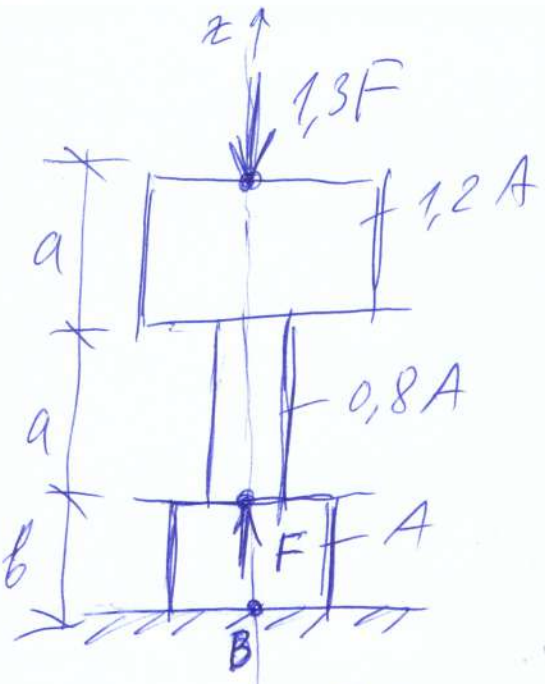


$a = 1,4$ м

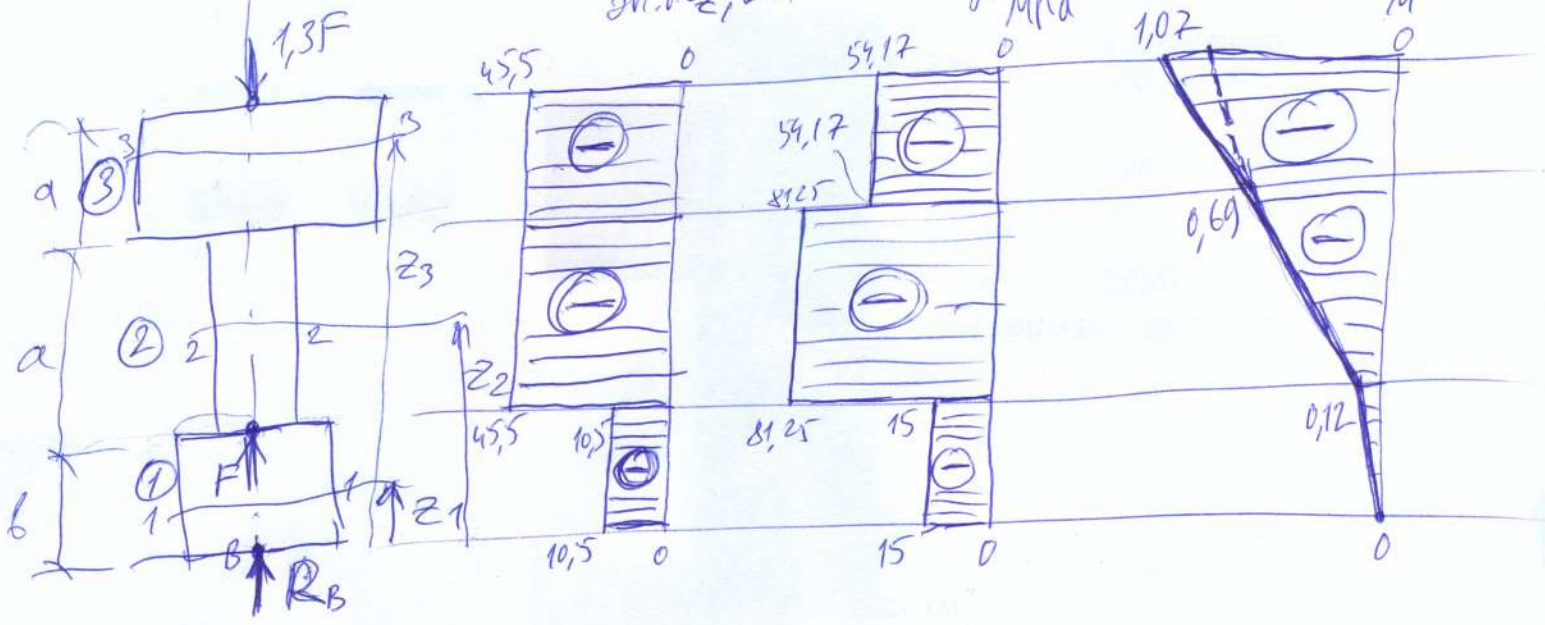
$b = 1,6$ м

$A = 7$ см^2

$F = 35$ кН

$E = 2 \cdot 10^5$ МПа

$[\sigma] = 210$ МПа



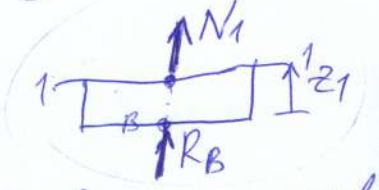
$\sum_{i=1}^{n} F_{iz} = 0$

раст. силы "+"; сжим. силы "−"

$R_B + F - 1,3F = 0$

$R_B = 1,3F - F = 0,3F \cdot 0,3 \cdot 35 = 10,5$ кН

N_z: ① $0 \le z_1 \le b$

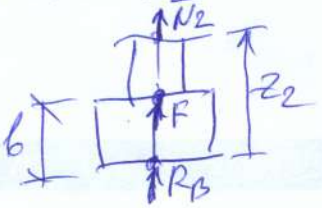


$\sum_{i=1}^{n} F_{iz} = 0$

$N_1 + R_B = 0$

$N_1 = -R_B = -10,5$ кН

② $b \le z_2 \le a+b$



$\sum_{i=1}^{n} F_{iz} = 0$

$R_B + F + N_2 = 0$

$N_2 = -R_B - F = -10,5 - 35 = -45,5$ кН

N_z: ③ $a+b \le z_3 \le 2a+b$

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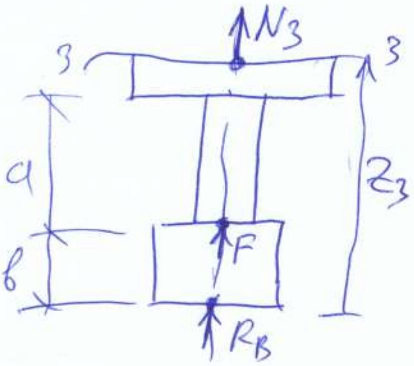


$$\sum_{i=1}^{n} F_{iz} = 0$$

$$R_B + F + N_3 = 0$$

$$N_3 = -45{,}5 \text{ кН}$$

$$\text{МПа} = \frac{\text{МН}}{\text{м}^2}$$

σ_z: ① $\sigma_1 = \frac{N_1}{A} = \frac{-10{,}5 \text{ кН}}{7 \text{ см}^2} \cdot \frac{10^{-3}}{10^{-4}} = -15 \text{ МПа}$

② $\sigma_2 = \frac{N_2}{0{,}8A} = \frac{-45{,}5(\cdot 10)}{0{,}8 \cdot 7} = -81{,}25 \text{ МПа}$

③ $\sigma_3 = \frac{N_3}{1{,}2A} = \frac{-45{,}5(\cdot 10)}{1{,}2 \cdot 7} = -54{,}17 \text{ МПа}$

$\sigma_{max} = |\sigma_2| = 81{,}25 < [\sigma]$

$\Delta l(z)$: ① $0 \le z_1 \le b$

$$\Delta l_1(z) = \frac{N_1 \cdot z_1}{E \cdot A}$$

$$\Delta l_1(0) = 0$$

$$\Delta l_1(b) = \frac{N_1 \cdot b}{E \cdot A} = \underbrace{\frac{-10{,}5 \cdot 1{,}6}{2 \cdot 10^5 \cdot 7}}_{-12 \cdot 10^{-5}} \cdot \frac{10^{-3}}{10^{-4}} = -0{,}12 \cdot 10^{-3} \text{ м} \quad (-0{,}12 \text{ мм})$$

② $b \le z_2 \le a+b$

$$\Delta l_2(z) = \Delta l_1(b) + \frac{N_2(z_2 - b)}{E \cdot 0{,}8A} = ~~-0{,}12 \cdot 10^{-3} + -45{,}5(~~$$

$$\Delta l_2(b) = \Delta l_1(b) + \frac{N_2(b-b)}{E \cdot 0{,}8A} = \Delta l_1(b) = -0{,}12 \cdot 10^{-3} \text{ м}$$

$$\Delta l_2(a+b) = \Delta l_1(b) + \frac{N_2 \cdot a}{E \cdot 0{,}8A} = -0{,}12 \cdot 10^{-3} + \frac{-45{,}5 \cdot 1{,}4(\cdot 10)}{2 \cdot 10^5 \cdot 0{,}8 \cdot 7} =$$

$$= (-0{,}12 - 0{,}57) \cdot 10^{-3} = -0{,}69 \cdot 10^{-3} \text{ м}$$

$\Delta l(z)$: ③ $a+b \le z_3 \le 2a+b$

$$\Delta l_3(z) = \Delta l_2(a+b) + \frac{N_3 (z_3 - a - b)}{E \cdot 1,2 \cdot A}$$

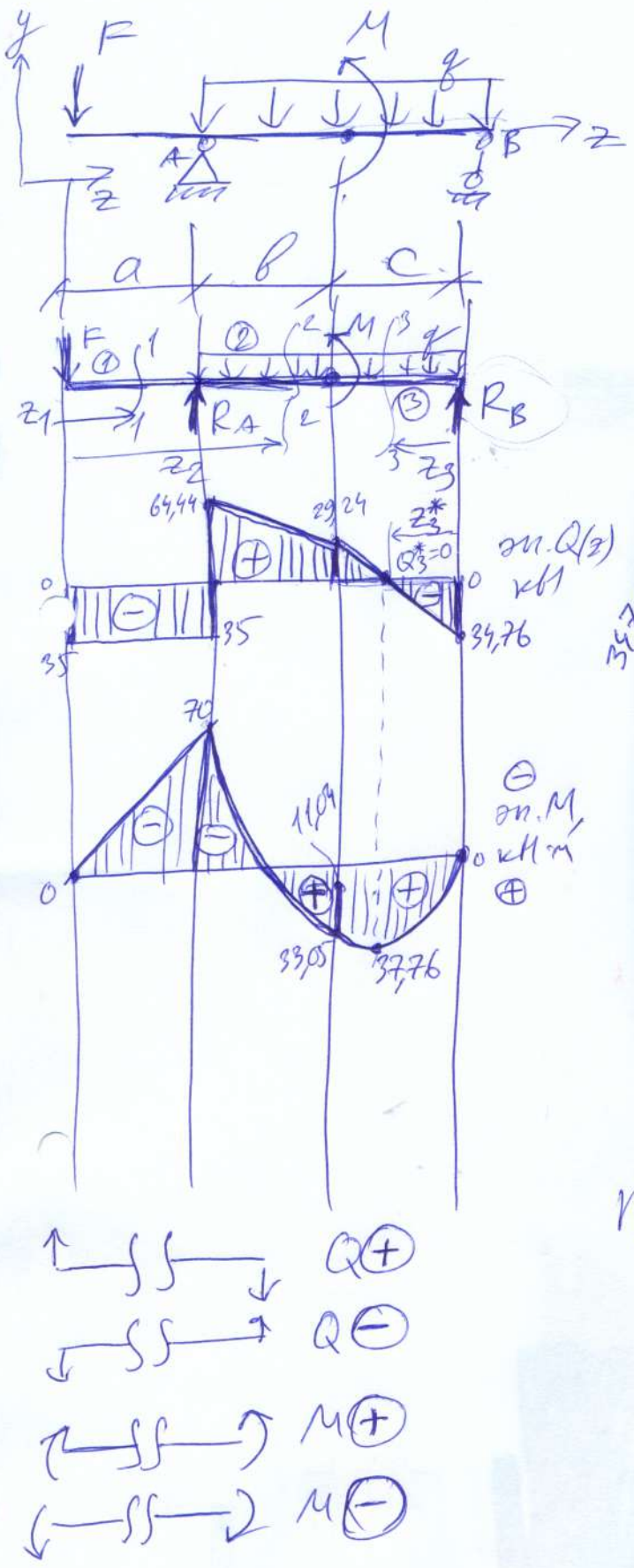
$$\Delta l_3(a+b) = \Delta l_2(a+b) = -0,69 \cdot 10^{-3}\ м$$

$$\Delta l_3(2a+b) = \Delta l_2(a+b) + \frac{N_3 \cdot a}{E \cdot 1,2A} = -0,69 \cdot 10^{-3} -$$

$$- \frac{45,5 \cdot 1,4 \cdot (\cdot 10)}{2 \cdot 10^5 \cdot 1,2 \cdot 7} = (-0,69 - 0,38) \cdot 10^{-3} =$$

$$= -1,07 \cdot 10^{-3}\ м$$

5.2



$a = 2$ м $\quad b = 2{,}2$ м $\quad c = 4$ м

$F = 35$ кН $\quad M = 22$ кН·м

$q = 16$ кН/м

Реакции опор:

$$\sum_{i=1}^{n} M_A = F \cdot a + M - q \cdot (b+c)\frac{(b+c)}{2} + R_B \cdot (b+c) = 0$$

$$R_B = \frac{q \cdot (b+c)^2}{2} - F \cdot a - M = 16\frac{(2{,}2+4)^2}{2} - \frac{-35 \cdot 2 - 22}{2{,}2+4} = \frac{215{,}52}{2{,}2+4} = 34{,}76 \text{ кН}$$

$$\sum_{i=1}^{n} M_B = F \cdot (a+b+c) + M + q(b+c)\frac{(b+c)}{2} - R_A \cdot (b+c) = 0$$

$$R_A = \frac{F(a+b+c) + M + q(b+c)^2/2}{(b+c)} = \frac{35 \cdot (2+2{,}2+4) + 22 + 16\frac{(2{,}2+4)^2}{2}}{2{,}2+4} =$$

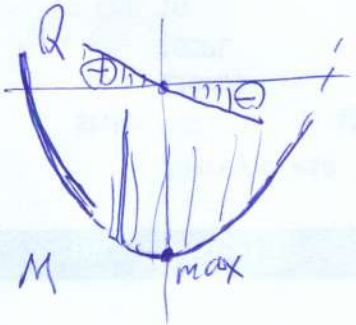
$$= 99{,}44 \text{ кН}$$

Проверка:

$$\sum_{i=1}^{n} F_{iy} = 0$$

$$-F - q(b+c) + R_A + R_B = 0$$

$$-35 - 16 \cdot (2{,}2+4) + 99{,}44 + 34{,}76 = 0$$



① $0 \le z_1 \le a$

$Q_1(z) = -F = -35$ kH

$M_1(z) = -F \cdot z_1$ $\quad M_1(0) = 0$

$M_1(a) = -F \cdot a = -35 \cdot 2 = -70$ kH·M

② $a \le z_2 \le a+b$

$Q_2(z) = -F + R_A - q(z_2 - a)$

$Q_2(a) = -F + R_A = -35 + 99{,}44 = 64{,}44$ kH

$Q_2(a+b) = -F + R_A - 16 \cdot 2{,}2 = -35 + 99{,}44 - 35{,}2 =$

$= 29{,}24$ kH

$M_2(z) = -F \cdot z_2 + R_A(z_2 - a) - q(z_2 - a)\frac{(z_2 - a)}{2}$

$M_2(a) = -F \cdot a = -70$ kH·M

$M_2(a+b) = -F \cdot (a+b) + R_A \cdot b - q \cdot \frac{b^2}{2} = -35 \cdot (2+2{,}2) + 99{,}44 \cdot 2{,}2$

$- 16 \cdot \frac{2{,}2^2}{2} = 33{,}05$ kH·M

③ $0 \le z_3 \le c$

$Q_3(z) = -R_B + q \cdot z_3$

$Q_3(0) = -R_B = -34{,}76$ kH

$Q_3(c) = -R_B + q \cdot c = -34{,}76 + 16 \cdot 4 = 29{,}24$ kH

$M_3(z) = R_B \cdot z_3 - q \cdot z_3 \cdot \frac{z_3}{2}$

$M_3(0) = 0$

$M_3(c) = R_B \cdot c - q \cdot \frac{c^2}{2} = 34{,}76 \cdot 4 - 16\frac{4^2}{2} = 11{,}04$

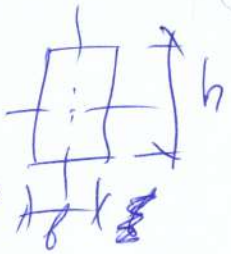
$Q_3(z^*) = -R_B + q \cdot z_3^* = 0$ $\quad z_3^* = \frac{R_B}{q} = \frac{34{,}76}{16} = 2{,}17$ m $< c = 4$ m

$M_3(z^*) = R_B \cdot z_3^* - q\frac{(z_3^*)^2}{2} = 34{,}76 \cdot 2{,}17 - 16 \cdot \frac{(2{,}17)^2}{2} = 37{,}76$ kH·M

Момент сопрот.:

$$W_x \geq \frac{|M_{max}|}{[\sigma]} = \frac{70 \cdot 10^{-3}}{210} = 3{,}33 \cdot 10^{-4}\ м^3 \quad м^2 \cdot м$$

Прямоуг.: $h = 4 \cdot b$



$$W_x = \frac{b \cdot h^2}{6} = \frac{16 \cdot b^3}{6} \geq 3{,}33 \cdot 10^{-4}\ м^3$$

$$b \geq \sqrt[3]{\frac{6}{16} \cdot 3{,}33 \cdot 10^{-4}} = 0{,}05\ м = 5\ см$$

$$h = 4 \cdot b = 0{,}2\ м = 20\ см$$

$$A_▨ = h \cdot b = 20 \cdot 5 = 100\ см^2$$

Круглое сечение:

$$W_x = \frac{\pi \cdot D^3}{32} \geq 3{,}33 \cdot 10^{-4}\ м^3$$

$$D \geq \sqrt[3]{\frac{32}{\pi} \cdot 333 \cdot 10^{-4}} = 0{,}15\ м = 15\ см$$

$$A_● = \frac{\pi D^2}{4} = \frac{\pi \cdot 15^2}{4} = 176{,}72\ см^2$$

Двутавр. сеч. — по сортаменту: $W_x = 3{,}33 \cdot 10^{-4}\ м^3 = 333{,}33\ см^3$

I 27 $W_x = 371\ см^3$; $A_I = 40{,}2\ см^2$

$$\frac{A_●}{A_I} = \frac{176{,}72}{40{,}2} = 4{,}4$$

$$\frac{A_▨}{A_I} = \frac{100}{40{,}2} = 2{,}49$$

$$A_● : A_▨ : A_I = 4{,}4 : 2{,}49 : 1$$