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Federal State Budgetary Educational Establishment
of Higher Education
"Ufa University of Sciences and Technologies"

strength of materials
department

Course Work

"Strength calculation in tension, torsion and bending"

Variant № 1

ТЭД-217б

	Surname and name	Date	Signature
Completed by	Аль-харети Салим	11.12.23	
Checked by			
Accepted by			

(6)

USATU

кафедра СОПРОТИВЛЕНИЯ МАТЕРИАЛОВ

Computational and graphical work of strength of material

Group	Name and surname	Variant
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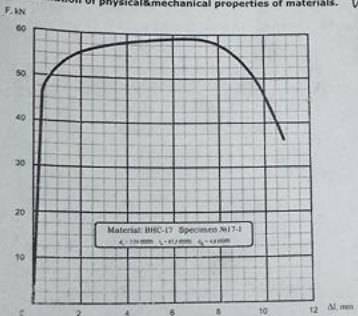
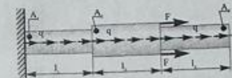
Date of issue	Deadline	Lecturer
25.09.2023.	11.12.2023	[signature]

✓ **1. Calculation of physical&mechanical properties of materials.**



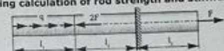
Task: according to a given diagram of material tension, it is necessary to determine the basic mechanical characteristics - the limit of proportionality, yield limit, strength limit, tensile stress. Determine the cross-sectional area of the sample before and after the tests, the relative residual elongation, narrowing. Calculate permissible stresses.

✓ **2. Designing calculation of strength of staged rod.**



Task: for a given stepped rod it is necessary to build distribution diagrams of longitudinal forces, plot of stresses in fractions of the area cross-section A. Find the cross-sectional area A according to strength conditions. Plot normal stress. Construction material is taken from task 1.

3. Checking calculation of rod strength and stiffness.



Task: for a rod with a constant cross-sectional area A4, it is necessary to plot the longitudinal forces and axial displacements, perform strength and stiffness calculations.

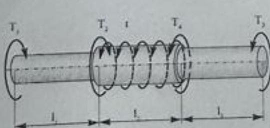
Input data for tasks 2 and 3:

F, kN	l_1, m	l_2, m	l_3, m
33	0,2	0,4	1,0
q, kN/m	**A_1/A**	**A_2/A**	**A_3/A**
14	2,5	1,5	2,7

Additional data for task 3:

Material
20X
A_4, cm^2
7,7

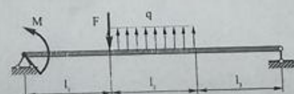
✓ **4. Checking calculation of strength of staged rod under torsion.**



Task: plot torque moments, shear stresses in fractions of d ^ 3. Perform strength analysis and determine the base rod diameter d. Plot relative and absolute rotation angles, shear stresses and distribution diagram of tangential radial stress in a dangerous section.

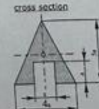
l_1, m	l_2, m	l_3, m	t, kNm/m	T_1, kNm	T_2, kNm	T_3, kNm
0,3	0,8	0,5	22	36	31	15
D_1/d	**d_1/d**	**D_2/d**	**d_2/d**	**D_3/d**	**d_3/d**	**Material**
2.6	0,4	3,0	0,4	2,1	0,4	АМцМ

5. Designing calculation of strength under bending.



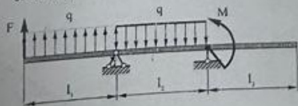
Task: to draw internal force factors distribution diagrams. Match sizes of beam cross section according to strength conditions. Plot dangerous section stress distribution with noticing the most loaded points. Suggest the section position best option.

cross section



l_1, m	l_2, m	l_3, m	F, kN	q, kN/m	M, kNm	Material
0,2	0,3	0,2	20	5	5	СЧ12-28

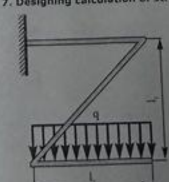
✓ **6. Cheking calculation of beam made of rolled sections.**



Section № 12

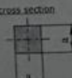
Task: to draw plots of internal force factors, stress distribution in a dangerous section with indicating the most loaded points. Check that the strength condition is met. The section is made of standard rolling sections

7. Designing calculation of strength of plane frame.



Task: to draw plots of internal force factors distribution, hazardous section stress distribution indicating the most loaded points. Select a typical size of section according to strength condition.

cross section

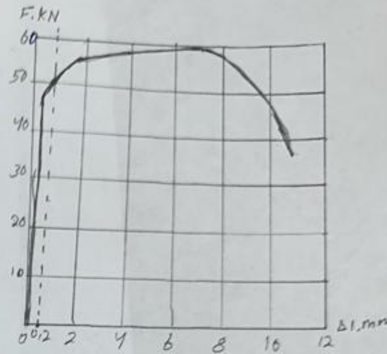


Input data for tasks 6 and 7:

l_1, m	l_2, m	l_3, m	F, kN	q, kN/m	M, kNm	Steel brand
0,7	0,6	0,5	43	41	24	Ст5

1. Calculation of physical & mechanical properties of materials.

Task: according to given diagram of materil tension, it is necessary to determine the basic mechanical characteristics the limit of proportionality, yield limit, strength limit tensile stress. Determine the cross sectional area of the sample before and after the tests the relative residual elongation narrowing. Calculate permissible stresses.



Material BHC-17, Specimen №7!

$d_0 = 7{,}99$ mm $l_0 = 87{,}3$ mm

$d_k = 4{,}8$ mm

$L_0 = 87{,}3$ mm

$\Delta l_{0,2} = L_0 \cdot \frac{0{,}2}{100} = 0{,}175$ mm

$[\sigma]$ - ? σ_y - σ_{dang}

$[\sigma] = \frac{\sigma_{dang}}{n}$ $\frac{A}{B}$

for plastic mat $n = 1{,}5 \dots 2{,}5$

F_y - yield force $F_{0,2} = 50$ kN

Δl, mm. $\sigma_{0.2}$ $\sigma_{0,2} = \frac{F_{0,2}}{A_0}$

$\sigma_{0,2} = \frac{F_{0,2}}{A_0}$

$\Delta L = 0{,}175$ mm that corresponds to $d_0 = 7{,}99$ mm

$\varepsilon = 0{,}2\%$ $A_0 = \frac{\pi \cdot d_0^2}{4}$

If yield plateau is absent

$\sigma_{0,2}$ - conventional yield limit

we have $\varepsilon = 0{,}2\%$

$\varepsilon = \frac{\Delta L}{L_0} \cdot 100 = 0{,}2$

$\Delta l = \frac{0{,}2}{100} \cdot L_0 = \Delta L = \frac{0{,}2}{100} \cdot 87{,}3 = 1{,}746 \cdot 10^{-1} = 0{,}175$ mm

$A_0 = \frac{\pi \cdot 7{,}99^2 \text{ mm}}{4} = 50{,}1^2$ mm

$\sigma_{0,2} = \frac{51000 N}{50{,}1 mm^2} = 1017{,}9$ MPa

$[\sigma] = \frac{1017{,}9}{1{,}5} = 678{,}6$ MPa ✓

② Desingning calculation of strength of staged rod.

Task: for a given stepped rod it is necessary to build distribution digrams of longitudinal forces, plot of stresses in fractions of the area cross-section A, find the cross-sectional area A according to strength conditions. Plot normal stress. Construction material is taken from task 1.

① to find R?

$\frac{A_1}{A_0} = 1 \Rightarrow A_1 = 1\cdot A_0$

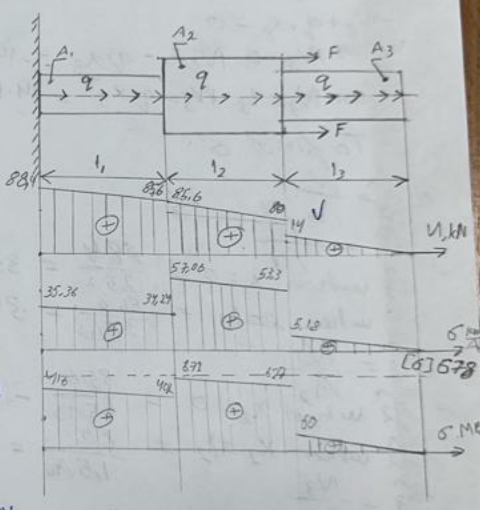
$\sum F_x = 0$

$+R + 2F + q\cdot l_1 + q\cdot l_2 + q\cdot l_3 = 0$

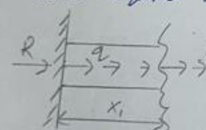
$R = -2F - q\cdot l_1 - q\cdot l_2 - q\cdot l_3$

$= -2\cdot 33 - 14\cdot 0.2 - 14\cdot 0.4 - 14\cdot 1$

$= 88,4$ kN



2.1 To find N_1?



$\sum F_x = 0$

$N_1 + R + q\cdot x_1 = 0 \quad N_1 = -R - q\cdot x_1$

when $x_1 = 0$

$N_1 = 88,4 - 14\cdot 0 = 88,4$ kN

when $x_1 = l_1$

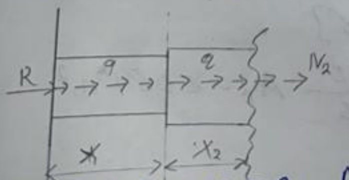
$N_1 = 88,4 - 14\cdot 0,2 = 85,6$ kN

Input data for task 2

F, kN	l_1, m	l_2, m	l_3, m
33	0.2	0.4	1.0

q, kN/m	A_1/A	A_2/A	A_3/A
14	2.5	1.5	2.7

2.2 to find N_2?



$N_2 + R + q\cdot x_1 + q\cdot x_2 = 0 \quad N_2 = -R - q\cdot x_1 - q\cdot x_2$

when $x_2 = 0$

$N_2 = -R - q \cdot x_2 - q \cdot x_2$

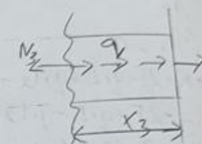
$88{,}4 - 14 \cdot 0{,}2 = 85{,}6 \text{ kN}$

when $x_2 = l_2$

$N_2 = -R - q \cdot l_1 - q \cdot x_2 = 88.4 - 14 \cdot 0{,}2 - 14 \cdot 0{,}4 = 80 \text{ KN}$

2.3 To find N_3

$-N_3 + q \cdot x_3 = 0$



when $N_3 = 0$ $N_3 = -q \cdot x_3 = -14 \cdot 0 = 0$

when $N_3 = l_3$ $N_3 = q \cdot x_3 = 14 \cdot 1 = 14 \text{ KN}$

③ To find σ

$\sigma = \frac{N}{A_0}$

$\sigma_1 = \frac{N_1}{A_1}$

σ_1 when $x_1 = 0 = \frac{88.4}{2.5 \cdot A_0} = 35{,}36 \cdot \frac{kN}{A_0}$

σ_1 when $x = l_1 = \frac{85{,}6}{2{,}5 A_0} = 34{,}24 \frac{kN}{A_0}$

$\sigma_2 = \frac{N_2}{A_2}$

σ_2 when $x_2 = 0 = \frac{85{,}6}{1{,}5 A_0} = 57{,}06 \frac{kN}{A_0}$

σ_2 when $x_2 = l_2 = \frac{80}{1{,}5 A_0} = 53{,}3 \frac{kN}{A_0}$

$\sigma_3 = \frac{N_3}{A_3}$

σ_3 when $x_3 = 0 = 0$

σ_3 when $x_3 = l_3 = \frac{14}{2.7 A_0} = 5{,}18 \cdot \frac{kN}{A_0}$

$\sigma_{max} \leq [\sigma] = \frac{57{,}06 \cdot 10^3}{A_0} \leq [\sigma]$

$A_0 \geq \frac{|57{,}06 \cdot 10^3|}{678{,}6}$ $A_0 \geq \frac{57{,}06 \cdot 10^3}{678.6}$ $A_0 = 0{,}084^3 m^2$

$= 84 mm$

let u take A_0 $85 mm^2$

(6)

checking

$\frac{N}{mm^2} = MPa \quad \frac{N}{MPa} = mm^2$

$\sigma_1 \quad \frac{35.36 \cdot 10^3}{85} = 416\ MPa, \quad \frac{34,24 \cdot 10^3}{85} = 402\ MPa$

$\sigma_2 \quad \frac{57,06 \cdot 10^3}{85} = 671\ MPa, \quad \frac{53,3 \cdot 10^3}{85} = 627\ MPa$

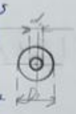
$\sigma_3 \quad \frac{5.18 \cdot 10^3}{85} = 60\ MPa$

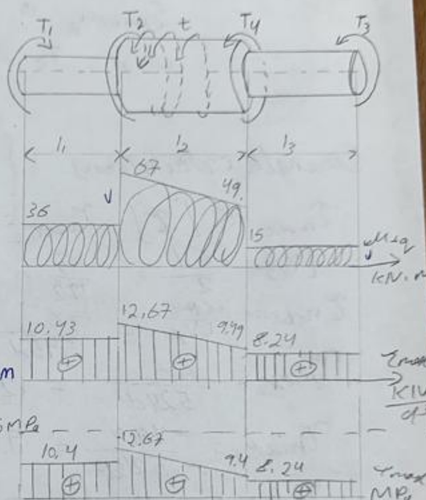
✓

⑥ ... beam made of rolled sections

④ Checking calculation of strength of staged rod under torsion

Task: polt torque moments, shear stresses in sections of d^3 perform strength analysis and determine the base rod dimeter d. Plot relative and absolut rotation angles shear stesses and distrbution diagram of tangential radial streess in a dangerous section.



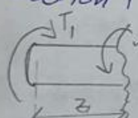


$-T_1 - T_2 + t\cdot l_2 + T_4 + T_3 = 0$

$T_1 = T_1 + T_2 - t\cdot l_2 - T_3$

$36 - 31 - 22\cdot 0,8 - 15 = 34,4\ KN.m$

Section 1

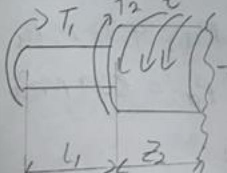


$\sum mom_z = 0$

$-T_1 + M_{tq1} = 0$

$M_{tq_1} = T_2 = 36\ KN.m$

Section 2 $\sum mom_z = 0$



$-T_1 - T_2 + t\cdot z_2 + M_t = 0$

$M_{q2} = T_1 + T_2 - t\cdot z_2$

whe $z_2 = 0$

$M_{tq2} = T_2 - T_2 \cdot -36 + 31 = 67\ KN.m$

when $z_2 = L_2$

$M_{tq2} = T_1 + T_2 - t\cdot L_2$

$36 + 31 - 22\cdot 0.8 = 49,4\ KN.m$

Section 3

$\Sigma mom_z = 0$

$M_{q3} = T_3 = 15\ kN \cdot m$

Strength calculations

$\tau_{max} \leq [\tau] \quad \tau_{max_2} = 12,67$

$[\tau] = \frac{[\sigma]}{2} = \frac{\sigma_y}{n2} = \frac{\sigma_y}{4} = \frac{60}{4} = 15$

$\tau_{max} = \frac{M_{tq}}{W_{p1}} = \frac{36}{3.45d} = 10.43 \frac{kN}{d^3}$

$\tau_{max_2} = \frac{67}{5.29d^3} = 12,67 \frac{kN}{d^3}$

$\tau_{max_2} = \frac{49.9}{5.29d^3} = 9.43 \frac{kN}{d^3}$

$\tau_{max_3} = \frac{15}{1.82d^3} = 8,24 \frac{kN}{d^3}$

Strength condition

$\frac{12.67 kN \cdot m}{d^3} \leq 15 MPa \quad d \geq \sqrt[3]{\frac{12.67 \cdot 10^3}{15 \cdot 10^6}}$

$\geq 0,095\ m \geq 95 mm$ let's take $d = 100\ mm$?

Checking:

$\frac{9,13 kNm}{d^3} = \frac{9.43 \cdot 10^3}{0.1^3} = 9.43 \cdot 10^6\ Pa = 9,43\ MPa$

$\frac{8.24 kNm}{d^3} = \frac{8,24 \cdot 10^3}{0.1^3} = 8,24 \cdot 10^6\ Pa = 8.24\ MPa$

$\theta_2^{z_2 = 0} \frac{M_{q2}}{G \cdot I_{p2}} \quad I_{p2} = \frac{\pi \cdot D^4}{32} (1 - \alpha^4)$

$\theta_2^{z_2 = 0} \frac{67 \cdot 10^3}{27 \cdot 10^9 \cdot 0.000794989} = 0,001214\ rad/m = 3,12 rad/m$

$G = 27\ GPa$

$I_{p1} = \frac{\pi D_1^4}{32} (1 - \alpha^4) = \frac{\pi (2,601)}{32} (1 - 0,15^4) = 4,48 \cdot 10^{-4} m^4$

$\alpha_2 = \frac{d_2}{D} = \frac{0,4}{3,0} = 2,8 \cdot 10^{-3}\ rad/m = 2,98\ rad/m$

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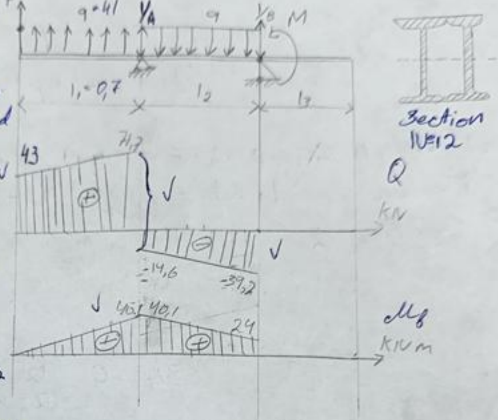
⑥ Cheking calculation of beam made of rolled sections

Task: to draw plots of internal force factors, stress distribution in a dangerous section with indicating the most loaded points. Check that the section is made of standard rolling sections



$\sum F_y = 0 \quad + X_A = 0$ ✓

$F + q \cdot l_1 + Y_A - q \cdot l_2 + Y_B + M = 0$

$\sum F_y = 0 \quad + q \cdot l_1 - q \cdot l_2 + f + Y_A + Y_B$

$\sum mom_A = 0$

$-F \cdot L_1 - R \cdot q \cdot L_1 \cdot \frac{L_1}{2} - q \cdot l_2 \cdot \frac{l_2}{2} + Y_B \cdot l_2 + M = 0$

$$Y_B = \frac{F \cdot l_1 + q \cdot l_1 \cdot \frac{l_1}{2} + q \cdot l_2 \cdot \frac{l_2}{2} - M}{l_2}$$

$$Y_B = \frac{43 \cdot 0,7 + 41 \cdot 0,7 \cdot \frac{0,7}{2} + 41 \cdot 0,6 \cdot \frac{0,6}{2} - 24}{0,6} = 39,208 \text{ kN}$$ ✓

l1, m	l2, m	l3, m	F, kN	q, kN/m	M, kNm	Steel brand
0,7	0,6	0,5	43	24	24	CT5

$\sum mom_B = 0$

$-F(l_1 + l_2) - q \cdot l_1 (\frac{l_1}{2} + l_2) - Y_A \cdot l_2 + q \cdot l_2 \cdot \frac{l_2}{2} + M = 0$

$$Y_A = \frac{-F(l_1 + l_2) - q \cdot l_1 (\frac{l_1}{2} + l_2) + q \cdot l_2 \cdot \frac{l_2}{2} + M}{l_2}$$

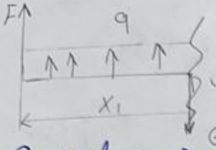
$$Y_A = \frac{-43(0,7+0,6) - 41 \cdot 0,7 (\frac{0,7}{2} + 0,6) + 43 \cdot 0,6 \cdot \frac{0,6}{2} + 24}{0,6} = -86,3 \text{ kN}$$

Checking

$q \cdot l_1 - q \cdot l_2 + f + Y_A + Y_B = 0$

$41 \cdot 0,7 - 41 \cdot 0,6 + 43 + 39,2 + (-86,3) = 0$ ✓

Section



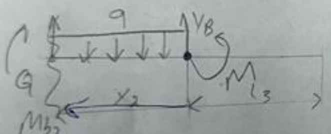
$\Sigma F_x = 0$

$\Sigma F_y = +F + q \cdot x_1 - Q_1 = 0 \quad Q_1 = F + q x_1$

Q_1 when $x_1 = 0$ $\quad Q_1 = f + q x_1 \quad 43 + 41 \cdot 0 = 43\,kN$ ✓

Q_1 when $x_1 = l_1$ $\quad Q_1 = f + q x_1 \quad 43 + 41 \cdot 0{,}7 = 71{,}7\,kN$ ✓

Section 2



$\Sigma F_y = 0 \quad Q_2 - q \cdot x_2 + Y_B = 0$

$Q_2 = q_2 \cdot x_2 - Y_B$

Q_2 when $x_2 = 0$ $\quad q_2 \cdot x_2 - Y_B \quad 41 \cdot 0 - 39{,}208 = -39{,}208\,kN$

Q_2 when $x_2 = L$ $\quad q_2 \cdot x_2 - Y_B \quad 41 \cdot 0{,}6 - 39{,}208 = -14{,}60\,kN$

$M_{b_1} = +f \cdot x_1 + q \cdot x_1 \cdot \frac{x_1}{2} \quad M_{b_1}(x_1 = 0) = 0$

$M_{b_1}(x_1 = L_1) \; f \cdot L_1 + \frac{q L_1^2}{2} \quad 43 \cdot 0{,}7 + \frac{41 \cdot 0{,}7^2}{2} = 40{,}145$

$\Sigma mom_2 = 0 \cdot \; -M_{b_2} - q \cdot x_2 \cdot \frac{x_2}{2} + Y_B \cdot x_2 + M = 0$

$M_{b_2} = -q \cdot l_2 \cdot \frac{x_2}{2} + Y_B \cdot x_2 + M$

$M_{b_2}(x_1 = 0) \quad M_{b_2} = M = 24\,kN \cdot m$

$M_{b_2}(x_2 = l_2) \quad M_{b_2} = -q \cdot l_2 \frac{l_2}{2} + Y_B \cdot l_2 + M$

$-41 \cdot 0{,}6 \cdot \frac{0{,}6}{2} + 39{,}208 \cdot 0{,}6 + 24$

$= 40{,}195\,kN \cdot m$

$\sigma_{max} = \frac{M_b^{max}}{W_x} = \frac{M_b^{max}}{2 W_{x1}} = \frac{40{,}145 \cdot 10^3}{58{,}4 \cdot 10^{-5}} = 343\,MPa$

$[\sigma] = \frac{\sigma_y}{2} = \frac{285\,MP}{2} = 142{,}5\,MPa$

According to σ_{max}, $[\sigma]$ its will not be able to carry the load so it's will braki