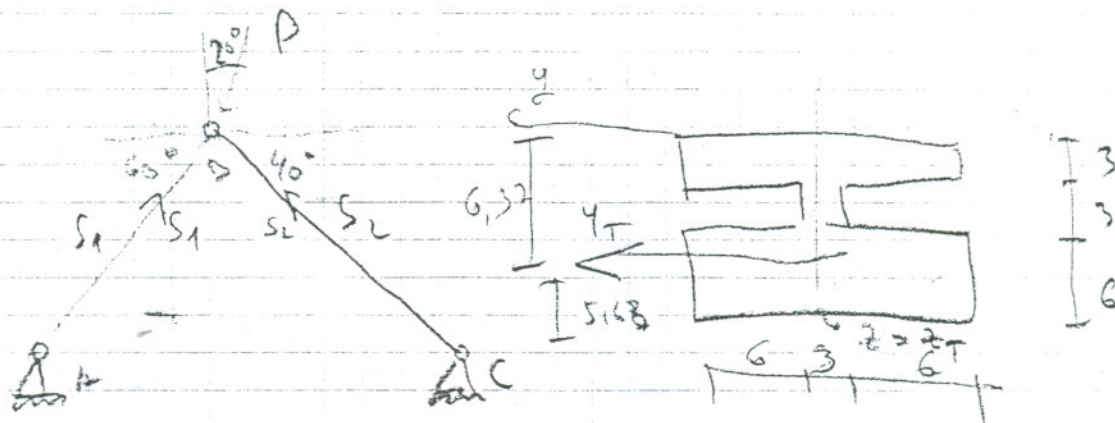
$$= - \frac{40000}{69489,52 \cdot 10^{-2}} \cdot (-20) \cdot 10^{-2} =$$

$$= 11,51 \text{ МПа}$$

$$\tau_{AB} = \tau_{max} = 0,0782 \text{ МПа}$$

$$S^B = \begin{bmatrix} 11,51 & 0 & 0,0732 \\ 0 & 0 & 0 \\ 0,732 & 0 & 0 \end{bmatrix}$$

③ 436324e 3.4)



$$\begin{aligned} \overline{AB} &= 3\text{m} & E &= 210 \\ \overline{BC} &= 3,5\text{m} & G &= 240\text{M} \\ G_{\text{ка}} &= 40-17 \end{aligned}$$

$$\sum x = 0; \quad \sum y = 0;$$

$$S_1 = 0,853P \quad S_2 = 0,176P$$

$$A = 15 \cdot 12 - 2 \cdot 6 \cdot 3 = 36$$

$$A = 144$$

$$L_T = \frac{15 \cdot 12 \cdot 6 - 2 \cdot 6 \cdot 3 \cdot 4,5}{15 \cdot 12 - 2 \cdot 6 \cdot 3} = 6,37$$

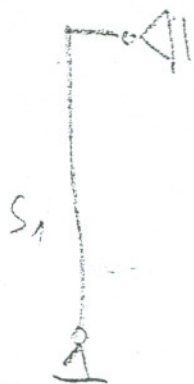
$$I_y = \frac{1}{12} \cdot 3^3 \cdot 15 + 3 \cdot 15 \cdot (4,87)^2 + \frac{1}{12} \cdot 6^3 \cdot 15 + 6 \cdot 15 \cdot 2,60^2 =$$

$$I_y = 2031,45 \text{ cm}^4$$

$$I_x = \frac{1}{12} \cdot 3 \cdot 15^3 + \frac{1}{12} \cdot 6^3 \cdot 15 + \frac{1}{12} \cdot 6 \cdot 15^3 =$$

$$I_x = 2538 \text{ cm}^4 \quad I_y = I_{min}$$

$$i_{min} = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{2031,25}{144}} = \sqrt{14,1} = 3,75$$



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

$$\lambda_{S_1} = \frac{300}{3,75} = 80$$

$$l_2 = l = 2,5 \text{ m}$$

$$\lambda_{S_2} = \frac{350}{3,75} = 93,33 = \underline{\underline{\lambda_{max}}}$$

$$\sigma_{cr} = m \left(\pi^2 \cdot \frac{E}{\lambda^2} \right) = 237,94 \text{ MPa}$$

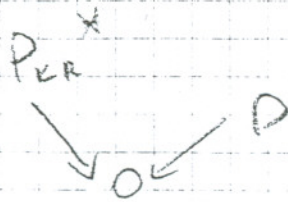
$$310 - 1,92 \cdot 93,33 = \boxed{130,5 \text{ MPa}}$$

$$\sigma_{cr} = 240 \text{ MPa}$$

-8-

$$P_{KR}^* = G_{KR} \cdot A = 130,9 \cdot 10^6 \cdot 144 \cdot 10^{-4} = 1,89 \text{ MN}$$

~~$$P_{KR} = 130,9 \cdot 1,89 \text{ MN} = 0,644 \text{ MN}$$~~



$$S_2 = 0,176 P$$

$$1,89 \text{ MN} = 0,176 P$$

$$P = 10,63 \text{ MN}$$

$$\frac{P_{KR}}{n_s} = P_{dop}$$

$$P_{dop} = \frac{10,63}{2,5} = \underline{\underline{3,05 \text{ MN}}}$$

STAP 1

$$\lambda_{s1} = 80 \quad l_{s1} = 3 \text{ m}$$

$$G_{KR} = \min \left\{ \begin{array}{l} \pi^2 \frac{210 \cdot 10^9}{80^2} = 327,85 \text{ MPa} \\ 310 - 1,92 \cdot 80 = 156,4 \text{ MPa} \\ 240 \text{ MPa} \end{array} \right.$$

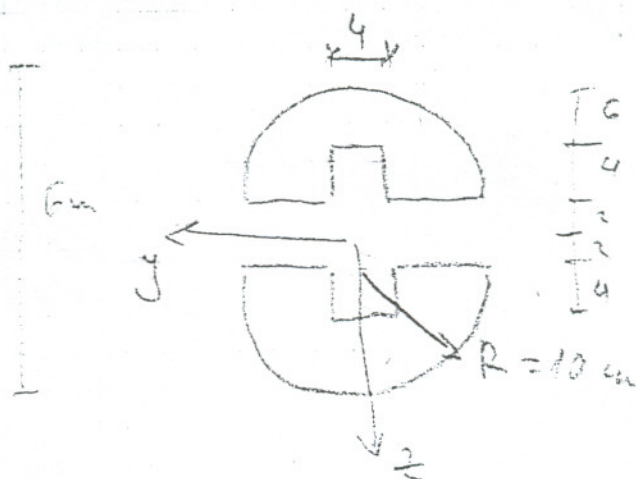
$$P_{KR}^* = 156,4 \cdot 10^6 \cdot 144 \cdot 10^{-4} = 2,252 \text{ MN}$$

$$P_{KR} = \frac{2,252}{0,953} = 2,363 \text{ MN} \quad S_1 = 0,953 P$$

$$P_{dop} = \frac{2,363}{3,5} = 0,625 \text{ MN}$$

$$P = \frac{S_1}{0,953}$$

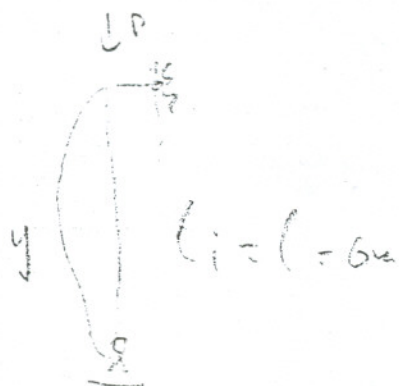
④ чобуға 4. 6



$$I_z = \frac{10^4 \pi}{4} - \frac{1}{12} \cdot 4^3 \cdot 8 = 7811,31$$

$$I_y = \left[2 \cdot 0,03488 \cdot 10^4 + \left(2 + \frac{4}{3} \frac{10}{\pi} \right)^2 \cdot \frac{10^4 \pi}{4} - \frac{1}{12} \cdot 4^4 - 4^2 \cdot 4^2 \right] \cdot 2 = 13889,35 \text{ cm}^4$$

$$A = 10^2 \pi - 4 \cdot 8 = 237,16 \text{ cm}^2$$



$$l_2 = 2 \text{ cm}$$

$$l_y = \sqrt{\frac{13889,35}{237,16}} = 2,02 \text{ cm}$$

$$l_z = \sqrt{\frac{7811,31}{237,16}} = 5,26$$

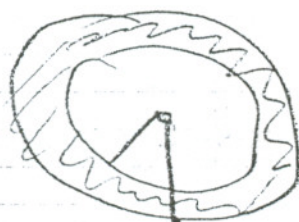
$$l_y = \frac{600}{2,02} = 35,42$$

$$l_z = \frac{410}{5,26} = 79,85$$

$$G_{kr} = \min \begin{cases} \pi^2 \cdot \frac{E}{\lambda^2} = 283,7 \text{ MPa} \\ 310 - 4,92 \cdot \lambda = 145,9 \text{ MPa} \\ 200 \text{ MPa} \end{cases}$$

$$P_{kr} = G_{kr} \cdot A = 145,9 \cdot 10^6 \cdot 282,16 \cdot 10^{-4} = \underline{\underline{4116,71 \text{ kN}}}$$

⑤ Условие 2.



$$R = 4 \text{ м}$$

$$R_1 = 10 \text{ см}$$

$$R_2 = 20 \text{ см}$$

$$I_y = I_x = \frac{20^4 \pi}{4} - \frac{10^4 \pi}{4} = 112309,72 \text{ см}^4$$

$$A = 20^2 \pi - 10^2 \pi = 942,48 \text{ см}^2$$

$$i = \sqrt{\frac{112309,72}{942,48}} = 11,13$$

$$l_i = 0,7 l = 2,8 \text{ м}$$

$$\lambda = \frac{280}{11,13} = 25,04 \quad \lambda = \frac{l_i}{r}$$

$$G_{kr} = \min \begin{cases} \pi^2 \frac{E}{\lambda^2} = 507,2 \text{ MPa} \\ 32 - 0,1 \cdot \lambda = 33,99 \text{ MPa} \\ 32 \text{ MPa} \end{cases}$$

$$P_{kr} = 32 \cdot 10^6 \cdot 942,48 \cdot 10^{-4} = 3,015 \text{ MN}$$

$$\delta) P_{\text{dop}} = 200 \text{ kN} \quad u_s = 2$$

$$P_{\text{kr}} = P_{\text{dop}} \cdot u_s = 1400 \text{ kN}$$

$$\sigma_{\text{kr}} = \frac{P_{\text{kr}}}{A} = \frac{1400 \cdot 10^3}{247,43 \cdot 10^{-6}} = 14,35 \text{ MPa}$$

$$14,35 \text{ MPa} = \sigma^0 \cdot \frac{E}{\lambda^2} \Rightarrow \lambda_1 = 145,33$$

$$14,85 = 37 - \lambda \cdot 0,12 \Rightarrow \lambda_2 = 137,58$$

$$145,33 = \frac{l_{i1}}{4,48}$$

$$137,58 = \frac{l_{i2}}{4,48}$$

$$l_{i1} = 1630,73$$

$$l_{i2} = 2062,6$$

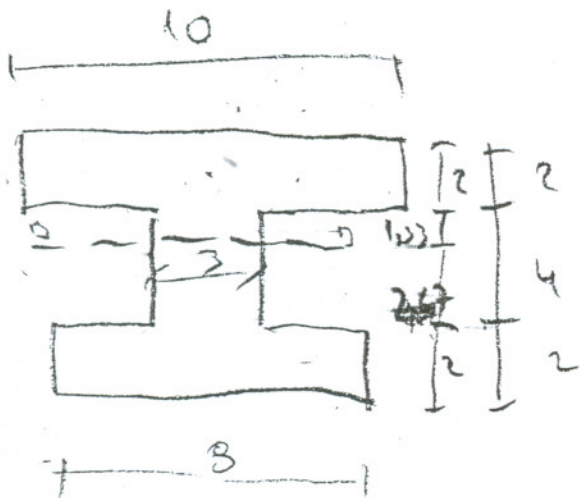
$$= l_{\text{max}}$$

$$l = \frac{l_i}{0,2}$$

$$l_{\text{max}} = 2948 \text{ cm}$$

6) Единица. Грани. Авария

-12-



$$A = 10 \cdot 2 + 3 \cdot 4 + 8 \cdot 2 = 24 \text{ cm}^2$$

$$\frac{A}{2} = 24 \text{ cm}^2$$

$$24 = 16 + 3 \cdot z$$

$$8 = 3z$$

$$z = 2,67$$

здесь единица. Авария

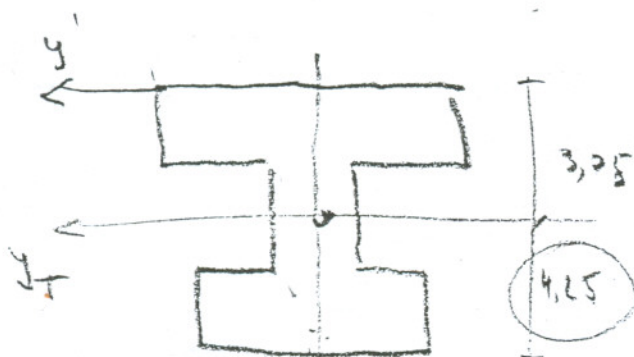
$$W^* = 8 \cdot 2 \cdot 2,67 + 2,67 \cdot 3 \cdot 1,535 + 3 \cdot 1,53 \cdot 0,665 + 10 \cdot 2 \cdot 2,33 = 118,67 \text{ cm}^3$$

$$M^* = W^* \cdot 6 \tau$$

$$M^* = 118,67 \cdot 6 \tau$$

$$f = \frac{W^*}{W_y} = \frac{W^*}{W_y}$$

ошибка
момента



$$z_T = \frac{10 \cdot 2 \cdot 1 + 3 \cdot 4 \cdot 4 + 8 \cdot 2 \cdot 7}{48}$$

$$z_T = 3,75$$

$$z = z_T$$

$$W_y = \frac{I_y}{z_{max}}$$

$$W_x = \frac{I_x}{z_{max}}$$

max расстояние от
центра

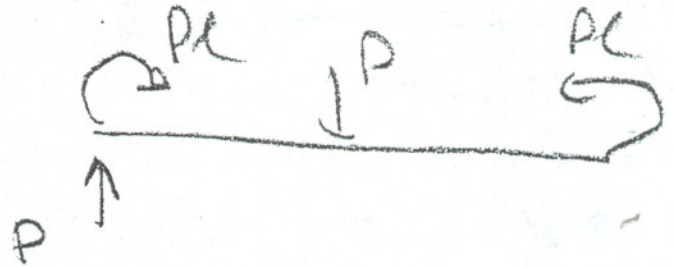
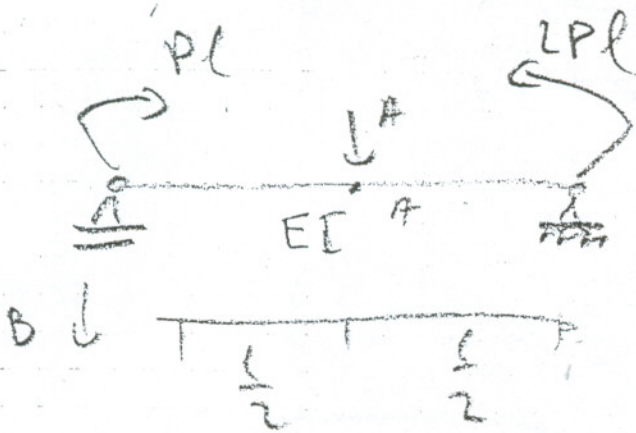
$$I_y = \frac{1}{12} \cdot 2^3 \cdot 10 + 2 \cdot 10 \cdot 6,25^2 + \frac{1}{12} \cdot 4^3 \cdot 3 + 4 \cdot 3 \cdot 0,25^2 + \frac{1}{12} \cdot 2^3 \cdot 8 + 8 \cdot 2 \cdot 3,25^2 = 349 \text{ cm}^4$$

$$W_y = \frac{349}{4,25} = 82,12 \text{ cm}^3$$

$$f = \frac{118,67}{82,12} = 1,43$$

$$N^* = G_{TEC} \cdot A$$

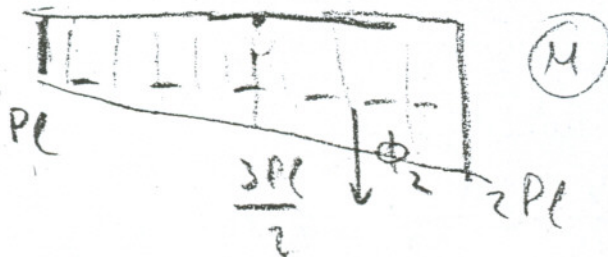
⑦ ystid - mtrud 1,7



$$\sum M_C = 0 : -B \cdot l + PL - 2PL = 0$$

$$B \cdot l = -P \cdot l \quad B = -P$$

$$\sum Y = 0 : P - A = 0 \quad \underline{\underline{A = P}}$$



$$\sum M_{\frac{l}{2}} = 0$$

$$PL + P \cdot \frac{l}{2} = \frac{3PL}{2}$$

$$\phi_1 =$$

$$\phi_2 =$$