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Methodological guidelines

for performing calculation and graphic work

on the subject

"METAL STRUCTURES DESIGN"

(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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INTRODUCTION

Methodological guidelines for performing calculation and graphic work on the subject “Metal Structures Design” are intended for full-time and part-time Bachelor’s Degree students on specialty 192 – Building Industry and Civil Engineering, of educational program “Industrial and Civil Engineering”. The manual should be used to master the skills of calculating and designing elements and units of light metal roof trusses in practice.

Calculation and graphic work consists of an explanatory note (10–15 sheets of A4 format) and light metal truss units working drawings on A 4 sheets, using the Structure CAD Office v. 21.1 “Comet” post-processor.

Explanatory note calculation part design. The calculation part is drawn up in the form of an explanatory note containing:

– title page;

– educational task to perform calculation and graphic work;

– calculation and graphic work content;

– introduction;

– the units of the calculation part (the numbering, the names of the units and items of the explanatory note must completely comply with these guidelines);

– references.

The introduction describes:

– basic structure design requirements;

– substantiation of the made constructive decisions;

– content of the calculation and graphic parts of the current work (shortly).

Each unit of the explanatory note calculation part should contain:

– substantiation of accepted methods of calculation and selected constructive decisions;

– design schemes and internal efforts diagrams;

– calculation formulas and vectors explanations used in them;

– substantiation of all values used in the calculation;

– references to regulatory and technical literature;

– the calculation results and the calculation conclusions.

In the process of calculating and designing truss elements, drawings must be shown in the explanatory note, with all dimensions obtained or used in the calculation.

The quantity of all values, used in the calculation or obtained as a result of the calculation, must be accompanied by indication of units measurement (for example: kN, MPa, cm^2). The values in the formulas are usually substituted in the same units of measurement. It should be noted, that the most errors in calculations arise from the substitution of formulas for values with different units of measurement.

All values, obtained from the calculation, should be rounded off. It is recommend to follow the subsequent rounding off rules:

– the tension values are rounded off to 0,1 kN/cm^2;

– load values and calculation efforts are rounded off to three significant figures, regardless of the position of the comma, for example:

$$5\,673{,}29 = 5670,$$
$$1{,}347\,293 = 1{,}35,$$
$$0{,}092\,175 = 0{,}092;$$

– the truss sections geometric characteristics are rounded off to four significant figures;

– the values of the coefficients, which are calculated, are rounded off to two or three significant figures;

– the dimensions of the sheet elements, obtained from the calculation, the holes location, etc.: length and width – are rounded off to 10 (5) mm larger; thickness – to 1–2 mm larger, finally the thickness is accepted in accordance with the thick-sheet steel assortment steel.

Graphic part design. The graphic part is made on A4 sheets. Examples of graphic part design are given in the corresponding units of the manual.

Elements drawings are prepared for the structure further manufacture, so it is important to indicate all the necessary dimensions, which can be divided into three groups:

– mounting dimensions – the dimensions of structure in axes and in height (taken from the diagrams of the elements arrangement), as well as bindings to these axes (taken from the drawings of the structures joints connections);

– detailed elements dimensions, from which the structure is made off;

– dimensions, which indicate the relative position of the elements in the structure.

On the elements drawings the weld cathetuses, the holes diameters for the bolts and their position are shown The weld cathetuses and diameters are indicated in the drawing notes or depicted on the structure. The holes positions are taken from the structure joints drawings.

During the metal structures drawing preparation, it is necessary to follow the scaling general rules:

– elements schemes are depicted on a scale of 1:100, 1:150, 1:200, structure joints – on a scale of 1:5, 1:10, 1:20. The main requirement – is the clarity of the image, even if you have to zoom it out (especially when profiles drawings are preparing).

Metal structures, in the detailed elements drawings, are depicted on two scales:

– the dimensions in the axes in the scale of 1:20, 1:50;

– the cross-section, the vertical and horizontal joints dimensions are represented on a larger scale of 1:10, 1:15, 1:20.

Line thickness is:

– axes and dimension lines – 0,3–0,4 mm;

– contours of elements – 0,5–0,6 mm;

– the elements, that fall into the cross-section, are depicted with thicker lines to 0,7–0,8 mm;

– factory welds are represented by the dashes (1×1 mm with a gap of 1 mm);

– mounting welds – by crosses (1×1 mm with a gap of 1 mm).

1 ROOF TRUSSES: GENERAL TERMS

Truss is a key element of any building made of steel, with no exceptions. Throughout its history, mankind has invented a great number of them, using a variety of materials and geometries. This type of construction has a high load capacity with relatively small dimensions. Since ancient times, it has been hardly possible to invent something simpler and more practical for the organization of the roof of any building or structure.

Steel trusses have become widespread in many fields of building industry: in coatings and overlaps of industrial and civil buildings, bridges, supports of transmission lines, conveyor galleys, communication objects, etc. Depending on the purpose, operating conditions, architectural requirements and the load application layout scheme, they can take a variety of constructive forms - from lightweight bar structures to heavy trusses, whose rods are made up of several high profile elements.

Until recently, light trusses from double hot-rolled angles were widely used in the coatings and overlaps of various buildings. Such sections have a wide range of areas, convenient for the truss joints design on the gusset plates. Metal trusses, which made off double angles, can be used in the buildings span of 18 to 42 m in all climatic areas of structure erection. However, due to the large number of elements with different sizes, such trusses are quite laborious in manufacturing and can only be used in justified cases. It is not allowed to operate such trusses in medium- and highly aggressive environments due to the presence of cracks between the angles, and they should not be used at extracurricular loads, which cause significant chords local bending.

A truss – is a lattice-through construction, consisting of separate rectilinear rods, connected between themselves in joints, that form a geometrically unchanging system. The load on the truss is mostly applied at the joints, so in individual rods only longitudinal compression or tensile forces occur, when the truss is bending. Due to this, metal is used more rationally in trusses than in beams, so they are lighter in weight, more economical, but more laborious in manufacturing.

2 ROOF TRUSSES: APPLICATION AND CLASSIFICATION

Steel trusses are widely used in the roofs of industrial and residential buildings, hangars, railway stations, sports facilities, markets and other structures. Static features distinguish such trusses:

– beam type – single span, multi-span and cantilever;
– arch;
– frame type;
– cable-stayed.

Split beam trusses are the most widely used in industrial and civil engineering - they are the simplest for manufacturing and installation.

The geometric scheme of the truss is characterized by the outline of the chords and the view of the truss web.

In modern engineering practice, the most common types of trusses are:

– truss with parallel chords (Fig. 1, e);
– trapezoidal truss (Fig. 1, a, b);
– triangular truss (Fig. 1, c, d);
– segmental (arched girder) truss (Fig. 1, f).

Trusses with parallel chords and trapezoidal trusses are the simplest in design and manufacture. These properties determine their widespread use in industrial and civil engineering for various purposes. Despite the high technical and economic indicators, they are used mainly at spans of 18 to 42 m, since they have a small building height compared to other outlines trusses.

The triangular trusses have the biggest height, they are used for spans of not more than 36 m. This is caused, first of all, by the use of small-sized materials – flat and wavy slate sheets, roofing steel of various configuration, roof tiles, which need the slope within 25–45°.

Segmental trusses are the most economical in cost, but they have significant disadvantages, as well as triangular ones: high complexity due to different lattice web elements lengths and upper chord curvature.

The static unchanging of the truss is achieved by the use of a lattice web forming a system of triangles. The lattice web of the truss runs transversely and performs the function of a solid beam. The truss own weight, the complexity of its production and its outline straightly depends on the lattice web.

The most common is the triangular web because its total length and number of joints are smaller than in trusses with other types of lattice webs. The rational lattice web angle to the truss bottom chord is 45...50°. The main disadvantage of the triangular lattice web – is the considerable length of the chord panels, especially at large truss spans. The brace lattice web (verticals and diagonals braces) is used most efficiently in low-height trusses. The peculiarity of such a lattice web is that from its direction to the bearing points there is an opportunity to regulate the effort signs. The inclination angles of the diagonal brace to the lower chord within 35–45° are more economical and favorable for the normal operation of the truss braces.

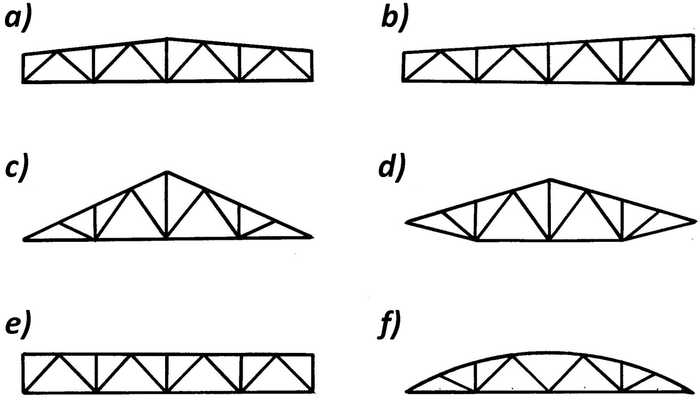


Figure 1 – Types of roof trusses along the chords outline

In trusses with parallel chords and in trapezoidal trusses, it is advisable to design the diagonal braces by flowing from the bearing point - then they will be outstretched, and the short verticals – will be compressed. For trusses of triangular and segmental outlines, on the contrary, in the lattice braces, the lower elements are compressed and the outputs are outstretched. Despite this, during the lattice web construction, trusses are often designed with flowing form braces to reduce their length.

The cross web is used in trusses operating on alternating load (fig. 2, e). In this case, the lattice web braces work only in tension. When in one of the braces compression occurs – it is switched off, so the second brace is operating in tension. A type of triangular lattice – is a rhombic lattice web with the features of high rigidity and strength under the action of large lateral forces.

In interfloor overlaps, when the space between the upper and lower chords is used for operational purposes, non-braced trusses are used. The disadvantage of such trusses is the presence of significant bending moments in the chords and verticals, which causes an increase in steel total costs.

At significant truss heights and a rational inclination braces angle (35–45°) the panels of the upper truss chord are large in size, which are not favorable for the placement of beams and slabs. In these truss panels, local bending moments are caused by extracurricular loading. The length of the upper chord panels can be reduced by inserting special trunks into the main truss lattice web, which also leads to a decrease in the estimated length of the braces in the truss area (fig. 2, d).

The general size of the truss - is the span and the height. The span of the production buildings roof trusses is usually taken in multiples of 6 m (18, 24, 30, 36 and 42 m). To simplify manufacturing and design, prefabricated steel trusses have standard geometric schemes for different spans. The length of the upper chord panel in typical truss is 3 m.

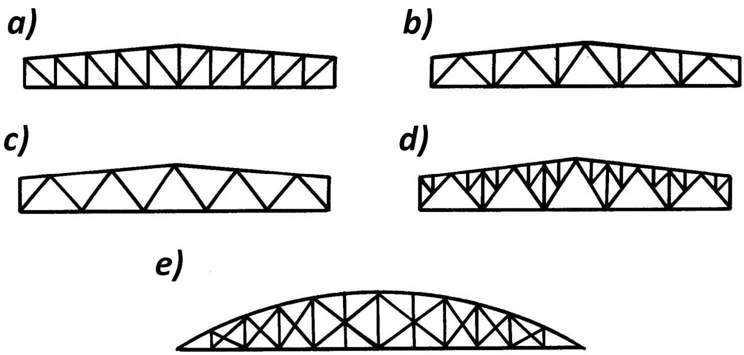


Figure 2 – Types of truss lattice web system

The optimal height h_{opt} in the mid-span of the trapezoidal truss is determined by the condition of minimum self-weight and beam rigidity (deflection), as well as the transportation possibility. The truss weight is minimal when the masses of chords and braces (with gusset plates) are equal to each other, which is observed at large ratios of truss height and span. Such a large height of roof trusses is unprofitable because of the conditions of transportation and installation, since in this case the truss has to be transported by separate elements and at the assembly place builders have to carry out truss separate element mounting, with significant increase in time and total cost. In practice, the truss height in the mid-span is assumed to be below the optimum transport condition so that the truss can be easily transported.

Generally, the total height of the trapezoidal truss and trusses with parallel chords is taken within the range 1/6–1/12 of the truss span. This makes possible to divide the truss into two (sometimes three) equal mirror parts that would meet the requirements of the railway transportation dimensions (the maximum equal mirror part should not exceed 3,8 m in height and 3,2 m in width). In typical trusses for all spans from 18 to 36 m, the height at the bearing point is assumed to be trapezoidal – 2200 mm, and for trusses with parallel chords – 3150 mm. The height of the triangular trusses is due to the roof slope and, normally, is 1/2–1/4 of the span.

3 LOADS COLLECTION

The calculation of beam trusses is performed in the following sequence:

– setting up a truss calculation scheme;
– loads determination and loads collection;
– determination of efforts in truss elements;
– selection of cross-sections of tensioned and compressed elements;
– compilation of a common efforts table, cross-sections and stresses in the elements of the truss;
– calculation of truss joints connections, including assembly joints.

The estimated truss scheme looks like the axial rods lines, which joints connections are conditionally hinged. The connection at the joints is rigid, however, if the ratio of the rod cross-section height to its length is $h / l < 1/15$, the additional stresses due to the rigidity of the joint can be ignored.

3.1 Loads collection on a truss

Roof trusses are calculated on the following types of loads, which are arranged in the form of concentrated forces at the truss joints:

– permanent load from the roof mass and its own construction mass;

– temporary load from the snow, wind and overhead lifting and transport equipment, outboard communications, electric lighting installations, fans, galleries.

The main factors, during the trusses calculation, is the permanent and snow loads. Wind load causes in truss elements, as a rule, efforts of the opposite sign in comparison with efforts from weight of a roof construction and snow. Therefore, during the truss calculation, wind load should be taken into account if its value exceeds the roof construction weight (for light roofs and in areas with high wind loads), as well as for a roof slope of more than 30°. During the truss calculation, the wind load on the roof lanterns is not taken into account.

In the case of mounting wall panels to the bearing vertical, wind load is applied to the truss chords.

Most loads are evenly distributed, they are calculated first by one square meter, then determine the load area that falls on one truss joint, and after that find the axial force applied at each joint.

Permanent loads acting on the truss consist of the total roof construction weight, truss weight, roof connections and roof beams weight.

The total roof construction weight is determined by summing its individual layers:

$$q_{roof}^{char} = \left(\frac{q^{char}}{1000} + \frac{0{,}018}{B} \right) \alpha \cdot L, \qquad (1)$$

where q_{char} – total characteristic evenly distributed load from own weight of a roof construction and snow, technological equipment, etc., kN/m^2;

B – roof truss bay, m;

L – roof truss span, m;

α – the coefficient depending on the beam type and steel grade: α = 1,4 – for low carbon steels, α = 1,3 – for low allow steels.

The permanent loads collection is recommended to be carried out in a tabular form (tabl. 1).

Table 1 – Permanent loads on a truss

Name of the load	Characteristic load, kN/m^2	Reliability coefficient for the ultimate load, γ_{fm}	Operation load, kN/m^2
…	…	…	…

Truss joint permanent load (kN) is collected from a van area equal to the distance between trusses multiplied by the size of the upper chord panel:

$$P_{joint}^{char} = \left(q_{tr} + \frac{q_{roof}^{char}}{cos\beta} \right) \cdot B \cdot d, \qquad (2)$$

where q_{tr} – truss and connections own weight, kN/m^2;

q_{roof} – total roof construction weight, kN/m^2;

B – roof truss bay, m;

d – length of the truss top chord panel;

β – the inclination angle of the upper belt chord to the horizon.

The snow load depends on the snow area where the house is designed, the roof construction profile, the presence of roof lanterns, the number of spans, the roof slope size. The calculated operation load from the snow mass per 1 m^2 is determined by the Eq. (3):

$$s = \gamma_{fe} s_0 C. \qquad (3)$$

where γ_{fe} – the reliability coefficient for the snow load operational value, determined according to par. 8.12 [1];

s_0 – the characteristic value of the snow load, which depends on the building area, and is accepted according to par. 8.5 [1];

C – the coefficient determined according to par. 8.6 [1].

The concentrated snow load on the truss joint also goes down, multiplying the estimated snow load by the area relevant to the site:

$$S_{joint}^{char} = S \cdot B \cdot d. \qquad (4)$$

The design scheme of roof truss from double metal angles is taken in the form of a rod system with hinged joints. When calculating light trusses, it is assumed that the axes of all the rods are straight, located in one area and intersect at one node (at the center of the joint).

If the axes of the truss rods do not intersect at one point, then the truss elements should be calculated taking into account the corresponding bending moments. Joint moments distribute in proportion to the linear stiffness of the elements adjacent to the joint. The eccentricities at the joints, with the exception of the bearing ones, may not be taken into account, unless they exceed 5 % of the chord height in the trusses from double metal angles. The moments from the axes offset of the truss chords, when changing the cross-sections, are not allowed to be taken into account if this offset does not exceed 1,5 % of the chord height.

3.2 Determination of design efforts

Using the special software allows to calculate almost any truss scheme. The program determines the calculated forces in the rods, taking into account the integration of present loads, and can select cross-sections of the rods.

One of the most convenient and easy-to-use methods for determining the calculated efforts at a truss rods is, in our view, a Structure CAD Office post-processor “Crystal”.

The calculation and graphic work does not provide for the static calculation of the roof truss as a whole, but only the determination of the calculated effort in individual typical joints. At the same time, these joints are statically defined, so the determination of calculated forces in the elements is possible by one of the Structural Mechanics methods (for example - the Method of Joints).

4 STRUCTURAL TRUSS CALCULATION

The structural truss calculation includes three main steps:

– determination of the estimated length of truss elements;

– selection of cross-sections of truss elements;

– design of truss joints.

4.1 Estimated length of truss elements

The truss rods work mainly for longitudinal compression or tension. For compressed rods flexibility is essential (rod stability depends on longitudinal bending):

In this case, the bearing capacity of the compressed rod also depends on its design length:

$$\lambda_{ef} = l_{ef} / i_{min}, \qquad \lambda_{ef,1} = l_{ef.1} / i_{min}. \tag{5}$$

In this case, the bearing capacity of the compressed rod also depends on its design length:

$$l_{ef} = \mu \times l, \tag{6}$$

where l – the geometric rod length; μ – a coefficient that takes into account the method of fixing the rod ends; i_{min} – minimum radius of inertia.

Since, it is not known in advance which direction the rod will bend during the loss of stability, it is necessary to know the calculated length and stability both in the truss area and in the direction perpendicular to the truss area (from the truss area). The strength of the tensioned rods does not depend on their length, but too long and thin rods can sag under their own weight, as well as oscillate under the influence of minor forces. That is why the flexibility of the tensioned truss elements is also limited by the norms. So, it is necessary to know the estimated length of the tensioned rods in the truss area and from the truss area [1]. The design length of the flat truss rods and their flexibility should not exceed the requirements given in tables 2–4.

Table 2 – Estimated length of flat truss and connections

The direction of the truss the longitudinal bend	Estimated length l_{ef} and $l_{ef.1}$		
	chords	extreme diagonals and extreme verticals	the rest of the lattice web elements
1 In the truss area l_{ef}: a) for trusses, except those specified in pos. 1, b; b) for welded trusses with elements, which are made of single angles; trusses with direct attachment of lattice web elements to the chords	l l	l l	$0{,}8l$ $0{,}9l$
2 In the direction perpendicular to the truss area (from the truss area) $l_{ef.1}$: a) for trusses, except those specified in pos. 2, b; b) for trusses with closed profile chords with lattice web elements directly attached to the chords	l_1 l_1	l_1 l_1	l_1 $0{,}9l_1$
3 In any direction for welded trusses, which elements are made of single angles, at equal distances between the elements joint points in the area and from the truss area ($l_{ef} = l_{ef.1}$)	$0{,}85l$	l	$0{,}85l$
Note. l – is a geometrical element length (between the centers of the closest joints) in the truss area; l_1 – is the distance between joints, fixed from offset from the truss area (by truss chords, special connections, rigid roof slabs, with welds or bolts directly attached to the chords, etc.).			

Table 3 – Boundary flexibility of tensioned elements

Construction elements	Boundary flexibility of tensioned elements λ_u acting loads on a construction		
	dynamic	static	from crane
1 Flat trusses chords and extreme diagonals (including braking trusses) and structural constructions	250	400	250
2 Elements of trusses and structural constructions, except those specified in pos. 1	350	400	300
3 Bottom chords of beams and crane tracks trusses	–	–	150
4 Elements of vertical connections between columns (lower than crane track)	300	300	200
5 Other connection elements	400	400	300
6 Racks and cross-arms chords and extreme diagonals, cross-arms tractions of overhead power lines bearing parts, transport open switchgears and contact networks	250	–	–
7 Bearing parts elements of overhead power lines, transport switchgears and contact networks, except those specified in pos. 6-8	350	–	–
8 T-section and cross-section spatial constructions elements (and in the braking cross-arms of overhead power lines bearing parts elements – from single metal angles), subject to the influence of wind loads	150	–	–
Note. In non-dynamic structures, the flexibility of tensioned elements should only be checked in vertical areas.			

Table 4 – Boundary flexibility of compressed elements

Construction elements	Boundary flexibility of compressed elements λ_u
1 Chords, extreme verticals and diagonals that transmit bearing reactions forces: a) flat trusses, structural constructions and spatial constructions of pipes or double metal angles up to 50 m height; b) spatial structures from single metal angles, as well as spatial constructions from pipes and double metal	180–60 α 120
2 Elements, except those specified in pos. 1 and 7: a) flat trusses, welded spatial and structural constructions from single metal angles, spatial and structural constructions from pipes and double metal angles; b) spatial and structural constructions form single metal angles with bolted connections	210–60 α 220–40 α
3 Trusses top chords, not fixed during the mounting (boundary flexibility, after finishing the mounting, should be taken according to pos. 1)	220
4 Main columns	180–60 α
5 Secondary columns (fachwerk columns verticals, lanterns, etc.), columns grid elements, elements of vertical connections between columns (below the tracking beams)	210–60 α
6 Elements of connections, except those specified in pos. 5, as well as the rods designed to reduce the compressed elements estimated length and other unloaded elements (except those specified in pos. 7)	150
7 T-section and cross-section compressed and unloaded elements of the spatial constructions, which separate the wind loads effects, checking the flexibility in the vertical area	150
Note. α – a coefficient accepted at least 0,5.	

4.2 Selection of truss elements cross-sections

After determining the calculated efforts, a selection of cross sections of the truss elements is given. It is necessary to follow next engineering recommendations:

– cross sections of the same size but different thicknesses or grades of steel should not be used in one truss structure;

– for the convenience of the total metal gathering, the number of profiles calibers, adopted in the truss, makes limited: at truss span $L < 36$ m, it is recommended to take 5-6 different calibers, at span $L > 36$ m – 7;

– to prevent the rods damage during transportation and mounting, as well as to ensure the quality of welding and increase corrosion resistance, the minimum profile of the trusses metal angles are appointed: equilateral - 50×5 mm, non-equilateral – 63×40×5 mm;

– to reduce the total steel cost, it is advisable to design the most loaded elements of the truss (chords, extreme diagonals) of high strength steel, and other elements - of ordinary steel.

Light trusses rods operate in relatively favorable conditions, so it is advisable to design them using the semi-quiet melting steels. Gusset plates operate under difficult conditions (the presence of welding stresses, the concentration of stresses near the seams, the flat field of tensile stresses), which increases the risk of brittle destruction and requires the use of better quality steel.

The trusses rods work mainly on central compression or tension, so it is advisable to take their cross section as equidistant in the main axes area.

For the trusses the most common are cross sections made up of two equilateral or non-equilateral metal angles, channels or rectangular pipes. For better stability of the truss upper compressed chord it is advisable to use non-equilateral metal angles, mounting their wider shelves in the horizontal area.

The transversal cross-section of all truss elements can be made from single metal angles. Recently, light trusses made entirely of equal equilateral single metal angles, have been used in construction. In such trusses the total steel costs are the same as in conventional trusses, but the manufacturing laboriousness is less due to fewer elements. In addition, such trusses have higher corrosion resistance and are therefore used in areas with aggressive environments.

Compared to new structural designs, trusses with efficient rolling, bending and welding profiles have a bigger total mass and production laboriousness, so they are less used recently in practice. Trusses with round welded pipes are the most economical in total steel cost, but they are more laborious to manufacture than rectangular pipes and single metal angles.

Aluminum alloy truss rods are made similar to steel trusses rods.

4.3 Calculation of steel structures elements with central tension and compression

The calculation of the steel elements strength with a characteristic resistance $R_{yn} \leq 440$ N/mm^2 at central tension should be performed according to the Eq. (7):

$$\frac{N}{A_n R_y \gamma_c} \leq 1. \qquad (7)$$

The calculation of the strength of the tensile steel elements strength with the ratio $R_u / \gamma_u > R_{yn}$, which can be operated even after reaching the metal yield strength, as well as the steel elements with a characteristic resistance $R_{yn} \leq 440$ N/mm^2 should be performed according to the Eq. (1) with the change of value R_{yn} on R_u / γ_u.

The calculation of the stability of solid cross section elements at the central compression:

$$\frac{N}{\varphi A R_y \gamma_c} \leq 1, \qquad (8)$$

where γ_c – structure working conditions coefficient, which is accepted according to par. 5.4 [2];

φ – the coefficient of stability at central compression, which value at $\lambda \geq 0{,}4$ must be calculated by the formula:

$$\varphi = \frac{0.5}{\bar{\lambda}^2}\left(\delta - \sqrt{\delta^2 - 39.48\bar{\lambda}^2}\right). \qquad (9)$$

The value of the coefficient δ in the Eq. (9) should be calculated by the formula:

$$\delta = 9{,}87 \times (1 - \alpha + \beta \times \lambda^2) + \lambda^2, \qquad (10)$$

where α and β – the coefficients, characterizing the initial irregularities of the form and residual stresses and are determined according to Table 5, depending on the type of the rod cross-section and on the type of resistance curve *a*, *b* and *c*, which are shown in figure 3.

The values of the coefficients φ, calculated by the Eq. (9), should be taken not more than $7{,}6 / \lambda_2$ for the type:

– stability curve *a* at $\lambda > 3{,}8$;

– stability curve *b* at $\lambda > 4{,}4$;

– stability curve *c* at $\lambda > 5{,}8$.

For values of λ < 0,4, it is allowed to take φ = 1,0 for all types of the stability curve. The values of the coefficients are shown in таble 6.

Table 5 – The values of the coefficient α and β

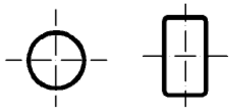
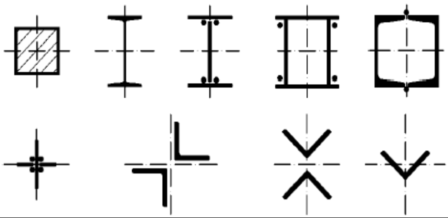
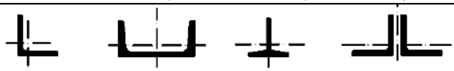
Cross-section type	Resistance curve type	Value of the coefficients	
		α	β
	*a*	0,03	0,06
	*b*	0,04	0,09
	*c*	0,04	0,14

Table 6 – Coefficients of stability at central compression

Conditional flexibility λ	Coefficient φ for types of stability curves			Conditional flexibility λ	Coefficient φ for types of stability curves		
	a	*b*	*c*		*a*	*b*	*c*
1	2	3	4	5	6	7	8
0,4	999	998	992	5,4	261	261	255
0,6	994	986	950	5,6	242	242	240
0,8	981	967	929	5,8	226	226	226
1,0	968	948	901	6,0	211		
1,2	954	827	878	6,2	198		
1,4	938	905	842	6,4	186		
1,6	920	881	811	6,6	174		
1,8	900	855	778	6,8	164		
2,0	877	826	744	7,0	155		
2,2	851	794	709	7,2	147		
2,4	820	760	672	7,4	139		

Continuation of table 6

1	2	3	4	5	6	7	8
2,6	785	722	635	7,6	132		
2,8	747	683	598	7,8	125		
3,0	704	643	562	8,0	119		
3,2	660	605	526	8,5	105		
3,4	615	562	492	9,0	094		
3,6	572	524	460	9,5	084		
3,8	530	487	430	10,0	076		
4,0	475	453	401	10,5	069		
4,2	431	421	375	11,0	063		
4,4	393	392	351	11,5	057		
4,6	359	359	328	12,0	053		
4,8	330	330	308	12,5	049		
5,0	304	304	289	13,0	045		
5,2	281	281	271	14,0	039		
Note. The values of the coefficient φ have been increased in 1 000 times.							

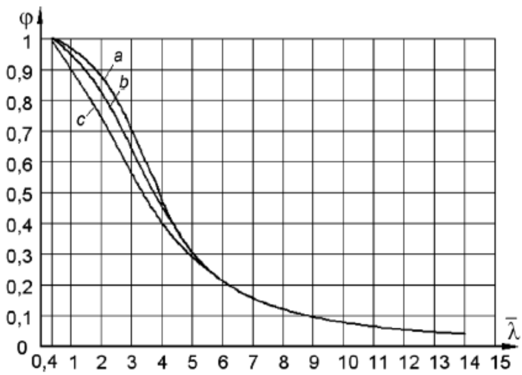


Figure 3 – Stability curves *a*, *b*, *c*

5 CALCULATION AND DESIGN OF TRUSS JOINTS

5.1 Design of truss welded joints

The welds, that connect the individual lattice web rods with the gusset plate at the joint, are calculated on the force value in that rod. The welds, that attach the gusset plate to the upper and lower chords, are calculated for the difference in efforts in the adjacent chord panels.

If there is a calculated force N in the lattice web rod, and the cross-section consists of double metal angles, then each metal angle has an $N_1 = 0{,}5N$ effort. This effort, as well as the effort on single metal angle trusses, should be perceived by the welds that connect the metal angle to the gusset plate.

There are two options for attaching the metal angles to the gusset plate at the joints. In the first embodiment, the attachment is provided only with flank seams with the possibility of their removal by 20 mm at the end of the metal angle. In the second embodiment, the front and flank seams are used for attachment together (fig. 4).

In the first case, the seam of the metal angle pickaxe is calculated on the effort:

$$N^p = (b - z_0)N_1. \tag{11}$$

And the seam of the metal angle feather is calculated on the effort:

$$N^{feath} = z_0 N_1, \tag{12}$$

where b – is a height of the metal angle shelf;

z_0 – distance to the center of metal angle gravity.

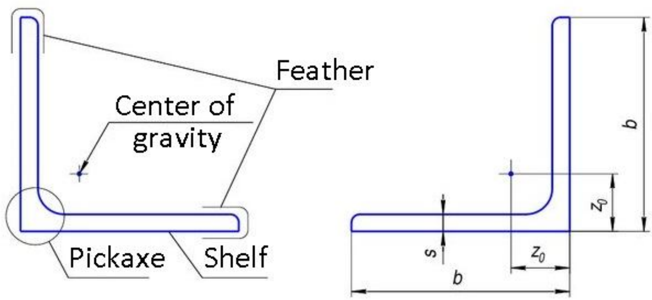


Figure 4 – Metal angle profile elements

In the second case, the force that is perceived by the frontal seam, that is, is first determined:

$$N^{fr} = \gamma_c k_f^{fr} l_w^{fr} \left(R_{wf} \gamma_{wf} \beta_{wf}\right), \tag{13}$$

where R_{wf} – design resistance of the weld;

γ_{wf} and β_{wf} – coefficients that depend on the type of welding.

The rest of the effort:

$$N_2 = N_1 - N^{fr}. \tag{14}$$

The height of the weld (cathetus) is advisable to take depending on the minimum thickness of the connecting elements:

$$k_f^p = 1{,}2 \times t_{\min};$$
$$k_f^{feath} = 0{,}8 \times t_{\min}. \quad (15)$$

The length of the welds shall be at least 40 mm and is determined as:

$$l_w^p = \frac{N \cdot (b - z_0)}{4 \cdot b \cdot \beta_f \cdot k_f^p \cdot \gamma_{wf} \cdot R_{wf} \cdot \gamma_c} + 1; \quad (16)$$

$$l_w^{feath} = \frac{N \cdot z_0}{4 \cdot b \cdot \beta_f \cdot k_f^{feath} \cdot \gamma_{wz} \cdot R_{wz} \cdot \gamma_c} + 1. \quad (17)$$

The fastening seam of the upper chord to the gusset plate is calculated on the effort in the upper chord, which is defined as:

$$N = \sqrt{(N_2 - N_1)^2 + P^2}, \quad (18)$$

where N_1, N_2 – efforts in adjacent upper chord panels;
P – joint load on the upper chord of the truss.

The number of the seams with different thicknesses throughout the truss should not exceed 3 or 4. It is desirable to have no more than two sizes of seams at one joint. The weld lengths, obtained in the calculation, are rounded up to 10 mm.

5.2 Engineering features of trusses designed from double metal angles

In the trusses from double metal angles, the rods at the joints are joined together by the help of gusset plates located between the metal angles. The metal angles are fixed to the gusset plates by welding, rarely by bolts.

During the calculation of the welded trusses joints from double metal angles, the sizes and cathetuses of the welds are determined and the dimensions of the gusset plates are assigned. Factory welded joints of truss elements are recommended to make by semi-automatic welding, manual welding is permitted at mounting.

The construction of the truss should be started with the drawing of the elements axial lines converging at the joints. The axial lines of the rods must coincide with the centers of gravity of the cross-sections.

In the presence of the rods misalignment in the joints, it is necessary to take into account the additional nodal moment when calculating the truss.

In the case where the cross-section of the chord along the length of the truss varies, the geometrical scheme allows to center elements of the chord along the centerline. For bearing convenience of the adjacent elements (beams, slabs, decks) the upper facet of the chord is kept at one level. If the mutual displacement of the gravity centers axes exceeds the above-mentioned requirement (H – the lower height of the chord section), then the additional moment must be taken into account in the calculations. To provide normal joint work, two double metal angles are connected along the length by gaskets. The distance between the gaskets shall be: not more than $40i$ for compressed elements and $80i$ for tensioned elements (i – inertia radius of one metal angle). At the same time, at least two gaskets are placed in the compressed elements.

On the assumption of the welds placement condition, the gasket width is taken equal to b_{gask} = 60–100 mm, and the length $l_{gask} = b_{corn} +$ + (20–30 mm). The gasket thickness is equal to the thickness of the gusset plate. Whenever possible, the number of gasket sizes should be kept to a minimum.

During the design, the trusses rods are centered at the joints on the axes that pass through the centers of their mass with a rounding off up to 5 mm. The axial lines of the trusses rods at the joints should converge at one point, otherwise, there will be an additional moment in the joint $M = N \times e$, that will bend the converging rods at the joint.

To reduce the weld stresses at the trusses joints with gusset plates, the rods are not adjusted to the chords by a distance $a = 6t$, but not more than 80 mm (t – is the thickness of the gusset plate). A distance of at least 50 mm remains between the ends of the connecting elements of the truss chords.

It is advisable to take the gusset plates thickness of all joints permanently depending on the design effort in the extreme diagonals (tabl. 7).

Table 7 – The definition of the gusset plates thickness

Effort in extreme diagonals (verticals), kN	up to 200	from 200 to 450	from 450 to 750	from 750 to 1150	from 1150 to 1500
Gusset thickness, mm	8	10	12	14	16

In the current calculation and graphic work, the construction of truss joints is performed using the Structure CAD Office v. 21.1 "Comet" post-processor, operating the data obtained from the settlement calculation. The algorithm for using the "Comet" post-processor is shown on figure 5–10.

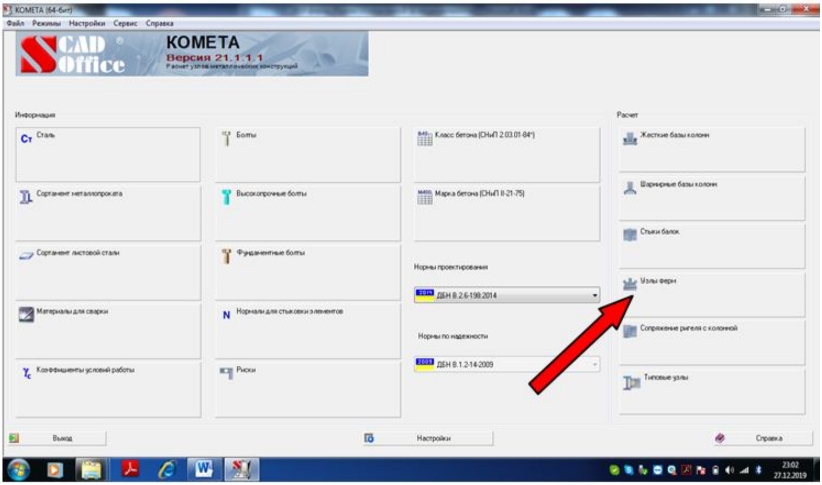


Figure 5 – “Comet” post-processor interface screenshot

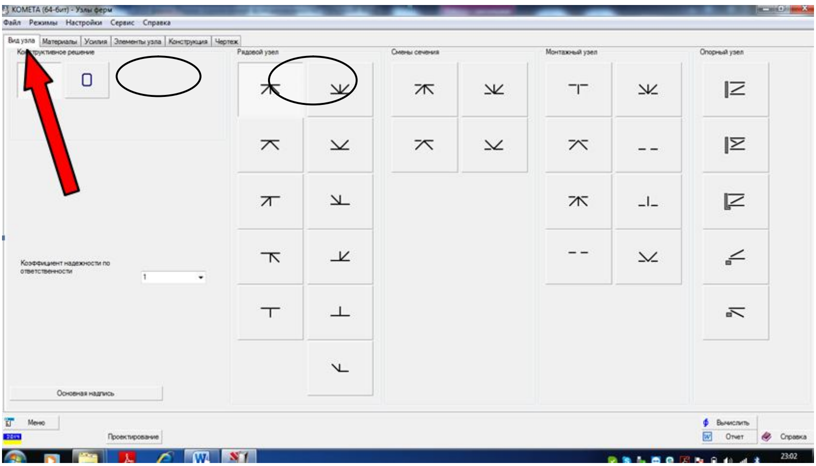


Figure 6 – Specifying data in the “Joint form” tab

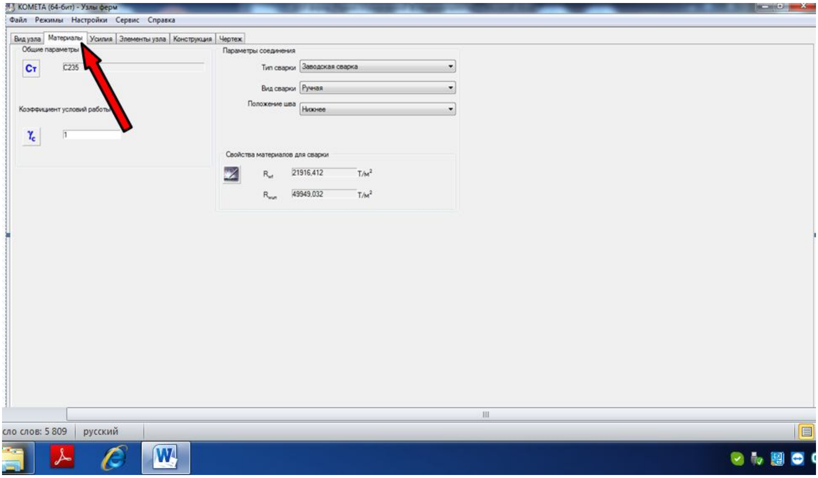


Figure 7 – Selection of material and type of welding elements

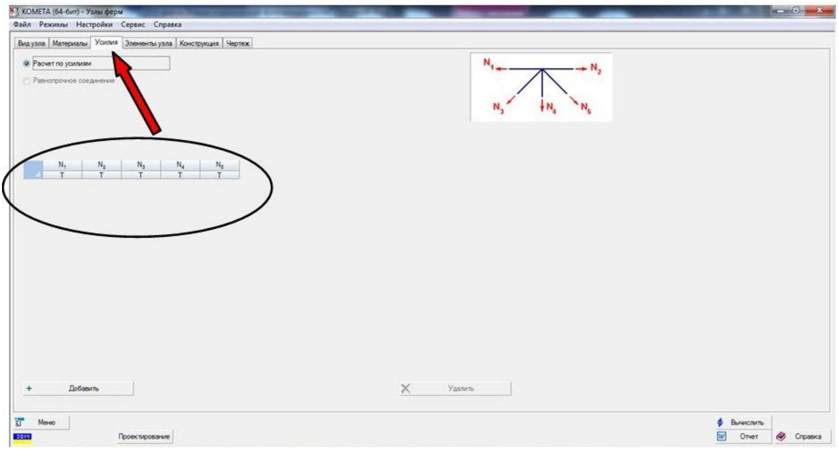


Figure 8 – Specifying of active efforts in the truss joint

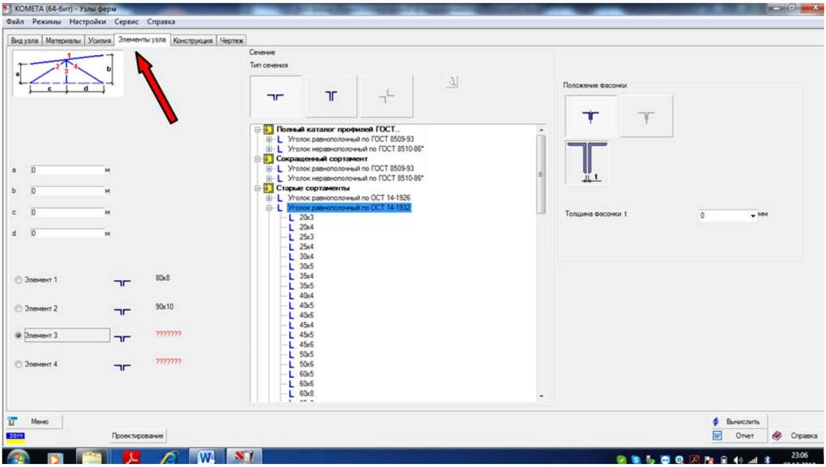


Figure 9 – Specifying the elements geometric lengths and the metal profile sizes

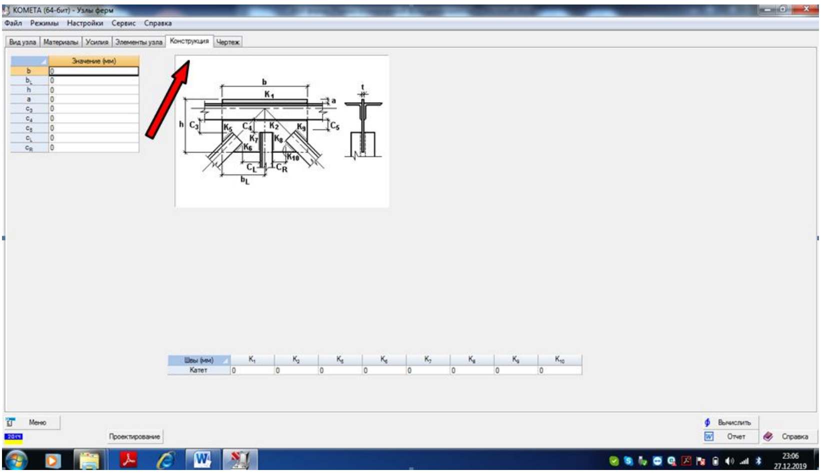


Figure 10 – Specifying construction requirements for the design and calculation parameters of welds

6 EXAMPLES OF CALCULATION

An example of calculation with the following data is given below.

Table 8 – Initial data

α_1^0	α_2^0	N_1 kN	N_2 kN	i	mate-rial	q_{roof}^{char} kN\m^2	B m	d m	L_1 m	L_2 m	L_3 m	L_4 m	L_5 m
51	49	750	940	1:5	C235	10	6	3	3	3	3,6	3,8	2,5

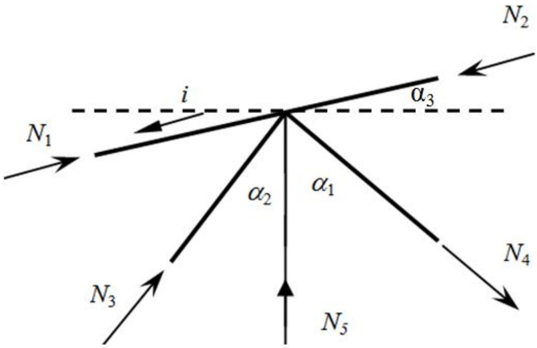


Figure 11 – Joint scheme

6.1 Determination of the value of the estimated joint load

Initial characteristics:

$$N_5 = P_{joint};$$

$$P_{joint}^{char} = \left(\frac{q_{roof}^{char}}{cos\beta}\right) \cdot B \cdot d;$$

$$P_{joint}^{char} = \left(\frac{10}{0.9987}\right) \cdot 6 \cdot 3 = 180kN;$$

$$P_{joint}^{op} = \gamma_f P_{joint}^{char};$$

$$\gamma_f = 1,15;$$

$$P_{joint}^{op} = 1,15 \cdot 180 = 207kN;$$

$$N_5 = P_{joint}^{op} = 207kN.$$

Determining unknown efforts using a joint diagram based on the direction of efforts:

$$\sum x = N_1 \cos\alpha_3 - N_2 \cos\alpha_3 + N_3 \sin\alpha_2 + N_4 \sin\alpha_1 = 0\,;$$

$$\sum y = N_5 + N_3 \cos\alpha_2 - N_4 \cos\alpha_1 + N_1 \sin\alpha_3 + N_2 \sin\alpha_3 = 0\,;$$

$$N_4 = \left(N_5 + N_3 \cos\alpha_2 + N_1 \sin\alpha_3 + N_2 \sin\alpha_3\right)\cos\alpha_1\,.$$

The truss top chord slope is i = 1:5.

So:

$tg\alpha_3$ = 0,05; α_3 = 2,9^0; $\cos\alpha_3$ = 0,998; $\sin\alpha_3$ = 0,051;

α_1 = 51^0; $\cos\alpha_1$ = 0,629; $\sin\alpha_1$ = 0,777;

α_2 = 49^0; $\cos\alpha_2$ = 0,656; $\sin\alpha_2$ = 0,755.

$$N_4 = \frac{207 + N_3 \cdot 0{,}656 + 750 \cdot 0{,}051 + 940 \cdot 0{,}051}{0{,}629} =$$

$$= \frac{(293{,}7 + N_3 \cdot 0{,}656)}{0{,}629} = 467 + 1{,}043 \cdot N_3.$$

Substituting N_4 value, we have next equation:

$$N_1 \cdot \cos\alpha_3 - N_2 \cdot \cos\alpha_3 + \left(467 + 1{,}043 \cdot N_3\right) \cdot \sin\alpha_1 + N_3 \cdot \sin\alpha_2 = 0;$$

$$750 \cdot 0{,}998 - 940 \cdot 0{,}998 + 352{,}6 + 0{,}787 \cdot N_3 + 0{,}755 \cdot N_3 = 0;$$

$$162{,}6 + 1{,}542 \cdot N_4 = 0;$$

$$N_3 = -105{,}44 kN.$$

The obtained sign “-” mean that the direction of the force N_3 must be reversed, so the diagonal N_3 is tensioned:

$$N_4 = 467 + 1{,}043 \times (-105{,}44) = 357 \text{ kN}.$$

6.2 Selection of the cross-section of the compressed upper chord

Initial characteristics:

$$N_2 = 940 \text{ kN};$$

$$A = \frac{N_2}{2 \cdot \varphi \cdot R_y \cdot \gamma_c}.$$

Using Tables 2–5 we define that:

$l_{ef} = l_{ef1} = l$ = 300,4 cm (taking into account the slope of the top chord);

$$\gamma_c = 0{,}8;$$

$$\lambda_u = 120.$$

According to Table 6 φ = 0,562:

$$A = \frac{940}{2 \cdot 0{,}562 \cdot 23 \cdot 0{,}8} = 45{,}45 cm^2.$$

So, we accept the cross-section from two equilateral double metal angles 2∟ 160×14 mm with:

$$A^f = 43,57\ cm^2;$$
$$i_x = 4,9\ cm;$$
$$i_y = 6,91\ cm;$$
$$z_0 = 4,47\ cm.$$

Checking obtained results:

$$\lambda_{max} = \lambda_x = \frac{300,4}{4,9} = 61,21 < \lambda_u = 120;$$

$$\bar{\lambda} = \lambda\sqrt{\frac{R_y}{E}} = 61,21\sqrt{\frac{23}{2,06\cdot 10^4}} = 2,045.$$

According to Table 5 $\alpha = 0,04$ and $\beta = 0,14$, then:

$$\delta = 9,87 \times (1 - \alpha + \beta \times \lambda^2) + \lambda^2 = 9,87 \times (1 - 0,04 + 0,14 \times 2,45^2) + 2,045^2 = = 19,97;$$

$$\varphi = \frac{0,5}{\bar{\lambda}^2}\left(\delta - \sqrt{\delta^2 - 39,48\bar{\lambda}^2}\right) = \frac{0,5}{2,045^2}\left(19,97 - \sqrt{19,97^2 - 39,48\cdot 2,045^2}\right);$$

$$\varphi = 0,563;$$

$$i_{ef} = i_{ef1} = \frac{l_{(ef,ef1)}}{\lambda} = 300,4/61 = 4,91cm.$$

Checking the strength of the accepted cross-section of the truss top chord:

$$\sigma = \frac{940}{2\cdot 0,563\cdot 43,57\cdot 23\cdot 0,8} = 1,04 \geq 1$$

We have an overvoltage of the accepted cross-section of the truss top chord, so we need to determine whether it is within the norms:

$$\frac{1,04 - 1}{1,04}\cdot 100\% = 3,84 \leq [5\%].$$

Therefore, we accept the top chord cross-section of double equilateral angles 2∟ 160×14 mm.

6.3 Selection of the cross-section of the compressed vertical

Initial characteristics:

$$N_5 = 207\ kN;$$

$$A = \frac{N_2}{2\cdot\varphi\cdot R_y\cdot\gamma_c}.$$

Using Tables 2–5 we define that:

$$l_{ef} = 0{,}8l = 0{,}8 \times 250 = 200 \text{ cm};$$
$$l_{ef1} = l = 250 \text{ cm};$$
$$\gamma_c = 0{,}8;$$
$$\lambda_u = 120.$$

According to Table 6 $\varphi = 0{,}562$

$$A = \frac{207}{2 \cdot 0{,}562 \cdot 23 \cdot 0{,}8} = 10{,}01 cm^2.$$

So, we accept the cross-section from two equilateral double metal angles 2∟ 80×7 mm with:

$$A^f = 10{,}85 \text{ cm}^2;$$
$$i_x = 2{,}45 \text{ cm};$$
$$i_y = 4{,}11 \text{ cm};$$
$$z_0 = 2{,}23 \text{ cm}.$$

Checking obtained results:

$$\lambda_{ef} = \frac{200}{2{,}45} = 81 < \lambda_u = 120;$$
$$\lambda_{ef1} = \frac{250}{4{,}11} = 61 < \lambda_u = 120;$$
$$\bar{\lambda} = \lambda\sqrt{\frac{R_y}{E}} = 81\sqrt{\frac{23}{2{,}06 \cdot 10^4}} = 2{,}71.$$

According to Table 5 $\alpha = 0{,}04$ and $\beta = 0{,}14$, then:

$$\delta = 9{,}87 \times (1 - \alpha + \beta \times \lambda^2) + \lambda^2 = 9{,}87 \times (1 - 0{,}04 + 0{,}14 \times 2{,}71^2) + 2{,}71^2 = $$
$$= 26{,}92;$$
$$\varphi = \frac{0{,}5}{\bar{\lambda}^2}\left(\delta - \sqrt{\delta^2 - 39{,}48\bar{\lambda}^2}\right) = \frac{0{,}5}{2{,}71^2}\left(26{,}92 - \sqrt{26{,}92^2 - 39{,}48 \cdot 2{,}71^2}\right);$$
$$\varphi = 0{,}413;$$
$$i_{ef} = i_{ef1} = \frac{l_{(ef,ef1)}}{\lambda} = 250/81 = 3{,}08 cm.$$

Checking the strength of the accepted cross-section of the truss vertical:

$$\sigma = \frac{207}{2 \cdot 0{,}413 \cdot 10{,}85 \cdot 23 \cdot 0{,}8} = 1{,}26 \geq 1.$$

We have an overvoltage of the accepted section, so we accept a larger metal profile number.

We accept the cross-section from two equilateral double metal angles 2∟ 80×10 mm with:

$$A^f = 15{,}14 \text{ cm}^2;$$
$$i_x = 2{,}42 \text{ cm};$$
$$i_y = 4{,}13 \text{ cm};$$
$$z_0 = 2{,}35 \text{ cm}.$$

Checking obtained results:

$$\lambda_{ef} = \frac{200}{2{,}42} = 82 < \lambda_u = 120;$$

$$\lambda_{ef1} = \frac{250}{4{,}13} = 60 < \lambda_u = 120.$$

That is $\varphi = 0{,}413$.

Checking the strength of the accepted cross-section of the truss vertical:

$$\sigma = \frac{207}{2 \cdot 0{,}413 \cdot 15{,}14 \cdot 23 \cdot 0{,}8} = 0{,}9 \le 1.$$

We have an overvoltage of the accepted cross-section of the truss vertical, so we need to determine whether it is within the norms:

$$\frac{1-0{,}9}{1} \cdot 100\% = 10 \ge [5\%].$$

Therefore, we accept the vertical cross-section N_5 of double equilateral angles 2∟ 80×10 mm.

6.4 Selection of the cross-section of the tensioned diagonal

Initial characteristics:

$$N_3 = 105{,}44 \text{ kN};$$
$$l_{ef} = 0{,}8 l_3 = 0{,}8 \times 360 = 288 \text{ cm};$$
$$l_{ef1} = l_3 = 360 \text{ cm};$$
$$\lambda_{np} = 400;$$
$$\gamma_c = 1{,}1;$$
$$A = \frac{N_3}{2 \cdot R_y \cdot \gamma_c} = \frac{105{,}44}{2 \cdot 23 \cdot 1{,}1} = 2{,}09 cm^2.$$

The diagonal is designed of double equilateral angles.

Using construction considerations, we accept double equilateral angles 2∟ 50×5 mm:

$A^f = 4{,}8$ cm^2;

$i_x = 1{,}53$ cm;

$i_y = 2{,}45$ cm;

$z_0 = 1{,}42$ cm.

$$\sigma = \frac{105.44}{2 \cdot 4{,}8 \cdot 23 \cdot 1{,}1} = 0{,}434 \leq 1.$$

$A = A^f$ (the cross-section has no technological holes):

$$\lambda_{ef} = \frac{288}{1{,}53} = 188 < 400;$$

$$\lambda_{ef1} = \frac{360}{2{,}45} = 147 < 400.$$

Therefore, we accept the diagonal cross-section N_3 of double equilateral angles 2∟ 50×5 mm.

6.5 Selection of the cross-section of the tensioned diagonal

Initial characteristics:

$N_4 = 357$ kN;

$l_{ef} = 0{,}8 l_4 = 0{,}8 \times 380 = 304$ cm;

$l_{ef1} = l_4 = 380$ cm;

$\lambda_{np} = 400$;

$\gamma_c = 1{,}1$;

$$A = \frac{N_4}{2 \cdot R_y \cdot \gamma_c} = \frac{357}{2 \cdot 23 \cdot 1{,}1} = 7{,}06 cm^2.$$

The diagonal is designed of double equilateral angles 2∟63 × 6 mm:

$A^f = 7{,}28$ cm^2;

$i_x = 1{,}93$ cm;

$i_y = 2{,}75$ cm;

$z_0 = 1{,}78$ cm;

$$\sigma = \frac{357}{2 \cdot 7{,}28 \cdot 23 \cdot 1{,}1} = 0{,}97 \leq 1.$$

$A = A^f$ (the cross-section has no technological holes):

$$\lambda_{ef} = \frac{304}{1{,}93} = 158 < 400; \ \lambda_{ef1} = \frac{380}{2{,}75} = 1387 < 400.$$

Therefore, we accept the diagonal cross-section N_4 of double equilateral angles 2∟63 × 6.

6.6 Calculation of weld parameters

Effort in element N_4 = 357 kN, effort in cross-section 2∟ 63×6 mm z_0 = 1,78 cm.

Depending on the maximum effort at the joint (tabl. 7), the thickness of the gusset plate is accepted 14 mm. Therefore $t_{min} = t_{angle}$ = 6 mm:

$$k_f^p = 1{,}2 \times 6 = 7{,}2 \text{ mm, we accept 8 mm;}$$

$$k_f^{feath} = 0{,}8 \times 6 = 4{,}8 \text{ mm, we accept 6 mm.}$$

The calculation is performed on the weld metal.

So:

$$R_{wf} = 18 \text{ kN/cm}^2;$$

$$\gamma_{wf} = 1;$$

$$\beta_{wf} = 0{,}7 \text{ – manual welding;}$$

$$l_w^p = \frac{357 \cdot (6.3 - 1{,}78)}{2 \cdot 6.3 \cdot 0{,}7 \cdot 0{,}8 \cdot 1 \cdot 18 \cdot 1} + 1 = 13{,}7 cm.$$

We accept 14 cm.

$$l_w^{feath} = \frac{357 \cdot 1{,}78}{2 \cdot 6.3 \cdot 0{,}7 \cdot 0{,}6 \cdot 1 \cdot 18 \cdot 1} + 1 = 7{,}67 cm.$$

We accept 8 cm.

Effort in element N_3 = 105,44 kN, effort in cross-section - 2∟ 50×5 z_0 = 1,42 cm.

$$k_f^p = 1{,}2 \times 5 = 6 mm;$$

$$k_f^{feath} = 0{,}8 \times 5 = 4 mm;$$

$$l_w^p = \frac{105.44 \cdot (5 - 1{,}42)}{2 \cdot 5 \cdot 0{,}7 \cdot 0{,}6 \cdot 1 \cdot 18 \cdot 1} + 1 = 5{,}99 cm.$$

We accept 6 cm.

$$l_w^{feath} = \frac{105.44 \cdot 1{,}42}{2 \cdot 5 \cdot 0{,}7 \cdot 0{,}4 \cdot 1 \cdot 18 \cdot 1} + 1 = 3{,}97 cm.$$

We accept 4 cm.

Effort in element N_5 = 207 kN, effort in cross-section – 2∟ 80×10 mm z_0 = 2,35 cm:

$$k_f^p = 1{,}2 \times 10 = 12 mm;$$

$$k_f^{feath} = 0{,}8 \times 10 = 8 mm;$$

$$l_w^p = \frac{207 \cdot (8 - 2{,}35)}{2 \cdot 8 \cdot 0{,}7 \cdot 1{,}2 \cdot 1 \cdot 18 \cdot 1} + 1 = 5{,}83 cm.$$

We accept 6 cm.

$$l_w^{feath} = \frac{207 \cdot 2{,}35}{2 \cdot 8 \cdot 0{,}7 \cdot 0{,}8 \cdot 1 \cdot 18 \cdot 1} + 1 = 4{,}02cm.$$

We accept 4 cm.

Efforts in truss top chord N_2 = 940 kN, N_1 = 750 kN, cross-section – 2∟ 160×14 mm z_0 = 4,47 cm.

$k_f^p = 1{,}2 \times 14 = 16{,}8$ mm; we accept 18 mm;

$k_f^{feath} = 0{,}8 \times 14 = 11{,}2$ mm; we accept 12 mm;

$$N = \sqrt{(940 - 750)^2 + 207^2} = 281kN;$$

$$l_w^p = \frac{281 \cdot (16 - 4{,}47)}{2 \cdot 16 \cdot 0{,}7 \cdot 1{,}8 \cdot 1 \cdot 18 \cdot 1} + 1 = 5{,}46cm.$$

We accept 6 cm.

$$l_w^{feath} = \frac{281 \cdot 4{,}47}{2 \cdot 16 \cdot 0{,}7 \cdot 1{,}2 \cdot 1 \cdot 18 \cdot 1} + 1 = 3{,}59cm.$$

We accept 4 cm.

After the truss joint designing, it is necessary to perform the recalculation of the welded joints cathetuses of the top chord attachment to the gusset plate. We need to specify the calculated data into Structure CAD Office v. 21.1 “Comet” post-processor and automatically get the drawings of the corresponding truss joint (fig. 12).

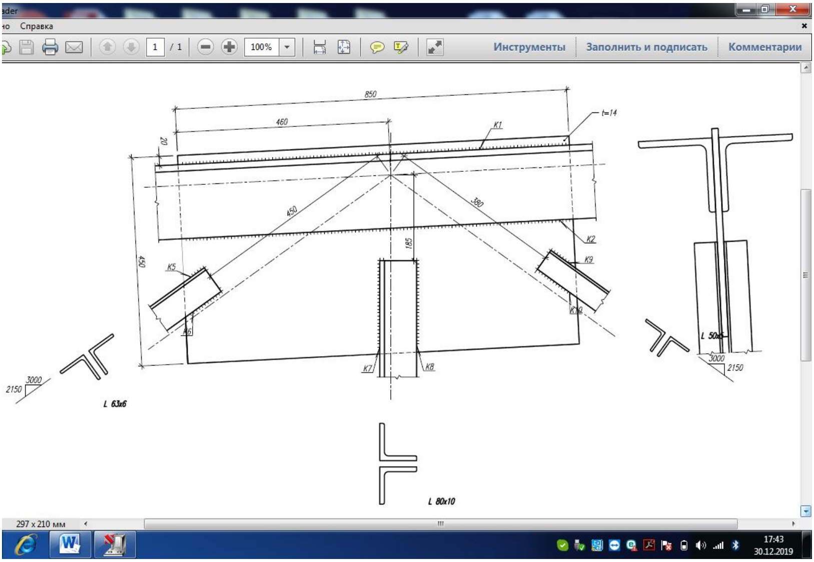


Figure 12 – Calculated joint drawings made in “Comet” post-processor

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GLOSSARY

Roof truss – кроквяна ферма
Lattice web system, truss web – система решітки
Top chord, upper chord – верхній пояс
Bottom chord, lower chord – нижній пояс
Span – проліт
Bay – крок
Verticals – стійки
Diagonals, braces – розкоси
Extreme verticals – опорні стійки
Extreme diagonals – опорні розкоси
Bearing point – опорна точка
Gusset plate – фасонка
Rise – висота ферми (від опори до конька)
Cross-section, cross section – переріз
Metal angle – кутик
Equilateral metal angle – рівнобокий кутик
Non-equilateral metal angle – нерівнобокий кутик
Feather – перо
Pickaxe – обушок
Roof slope – нахил покрівлі
Gasket – прокладка
Cathetus – катет
Rod – стрижень
Joint – вузол
Peak joint – коньковий вузол
T-section – тавровий переріз

ANNEX A
Tasks for students

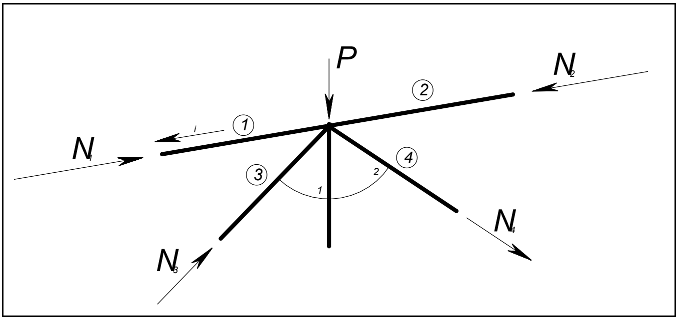

Figure A.1 – Design scheme for calculation № 1

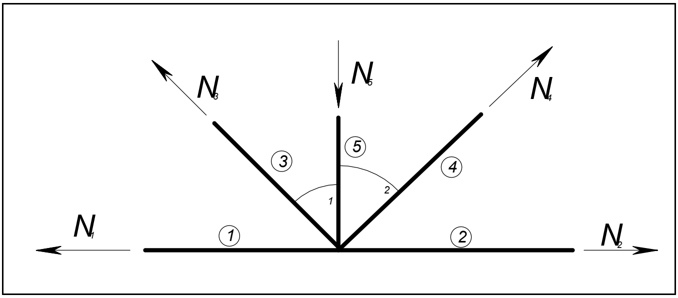

Figure A.2 – Design scheme for calculation № 2

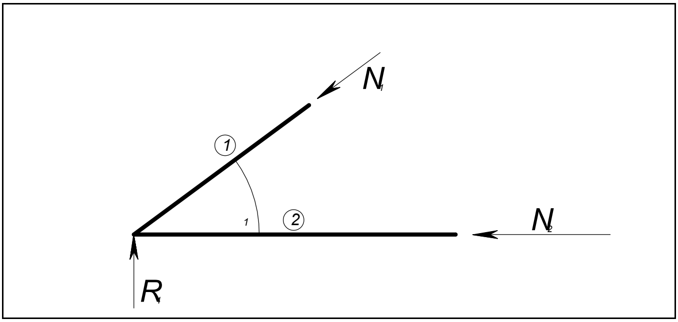

Figure A.3 – Design scheme for calculation № 3

Table A.1 – Initial data for calculation

Penultimate number of record book	g_{roof}^{char}, kN/m²	*B,* m	*D,* m	α_1 degrees	α_2 degrees	Top chord slope *i*, %	Design steel resistance R_y, kN/cm²
0	6,9	6	3	52	55	10	24
1	7,2	6	3	50	50	9	24
2	3,8	12	3	50	55	8	24
3	4,0	12	3	53	50	10	24
4	7,0	6	3	48	52	11	24
5	3,9	12	3	50	53	9	24
6	4,2	12	3	45	50	8	24
7	7,1	6	3	45	55	11	24
8	4,3	12	3	48	53	10	24
9	8,1	6	3	49	51	11	24

Element length:
scheme № 1: $l_3 = 3{,}2$ m, $l_4 = 3{,}6$ m;
scheme № 2: $l_3 = 3{,}2$ m, $l_5 = 2{,}5$ m, $l_1 = 6{,}0$ m, $l_2 = 6{,}0$ m;
scheme № 3: $l_1 = 3{,}8$ m, $l_2 = 6{,}0$ m.

Table A.2 – Forces and efforts

Last number of record book	scheme № 1		scheme № 2		scheme № 3
	N_1, kN	N_2, kN	N_1, kN	N_2, kN	*R*, kN
0	620	810	750	900	820
1	755	862	800	960	750
2	750	940	690	965	970
3	670	860	800	950	870
4	805	912	850	910	800
5	770	960	710	985	950
6	750	900	750	940	820
7	800	960	670	860	750
8	690	965	805	912	870
9	800	950	770	960	800

Виробничо-практичне видання

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до виконання розрахунково-графічної роботи
з курсу

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