MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

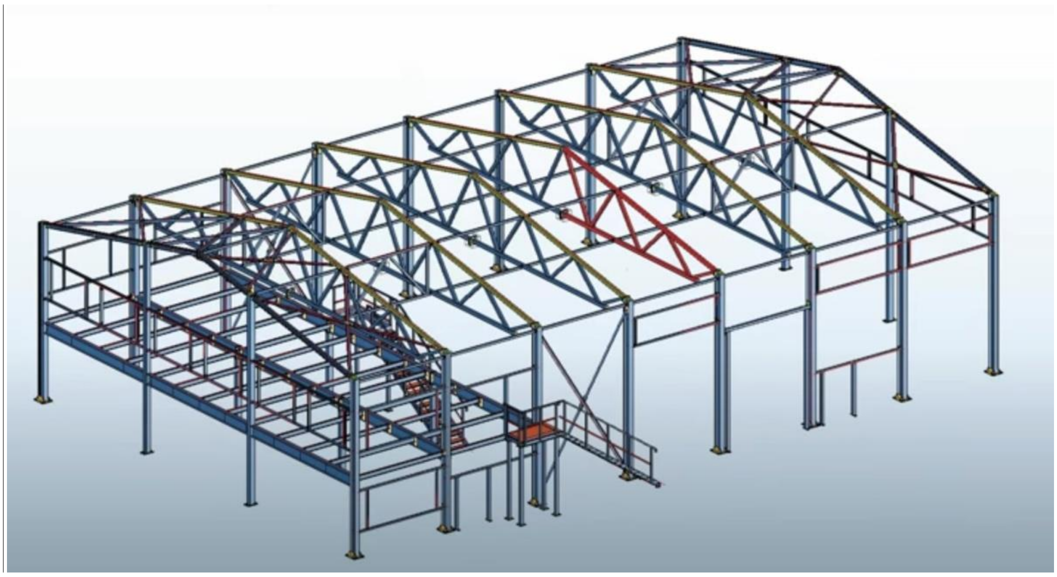
O. M. BEKETOV NATIONAL UNIVERSITY
of URBAN ECONOMY in KHARKIV

METHODOLOGICAL RECOMMENDATIONS

for independent and practical work
on the subject

«METAL STRUCTURES DESIGN»
(special course)

(for all educational forms Bachelor's Degree students
on specialty 192 – Building Industry and Civil Engineering,
of educational program "Civil and Industrial Engineering")



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CONTENT

INTRODUCTION

The educational discipline “Metal Structures Design. Special Course” is one of the profiling disciplines of the professional training of Bachelors in Engineering. The purpose of the discipline is to study the types, branches of rational use, structural forms and methods of designing load-bearing metal structures, buildings and structures of various purposes.

As a result of studying the academic discipline, the student should know the nomenclature, areas of rational use of metal structures, structural schemes, operation and design principles of the main types of load-bearing structures of industrial and civil buildings, types, structural schemes and features of structures design. In addition, the student learns to calculate and design elements and joints of metal structures, to develop calculation schemes of structures, to determine loads, forces in elements and their cross-sections, to design joints of common metal structures, to perform drawings of various MS brands. The ability to calculate and design steel structures, their elements and joints, to use normative and reference literature is acquired in practical classes.

The purpose of independent work of applicants is to study the theoretical part of the course in depth, to acquire the skills of calculation and construction of elements and joints of steel structures in accordance with current design standards, as well as the skills of using normative and reference literature.

Independent work of applicants is reduced to three tasks:

− studying the theoretical part of the course;

− obtaining the skills of calculating metal structures of common types;

− obtaining the skills of designing common steel structures types.

Applicants should organize their work in the specified areas according to the recommendations below, using the methodical guidelines, educational, regulatory and reference sources indicated in the list.

Normative documents, textbooks, training manuals, reference literature and methodical recommendations, necessary for independent study of the theoretical part of the course and acquisition of the necessary practical skills, are available on the distance education site of O. M. Beketov NUUE (URL: https://dl.kname.edu.ua).

1 STUDYING THE THEORETICAL PART OF COURSE

It is recommended to study the theoretical part of the course according to normative and educational literature [1−6]. The list of program questions below contains a summary of each question and detailed references to literature sources available to students in paper or electronic form.

During the studying program questions, based on the indicated sources, it is desirable to make a concise synopsis according to the given abstract of the question. This will help systematize knowledge of each question and speed up preparation for the exam. When writing the exam, the answers to the questions should be accompanied by construction sketches, calculation schemes, formulas and explanations, which should be found in the recommended textbooks [4, 5] and in the design standards [1−3].

In addition to theoretical questions, the exam includes simple tasks on the calculation of elements and joints of steel structures, samples of which are given in Section 4 of these methodological guidelines. Recommendations for its solution with references to design normative are also given for each problem [1−3].

2 LIST OF PROGRAM QUESTIONS AND RECOMMENDATIONS ABOUT THEIR STUDYING

Table 2.1 – Program questions

Content of program questions	References
1	2
1 Requirements and means of ensuring reliability of constructions Basic terms of reliability theory. Requirements for the reliability of building structures and means of its ensuring	[1] – section 4; [6] – question 2
2 Classification of construction objects and structures by responsibility and term of operation Classes of consequences (responsibility) of buildings and structures for SBN B.1.2-14-2009. Categories of construction responsibility. The terms of operation of buildings and structures are established	[1] – section 5, annex A; [3] – section 5.3, annex A; [6] – question 3
3 Loads from self-weight of structures and technological loads Determination of constant load, technological loads on the ceiling, loads from crane equipment	[2] – sections 5, 6, 7; [6] – question 8

Continuation of table 2.1

1	2
4 Atmospheric loads and influences Snow, wind and ice-wind load; influence of climatic temperature. Determination of atmospheric loads according to SBN B.1.2-2:2006	[2] – sections 8–11; [6] – question 9
5 Peculiarities of operation and design of crane beams Purpose, areas of application and requirements for crane beams. Loads and design efforts. Under-crane beams with and without braking platforms, features of operation and cross-section selection under the action of loads from bridge cranes. The operation of the upper chord zone of the crane beams and the principles of taking into account its stress state. Endurance requirements and their consideration in the design of crane beams. Design features of upper chord welds, stiffeners and support joints	[2] – section 7; [3] – par. 9.3, 17.7, section 5; [4] – p. 146–152; [5] – p. 425–451
6 System of truss connections Appointment and the main functions of the roof connections system. Rules for placing connections in the roofs of buildings of various purposes. Horizontal connections along the upper and lower chords of the trusses, vertical connections, spacers and stretchers. Peculiarities of designing connections on trusses of various structural forms. Work and calculation of roof conenctions	[3] – par. 17.2, 17.5; [4] – p. 109–110; [5] – p. 269–271, 322–326; [7] – section 1.1
7 Determination of loads and forces in truss rods Loads acting on the roof of industrial and public buildings. Determination of estimated values of constant, climatic and technological loads according to SBN (Eurocode). Calculation scheme and static calculation of rafter trusses. Determination of calculated forces in rods taking into account the most unfavorable combinations of loads	[2] – sections 5–9; [4] – p. 113–115; [5] – p. 275–277, 373–376; [7] – par. 1.3, 3.1
8 Calculated lengths and ultimate flexibility of truss rods Peculiarities of work under the load of trusses from angles and pipes when the stability of individual rods is lost. Justification of the coefficients of the reduction of the length of truss rods from equilateral angles and rolled I-beams, round and rectangular pipes (bent-welded closed profiles). Determination of the estimated length of the chords and rods of the lattice in the plane and from the plane of the truss according to SBN. Standardization of ultimate flexibility of compressed and stretched rods of trusses in SBN	[3] – par. 13.1, 13.4; [4] – p. 115–116; [5] – p. 277–278; [7] – par. 3.2
9 Selection of the type and cross-sections of rods of light trusses Types of cross-sections of rods of light trusses, their comparative analysis and areas of rational use. Selection of the type of cross-sections of rods from equilateral angles, rolled I-beams and rectangular tubes for chords and lattices of trusses in accordance with the ratio of calculated lengths and structural requirements. Calculation of truss rods for central compression and tension, selection of sections to ensure strength, stability, ultimate flexibility and structural requirements. Design and installation of connecting spacers in truss rods from paired angles	[3] – par. 8.1, 13.4; [4] – p. 116–117; [5] – p. 271–273, 279–283; [7] – par. 3.2
10 Design of intermediate truss joints Design and calculation of intermediate joints of rafter trusses from paired angles and trusses with chords made of rolling I-beams (the order of determining the size of the welds for attaching the lattice rods to the profiles). Basics of construction and calculation of truss joints from square, rectangular and round pipes (unshaped connections of lattice rods with chords with fillet or butt welds). Intermediate joints of the trusses in the zones where the cross-sections of the chord is variable	[3] – par. 16.1, 17.3; [4] – p. 117–128; [5] – p. 284–287, 291–295, 387; [7] – par. 3.3

Continuation of table 2.1

1	2
11 Support joints of trusses The construction of the support joints of the trusses from paired angles and rolled I-beams, round and rectangular pipes with hinged support on steel columns. Calculation of the cross-section of the support flange and welds of its fastening. The design of the support joints of the trusses. Calculation of the plan area and thickness of the base plate. Construction of fasteners using anchor bolts	[3] – section 11, par. 16.1, 17.3; [4] – p. 117–128; [5] – p. 290–291, 294, 296, 376–380, 387; [7] – par. 3.4
12 Assembly joints of light trusses The necessity for arrangement and requirements for the design of the enlarging assembly joints of the trusses. Designs of enlargement joints: with overlays on welding, with overlays on friction high-strength bolts, with flanges and high-strength bolts. The calculation procedure and features of the design of joints of the specified types	[3] – par. 16.1, 16.3, 17.3, 17.12, 17.14; [4] – p. 117–128; [5] – p. 287–289, 295; [7] – par. 3.5
13 Design features of heavy trusses Design features of heavy trusses. Types of sections of rods of heavy trusses. Peculiarities of operation, calculation and construction of truss chords in the presence of extranodal loads. Separation of heavy trusses into halves and their transportation. Principles of construction of heavy truss joints on assembly welding and high-strength bolts	[5] – p. 273–274, 283–284, 297–298
14 Layout of frames of one-story industrial and civil buildings Purpose and types of one-story buildings. General structural scheme and frame elements. Rafter and under-rafter trusses, fence structures, columns and under-crane beams, their functions. The general scheme of frame connections. Grid of columns, thermal seams and their constructive solutions	[3] – par. 17.2, 17.5; [4] – p. 103–106, 110; [5] – p. 302–310, 311–313, 326–333
15 Connections of frame system of one-story industrial buildings Purpose and schemes of frames connections of a one-story building. Vertical connections on columns and trusses, beams on the upper and lower chords of the trusses. Functions, installation requirements and construction of conections. Loads perceived by connections, principles of selection of sections and construction of joints	[3] – par.17.5; [4] – p. 108–110; [5] – p. 319–326, 333–335
16 Layout of the transverse frame of a one-story industrial building Initial technological and architectural data for the layout of the transverse frame. The procedure for determining the main dimensions of the frame and its elements: the span, marks of the crane beams, the bottom and top of the crossbar, the highest point of the building, the structural diagram of the crossbar, the structural diagram and the width of the columns (upper and lower parts in the presence of crane structures), deepening of the foundation. Types of crossbar connection with columns	[4] – p. 106–108; [5] – p. 313–318
17 Loads on the frame of a one-story industrial building and determination of forces in the elements of the transverse frame List of loads acting on the frame: permanent, atmospheric, crane, technological. The procedure for determining loads according to standard SBN B.1.2-2:2006 “Loads and influences”. The method of determining the equivalent wind load on the transverse frame. Establishing a list of possible frame loads and performing a static calculation for the action of permanent, atmospheric and technological loads	[2] – sections 5, 7, 8, 9; [4] – p. 128–136; [5] – p. 336–348

Continuation of table 2.1

1	2
18 Types of columns of one-story industrial buildings and their fields of application Columns of constant cross-section as an element of public and craneless industrial buildings. Columns with consoles for overhead cranes of small capacity. Stepped columns of industrial buildings. Schemes of solid and cross-section columns. Comparative analysis of columns of different types. Principles of column type selection and cross-sectional layout	[4] – p. 136–137; [5] – p. 391–392
19 Determination of design forces in columns of one-story industrial buildings Rules for taking into account the joint action of loads. Coefficient of load coupling. Determination of forces in calculated cross-sections of columns under the action of various combinations of loads. Selection of calculated combinations of forces for the design of columns of constant cross-section and stepped columns	[4] – p. 136, 138; [5] – p. 362–365
20 Estimated column lengths of one-story industrial buildings Ensuring stability of the columns in the plane and out of the plane of the transverse frame. Idealized schemes for securing the ends of columns in single-span and multi-span frames and calculated lengths of columns of constant cross-section in the plane of the frame. Factors affecting the calculated length of the upper and lower parts of stepped columns in the plane of the frame and the order of their determination according to SBN B.2.6-163:2014 (Eurocode). Determination of the calculated length of columns according to the scheme of vertical connections	[3] – par. 13.3; [4] – p. 137–138; [5] – p. 392–396
21 Types and selection of cross-sections of continuous eccentrically compressed columns Types of cross-sections of rolled and folded eccentrically compressed columns. Limit states of an eccentrically compressed rod and initial data for calculation. Layout of the cross-section, verification of strength and stability in the plane of action of the bending moment (in the plane of the frame) according to SBN B.2.6-163:2014 (Eurocode 3). Verification of stability from the plane of action of the bending moment. Ensuring the local stability of the wall and shelf of eccentrically compressed column of a folded I-beam cross-section. Installation of transverse and longitudinal stiffeners	[3] – par. 10.1, 10.2, 10.4; [4] – p. 138–139; [5] – p. 396–400
22 Types and selection of cross-sections of double-branch eccentrically compressed columns Types and principles of arrangement of cross-sections of double-branch eccentrically compressed columns. Limit states of eccentrically compressed rod and initial data for calculation. The order of selection of the section of individual branches of the column from the conditions of stability in the plane and from the plane of the frame as centrally compressed rods. Development of the scheme of the connecting lattice taking into account the stability of the column branches in the plane of the transverse frame. Checking the stability of the column as a whole in the plane of action of the bending moment (in the plane of the frame) according to Eurocode 3 or standard SBN B.2.6-163:2014. Stiffness diaphragm setting	[3] – par. 8.1, 10.3; [4] – p. 139–141; [5] – p. 401–403

Ending of table 2.1

1	2
23 Grids of eccentrically compressed columns The selection of the lattice scheme taking into account the width of the double-branch column and ensuring the stability of the branches in the plane of the transverse frame. Force factors for lattice calculation: actual and conditional transverse force. Determination of forces in braces and rods of the column lattice. Selection of cross-sections of lattice elements for central compression, taking into account the additional coefficient of working conditions according to SBN B.2.6-163:2014. The construction of the attachment joints of the lattice elements to the column branches	[3] – par. 10.3.7, 8.1.3, 8.1.4, 8.2.7, 8.2.9, table 5.1; [4] – p. 141; [5] – p. 402–403
24 Column heads with hinged and rigid connection Designs of heads with hinged connection of the crossbar from above. Calculation of the thickness of the head rib and its connection to the column. Design of a rigid connection joint of a rafter truss with a column. Calculation of the support table for the vertical load from the crossbar. Design and calculation of the upper chord fastening unit on the flange and bolts or on the overlays. Designs of the joint of rigid fastening of the bolt-beam on the horizontal overlay or on the flange with high-strength bolts and its calculation	[3] – par. 16.1, 16.2, 17.4, 17.14; [4] – p. 119–120, 123, 141–142; [5] – p. 376–380
25 Joint of the upper and lower part of the stepped column of a one-story industrial building Requirements for the assembly, its construction, loads and forces transmitted through the assembly. Calculation and construction of the main elements of the joint: selection of the cross-section from the conditions of bending, shear and compression under the supporting ribs of the under-crane beams, welds of fastening the shelf of the upper part of the column to the cross-beam and the cross-arm to the under-crane branch of the lower part, overlays and welds of fastening the shelf of the upper part of the column to the tent branches of the lower part	[3] – par. 9.2, 16.1, 17.14; [4] – p. 142–143; [5] – p. 404–409
26 Bases of eccentrically compressed columns Functions and types of bases of eccentrically compressed columns. Design of a separate base of a double-branch column and a combined base for a column of a continuous cross-section. The procedure for constructing the calculation of a separate base for a separate branch and its differences from the base of a centrally compressed column. Determining the dimensions of the support plate of the base for the column of a solid section from the condition of the strength of the foundation. Calculation of the welds of the fastening of the traverses to the rod of a solid column, taking into account the effect of longitudinal force and bending moment	[3] – section 11; [4] – p. 143–145; [5] – p. 409–414
27 Operation and calculation of anchor bolts Purpose of anchor bolts. Selection of a combination of forces for the calculation of anchor bolts. Determination of forces in anchor bolts in the case of a separate base of a double-branch column and a combined base under a column of solid section. Selection of the cross-section of anchor bolts from the conditions of tensile work. Structural requirements for anchor bolts and their installation in the foundation. Calculation of the plate for attaching anchor bolts to the cross-arm	[3] – par. 16.2.9, 16.2.15; [4] – p. 144–145; [5] – p. 412–413

3 GENERAL RECOMMENDATIONS FOR IMPLEMENTATION OF INDIVIDUAL TASK

Each student receives an individual task for performing calculation and graphic work (CGW) with the necessary initial data. Students complete the task independently, prepare it and defend it during the semester or on the eve of the exam. During the implementation of CGW, one should be guided by methodical recommendations [6], as well as normative and reference literature [1−3].

Students need to follow the general rules for calculating metal structures:

− all calculations are performed according to SBN B.2.6-198:2014, references to which are given in the problem solving algorithms;

− when performing calculations, one should pay attention to the agreement of the dimensions of the values included in the calculation formulas. Experience shows that a significant part of errors in calculations occurs precisely as a result of using incorrect dimensions. As a rule, static calculations of structures are performed in meters and kilonewtons, and in the formulas of SBN [3] for calculations of elements and connections, all values are substituted in kilonewtons and centimeters;

− when performing calculations of steel structures, it is recommended to use the system of measurement units, which are derived units of the international SI system of units. Recommended units of measurement are described in table 3.1.

Table 3.1 – Recommended units of measurement

<table>
<tr><th colspan="2">Magnitude</th><th>Marking</th><th>Units</th><th>Conversion of value</th></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td colspan="2">Overall dimensions of structures</td><td>meters</td><td>m</td><td>1 m = 100 cm</td></tr>
<tr><td colspan="2">Dimensions and geometric characteristics of cross sections</td><td>centimeters</td><td>cm</td><td>1 cm = 10 mm</td></tr>
<tr><td colspan="2">Loads evenly distributed over the area</td><td>pascal</td><td>Pa</td><td>1 kN/m^2 = 1 000 Pa</td></tr>
<tr><td colspan="2">Concentrated loads, longitudinal and transverse forces</td><td>kilonewtons</td><td>kN</td><td>1 kN = 1 000 N</td></tr>
<tr><td rowspan="2">Bending, twisting and other moments of forces</td><td>in static calculations</td><td>kilonewtons on meter</td><td>kN·cm</td><td rowspan="2">1 kN·m = = 100 kN·cm</td></tr>
<tr><td>during verification of cross-sections</td><td>kilonewtons on centimeter</td><td>kN·cm</td></tr>
<tr><td colspan="2">Characteristic and calculated resistances and stresses in structures</td><td>kilonewtons on centimeter</td><td>kN/cm^2</td><td>1 kN/cm^2 = 10 MPa</td></tr>
</table>

The results of calculations are drawn up in the form of an explanatory note, which contains initial data, calculation formulas and tables, concise explanations, graphic illustrations.

During implementation of CGW, one should use design standards [1−3], textbooks [4, 5], reference materials and methodological instructions [6], which detail the procedure for performing CGW with references to normative, referentail and educational literature. If necessary, the student can get advice from the lecturer.

CGW consists of an explanatory note with the necessary calculations and justifications for the adopted technical decisions, as well as drawings of the developed joints of steel structures of the MS brands. The content and procedure for performing CGW on the topic “Calculation and design of steel roof truss joints” is reflected in methodological guidelines [6]. The explanatory note to CGW contains:

- static calculation and selection of cross-sections of truss rods;
- calculation of intermediate, support and mount truss joints;
- drawings of joints are performed on sheets of A4 format at a scale of 1:10.

During the implementation of CGW, it is verified step by step by the lecturer during consultations in order to identify and eliminate errors at the early stages of calculations, discussion and selection of appropriate technical solutions. The completed individual task is drawn up in accordance with the requirements of methodical guidelines [6]. Defense of CGW takes place before passing the exam.

4 RECOMMENDATIONS FOR PRACTICAL WORK

The purpose of practical classes is to acquire the skills of calculation and construction of elements and connections of steel structures in accordance with current design standards, skills of using normative and reference literature. Students solve typical tasks that are often encountered in design practice: calculation and construction of steel structures and their elements under central and off-center tension and compression; welded and bolted connections. In order to successfully solve the problems, it is necessary to use the current regulatory documents [1−3] and reference literature, which are referenced in the text of methodological guidelines, as well as to study the relevant sections of educational publications [4−6].

4.1 Calculation of elements of metal structures under different types of deformations

Purpose of class: to study the methods of calculating elements of steel structures according to SBN B.2.6-198:2014 Steel structures design (design under central and off-center compression and tension).

Initiat data: an individual task that contains the characteristics of structural elements necessary to verify and determine their bearing capacity under various types of deformations.

List of tasks of the practical class:

– verification of the strength and stiffness of the element under conditionally central tension, determining its bearing capacity according to the criteria of strength and stiffness;

– verification of stability and determination of the load-bearing capacity of a conditionally centrally compressed rod;

– verification of the strength and stability of an eccentrically compressed rod in the plane of action of the bending moment.

Algorithms for solving these problems are presented below with references to normative and reference literature, which applicants should use in the process of work. In order to clarify the order of performing calculations, setting and converting the dimensions of calculation parameters, the algorithms are accompanied by numerical examples.

4.1.1 Calculation of a conditionally centrally loaded rod

Perform a stability check and determine the load-bearing capacity of a rod hinged at the ends under conditional central tension and compression with the following data: length of the rod L = 2,4 m; section – angle ∟100×8; material – steel grade C255; the ultimate calculated value of the longitudinal force N = 150 kN; coefficient of working conditions γ_c = 1; the coefficient of responsibility γ_n = 1.

Calculation algorithm:

1) according to the assortment of rolled equilateral angles, we determine the geometric characteristics of the cross-section: area A = 15,6 cm^2 and the radius of inertia relative to the axis of least stiffness i_x = 1,98 cm;

2) according to table D.2 SBN [1], taking into account the thickness of the shaped rolled production t = 8 mm, we determine the calculated resistance of steel C255: R_y = 25,0 kN/cm^2;

3) since the ends of the rod are hinged, the calculated length coefficient is equal to μ = 1, the ultimate flexibility and conditional flexibility of the rod to determine the stability coefficient according to [3] are equal to:

$$\lambda = \frac{l_{ef}}{i} = \frac{240}{1{,}98} = 121,$$

$$\bar{\lambda} = \lambda\sqrt{\frac{R_y}{E}} = 121 \times \sqrt{\frac{25}{20600}} = 4{,}22\,;$$

4) within accordance with table 8.1 [3], the calculation should be carried out according to the stability curve of type “b”, for which, according to table A.2, we obtain the stability coefficient φ = 0,419;

5) checking stability according to the formula (8.3) of SBN [3]:

$$\frac{N \cdot \gamma_n}{\varphi \cdot A \cdot R_y \cdot \gamma_c} = \frac{150 \times 1}{0{,}419 \times 15{,}6 \times 25 \times 1} = 0{,}92 \le 1;$$

6) load-bearing capacity of the rod under tension N_t and under compression N_c according to formulas (8.1) and (8.3) SBN [3], are equal to:

$$N_t = \frac{A \cdot R_y \cdot \gamma_c}{\gamma_n} = \frac{15{,}6 \times 25 \times 1}{1} = 390\,\text{kN},$$

$$N_c = \frac{\varphi \cdot A \cdot R_y \cdot \gamma_c}{\gamma_n} = \frac{0{,}419 \times 15{,}6 \times 25 \times 1}{1} = 163{,}4\,\text{kN};$$

7) comparison of the values of N, N_c and N_t shows that the rod can withstand a compressive load of 13,4 kN more than the specified one, and its bearing capacity in tension is 2,4 times greater than in compression.

4.1.2 Calculation of eccentrically compressed rod

It is necessary to perform a stability verification in the plane of action of the bending moment of an eccentrically compressed rod with a free upper end and rigid anchoring in the foundation with the following data: length L = 2,8 m; limit calculated values of longitudinal force N = 120 kN; bending moment M = 11,4 kNm; cross-section – rectangular bent closed profile 140×60×6; construction material – steel grade C235; coefficient of working conditions γ_c = 1; the coefficient of responsibility γ_n = 1.

Calculation algorithm:

1) according to the assortment of bent closed profiles we determine the geometric characteristics of the cross-section: area A = 22,8 cm^2, moment of resistance W = 65,6 cm^3 and the radius of inertia relative to the axis of greater rigidity i_x = 4,68 cm;

2) according to table D.2 of the SBN [3], taking into account the thickness of the rolled sheet t = 6 mm, we need to determine the calculated resistance of C 235 steel: R_y = 23,0 kN/cm^2;

3) within accordance with table 13.7 SBN [3] with a rigidly fixed lower and free upper end of the rod, the coefficient of the calculated length μ = 2;

4) ductility and conditional flexibility of the rod are equal to:

$$\lambda = \frac{l_{ef}}{i} = \frac{\mu \times L}{i} = \frac{2 \times 280}{4{,}68} = 120\,,$$

$$\bar{\lambda} = 120\sqrt{\frac{R_y}{E}} = 121 \times \sqrt{\frac{23}{20600}} = 4{,}00\,;$$

5) the relative eccentricity of the load according to par. 10.2.2 SBN [3]:

$$m_x = \frac{e \cdot A}{W_c} = \frac{M \cdot A}{N \cdot W_c} = \frac{1140 \times 22{,}8}{120 \times 65{,}6} = 3{,}30\,;$$

6) the ratio of the areas of the shelf and the wall of the profile is equal to:

$$\frac{A_f}{A_w} = \frac{60 \times 6}{2 \times (140 - 12) \times 6} = 0{,}23;$$

7) the coefficient of influence of the cross-sectional shape is determined according to SBN [3]:

$$A_f / A_w = 0{,}23 \approx 0{,}25,$$

$$\eta = (1{,}45 - 0{,}05\, m_x) - 0{,}1\,(5 - m_x),$$

$$\overline{\lambda} = (1{,}45 - 0{,}05 \times 3{,}3) - 0{,}1\,(5 - 3{,}3) \times 4{,}0 = 0{,}545;$$

8) reduced relative eccentricity according to formula (10.7) SBN [3]:

$$m_{ef} = \eta\, m_x = 0{,}545 \times 3{,}30 = 2{,}00;$$

9) the coefficient of stability under off-center compression of the rod is determined according to SBN [3] depending on the conditional flexibility according to point 3 and the given relative eccentricity:

$$\varphi_e = 0{,}256;$$

10) the stability verification is performed according to the formula (10.6) of SBN [3]:

$$\frac{N \cdot \gamma_n}{\varphi_a \cdot A \cdot R_y \cdot \gamma_c} = \frac{150 \times 1}{0{,}256 \times 22{,}68 \times 23 \times 1} = 0{,}894 \le 1.$$

The test showed that the stability of the eccentrically compressed rod in the plane of action of the bending moment is ensured with a margin of 11%.

4.2 Calculation and design of metal structures joints

Purpose of the class: to study the calculation methods of welded and bolted connections of steel structures according to SBN B.2.6-198:2014 Steel structures design.

Initial data: an individual task that contains the constructions of joints and the characteristics of the elements necessary for the calculation.

List of tasks of the practical class:

– design calculation of the joint with the sheet using frontal and flank welded corner seams;

– determination of the load-bearing capacity of the joints with double-sided overlays on bolts working on a cut;

– calculation of the frictional joints on high-strength bolts.

Algorithms for solving these problems are presented below with references to normative and referential literature, which applicants should use in the process of work.

4.2.1 Calculation of the joint with fillet weld

We need to determine the value of the overhang of the tape with a cross-section $b_c \times t_c$ = 120 mm × 16 mm on a sheet with a thickness of t_s = 10 mm, which is necessary for connection the tape with frontal and flank welds (Fig. 4.1). The connection should be calculated for the value of the load-bearing capacity of the tape in tension, taking into account the coefficient of operating conditions $\gamma_c = 1$ and the coefficient of responsibility $\gamma_n = 1$. The material of the connecting elements is C245 steel grade, manual welding with E-42A electrodes. Joints of welds take the maximum possible size, taking into account standard sizes k_f = 3 mm − 10 mm, 12 mm, 14 mm, 16 mm.

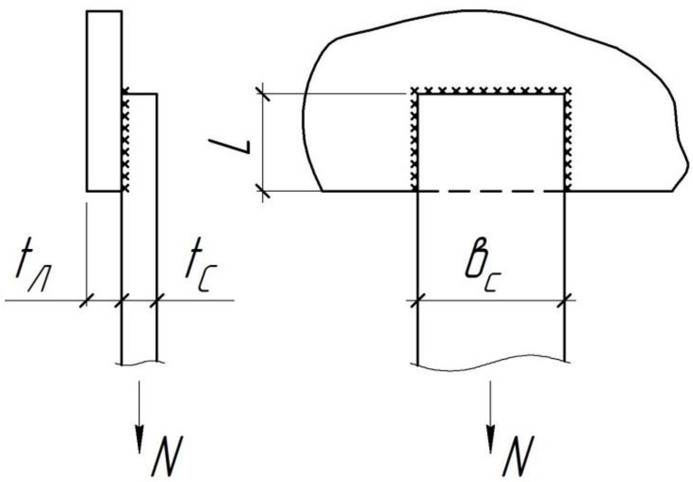

Figure 4.1 − Design of the weld connection, according to subsection 4.2.1

Calculation algorithm:

1) according to E.2 SBN [3] we need to determine the characteristic and calculated resistance of rolled sheet (of greater thickness) made of C245 steel grade: R_{un} = 37 kN/cm², R_y = 24 kN/cm²;

2) the load-bearing capacity of the tape under tension is calculated from the formula (1.4.1) SBN [3] taking into account the calculated resistance R_y = 24 kN/cm^2 and the cross-sectional area of the tape measuring 12 cm × 1,6 cm:

$$N = \frac{A_n \cdot R_y \cdot \gamma_c}{\gamma_n} = \frac{12 \times 1{,}6 \times 24 \times 1}{1} = 460{,}8\,\text{kN};$$

3) we determine the calculated resistances of corner welds made by electrodes E-42A, according to the weld metal R_{wf} = 18 kN/cm^2 (table D.2 SBN [3]) and according to the fusion border of metal $R_{wz} = 0{,}45R_{un}$ = 0,45 × 37 = 16,7 kN/cm^2 (table. 7.3 SBN [3]);

4) according to the recommendations of par. 16.1.5 SBN [3] we determine the maximum possible leg of a corner weld with rounding to the nearest smaller standard size: $k_f \le t_s$ = 16 mm, $k_f \le 1{,}2 \times t_s$ = 12 mm. Accepted $k_f \le$ 12 mm;

5) according to table 16.2 SBN [3], depending on the type of welding (manual), the position (lower) and the leg of the welds (k_f = 12 mm), we determine the coefficients of the shape of the weld β_f = 0,7 and β_z = 1,0;

6) from formulas (16.2) and (16.3) SBN [3] we determine the calculated lengths of welds from the conditions of the strength of the weld metal and the metal of the fusion boundary:

$$l_{wf} = \frac{N \cdot \gamma_n}{\beta_f \cdot k_f \cdot R_{wf} \cdot \gamma_c} = \frac{460{,}8 \times 1}{0{,}7 \times 1{,}2 \times 18 \times 1} = 30{,}5\ cm,$$

$$l_{wz} = \frac{N \cdot \gamma_n}{\beta_z \cdot k_f \cdot R_{wz} \cdot \gamma_c} = \frac{460{,}8 \times 1}{1{,}0 \times 1{,}2 \times 16{,}7 \times 1} = 23{,}0\ cm;$$

7) the required length of the overhang is determined by the larger calculated length of the weld, taking into account the length of the frontal welds, equal to the width of the tape b_c = 12 cm, and a gap of length k_f (during design of the connection according to Fig. 4.1, the gaps at both ends of the weld are opposite each other):

$$L = (30{,}5 - 12)/2 + 1{,}2 = 10{,}5\,cm.$$

Having converted the obtained value into millimeters with rounding up to 10 mm on the larger side, we finally accept the allowance of L = 110 mm.

4.2.2 Calculation of the joint on bolts acting on shear

Determine the load-bearing capacity of connecting tapes of C255 steel with a cross section of 140 mm × 16 mm with two-sided overlays with a cross-section of 140 mm × 12 mm on bolts acting on shear, according to the sample of Figure 4.2. The connection is made on bolts with a diameter of 16 mm, accuracy class B, strength class 5.6. The total number of bolts in the connection is 8. The coefficient of the working conditions of the bolted connection should be taken as equal: in the case of shearing – γ_b = 1, in the case of crumpling of the elements under the bolts of the accuracy class A – γ_b = 1, when the elements are crushed under bolts of accuracy classes B, C in a multi-bolt connection – γ_b = 0,9. The overall coefficient of operation of the structure γ_c = 1, and the coefficient of responsibility γ_n = 1.

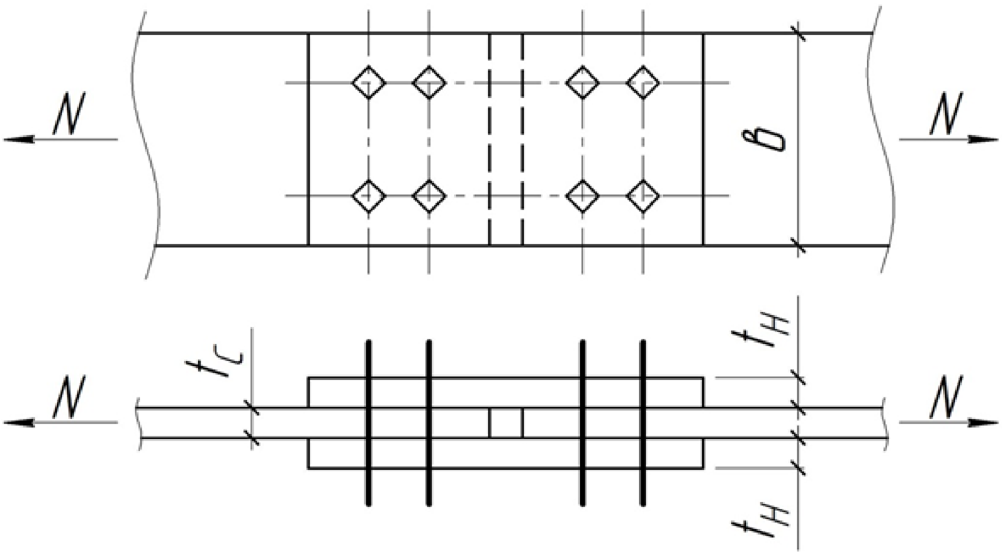

Figure 4.2 − Connection design with overlays, according to subsection 4.2.2

Calculation algorithm:

1) according to table SBN [3] we determine the estimated shear resistance of bolts of strength class 5.6 R_{bs} = 21 kN/cm^2;

2) according to table D.5 SBN [3] depending on the temporary resistance of the steel of the connecting elements R_{un} = 37 kN/cm^2, we determine the calculated resistance to crumpling under bolts of accuracy class B R_{bp} = 48,5 kN/cm^2;

3) cross-sectional area of the bolt A_b = 2,01 cm^2 is calculated from its nominal diameter, or is determined from table D.8 of the SBN [3];

4) a smaller amount of thicknesses of elements crumpled in one direction Σt =16 mm, determined by the design of the connection;

5) the coefficient of working conditions of the bolted connection should be determined according to table 16.4 depending on the number, location and accuracy class of the bolts. According to the conditions of the problem of a multi-bolt connection on bolts of accuracy class B, we accept γ_b = 1 in shear, and γ_b = 0,9 in bending;

6) using formulas (16.12) and (16.13) of SBN [3] we determine the load-bearing capacity of one bolt when sheared (2 shear planes) and crumpled:

$$N_{bs} = R_{bs} \cdot A_b \cdot n_s \cdot \gamma_b \cdot \gamma_c = 21{,}0 \times 2{,}01 \times 2 \times 1 \times 1 = 84{,}4\ kN,$$

$$N_{bp} = R_{bp} \cdot d_b \cdot \Sigma t_{\min} \cdot \gamma_b \cdot \gamma_c = 48{,}5 \times 1{,}6 \times 1{,}4 \times 0{,}9 \times 1 = 97{,}8\ kN;$$

7) according to the lower bearing capacity of one bolt (in our case – during shear) according to the formula (16.15) SBN [3] we determine the desired bearing capacity of the connection as a whole:

$$N = N_{b,\min} n_b / \gamma_n = 4 \times 84{,}4 / 1 = 337{,}6\ kN,$$

where n_b – the number of bolts on one side of the joint.

4.2.3 Calculation of the frictional connection on high-strength bolts

Determine the number of high-strength bolts in the frictional connection of the rod with the shape (Fig. 4.3) of the lattice structure and develop the diagram of the unit under the condition of single-row placement of bolts. The rod is made of two angles, placed together with wider shelves. Paired angle cross-section is accepted equal to ∟100 mm × 63 mm × 6 mm, static load on the joint (force in the rod) equal to N = 380 kN. Bolts made of steel 40X “select” should be chosen with the maximum possible diameter from the list of recommended ones (16 mm, 20 mm, 24 mm) with a difference in the diameter of the hole and the bolt up to 3 mm. The method of surface treatment is gas-flame.

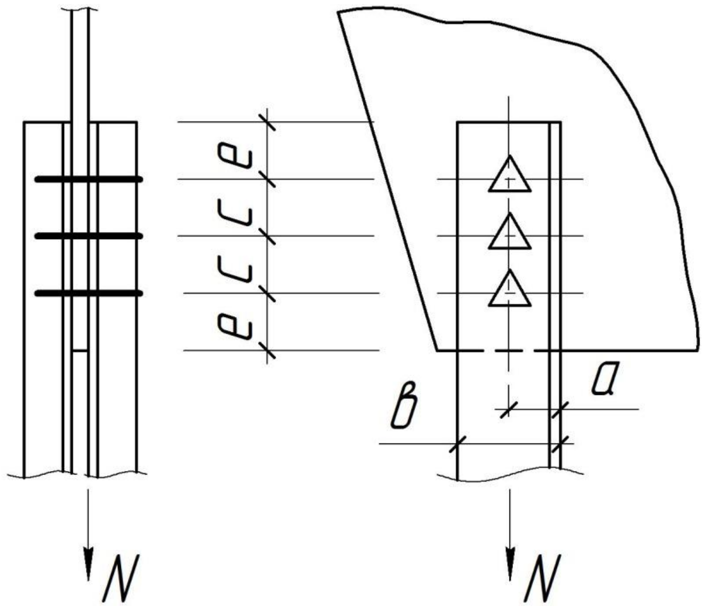

Figure 4.3 − Design of the connection on friction bolts, according to subsection 4.2.3

Calculation algorithm:

1) according to the assortment of rolled angles, given in appendix B, for a shelf with a width b = 100 mm, we determine the maximum possible diameter of the hole d = 23 mm and the value of the line a = 55 mm;

2) we select the maximum possible diameter of a high-strength bolt equal to d_b = 20 mm (recommended diameters – 16 mm, 20 mm, 24 mm), according to table D.7 SBN [3] we determine the calculated resistance of a bolt made of 40X steel R_{bh} = 77 kN/cm^2, from table D.8 SBN [3] we take the bolt net area A_{bn} = 2,45 cm^2;

3) from table 16.5 SBN [3] we select the coefficient of friction μ_s = 0,42 and the coefficient of reliability of the frictional connection γ_h = 1,12;

4) according to formula 16.17 SBN [3] we calculate the bearing capacity of one friction plane tightened by one high-strength bolt:

$$Q_{bh} = \frac{R_{bh} A_{bn} \mu}{\gamma_h} = \frac{77 \times 2{,}45 \times 0{,}42}{1{,}12} = 70{,}7\ kN;$$

5) the required number of bolts in the connection is determined by formula 16.18 SBN [3] taking into account the presence of two friction surfaces:

$$n = \frac{N \cdot A \cdot \gamma_n \cdot \mu}{Q_{bh} \cdot k \cdot \gamma_b \cdot \gamma_c} = \frac{380 \times 1}{70{,}7 \times 2 \times 0{,}8 \times 1} = 3{,}4 \approx 4 \text{ pcs};$$

6) coefficient of frictional connection operating conditions γ_b = 0.8 pre-accepted according to par. 16.3.4 SBN [3] for the number of bolts n < 5. If the calculated number of bolts does not correspond to the one taken into account when determining the coefficient γ_b, it should be recalculated with a refined value of γ_b;

7) we finally accept 4 bolts with a diameter of 20 mm. The construction of the connection consists in placing the bolts at minimum distances in accordance with the requirements of table 16.3 SBN [3]. As a margin of reliability, we consider that the characteristic resistance of the steel of the connecting elements R_{yn} > 390 MPa. Then, we accept the distance between the holes centers $3d = 3 \times 23 = 69 \approx 70$ mm, and the distance from the center of the hole to the edge of the element is taken equal to $2{,}5d = 2{,}5 \times 23 = 57{,}5 \approx 60$ mm. The total length of the corners on the pattern is equal to $3 \times 70 + 2 \times 60 = 330$ mm.

4.3 Determination of loads and forces in truss rods

Purpose of the class: to study the method of determining permanent and snow load on the truss according to SBN B.1.2-2:2006 Loads and influences and methods of determining forces in the truss rods.

Initial data: the scheme of the rafter truss, the type of roof and the area of construction.

The list and order of performance of the tasks of the practical class is determined according to [6], which should be guided in the process of working on the task:

1) for a given scheme of a rafter truss, determine the forces in the rods from the unit load on the joints;

2) with a given type of roof, develop its specific design in accordance with recommendations [6] and determine the operating and limit calculation value of the permanent load from the mass of the roof (per square meter of the horizontal projection of the roof). The calculation is performed in tabular form, guided by recommendations [6] and SBN B.1.2-2:2006 [2];

3) for the given construction area, guided by the recommendations of standard SBN B.1.2-2:2006 [2] and [6] regarding the determination of the snow load on the frame, establish the operational and limit calculation value of the snow load (per square meter of the horizontal projection of the roof);

4) determine the concentrated load at the joints of the truss from the mass of the roof and snow by multiplying the limit calculation values from points 2 and 3 by the size of the cargo area (multiplying the bay of the trusses by the distance between the joints);

5) in the table of forces in the truss rods, calculate the longitudinal forces in the rods from the action of permanent and snow loads by multiplying the corresponding forces from a single load by the value of permanent and snow loads in the truss joints from point 4. According to points 4.15–4.20 SBN B.1.2-2:2006 [2], the calculated forces in the truss rods are defined as the sum of the forces from the action of permanent and snow load with the coupling factor $\psi = 1$.

4.4 Selection of truss rods cross-sections

Purpose of the class: to study the methodology and acquire the ability to select cross-sections of centrally compressed and tensioned truss rods according to SBN B.2.6-198:2014 Steel structures design.

Initial data: truss scheme and forces in the rods, type of cross-section of the rods.

The list and order of performance of the tasks of the practical class:

1) based on SBN B.1.2-14-2009 [1] and SBN B.2.6-198:2014 [3] classify the truss and its elements (rods and profiles) and determine the numbers of the groups to which these structures belong;

2) guided by the knowledge gained in previous classes, select steel grades for truss rods and profiles and determine their design characteristics according to SBN B.2.6-198:2014 [3];

3) according to table 5 SBN B.1.2-14-2009 [1] determine the coefficient of responsibility γ_n for the design of the truss;

4) according to par. 5.4 SBN B.2.6-198:2014 [3] determine the coefficients of working conditions γ_c, necessary for the design of the truss;

5) according to the recommendations [6], select the cross-sections of chords, diagonals and verticals of the truss, taking into account the data specified in points 2, 3, 4. When calculating compressed rods, you can use the values of the stability coefficient given in Annex A. If possible, unify the selected cross-sections, avoiding this significant increase in the weight of the truss;

6) for truss rods from paired angles, determine the number of spacers necessary to ensure joint operation of the angles, according to recommendations [6] and par. 8.2.6 of SBN B.2.6-198:2014 [3].

4.5 Design of roof truss joints

Purpose of the class: to study typical designs, features of work and design methodology of intermediate, support and mount joints of light trusses.

Initial data: structural scheme of the building frame, forces and cross-sections of truss rods, selected in the course of practical exercises.

The list and order of tasks of the practical class:

1) after analyzing the cross-sections of the rods, select 2-3 cathetuses of welds that can be used to weld the truss. At the same time, one should follow the instructions of par. 16.1.5 of SBN B.2.6-198:2014 [3] and ensure that the selected weld cathetuses differ by no less than 2 mm;

2) according to the instructions of par. 16.1.16 of the SBN [3], determine the bearing capacity of one linear centimeter of each of the selected welds;

3) the recommendations [6] determine the welds cathetuses and lengths of the welds necessary for attaching each rod of the truss in the intermediate joints. When designing trusses from rectangular pipes, it is necessary to draw schemes of joints on a large scale, by which the length of the welds can be measured. In the case of cross-section of the fastening welds of adjacent rods, it is worth analyzing the possibility of replacing them with cross-sections with smaller overall dimensions;

4) guided by the recommendations [6], perform the calculations of the support joint of the truss, which include the determination of the dimensions of the support flange, the calculation of the welds of its attachment to the profile of the support joint or to the rods adjacent to this joint. The length of the flange fastening welds is measured on a scheme of the unit drawn on a sufficiently large scale;

5) select the design of the assembly connectionof the truss according to textbooks [46] and methodical recommendations [6]. Enlarging assembly joints of trusses from paired angles are usually performed on overlays. With chords made of rolled profiles and in trusses made of rectangular pipes, it is better to design mounting units on flange connections;

6) according to the recommendations [6], perform the calculation of the more loaded (as a rule, the lower) assembly joint of the truss. Flanged connections are designed taking into account the requirements of par. 17.12 of the SBN [3]. The calculation is accompanied by a joint scheme made on a sufficiently large scale.

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ANNEX A

Stability coefficients for the calculation of centrally compressed rods (according to SBN B.2.6-198:2014)

Table A.1 – Stability curve type "a"

$\bar{\lambda}$	0	0,02	0,04	0,06	0,08	$\bar{\lambda}$	0	0,02	0,04	0,06	0,08
0,3	1000	1000	1000	1000	1000	**4,7**	344	341	338	335	333
0,4	999	999	998	998	997	**4,8**	330	327	324	322	319
0,5	997	996	996	995	995	**4,9**	317	314	311	309	306
0,6	994	993	991	990	989	**5,0**	304	302	299	297	295
0,7	988	986	985	984	982	**5,1**	292	290	288	285	283
0,8	981	980	979	977	976	**5,2**	281	279	277	275	273
0,9	975	973	972	971	969	**5,3**	271	269	267	265	263
1,0	968	966	965	964	962	**5,4**	261	259	257	255	253
1,1	961	959	958	956	955	**5,5**	251	249	248	246	244
1,2	953	952	950	949	947	**5,6**	242	241	239	237	236
1,3	946	944	943	941	939	**5,7**	234	232	231	229	227
1,4	938	936	934	933	931	**5,8**	226	224	223	221	220
1,5	929	927	926	924	922	**5,9**	218	217	215	214	213
1,6	920	918	916	915	913	**6,0**	211	210	208	207	206
1,7	911	909	907	905	902	**6,1**	204	203	202	200	199
1,8	900	898	896	894	892	**6,2**	198	196	195	194	193
1,9	889	887	885	882	880	**6,3**	191	190	189	188	187
2,0	877	875	872	870	867	**6,4**	186	184	183	182	181
2,1	865	862	859	857	854	**6,5**	180	179	178	177	176
2,2	851	848	845	842	839	**6,6**	174	173	172	171	170
2,3	836	833	830	827	824	**6,7**	169	168	167	166	165
2,4	821	817	814	811	807	**6,8**	164	163	162	161	161
2,5	804	800	797	793	789	**6,9**	160	159	158	157	156
2,6	786	782	778	774	771	**7,0**	155	154	153	152	152
2,7	767	763	759	755	751	**7,1**	151	150	149	148	147
2,8	747	743	739	734	730	**7,2**	147	146	145	144	143
2,9	726	722	717	713	709	**7,3**	143	142	141	140	140
3,0	704	700	696	691	687	**7,4**	139	138	137	137	136
3,1	683	678	674	669	665	**7,5**	135	134	134	133	132
3,2	660	656	651	647	642	**7,6**	132	131	130	130	129
3,3	638	634	629	625	620	**7,7**	128	128	127	126	126
3,4	616	611	607	603	598	**7,8**	125	124	124	123	122
3,5	594	589	585	581	576	**7,9**	122	121	121	120	119
3,6	572	568	564	559	555	**8,0**	119	118	118	117	116
3,7	551	547	543	538	532	**8,1**	116	115	115	114	114
3,8	526	521	515	510	505	**8,2**	113	112	112	111	111
3,9	500	495	490	485	480	**8,3**	110	110	109	109	108
4,0	475	470	466	461	457	**8,4**	108	107	107	106	106
4,1	452	448	443	439	435	**8,5**	105	105	104	104	103
4,2	431	427	423	419	415	**8,6**	103	102	102	101	101
4,3	411	407	403	400	396	**8,7**	100	100	99	99	99
4,4	393	389	386	382	379	**8,8**	98	98	97	97	96
4,5	375	372	369	365	362	**8,9**	96	96	95	95	94
4,6	359	356	353	350	347	**9,0**	94	93	93	93	92

Table A.2 − Stability curve type “b”

$\bar{\lambda}$	0	0,02	0,04	0,06	0,08
0,3	1000	1000	1000	1000	1000
0,4	999	998	997	996	995
0,5	994	993	991	989	988
0,6	986	984	982	980	978
0,7	976	975	973	971	969
0,8	967	965	963	961	959
0,9	957	955	954	952	950
1,0	948	946	944	942	940
1,1	938	935	933	931	929
1,2	927	925	923	921	919
1,3	916	914	912	910	907
1,4	905	903	900	898	896
1,5	893	891	889	886	884
1,6	881	879	876	874	871
1,7	868	866	863	860	858
1,8	855	852	849	847	844
1,9	841	838	835	832	829
2,0	826	823	820	817	814
2,1	811	807	804	801	798
2,2	794	791	788	784	781
2,3	777	774	770	767	763
2,4	760	756	753	749	745
2,5	741	738	734	730	726
2,6	723	719	715	711	707
2,7	703	699	695	691	687
2,8	683	679	675	671	667
2,9	663	659	655	651	647
3,0	643	639	635	631	626
3,1	622	618	614	610	606
3,2	602	598	594	590	586
3,3	582	578	574	570	566
3,4	562	558	554	550	547
3,5	543	539	535	531	527
3,6	524	520	516	513	509
3,7	505	502	498	494	491
3,8	487	484	480	477	473
3,9	470	467	463	460	457
4,0	453	450	447	443	440
4,1	437	434	431	428	425
4,2	422	419	416	413	410
4,3	407	404	401	398	395
4,4	393	389	386	382	379
4,5	375	372	369	365	362
4,6	359	356	353	350	347

$\bar{\lambda}$	0	0,02	0,04	0,06	0,08
4,7	344	341	338	335	333
4,8	330	327	324	322	319
4,9	317	314	311	309	306
5,0	304	302	299	297	295
5,1	292	290	288	285	283
5,2	281	279	277	275	273
5,3	271	269	267	265	263
5,4	261	259	257	255	253
5,5	251	249	248	246	244
5,6	242	241	239	237	236
5,7	234	232	231	229	227
5,8	226	224	223	221	220
5,9	218	217	215	214	213
6,0	211	210	208	207	206
6,1	204	203	202	200	199
6,2	198	196	195	194	193
6,3	191	190	189	188	187
6,4	186	184	183	182	181
6,5	180	179	178	177	176
6,6	174	173	172	171	170
6,7	169	168	167	166	165
6,8	164	163	162	161	161
6,9	160	159	158	157	156
7,0	155	154	153	152	152
7,1	151	150	149	148	147
7,2	147	146	145	144	143
7,3	143	142	141	140	140
7,4	139	138	137	137	136
7,5	135	134	134	133	132
7,6	132	131	130	130	129
7,7	128	128	127	126	126
7,8	125	124	124	123	122
7,9	122	121	121	120	119
8,0	119	118	118	117	116
8,1	116	115	115	114	114
8,2	113	112	112	111	111
8,3	110	110	109	109	108
8,4	108	107	107	106	106
8,5	105	105	104	104	103
8,6	103	102	102	101	101
8,7	100	100	99	99	99
8,8	98	98	97	97	96
8,9	96	96	95	95	94
9,0	94	93	93	93	92

Table A.3 − Stability curve type “c”

$\bar{\lambda}$	0	0,02	0,04	0,06	0,08	$\bar{\lambda}$	0	0,02	0,04	0,06	0,08
0,3	1000	1000	1000	1000	1000	**4,7**	318	316	314	312	310
0,4	996	992	988	984	980	**4,8**	308	306	304	302	300
0,5	976	972	968	964	960	**4,9**	298	296	294	293	291
0,6	956	954	951	948	945	**5,0**	289	287	285	284	282
0,7	943	940	937	934	932	**5,1**	280	278	277	275	273
0,8	929	926	923	921	918	**5,2**	271	270	268	266	265
0,9	915	912	909	907	904	**5,3**	263	262	260	258	257
1,0	901	898	895	892	889	**5,4**	255	254	252	251	249
1,1	887	884	881	878	875	**5,5**	248	246	245	243	242
1,2	872	869	866	863	860	**5,6**	241	239	238	236	235
1,3	857	854	851	848	845	**5,7**	234	232	231	229	227
1,4	842	839	836	833	830	**5,8**	226	224	223	221	220
1,5	827	824	821	817	814	**5,9**	218	217	215	214	213
1,6	811	808	805	801	798	**6,0**	211	210	208	207	206
1,7	795	792	788	785	782	**6,1**	204	203	202	200	199
1,8	778	775	772	768	765	**6,2**	198	196	195	194	193
1,9	761	758	755	751	748	**6,3**	191	190	189	188	187
2,0	744	741	737	734	730	**6,4**	186	184	183	182	181
2,1	727	723	720	716	712	**6,5**	180	179	178	177	176
2,2	709	705	702	698	694	**6,6**	174	173	172	171	170
2,3	691	687	683	680	676	**6,7**	169	168	167	166	165
2,4	672	669	665	661	658	**6,8**	164	163	162	161	161
2,5	654	650	647	643	639	**6,9**	160	159	158	157	156
2,6	635	632	628	624	621	**7,0**	155	154	153	152	152
2,7	617	613	610	606	602	**7,1**	151	150	149	148	147
2,8	598	595	591	587	584	**7,2**	147	146	145	144	143
2,9	580	576	573	569	566	**7,3**	143	142	141	140	140
3,0	562	558	555	551	548	**7,4**	139	138	137	137	136
3,1	544	541	537	534	530	**7,5**	135	134	134	133	132
3,2	527	523	520	516	513	**7,6**	132	131	130	130	129
3,3	509	506	503	499	496	**7,7**	128	128	127	126	126
3,4	493	489	486	483	479	**7,8**	125	124	124	123	122
3,5	476	473	470	467	463	**7,9**	122	121	121	120	119
3,6	460	457	454	451	448	**8,0**	119	118	118	117	116
3,7	445	442	439	436	433	**8,1**	116	115	115	114	114
3,8	430	427	424	421	418	**8,2**	113	112	112	111	111
3,9	416	413	410	407	404	**8,3**	110	110	109	109	108
4,0	402	399	396	393	391	**8,4**	108	107	107	106	106
4,1	388	386	383	380	378	**8,5**	105	105	104	104	103
4,2	375	373	370	368	365	**8,6**	103	102	102	101	101
4,3	363	360	358	356	353	**8,7**	100	100	99	99	99
4,4	351	349	346	344	342	**8,8**	98	98	97	97	96
4,5	340	337	335	333	331	**8,9**	96	96	95	95	94
4,6	329	326	324	322	320	**9,0**	94	93	93	93	92

ANNEX B

Lines of rolled angles with one-row, two-row and chess-row installation of holes (according to SSTU 8509-03)

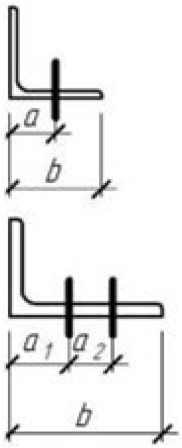
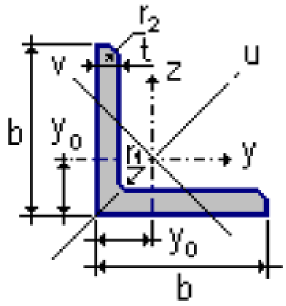
Schemes of holes location	Shelf width	One-row holes		Chess-row holes			Two-row holes		
	b, mm	dmax	**a**	dmax	**a1**	**a2**	dmax	**a1**	**a2**
	**45**	11	25						
	50	13	30						
	56	15	30						
	63	17	35						
	70	19	40						
	75	21	45						
	80	21	45						
	90	23	50						
	100	23	55						
	110	25	60						
	125	25	70	23	55	35			
Designations:	**140**	25	75	25	60	40	19	55	60
	160			25	65	60	23	60	70
d_{max} – largest hole	**180**						25	65	80
diameter	**200**						25	80	80
a, a_1, a_2 – lines	**220**						28	90	90
according to schemes	**250**						28	100	90

Figure B.1 – Lines for holes in rolled angles

ANNEX C

Shortened assortment of equilateral angles (according to SSTU 8509-03)

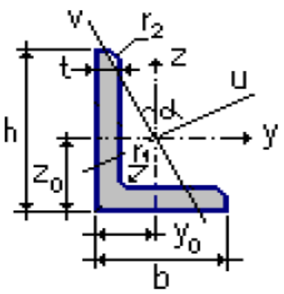


	b	t	r_1	r_2	A	$I_y=I_z$	W_y	i_y	I_u	i_u	I_v	W_v	i_v	I_{yz}	y_o	P
	мм	мм	мм	мм	$см^2$	$см^4$	$см^3$	мм	$см^4$	мм	$см^4$	$см^3$	мм	$см^4$	мм	кг/м
L50x5	50	5	5.5	1.8	4.8	11.2	3.13	15.3	17.77	19.2	4.63	2.3	9.8	6.57	14.2	3.77
L63x5	63	5	7	2.3	6.13	23.1	5.05	19.4	36.8	24.4	9.52	3.87	12.5	13.7	17.4	4.81
L70x5	70	5	8	2.7	6.86	31.94	6.27	21.6	50.67	27.2	13.22	4.92	13.9	18.7	19	5.38
L75x6	75	6	9	3	8.78	46.57	8.57	23	73.87	29	19.28	6.62	14.8	27.3	20.6	6.89
L80x6	80	6	9	3	9.38	56.97	9.8	24.7	90.4	31.1	23.54	7.6	15.8	33.4	21.9	7.36
L90x6	90	6	10	3.3	10.61	82.1	12.49	27.8	130	35	33.97	9.88	17.9	48.1	24.3	8.33
L90x7	90	7	10	3.3	12.28	94.3	14.45	27.7	149.67	34.9	38.94	11.15	17.8	55.4	24.7	9.64
L100x7	100	7	12	4	13.75	130.59	17.9	30.8	207.01	38.8	54.16	14.13	19.8	76.4	27.1	10.79
L100x8	100	8	12	4	15.6	147.19	20.3	30.7	233.46	38.7	60.92	15.66	19.8	86.3	27.5	12.25
L110x8	110	8	12	4	17.2	198.17	24.77	33.9	314.51	42.8	81.83	19.29	21.8	116	30	13.5
L125x8	125	8	14	4.6	19.69	294.36	32.2	38.7	466.76	48.7	121.98	25.67	24.9	172	33.6	15.46
L125x9	125	9	14	4.6	22	327.48	36	38.6	520	48.6	135.88	28.26	24.8	192	34	17.3
L140x9	140	9	14	4.6	24.72	465.72	45.55	43.4	739.42	54.7	192.03	35.92	27.9	274	37.8	19.41
L140x10	140	10	14	4.6	27.33	512.29	50.32	43.3	813.62	54.6	210.96	39.05	27.8	301	38.2	21.45
L160x10	160	10	16	5.3	31.43	774.24	66.19	49.6	1229.1	62.5	319.38	52.52	31.9	455	43	24.67
L160x11	160	11	16	5.3	34.42	844.21	72.44	49.5	1340.06	62.4	347.77	56.53	31.8	496	43.5	27.02
L160x16	160	16	16	5.3	49.07	1175.19	102.64	48.9	1865.73	61.7	484.64	75.92	31.4	690	45.5	38.52
L180x11	180	11	16	5.3	38.8	1216.44	92.47	56	1933.1	70.6	499.78	72.86	35.9	716	48.5	30.47
L180x12	180	12	16	5.3	42.19	1316.62	100.41	55.9	2092.78	70.4	540.45	78.15	35.8	776	48.9	33.12
L200x12	200	12	18	6	47.1	1822.78	124.61	62.2	2896.2	78.4	749.4	98.68	39.9	1073	53.7	36.97
L200x14	200	14	18	6	54.6	2097	144.17	62	3333	78.1	861	111.5	39.7	1236	54.6	42.8
L200x25	200	25	18	6	94.29	3466.21	245.59	60.6	5494.04	76.3	1438.38	172.68	39.1	2028	58.9	74.02
L200x30	200	30	18	6	111.54	4019.6	288.57	60	6351.0	75.5	1698.16	193.06	38.9	2332	60.7	87.56
L220x16	220	16	21	7	68.58	3175.44	198.71	68	5045.4	85.8	1305.52	153.34	43.6	1869	60.2	53.83
L250x16	250	16	24	8	78.4	4717.1	258.43	77.6	7492.1	97.8	1942.09	203.45	49.8	2775	67.5	61.55
L250x20	250	20	24	8	96.96	5764.87	318.76	77.1	9159.7	97.2	2370.01	242.52	49.4	3395	69.1	76.11

Figure C.1 − Shortened assortment of equilateral angles

ANNEX D

Shortened assortment of non-equilateral angles (according to SSTU 8510-86*)



	h	b	t	r_1	r_2	A	I_y	W_y	i_y	I_z	W_z	i_z	I_v	W_v	i_v	y_0	z_0	I_{yz}	tg α	P
	мм	мм	мм	мм	мм	см²	см⁴	см³	мм	см⁴	см³	мм	см⁴	см³	мм	мм	мм	см⁴		кг/м
L25x16x3	25	16	3	3.5	1.2	1.16	0.7	0.43	7.8	0.22	0.19	4.4	0.13	0.16	3.4	4.2	8.6	0.22	0.392	0.91
L30x20x3	30	20	3	3.5	1.2	1.43	1.27	0.62	9.4	0.45	0.3	5.6	0.26	0.25	4.3	5.1	10	0.43	0.427	1.12
L30x20x4	30	20	4	3.5	1.2	1.86	1.61	0.82	9.3	0.56	0.39	5.5	0.34	0.32	4.3	5.4	10.4	0.54	0.421	1.45
L32x20x3	32	20	3	3.5	1.2	1.49	1.52	0.72	10.1	0.46	0.3	5.5	0.28	0.25	4.3	4.9	10.8	0.47	0.382	1.17
L32x20x4	32	20	4	3.5	1.2	1.94	1.93	0.93	10	0.57	0.39	5.4	0.35	0.33	4.3	5.3	11.2	0.5	0.374	1.52
L40x25x3	40	25	3	4	1.3	1.89	3.06	1.14	12.7	0.93	0.49	7	0.56	0.41	5.4	5.9	13.2	0.96	0.385	1.48
L40x25x4	40	25	4	4	1.3	2.47	3.93	1.49	12.6	1.18	0.63	6.9	0.71	0.52	5.4	6.3	13.7	1.22	0.281	1.94
L40x25x5	40	25	5	4	1.3	3.03	4.73	1.82	12.5	1.41	0.77	6.8	0.86	0.64	5.3	6.6	14.1	1.44	0.374	2.37
L40x30x4	40	30	4	4	1.3	2.67	4.18	1.54	12.5	2.01	0.91	8.7	1.09	0.75	6.4	7.8	12.8	1.68	0.544	2.26
L40x30x5	40	30	5	4	1.3	3.28	5.04	1.88	12.4	2.41	1.11	8.6	1.33	0.91	6.4	8.2	13.2	2	0.539	2.46
L45x28x3	45	28	3	5	1.7	2.14	4.41	1.45	14.8	1.32	0.61	7.9	0.79	0.52	6.1	6.4	14.7	1.38	0.382	1.68
L45x28x4	45	28	4	5	1.7	2.8	5.68	1.9	14.2	1.69	0.8	7.8	1.02	0.67	6	6.8	15.1	1.77	0.379	2.2
L50x32x3	50	32	3	5.5	1.8	2.42	6.18	1.82	16	1.99	0.81	9.1	1.18	0.68	7	7.2	16	2.01	0.403	1.9
L50x32x4	50	32	4	5.5	1.8	3.17	7.98	2.38	15.9	2.56	1.05	9	1.52	0.88	6.9	7.6	16.5	2.59	0.401	2.4
L56x36x4	56	36	4	6	2	3.58	11.37	3.01	17.8	3.7	1.34	10.2	2.19	1.13	7.8	8.4	18.2	3.74	0.406	2.81
L56x36x5	56	36	5	6	2	4.41	13.82	3.7	17.7	4.48	1.65	10.1	2.65	1.37	7.8	8.8	18.7	4.5	0.404	3.46
L63x40x4	63	40	4	7	2.3	4.04	16.33	3.83	20.1	5.16	1.67	11.3	3.07	1.41	8.7	9.1	20.3	5.25	0.397	3.17
L63x40x5	63	40	5	7	2.3	4.98	19.91	4.72	20	6.26	2.05	11.2	3.73	1.72	8.6	9.5	20.8	6.41	0.396	3.91
L63x40x6	63	40	6	7	2.3	5.9	23.31	5.58	19.9	7.29	2.42	11.1	4.36	2.02	8.6	9	21.2	7.44	0.393	4.63
L63x40x8	63	40	8	7	2.3	7.68	29.6	7.22	19.6	9.15	3.12	10.9	5.58	2.6	8.5	10.7	22	9.27	0.386	6.03
L65x50x5	65	50	5	6	2	5.56	23.41	5.2	20.5	12.08	3.23	14.7	6.41	2.68	10.7	12.6	20	9.77	0.576	4.36
L65x50x6	65	50	6	6	2	6.6	27.46	6.16	20.4	14.12	3.82	14.6	7.52	3.15	10.7	13	20.4	11.46	0.575	5.18
L65x50x7	65	50	7	6	2	7.62	31.32	7.08	20.3	16.05	4.38	14.5	8.6	3.59	10.6	13.4	20.8	12.94	0.571	5.93
L65x50x8	65	50	8	6	2	8.62	35	7.99	20.2	18.88	4.93	14.4	9.65	4.02	10.6	13.7	21.2	13.61	0.57	6.77
L70x45x5	70	45	5	7.5	2.5	5.59	27.76	5.88	22.3	9.05	2.62	12.7	5.34	2.2	9.8	10.5	22.8	9.12	0.406	4.3
L75x50x5	75	50	5	8	2.7	6.11	34.81	6.81	23.9	12.47	3.25	14.3	7.24	2.73	10.9	11.7	23.9	12	0.436	4.79
L75x50x6	75	50	6	8	2.7	7.25	40.92	8.08	23.8	14.6	3.85	14.2	8.48	3.21	10.8	12.1	24.4	14.1	0.435	5.69
L75x50x7	75	50	7	8	2.7	8.37	46.77	9.31	23.6	16.61	4.43	14.1	9.69	3.69	10.8	12.5	24.8	16.18	0.435	6.57
L75x50x8	75	50	8	8	2.7	9.47	52.38	10.52	23.5	18.52	4.88	14	10.87	4.14	10.7	12.9	25.2	17.8	0.43	7.43
L80x50x5	80	50	5	8	2.7	6.36	41.64	7.71	25.6	12.68	3.28	14.1	7.57	2.75	10	11.3	26	13.2	0.387	4.49
L80x50x6	80	50	6	8	2.7	7.55	48.98	9.15	25.5	14.85	3.88	14	8.88	3.24	10.8	11.7	26.5	15.5	0.386	5.92
L80x60x7	80	60	7	8	2.7	9.42	59.61	10.87	25.2	28.74	6.43	17.5	15.58	5.34	12.9	15.3	25.2	24.01	0.546	7.39
L80x60x8	80	60	8	8	2.7	10.67	66.88	12.38	25	32.15	7.26	17.4	17.49	5.99	12.8	15.7	25.6	26.83	0.544	8.37
L90x56x5	90	56	5.5	9	3	7.86	65.28	10.74	28.8	19.67	4.53	15.8	11.77	3.81	12.2	12.6	29.2	20.54	0.384	6.17
L90x56x6	90	56	6	9	3	8.54	70.58	11.66	28.8	21.22	4.91	15.8	12.7	4.12	12.2	12.8	29.5	22.23	0.384	6.7
L90x56x8	90	56	8	9	3	11.18	90.87	15.24	28.5	27.08	6.39	15.6	16.29	5.32	12.1	13.6	30.4	28.33	0.38	8.77
L100x63x6	100	63	6	10	3.3	9.58	98.29	14.52	32	30.58	6.27	17.9	18.2	5.27	13.8	14.2	32.3	31.5	0.393	7.53
L100x63x7	100	63	7	10	3.3	11.09	112.86	16.78	31.9	34.99	7.23	17.8	20.83	6.06	13.7	14.6	32.8	36.1	0.392	8.7
L100x63x8	100	63	8	10	3.3	12.57	126.96	19.01	31.8	39.21	8.17	17.7	23.38	6.82	13.6	15	33.2	40.5	0.391	9.87
L100x63x10	100	63	10	10	3.3	15.47	153.95	23.32	31.5	47.18	9.99	17.5	28.34	8.31	13.5	15.8	34	48.6	0.387	12.14
L100x65x7	100	65	7	10	3.3	11.23	114.05	16.87	31.9	38.32	7.7	18.5	22.77	6.43	14.1	15.2	32.4	38	0.415	8.81
L100x65x8	100	65	8	10	3.3	12.73	128.31	19.11	31.8	42.96	8.7	18.4	25.24	7.26	14.1	15.6	32.8	42.64	0.414	9.99
L100x65x10	100	65	10	10	3.3	15.67	155.52	23.45	31.5	51.68	10.64	18.2	30.6	8.83	14	16.4	33.7	51.18	0.41	12.3
L110x70x6	110	70	6.5	10	3.3	11.45	142.42	19.11	35.3	45.61	8.42	20	26.94	7.05	15.3	15.8	35.5	46.8	0.402	8.98
L110x70x8	110	70	8	10	3.3	13.93	171.54	23.22	35.1	54.64	10.2	19.8	32.31	8.5	15.2	16.4	36.1	55.9	0.4	10.93
L125x80x7	125	80	7	11	3.7	14.06	226.53	26.67	40.1	73.73	11.89	22.9	43.4	9.96	17.6	18	40.1	74.7	0.407	11.04

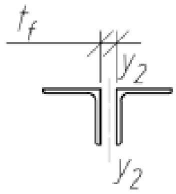
Figure D.1 – Assortment of non-equilateral angles

L125x80x8	125	80	8	11	3.7	15.98	225.62	30.26	40	80.95	13.47	22.8	48.82	11.25	17.5	18.4	40.5	84.1	0.406	12.58
L125x80x10	125	80	10	11	3.7	19.7	311.61	37.27	39.8	100.47	16.52	22.6	59.33	13.74	17.4	19.2	41.4	102	0.404	15.47
L125x80x12	125	80	12	11	3.7	23.36	364.79	44.07	39.5	116.84	19.46	22.4	69.47	16.11	17.2	20	42.2	118	0.4	18.34
L140x90x8	140	90	8	12	4	18	363.68	38.25	44.9	119.79	17.19	25.8	70.27	14.39	15.8	20.3	44.9	121	0.411	14.13
L140x90x10	140	90	10	12	4	22.24	444.45	47.19	44.7	145.54	21.14	25.8	85.51	17.58	19.6	21.2	45.8	147	0.409	17.46
L160x100x9	160	100	9	13	4.3	22.87	605.97	56.04	51.5	186.03	23.96	28.5	110.4	20.01	22	22.4	51.9	194	0.391	17.96
L160x100x10	160	100	10	13	4.3	25.28	666.59	61.91	51.3	204.09	26.42	28.4	121.16	22.02	21.9	22.8	52.3	213	0.39	19.85
L160x100x12	160	100	12	13	4.3	30.04	784.22	73.42	51.1	238.75	31.23	28.2	142.14	25.93	21.8	23.6	53.2	249	0.388	23.58
L160x100x14	160	100	14	13	4.3	34.72	897.19	84.65	50.8	271.6	35.89	28	162.49	29.75	21.6	24.3	54	232	0.385	27.26
L180x110x10	180	110	10	14	4.7	28.33	952.28	78.59	58	276.37	32.27	31.2	165.44	29.96	24.2	24.4	58.8	295	0.376	22.2
L180x110x12	180	110	12	14	4.7	33.69	1122.56	93.33	57.7	324.09	38.2	31	194.28	31.83	24	25.2	59.7	348	0.374	26.4
L200x125x11	200	125	11	14	4.7	34.87	1449.02	107.31	64.5	446.36	45.98	35.8	263.84	38.27	27.5	27.9	65	465	0.392	27.37
L200x125x12	200	125	12	14	4.7	37.89	1568.19	116.51	64.3	481.93	49.85	35.7	285.04	41.45	27.4	28.3	65.4	503	0.392	29.74
L200x125x14	200	125	14	14	4.7	43.87	1800.83	134.64	64.1	550.77	57.43	35.4	326.54	47.57	27.3	29.1	66.2	575	0.39	34.43
L200x125x16	200	125	16	14	4.7	49.77	2026.08	152.41	63.8	616.66	64.83	35.2	366.99	53.56	27.2	29.9	67.1	643	0.388	39.07

Continuationof Figure D.1

ANNEX E

Radius of inertia for two equilateral angles (according to SSTU 8509-03)



Number of angle	Dimensions (mm)		Radius of inertia i_{y2} (cm) for two angles at t_f (mm)			
	b	*t*	8	10	12	14
5	50	4	2.35	2.43	2.51	2.59
		5	2.38	2.45	2.53	2.61
		6	2.40	2.48	2.56	2.64
		7	2.42	2.50	2.58	2.66
		8	2.44	2.52	2.60	2.68
5.6	56	4	2.58	2.66	2.73	2.81
		5	2.61	2.72	2.77	2.85
6	60	4	2.74	2.82	2.89	2.97
		5	2.76	2.84	2.92	2.99
		6	2.79	2.86	2.94	3.02
		8	2.83	2.91	2.99	3.07
		10	2.87	2.95	3.03	3.11
6.3	63	4	2.86	2.93	3.01	3.09
		5	2.89	2.96	3.04	3.12
		6	2.9	2.99	3.06	3.14
7	70	4.5	3.21	3.21	3.29	3.37
		5	3.16	3.23	3.3	3.38
		6	3.18	3.25	3.33	3.4
		7	3.2	3.28	3.38	3.44
		8	3.22	3.29	3.37	3.45
		10	3.27	3.34	3.42	3.50
7.5	75	5	3.35	3.42	3.49	3.57
		6	3.3	3.44	3.52	3.6
		7	3.4	3.47	3.54	3.62
		8	3.43	3.5	3.57	3.65
		9	3.44	3.51	3.59	3.67
8	80	5.5	3.57	3.64	3.71	3.79
		6	3.58	3.65	3.72	3.8
		7	3.6	3.67	3.75	3.82
		8	3.62	3.69	3.77	3.84
		10	3.62	3.69	3.77	3.85
		12	3.7	3.78	3.85	3.93
9	90	6	3.96	4.04	4.11	4.19
		7	3.99	4.06	4.13	4.21
		8	4.01	4.08	4.16	4.23
		9	4.04	4.11	4.18	4.26
		10	4.05	4.13	4.20	4.28
		12	4.1	4.17	4.25	4.33

Figure E.1 – Radius of inertia for two equilateral angles

10	100	6.5	4.36	4.43	4.5	4.57
		7	4.38	4.45	4.52	4.59
		8	4.47	454	4.62	4.62
		10	4.44	4.52	4.59	4.66
		12	4.48	4.56	4.63	4.71
		14	4.53	4.6	4.68	4.76
		15	4.55	4.63	4.7	4.78
		16	4.64	4.72	4.72	4.8
11	110	7	4.78	4.85	4.92	5
		8	4.8	4.87	4.95	5.02
12	120	8	5.21	5.28	5.35	5.42
		10	5.25	5.32	5.39	5.47
		12	5.29	5.36	5.44	5.51
		15	5.35	5.43	5.5	5.58
12.5	125	8	5.39	5.46	5.53	5.6
		9	5.41	5.48	5.56	5.63
		10	5.44	5.52	5.58	5.66
		12	5.48	5.55	5.62	5.7
		14	5.52	5.6	5.67	5.75
		16	5.66	5.72	5.72	5.78
14	140	9	6.02	6.1	6.16	6.24
		10	6.05	6.12	6.19	6.26
		12	6.08	6.15	6.25	6.3
15	150	10	6.45	6.52	6.59	6.66
		12	6.49	6.56	6.63	6.70
		15	6.55	6.62	6.69	6.77
		18	6.60	6.68	6.75	6.82
16	160	10	6.84	6.91	6.97	7.05
		11	6.86	6.93	7	7.13
		12	6.88	6.95	7.02	7.09
		14	6.91	6.98	7.05	7.13
		16	6.95	7.03	7.1	7.18
		18	7	7.07	7.14	7.22
		20	7.04	7.11	7.18	7.26
18	180	11	7.67	7.74	7.81	7.82
		12	7.69	7.76	7.83	7.84
		15	7.75	7.82	7.89	7.96
		18	7.81	7.88	7.95	8.02
		20	7.84	7.91	7.98	8.06
20	200	12	8.48	8.55	8.62	8.69
		13	8.5	8.58	8.64	8.71
		14	8.52	8.6	8.66	8.73
		16	8.56	8.64	8.7	8.77
		18	8.61	8.68	8.75	8.82
		20	8.65	8.72	8.79	8.86
		24	8.72	8.79	8.86	8.93
		25	8.74	8.81	8.88	8.95
		30	8.83	8.9	8.97	9.05

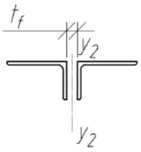
Continuation of Figure E.1

22	220	14	9.31	9.37	9.45	9.52
		16	9.35	9.42	9.49	9.56
25	250	16	10.55	10.62	10.68	10.75
		18	10.59	10.65	10.72	10.8
		20	10.62	10.69	10.76	10.83
		22	10.67	10.74	10.81	10.88
		25	10.72	10.79	10.86	10.93
		28	10.78	10.85	10.92	10.99
		30	10.82	10.89	10.96	10.03

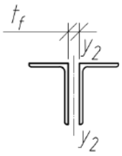
Ending of Figure E.1

ANNEX F

Radius of inertia for two non-equilateral angles (according to SSTU 8510-86*)



A.



B.

Number of angle	Dimensions, мм			i_{y1}, cm^4	i_{x1}, cm^4	Radius of inertia i_{y2} for two angles according to schemes							
						"A" at t_f (mm)				"B" at t_f (mm)			
	h	*b*	*t*			8	10	12	14	8	10	12	14
6.3/4	63	40	4	10.8	41.4	1.75	1.83	1.91	1.99	3.19	3.26	3.34	3.42
			5	13.1	49.9	1.78	1.89	1.94	2.02	3.21	3.29	3.36	3.45
			6	17.9	66.9	1.83	1.91	1.99	2.08	3.26	3.34	3.42	3.5
			8	15.2	56.7	1.93	2.01	2.08	2.17	3.49	3.56	3.64	3.72
7/4.5	70	45	5	20.8	69.7	2.13	2.21	2.28	2.36	3.67	3.75	3.83	3.9
7.5/5	75	50	5	25.2	83.9	2.15	2.22	2.3	2.38	3.7	3.78	3.86	3.94
			6	34.2	112	2.19	2.27	2.37	2.43	3.75	3.83	3	3.98
			8	20.8	84.6	2.08	2.16	2.23	2.3	3.94	4.02	91	4.19
8/5	80	50	5	25.2	102	2.1	2.18	2.26	2.34	3.97	4.05	4.11	4.21
9/5.6	90	56	5.5	32.2	132	2.29	2.36	2.44	2.52	4.4	4.47	4.13	4.63
			6	35.2	155	2.3	2.38	2.45	2.53	4.42	4.49	4.55	4.65
			8	47.8	194	2.35	2.43	2.51	2.58	4.47	4.52	4.57	4.7
10/6.333	100	63	6	49.9	198	2.55	2.62	2.7	2.77	4.84	4.92	4.62	5.07
			7	58.7	232	2.57	2.64	2.72	2.78	4.87	4.95	4.99	5.1
			8	67.6	266	2.59	2.66	2.74	2.82	4.89	4.97	5.02	5.12
			10	85.8	383	2.64	2.71	2.79	2.87	4.94	5.01	5.04	5.17
11/7	110	70	6.5	74.3	286	2.81	2.88	2.96	3.03	5.3	5.37	5.09	5.52
			7	80.3	309	2.82	2.89	2.97	3.04	5.31	5.38	5.45	5.53
			8	92.3	353	2.84	2.92	2.99	3.07	5.33	5.41	5.49	5.56
12.5/8	125	80	7	119	452	3.17	3.24	3.31	3.39	5.96	6.04	6.11	6.19
			8	137	518	3.19	3.27	3.34	3.41	5.98	6.06	6.13	6.21
			10	173	648	3.23	3.31	3.37	3.46	6.04	6.11	6.19	6.27
			12	210	781	3.28	3.35	3.43	3.51	6.08	6.15	6.23	6.31
14/9	140	90	8	194	727	3.55	3.61	3.69	3.76	6.64	6.72	6.79	6.86
			10	245	911	3.6	3.67	3.74	3.82	6.96	6.77	6.81	6.92
16/10	160	100	9	300	1221	3.87	3.95	4.02	4.09	7.6	7.67	7.75	7.82
			10	335	1359	3.9	3.97	4.04	4.12	7.62	7.69	7.77	7.84
			12	405	1634	3.9	4.02	4.09	4.16	7.67	7.75	7.82	7.9
			14	477	1910	3.98	4.05	4.13	4.2	7.51	7.78	7.86	7.94
18/11	180	110	10	444	1933	4.22	4.29	4.36	4.43	8.55	8.62	8.69	8.77
			12	537	2324	4.26	4.33	4.4	4.47	8.59	8.67	8.75	8.82
20/12.55	200	125	11	718	2920	4.79	4.86	4.93	5	9.44	9.51	9.59	9.66
			12	786	3189	4.81	4.88	4.95	5.02	9.46	9.54	9.62	9.68
			14	922	3726	4.85	4.92	4.99	5.06	9.5	9.58	9.65	9.73
			16	1061	4264	4.89	4.95	5.03	5.1	9.55	9.63	9.7	9.78
25/16	250	160	12	1634	6212	6.07	6.13	6.2	6.27	11.62	11.71	11.77	11.85
			16	2200	8308	6.14	6.21	6.27	6.34	11.73	11.78	11.86	11.94
			18	2487	9358	6.18	6.21	6.31	6.38	11.76	11.84	11.91	12
			20	2776	10410	6.2	6.28	6.28	6.42	11.81	11.95	12.03	12.1

Figure F.1 – Radius of inertia for two non-equilateral angles

Електронне навчальне видання

Методичні рекомендації
до організації самостійної роботи та проведення практичних занять
з навчальної дисципліни

«ПРОЄКТУВАННЯ МЕТАЛЕВИХ КОНСТРУКЦІЙ»
(спецкурс)

(для здобувачів першого (бакалаврського) рівня вищої світи всіх форм навчання зі спеціальності 192 − Будівництво та цивільна інженерія, освітня програма «Промислове та цивільне будівництво»)

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