BOOK OF COURSE WORKS
ON STRENGTH OF MATERIALS
FOR THE 2ND YEAR STUDENTS OF THE UACEG

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STRENGTH OF MATERIALS

GENERAL INSTRUCTIONS FOR THE SEMESTER WORK PREPARATION

I. Instruction for the coursework preparation

1. The courseworks have to be written with a pencil on one side only of white sheets of paper. The schemes and diagrams have to be drawn on a suitable scale.
2. A frame is drawn on each sheet of paper to mark the working field. The faculty number of the student must be written with a pen in the bottom right corner and the number of the individual variant – at the top right corner inside the frame.
3. Every coursework thus prepared must be submitted to the assistant professor for verification and approval not later than two weeks after typical worked or sample examples have been explained during classroom work. After approval of all courseworks they are compiled in a file and submitted to the assistant professor for final validation.

II. Instructions about the courseworks data

1. The problems of each topic must be solved by the student with the use of the correspondent numbers in the assistant professor's list.
2. Most parts of the parameters are given as functions of the four digits constituting the student's faculty number, say K1, K2, K3, K4. When a faculty number contains less than four digits, for example 198, then it is written as 0198, so that K1=0, K2=1, K3=9, K4=8. If the faculty number contains five digits, for example 14523, then the first digit is omitted, so that K1=4, K2=5, K3=2, K4=3.
3. Dimensions, loadings and other parameters to be needed for problem solutions are given together with the related drawings.

Coursework 1: **Internal forces in planar straight beams**

A planar straight beam is supported and loaded, as shown.

1. Determine the support reactions;

2. Determine the internal forces functions in each segment;

3. Draw the internal forces diagrams on a suitable scale;

4. Check the internal forces functions and diagrams using the differential check, the check about the type of the diagrams, area check and the check about the steps in the diagrams.

DATA: $a = 3 + 0{,}1.K_2\ [m];\quad b = 4 + 0{,}1.K_4\ [m];\quad c = 2 + 0{,}1.K_3\ [m];$

$q = 10 + K_2\ [kN/m];\quad F = 10 + K_4\ [kN];\quad M = 30 + K_3\ [kN\,m].$

Coursework 2: **Internal forces in planar frames**

A planar construction is supported and loaded, as shown.

1. Determine the support reactions;

2. Determine the internal forces functions in each segment;

3. Draw the internal forces diagrams on a suitable scale;

4. Check the internal forces functions and diagrams using the differential check, the check about the type of the diagrams, area check, the check about the steps in the diagrams and the check about the equilibrium of a joint.

DATA: $a = 2 + 0{,}1.K_4\ [m];\quad b = 3 + 0{,}2.K_3\ [m];\quad c = 2{,}5 + 0{,}3.K_2\ [m];\quad d = 2\,m;$

$q = 15 + K_4\ [kN/m];\quad F = 20 + K_3\ [kN];\quad M = 40 + K_2\ [kN\,m];\ t = 10 + K_2\ [kN/m].$

Coursework 3: **Internal forces in spatial constructions**

A spatial construction is supported and loaded, as shown.

1. Determine the support reactions;

2. Determine the internal forces functions in each segment;

3. Draw the internal forces diagrams on a suitable scale;

4. Check the internal forces functions and diagrams using the differential check, the check about the type of the diagrams, area check, the check about the steps in the diagrams and the check about the equilibrium of a joint.

DATA: $a = 3 + 0{,}1.K_2\ [m];\quad b = 4 + 0{,}1.K_4\ [m];$

$q = 10 + K_2\ [kN/m];\quad t = 12 + K_2\ [kN/m];\quad m_t = 15 + K_2\ [kN\,m/m];$

$F = 10 + K_4\ [kN];\quad M = 30 + K_3\ [kN\,m].$

Coursework 4: **Plane stress problem**

The normal and shearing stresses on two mutually perpendicular planes in the vicinity of a point belonging to the body worked in plane stress are given:

$\sigma_x = (-1)^{K3}(3 + 0{,}1K_4)\left[kN/cm^2\right];\qquad \sigma_y = (-1)^{K2}(2 + K_4)\left[kN/cm^2\right];$

$\tau_{xy} = \tau_{yx} = (-1)^{K4}(2 + 0{,}3.K_3)\left[kN/cm^2\right].$

Determine:

1. The principal normal stresses σ_1 and σ_2, and the angles α_1 and α_2 at which their normal axis are inclined with respect to x-axis;

2. The extreme values of the shearing stresses τ_{max} and τ_{min}, and the corresponding normal stress σ_{med};

3. The normal stress σ_α and the shearing stress τ_α on the plane inclined at an angle $\alpha = (-1)^{K2}(25 + K_3)^0$ with respect to x-axis.

Solve the problem analytically and graphically!

Coursework 5: **Principal axes and principal moments of inertia**

Determine analytically the principal axes and the principal moments of inertia of the plane figure shown. Draw the axes on the figure.

DATA: $a = 15 + 0{,}1.K_2\ [cm];\quad b = 12 + 0{,}1.K_4\ [cm].$

Coursework 6: **Statically indeterminate structures subjected to pure tension/compression**

- **Variants 1 – 15 and 27 - 30**

A rigid beam is supported and loaded, as shown in the figure. The rods 1 and 2 are made of steel, while their cross-sectional areas are A_1 and A_2, respectively.

1. Determine the support reactions and the forces in the rods 1 and 2;

2. Determine the cross-sectional areas A_1 and A_2 with accuracy of 0,1 cm^2;

3. Find the vertical displacement of section D in centimeters;

3. Check the normal stresses in the rods caused by the change of temperature $\Delta t = (-1)^{K_2}(30+K_4)\left[{}^0C\right]$ on the surface of rod 1. The coefficient of the linear thermal expansion of a steel is $\alpha_t = 10^{-5}\,\frac{1}{{}^OC}$, and the steel modulus of elasticity is $E = 2.10^4\ kN/cm^2$. The allowable normal stresses of a steel is also given: $\sigma_{allow} = 16\ kN/cm^2$.

- **Variants 16 – 26**

A steel column is supported and loaded, as shown in the figure.

1. Build an axial force diagram;

2. Determine the cross-sectional areas A_1 and A_2 with accuracy of 0,1 cm^2;

3. Find the displacement of section B in centimeters;

4. Check the normal stresses in the column caused by the change of temperature $\Delta t = (-1)^{K_2}(30+K_4)\left[{}^0C\right]$ on its surface. The coefficient of the linear thermal expansion of a steel is $\alpha_t = 10^{-5}\,\frac{1}{{}^OC}$, and the steel modulus of elasticity is $E = 2.10^4\ kN/cm^2$. The allowable normal stresses of a steel is also given: $\sigma_{allow} = 16\ kN/cm^2$.

DATA: $a = 2+0{,}1K_3\ [m];\quad b = 1{,}6+0{,}3K_3\ [m];\quad c = 1{,}8+0{,}2K_3\ [m];$

$$F = 400+K_2\ [kN];\quad \alpha = 30+K_4\ [{}^o];$$

$$\frac{A_1}{A_2} = 1{,}5+0{,}1.K_2,\quad t = 30+K_2\left[\frac{kN}{m}\right]\ .$$

***Coursework 7*:** **Special case of bending**

Variants 1 – 9 and 14 – 30

The steel beam is supported and loaded, as shown.

1. Build the internal forces diagrams;

2.1. <u>Cross-sections which dimensions depend on a parameter “**d**”:</u>

Determine the magnitude of the parameter “**d**” with accuracy of 1mm using the maximum normal stresses condition and check the result applying the maximum shearing stresses condition and the principal stresses condition (IV-th theory of failure);

2.2. <u>Cross-sections formed by steel profile(s):</u>

Determine the number of the profile(s) using the maximum normal stresses condition and check the result applying the maximum shearing stresses condition and the principal stresses condition (IV-th theory of failure);

3. Draw the normal and shearing stresses diagrams of the beam sections investigated;

4*. Determine the vertical displacement and the angle of rotation of section C using the integrals of Maxwell-Mohr solved by the rule of Vereschagin.

$\sigma_{allow} = 16\ [kN/cm^2]; \quad \tau_{allow} = 10\ [kN/cm^2]; E = 20000\ [kN/cm^2].$

Variants 10 – 13

The steel beam is supported and loaded, as shown in the figure, where all of the loads are expressed in a function of the intensity of distributed load “**q**”.

1. Build the internal forces diagrams in a function of “**q**”;

2. Determine the magnitude of “**q**” with accuracy of 1kN/m using the maximum normal stresses condition and check the results applying the maximum shearing stresses condition and the principal stresses condition (IV-th theory of failure);

3. Draw the normal and shearing stresses diagrams of the beam sections investigated;

4*. Determine the vertical displacement and the angle of rotation of section C using the integrals of Maxwell-Mohr solved by the rule of Vereschagin.

$a = 3 + 0{,}1.K_2\ [m]; \quad b = 4 + 0{,}1.K_4\ [m]; \quad c = 2 + 0{,}1.K_3\ [m];$

$d = 1 + 0{,}1K_2\ [cm];$

$\sigma_{allow} = 16\ [kN/cm^2]; \quad \tau_{allow} = 10\ [kN/cm^2]; E = 20000\ [kN/cm^2].$

*** Condition 4 is the last coursework. Its solution will be considered in the end of the semester!**

***Coursework 8*:** **General case of bending**

The beam is supported and loaded, as shown.

1. Build the internal forces diagrams;

2. Design the rectangular cross-section, if the beam is made of wood, according to the condition that the ratio $\frac{h}{b} = \left|\frac{M_y}{M_z}\right|$, but $\frac{h}{b} \in [0,5;2]$. Build the normal stresses diagrams and the shearing stresses diagrams of the sections investigated. $\sigma_{allow} = 1\,[kN/cm^2]$; $\tau_{allow} = 0,2\,[kN/cm^2]$;

3. Design the cross-section of the shape shown, if the beam is made of steel. Build the normal stresses diagrams of the section investigated. $\sigma_{allow} = 16\,[kN/cm^2]$.

***Coursework 9*:** **Deflection of beams**

The steel beam is supported and loaded, as shown.

1. Build the internal forces diagrams;

2. Write the kinematical boundary conditions;

3. Apply the Mohr's analogy method to determine the vertical displacement of section B and the angle of rotation of section C.

$E = 2.10^4\ kN/cm^2$; $I_1 = (15000 + 3k_4)\,kN/cm$ $\frac{I_1}{I_2} = 1.5 + k_3$

$a = 2.6 + 0,1K_3\ [m]$; $b = 3 + 0,3K_3\ [m]$;

$q = 5 + K_4\ [kN/m]$; $F = 20 + K_3\ [kN]$; $M = 30 + K_2\ [kNm]$

***Coursework 10*:** **Beams subjected to bending combined with shear and tension/compression**

The steel construction is supported and loaded, as shown.

1. Build the internal forces diagrams;

2. Design the cross-section of **I**-profile in the segment ***AC*** using the maximum normal stresses

condition and check the results applying the maximum shearing stresses condition and the principal stresses condition (IV-th theory of failure);

3. Draw the normal and shearing stresses diagrams of the sections investigated;

4*. Apply the integrals of Maxwell-Mohr solved by the rule of Vereschagin to determine:

- Variants 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23 – the vertical displacement of section C ;

- Variants 6 and 18 – the horizontal displacement of section C ;

- Variants 12 and 24 – the slope of section C .

$a = 3 + 0{,}1K_3\ [m];\quad b = 4 + 0{,}3K_3\ [m];\quad c = 2 + 0{,}2K_3\ [m];$ **A** – cross-sectional area of the link

$q = 5 + 0.1K_4\ [kN/m];\quad F = 20 + K_3\ [kN];\quad M = 30 + K_2\ [kNm]$

$\sigma_{allow} = 16\left[kN/cm^2\right];\quad \tau_{allow} = 10\left[kN/cm^2\right];\ E = 2.10^4\ kN/cm^2$

**** Condition 4 is the last coursework. Its solution will be considered in the end of the semester!***

***Coursework 11*:** **Eccentrically loaded members.**

Kern of the cross-section

- **Variants 1 – 15**

A short cast-iron column of the cross-section given is subjected to a **tensile** force F .

1. Determine the magnitude of the force, if its point of application is C_0 ;

2. Draw the normal stresses diagram;

3. Build the kern of the cross-section.

$\sigma_{allow,c} = 10\ kN/cm^2,\ \sigma_{allow,t} = 5\ kN/cm^2;$

$a = 4 + 0{,}1K_3\ [cm];\quad b = 5 + 0{,}3K_3\ [cm];\quad c = 3 + 0{,}2K_3\ [cm];$

- **Variants 16 – 30**

  A short cast-iron column of the cross-section given is subjected to a **compressive** force F .

  1. Determine the magnitude of the force, if its point of application is C_0 ;

  2. Draw the normal stresses diagram;

  3. Build the kern of the cross-section.

$\sigma_{allow,c} = 10\, kN / cm^2$, $\sigma_{allow,t} = 5\, kN / cm^2$;

$a = 4 + 0{,}1K_3\, [cm]$; $b = 5 + 0{,}3K_3\, [cm]$; $c = 3 + 0{,}2K_3\, [cm]$;

***Coursework 12*:** **Buckling of columns**

- **Variants 1, 5, 8, 10, 13, 17, 18, 19, 20 и 29**

  The steel column of the cross-section given is supported and loaded, as shown. Determine:

  1. The magnitude of the parameter "**a**";

  2. The safety coefficient.

- $b = 2a$; $F = 500 + K_3\, [kN]$; $\sigma_{allow} = 16\, kN / cm^2$

- **Variants 2, 3, 4, 6, 7, 9, 11, 12, 14, 15, 16, 21, 22, 23, 24, 25, 26, 27, 28, 30**

  The steel column of the cross-section given is supported and loaded, as shown. Determine:

  1. The magnitude of the compressive force F ;

  2. The safety coefficient.

$$\sigma_{allow} = 16\, [kN / cm^2].$$