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The verification static calculation of metal frame of the stage

Metal constructions

under contract № 31845-KM

2018

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Certificate № 00211 dated 15.06.2017

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Qualification certificate 000106* Architect engineer Shimanovsky Oleksandr Vitaliiovych* registration number 100

The verification static calculation of metal frame of the stage

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under contract № 3145-КМ

General Director, Corresponding Member NASU, Doctor of Engineering Science, Professor — **O.V.Shymanovsky**

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Project structural engineer — **O.S. Iliushenko**

2018

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	Head of Department	Holubova T.P.	
	Project Structural Engineer	Iliushenko O.S.	
	Head of group	Moskalenko H.S.	
	Principal Engineer	Kovalchuk M.O.	
	Category I Engineer	Zhahun-Linnyk A. A.	

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Project structural engineer 48
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1. General data

1.1 The design work "Verification static calculation of the metal frame of the stage" was performed on the basis of:

- Agreement No. 31845-KM as of 28 January 2018;
- Technical specification of Zinteco LLC (hereinafter referred to as the Customer);
- Drawings and technical data of the metal frame of the stage provided by the Customer.

1.2 According to the technical specification, the operation of the metal frame of the stage is possible in all regions of Ukraine, the value of the accepted wind load is given in section 3 "Design fundamentals".

1.3 The verification calculation was carried out in accordance with the current normative documents:

- DBN V. 1.2-2: 2006 "Loads and effects. Design standards";
- DSTU B V. 1.2-3:2006, "Deflections and displacements. Design requirements";
- DBN V. 2.6-198:2014 "Steel constructions. Design standards";
- DSTU B V. 2.6-199:2014 "Steel structures. Manufacturing requirements";
- DSTU B V. 2.6-200:2014 "Metal structures. Installation requirements".

1.4 This documentation is intellectual property of V.M.Shimanovsky Ukrinstalkon LLC (Company) and cannot be transferred for distribution to legal entities or individuals or otherwise used outside the contract without the consent of the Company. Any actions related to violation of personal non-property or property rights of the Company as a subject of copyright to this working documentation shall entail liability in accordance with the procedure established by law.

2. Characteristics of construction and design solutions

2.1 The concert stage is designed to serve mass concert and entertainment events. The General view and design solutions of the stage frame are shown on the sheets 1... 4 (Annex A).

2.2 The metal frame of the stage is of rectangular shape in plan view with dimensions *26.0x18.5m. Height to the bottom of trusses is 19.0 m. On the side of the foreground, the cover has an eaves clearance of L = 4.0m, and additional frames (right and left) for mounting overview screens, audio equipment, etc.

2.3 The bearing frame of the stage consists of the following structural elements:

- columns;
- spatial covering trusses;
- vertical and horizontal ties (joining I-beams);
- elements of half-timbering;
- base with supports;

2.4 Colums taken from round pipes diameter 720x8 length 21.0 m. In height, they consist of several parts connected by mounting joints.

2.5 Covering trusses are spatial, with a sectional area of 1.35x0.96m. The belts are made of 80x80x6 square tube, braces and spacers of 60x60x4 square tube. The length of the trusses consists of several elements of length

L = 5.0 m connected by the so-called "forks" and 35.5 mm diameter fingers.

2.6 The spatial rigidity of the frame is provided by vertical ties along the columns and horizontal ties of the covering. The diameter of the cables adopted is 16mm.

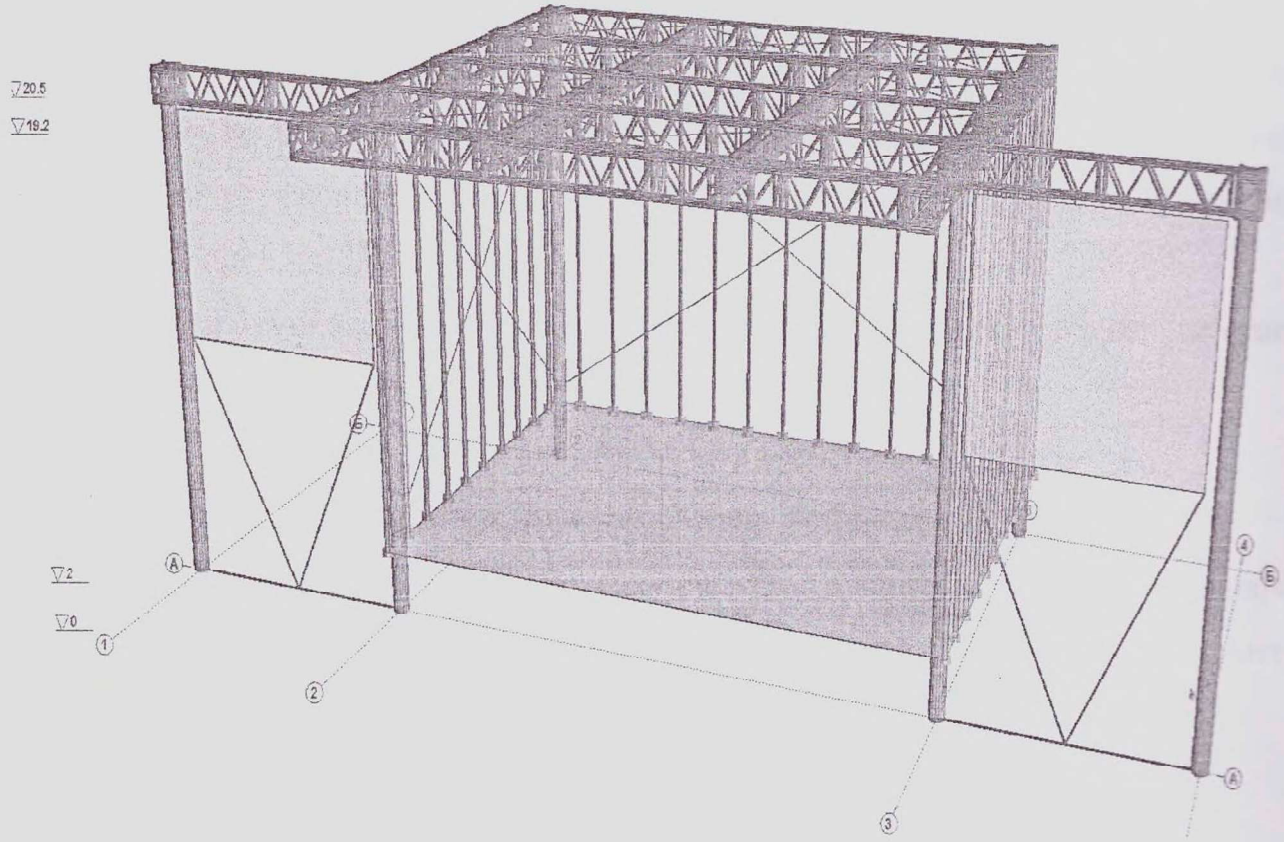
2.7 Enclosure structures of walls and covering are awning.

2.8 For the perception of wind load and fastening of the awning on three sides of the building and on the covering, there are additional elements of half-timbering and I-beams of special cross section.

2.9 The base of the carrying frame of the stage consists of separate structural elements (so-called "supports"), interconnected. The supports of the base are made in the form of containers for filling them with water or sand as ballast. In addition, reinforced concrete blocks, and the like, can serve as a ballast, which give additional load to base support.

2.10 Cross-arms are installed on columns on the mark +21.0 m to raise the covering frame and keep it in working position.

2.11 Additional frames are used to attach sound equipment and screens, which are loosened by means of guy-ropes to the elements of the supports.



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3. Design fundamentals

3.1 Verification static calculation of the stage metal frame is performed according to the existing regulations in force on the territory of Ukraine, as well as the technical specifications of the Customer.

3.2 The calculation is made for the following types of loads:

- own weight of the awning and metal structures of the frame;
- payload (weight of process equipment);
- wind load.

Snow load is absent. Operation in winter is not provided.

The service life of the building is 20 years.

3.3 Payload (according to the technical specifications of the Customer) consists of a variety of technological equipment (sound speakers, screens, spotlights, scenery, etc.). Places of application of loads and their value are given on the sheet 5, 6 (Annex A).

3.4 The calculated value of the wind load in accordance with the specification is taken in two options:

- W_0=25 kg/m^2, equal to wind speed V=20 m/sec;
- W_0=37 kg/m^2, equal to the speed of the wind V=24 m/sec.

The first option is the calculation of constructions at full filled walls and an awning covering. The second option provides for the complete filling of the covering and filling the lower half of the walls.

These options are accepted, taking into account the following prerequisites:

- at wind speed up to 15 m/sec operation of the stage is possible;
- if the wind speed reaches 20 m/sec, people's admission to the facility should be prohibited;
- it is necessary to reduce the windage of the structure, removing the side wall awning and covering canvas;
- when the wind speed reaches 24 m/sec, the structure should resist;

3.5 In the calculation combinations given in the sheets 8, 9, there are two variants of wind load and maximum payload (all the technological equipment is applied simultaneously).

3.6 Static calculations of the carrying frame, as well as checking their bearing capacity are performed using the software complex SCAD.

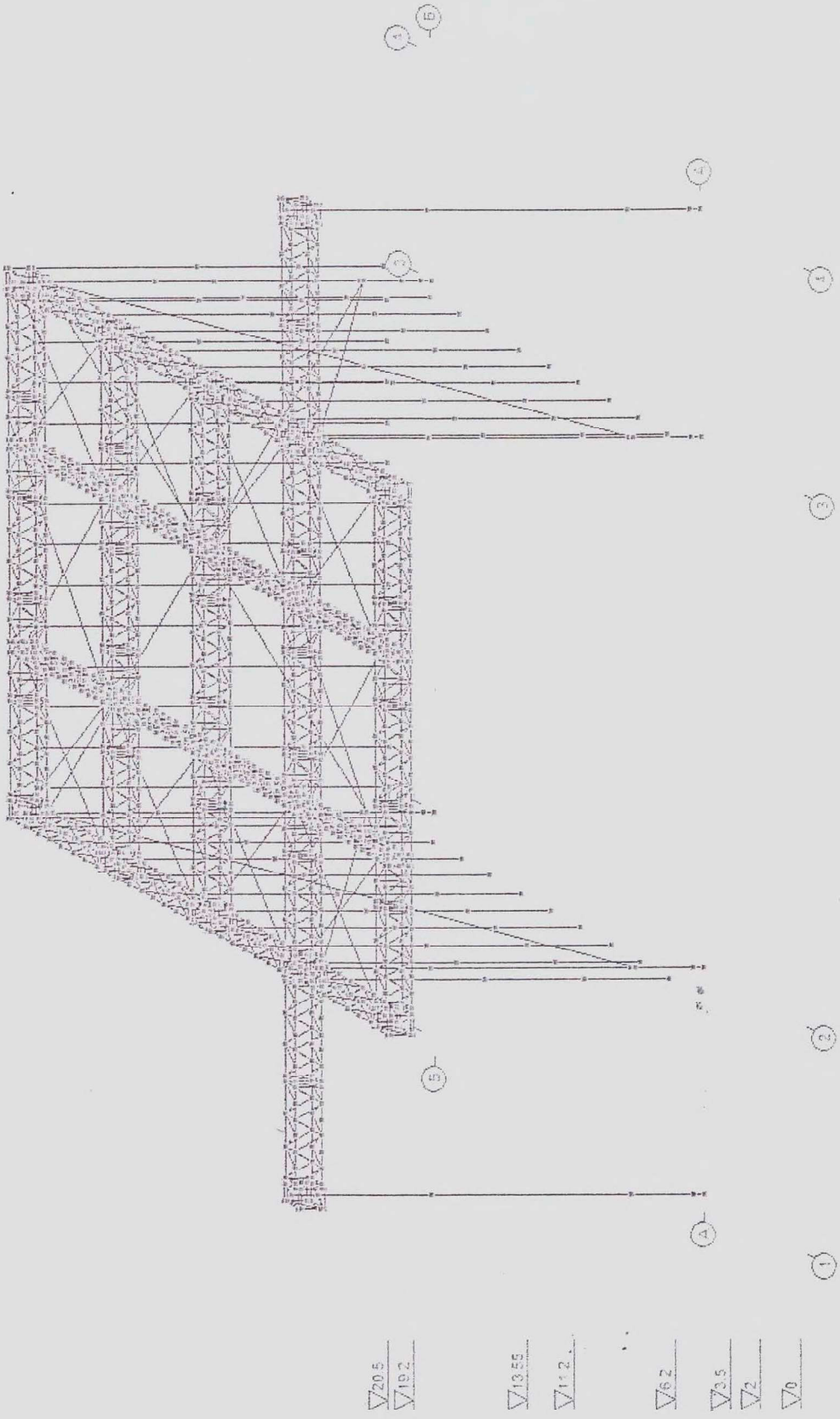
3.7 To check the carrying capacity of the elements of the frame adopted: metalwork steel grades - C245 (GOST 27772-88); carrier cables of ties - GOST 3063-80.

3.8 Load safety factors were taken according to DBN V 1.2- 2:2006 "Loads and effects" depending on the type of load.

3.9 According to DBN V 1.2-14-2008 "General principles of ensuring the solidity and constructional safety of buildings, facilities, building constructions and bases" (section 5, table 1) construction of the concert stage belongs to the class of consequences - CC2 (average consequences of responsibility); category of responsibility of construction - A and III difficulty category, as an object of local level.

The safety factor of responsibility -1.1

4. Structural design loads



Design diagram of the metal frame of the stage

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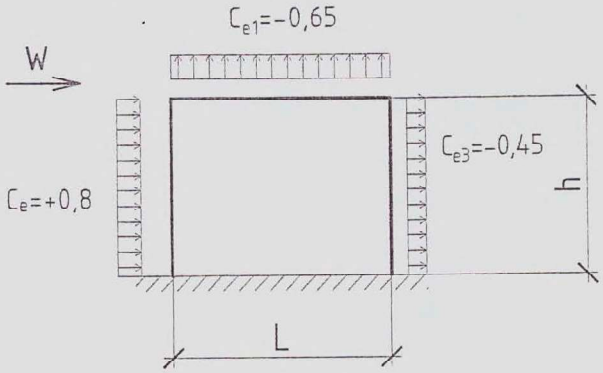
Diagrams of deposition of aerodynamics coefficients Ce for wind load

Diagram 1 (wind direction ± X)



Plan

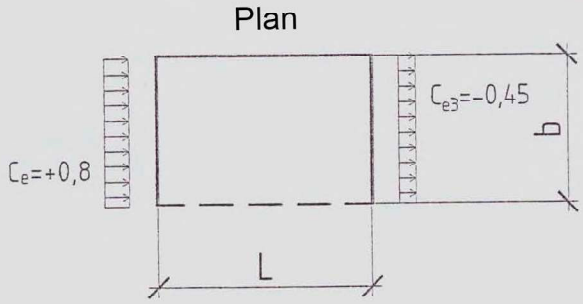
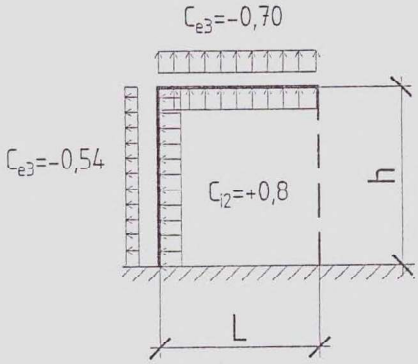


Diagram 2 (wind direction +Y)



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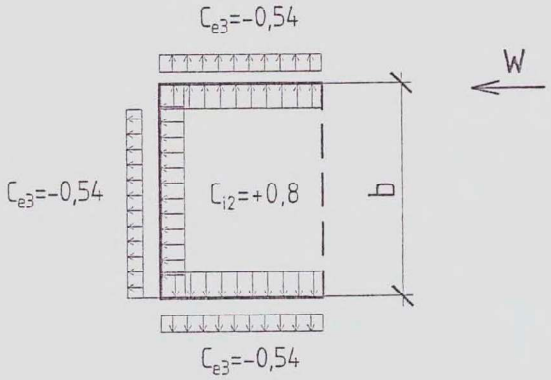
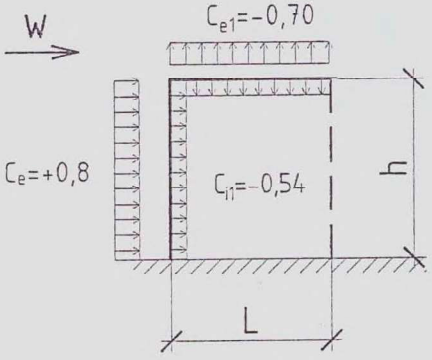
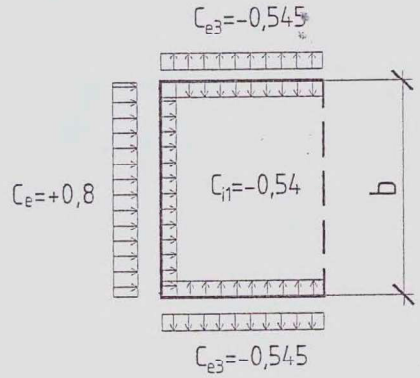


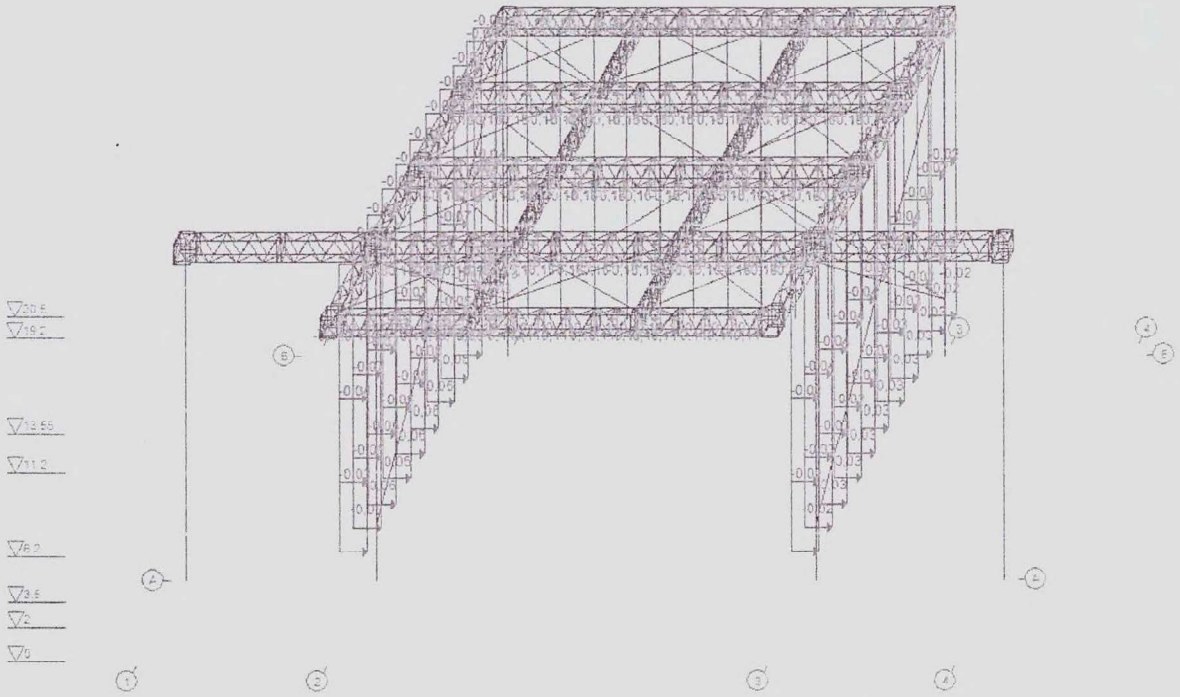
Diagram 3 (wind direction -Y)



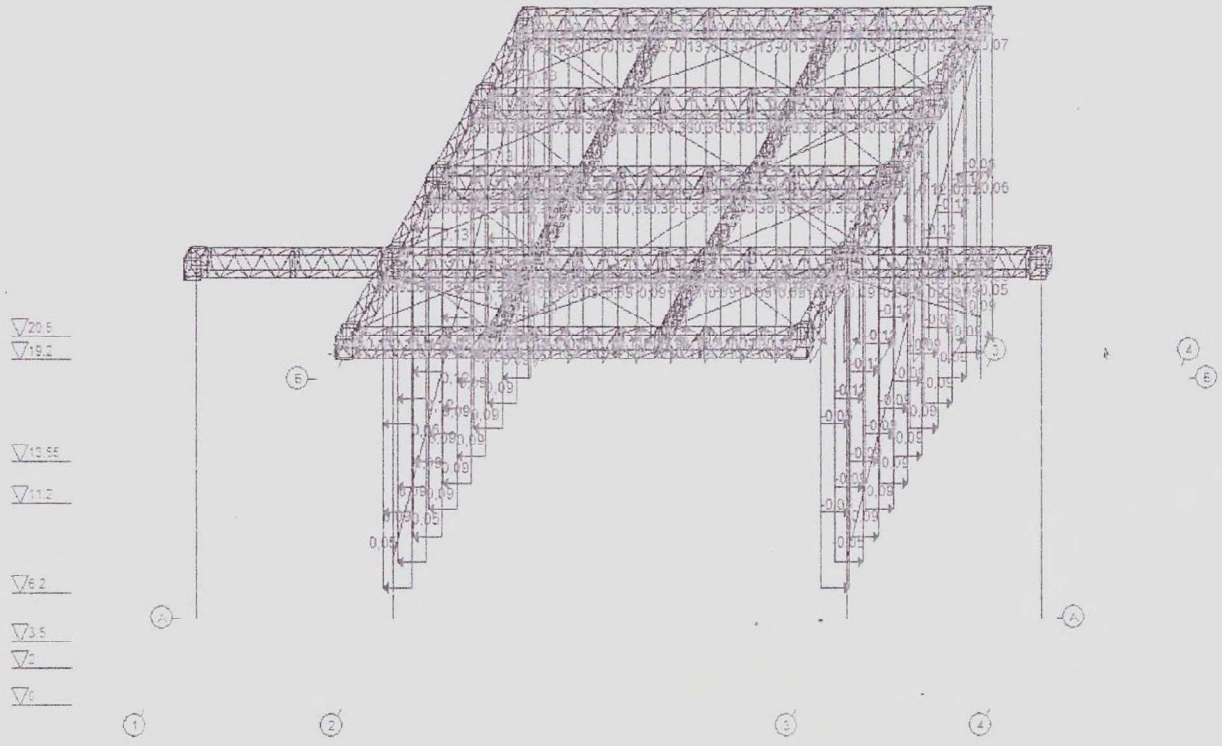
Plan



4.1. Calculated loads for the option W0 = 25 kg/m2



The diagram of wind load deposition along the letter axes (W0 = 25 kg/m2)



The diagram of wind load deposition along digital axes (toward the inside of the stage) (W0=25 kg/m2)

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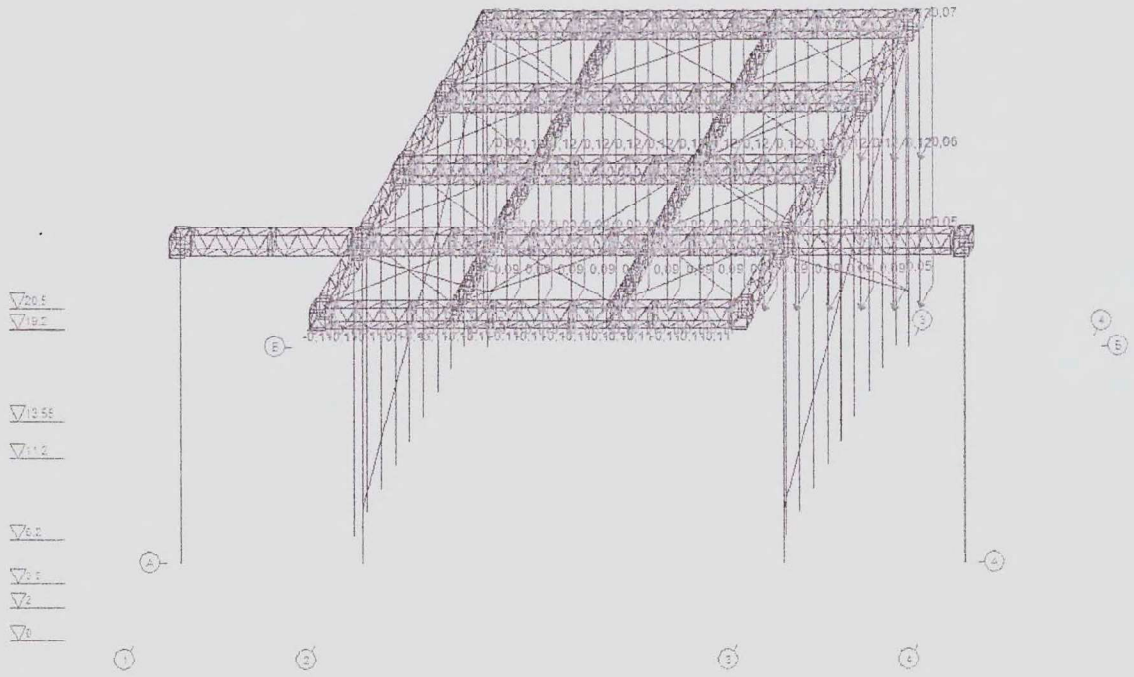
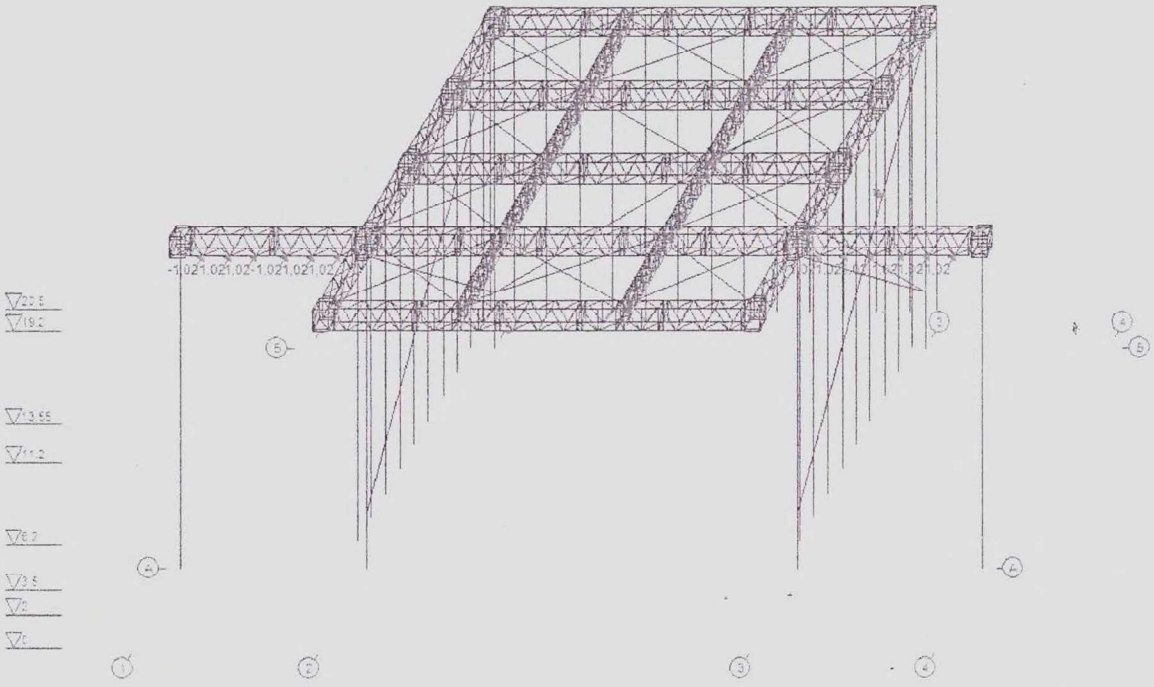


The diagram of wind load deposition along a digital axes (to the back wall of the stage) (W0=25kg/m2)



The diagram of wind load deposition from suspended screens (W0=25kg/m2)

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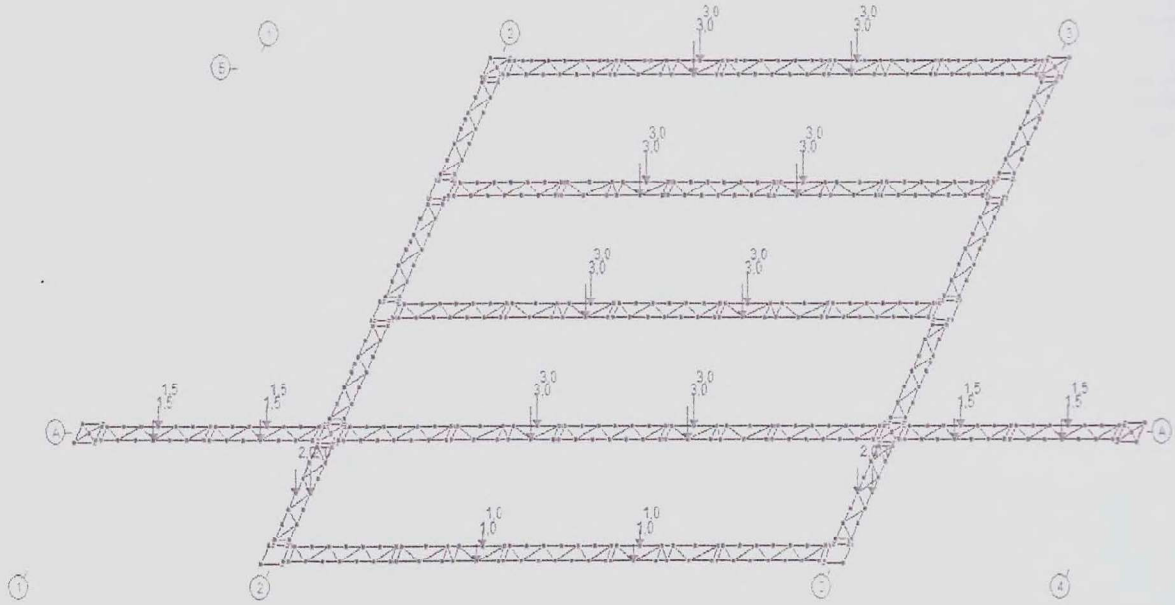
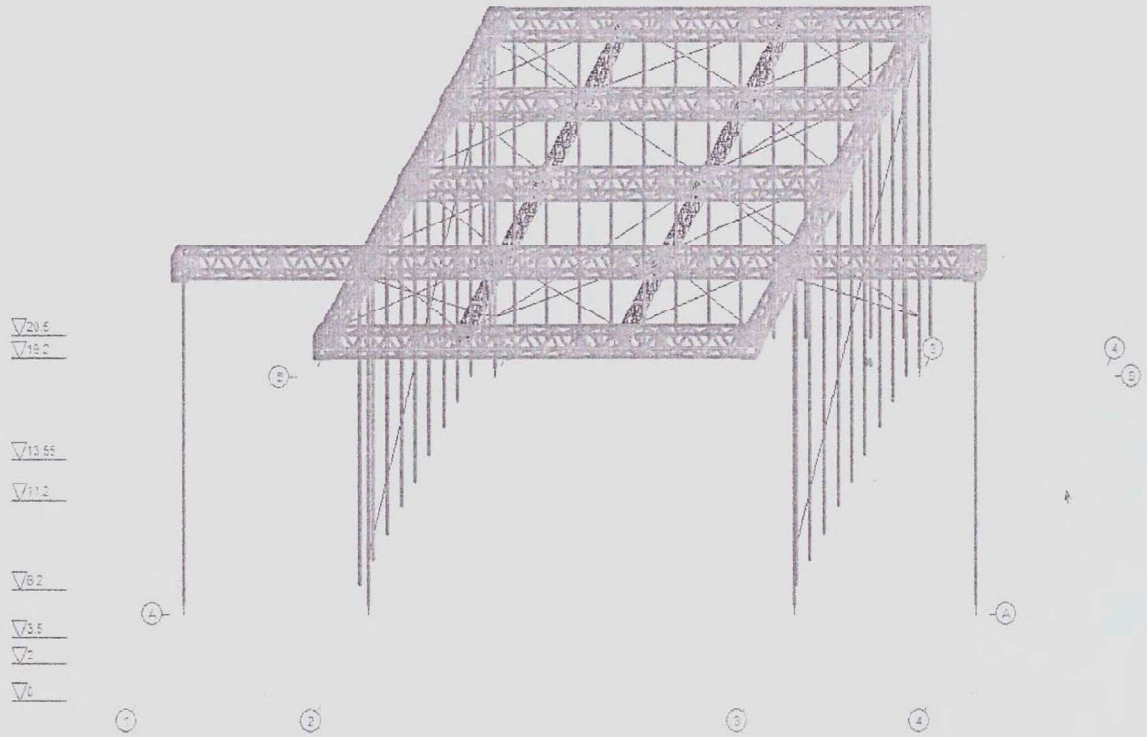
Content	Qty	Sheet	№ doc.	Signature	Date	31845-KM	Sheet 11



The diagram of load deposition from suspended equipment

4.2. Results of calculation for the option W0 = 25 kg/m2



General view of the structural diagram according to the calculation results for option W0=25 kg/m2
The green color on the diagram indicates the elements with load-carrying capacity utilization factors not exceeding 1.0.
The red color on the diagram indicates the elements with load-carrying capacity utilization factors exceeding 1.0.

The overall results of the calculation of the stage frame

Wind W0=25 kg/m2

№ of combination	Name of loads	Name of element	Maximum efforts N,	Horizontal movement (columns top), m	Vertical movement (deflection of the trusses), m	Maximum forces in the base of the column N1, tf
1	Own weight + suspended equipment	trusses belts	-23,6 /+23,1	0,005	-0,094	-46,8
		truss web	-8,1 /+8,9			
		vertical ties	+3,6			
		horizontal ties	-0,5 /+1,0			
2	Own weight + suspended equipment + wind W0 along the axes ±X	trusses belts	-20,2 /+19,1	0,027	-0,070	-38,4
		truss web	-6,3 /+6,9			
		vertical ties	-0,7 /+7,3			
		horizontal ties	-1,0 /+1,1			
3	Own weight + suspended equipment + wind W0 along the axes +Y	trusses belts	-17,7 /+19,5	0,077	-0,041	-24,9
		truss web	-4,5 /+4,8			
		vertical ties	-6,3 /+9,8			
		horizontal ties	-0,1 /+1,4			
4	Own weight + suspended equipment + wind W0 along the axes -Y	trusses belts	-26,6 /+25,2	0,080	-0,088	-53,4
		truss web	-7,7 /+8,4			
		vertical ties	-6,1 /+11,1			
		horizontal ties	-0,7 /+1,1			
5	Own weight + wind W0 along the axes ±X	trusses belts	-3,7 /+3,4	0,026	+0,005	-12,9
		truss web	-1,0 /+1,1			
		vertical ties	-2,0 /+6,0			
		horizontal ties	+1,5			
6	Own weight + wind W1 along the axes +Y	trusses belts	-7,8 /+9,4	0,020	+0,035	+11,2
		truss web	-3,7 /+3,6			
		vertical ties	-3,1 /+6,4			
		horizontal ties	+1,9			
7	Own weight + wind W1 along the axes - Y	trusses belts	-6,9 /+7,3	0,020	-0,015	-20,7
		truss web	-2,3 /+2,5			
		vertical ties	-2,7 /+6,9			
		horizontal ties	-0,3 /+1,4			

1. Efforts in the base column with the sign (+) means the presence of uplift.
2. Maximum allowable displacement in the column top is 110 mm.
3. Maximum allowable trusses deflection is 100 mm
4. The value of the coefficients of carrying capacity utilization for each group of elements of the frame of the stage are given in the diagrams in calculations.
5. Based on the uplift value in combination 6, the weight of the required ballast is:
   - 20 t for columns in axes 2, 3 run A
   - 12 t for columns in axes 1, 4 run A; in axes 2, 3 run B
6. Efforts in vertical ties are provided for two flat areas of ties.

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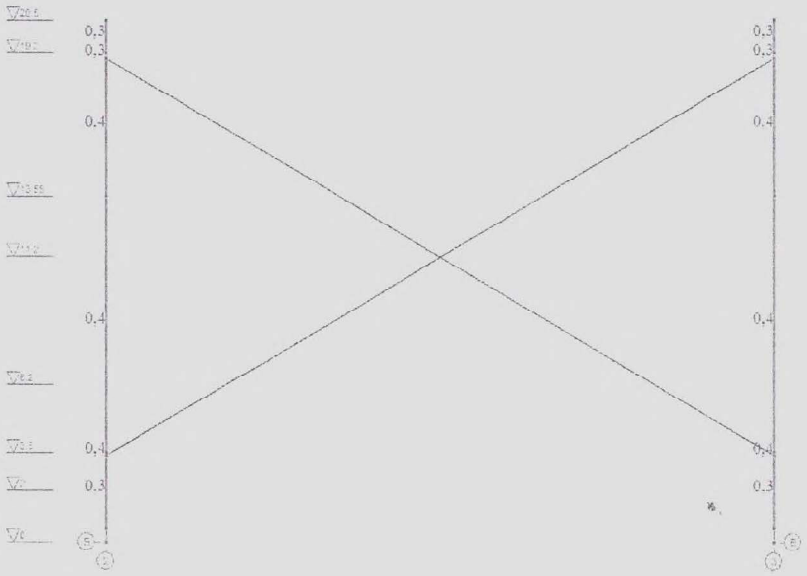
Load-carrying capacity utilization factors of columns along the axis A
(the largest of those determined by the criteria of strength and stability)



Load-carrying capacity utilization factors of columns along the axis B
(the largest of those determined by the criteria of strength and stability)

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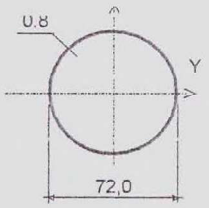
According to the results of the static verification calculation by the program SCAD of the spatial frame of the stage, the strength and stability of the elements for the action of the calculated load combinations are given in the following tables, where they are indicated by the values of the usage factors of the load-carrying capacity of the elements.

Columns in axes 1 and 4. Run A. Element No. 4353

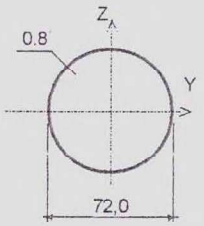


Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 150.0
Longitudinal electric-welded tubes GOST 10704-91 —ø720x8

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.07
Clause 9.2.1	strength under the action of bending moment Mz	0.14
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.14
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1, O, U1)	0.04
Clause 8.1.3	compressive stability in the plane X1, O, Z1 (X1, O, V1)	0.01
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.07
Cl.10.2.6, 10.2.8	stability from the plane of action of the moment Mz at off-center compression	0.01
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	0.99
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	0.5

The load-carrying capacity utilization factor 0.99 is the ultimate flexibility in the plane X1, O, Y1

Columns in axes 2 and 3. Run A. Element No. 4285

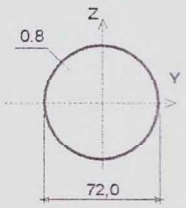


Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 150.0
Longitudinal electric-welded tubes GOST 10704-91 —ø720x8

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.14
Clause 9.2.1	strength under the action of bending moment Mz	0.27
Clause 9.2.1	strength under the action of the transverse force Qy	0.05
Clause 9.2.1	strength under the action of the transverse force Qz	0.01
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.38
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1, O, U1)	0.1
Clause 8.1.3	compressive stability in the plane X1, O, Z1 (X1, O, V1)	0.13
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.22
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	0.08
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	0.5

The load-carrying capacity utilization factor 0.99 is the ultimate flexibility in the plane X1, O, Z1

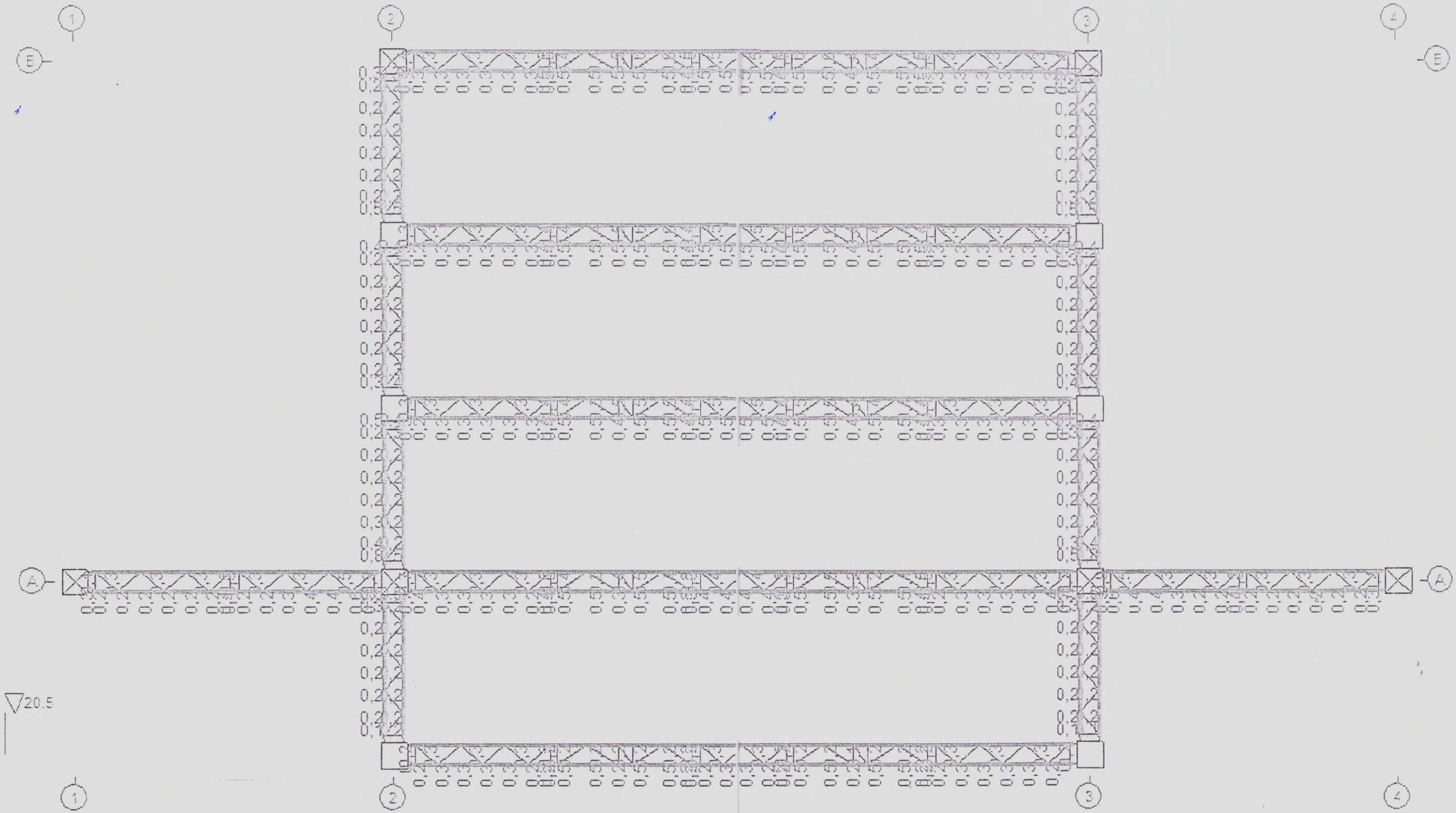
Columns in axes 2 and 3. Run A. Element No. 4432



Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 150.0
Longitudinal electric-welded tubes GOST 10704-91 — ⌀720x8

Checked by DBN V.2.6-198:2014	**Results of calculation** Factor	**Load-carrying capacity utilization factors**
Clause 9.2.1	strength under the action of bending moment My	0.32
Clause 9.2.1	strength under the action of bending moment Mz	0.17
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0.02
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.4
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1, O, U1)	0.06
Clause 8.1.3	compressive stability in the plane X1, O, Z1 (X1,O, V1)	0.06
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.29
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	0.41
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	0.41

The load-carrying capacity utilization factor 0.41 is the ultimate flexibility in the plane X1, O, Y1



Load-carrying capacity utilization factors
of the elements of the truss upper belts
(the largest of those determined by the criteria of strength and stability)

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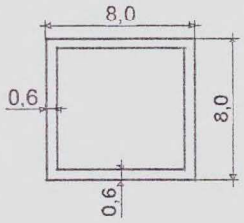
Ap

17

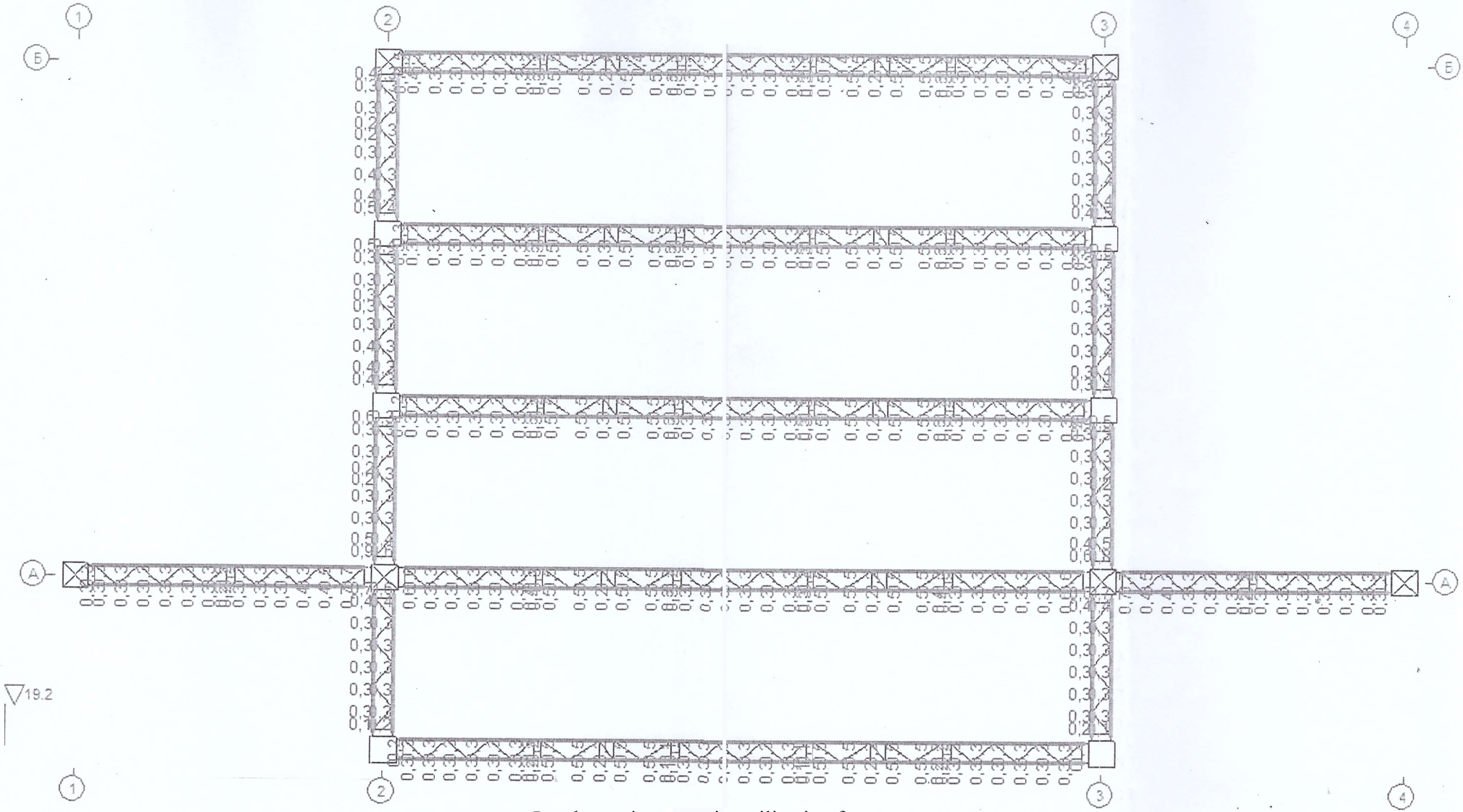
Truss upper belt. Element No. 1948



Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 150.0

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.12
Clause 9.2.1	strength under the action of bending moment Mz	0.21
Clause 9.2.1	strength under the action of the transverse force Qy	0.03
Clause 9.2.1	strength under the action of the transverse force Qz	0.01
Clause 10.1.1	trength under the mutual action of longitudinal force and bending moment excluding plastic	0.87
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1, O, U1)	0.39
Clause 8.1.3	compressive stability in the plane X1, O, Z1 (X1, O, V1)	0.39
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.25
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	0.17
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	0.17

The load-carrying capacity utilization factor 0.87 is the strength under the mutual action of longitudinal force and bending moment excluding plastic



Load-carrying capacity utilization factors
of the elements of the truss lower belts
(the largest of those determined by the criteria of strength and stability)

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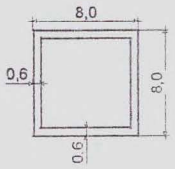
Truss lower belt. Element No. 1749

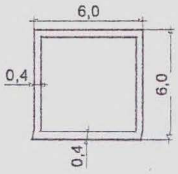


Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 150.0

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.14
Clause 9.2.1	strength under the action of bending moment Mz	0.2
Clause 9.2.1	strength under the action of the transverse force Qy	0.03
Clause 9.2.1	strength under the action of the transverse force Qz	0.02
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.84
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1, O, U1)	0.71
Clause 8.1.3	compressive stability in the plane X1, O, Z1 (X1, O, V1)	0.71
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.35
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	0.35
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	0.14

Load-carrying capacity utilization factor 0.84 is the strength under the mutual action of longitudinal force and bending moment excluding plastic

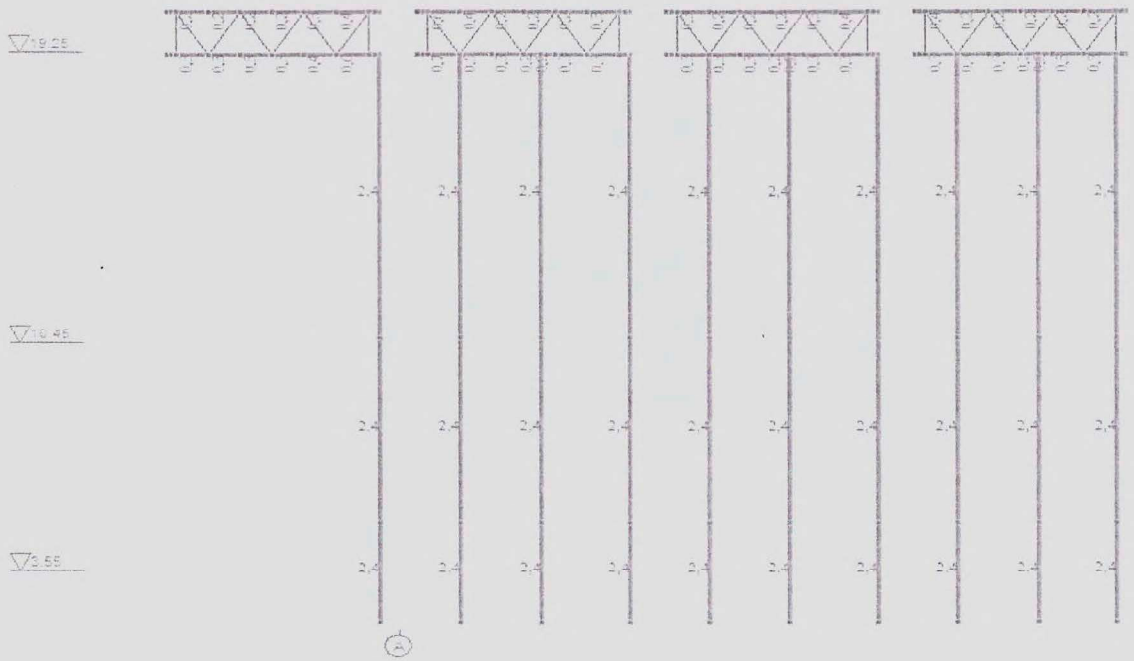
Truss web. Element No 2714



Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 200.0

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.2
Clause 9.2.1	strength under the action of bending moment Mz	0.02
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0.01
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.58
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1, O, U1)	0.46
Clause 8.1.3	compressive stability in the plane X1, O, Z1 (X1, O, V1)	0.46
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.67
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	0.33
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	0.33

Load-carrying capacity utilization factor 0.67 is stability in the plane of action of the moment My at off-center compression.

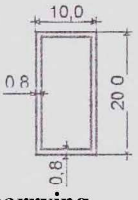


Load-carrying capacity utilization factors of the elements of framework structure vertical posts.

(the largest of those determined by the criteria of strength and stability)

Framework structure. Elements No 4322

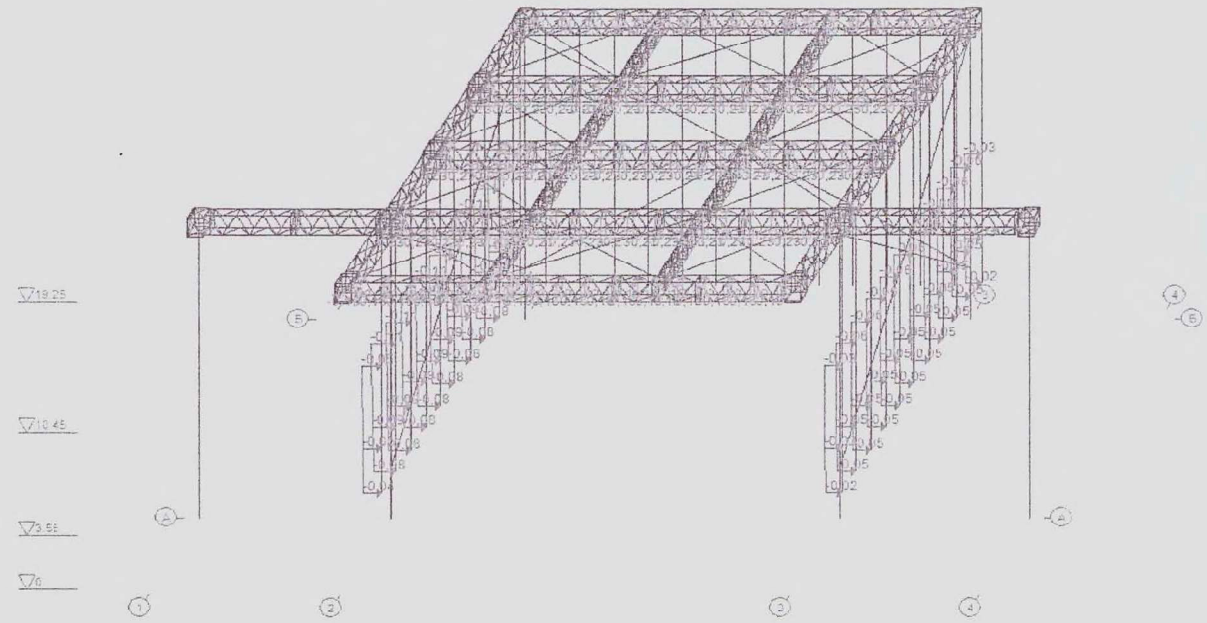
Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility – 180.0



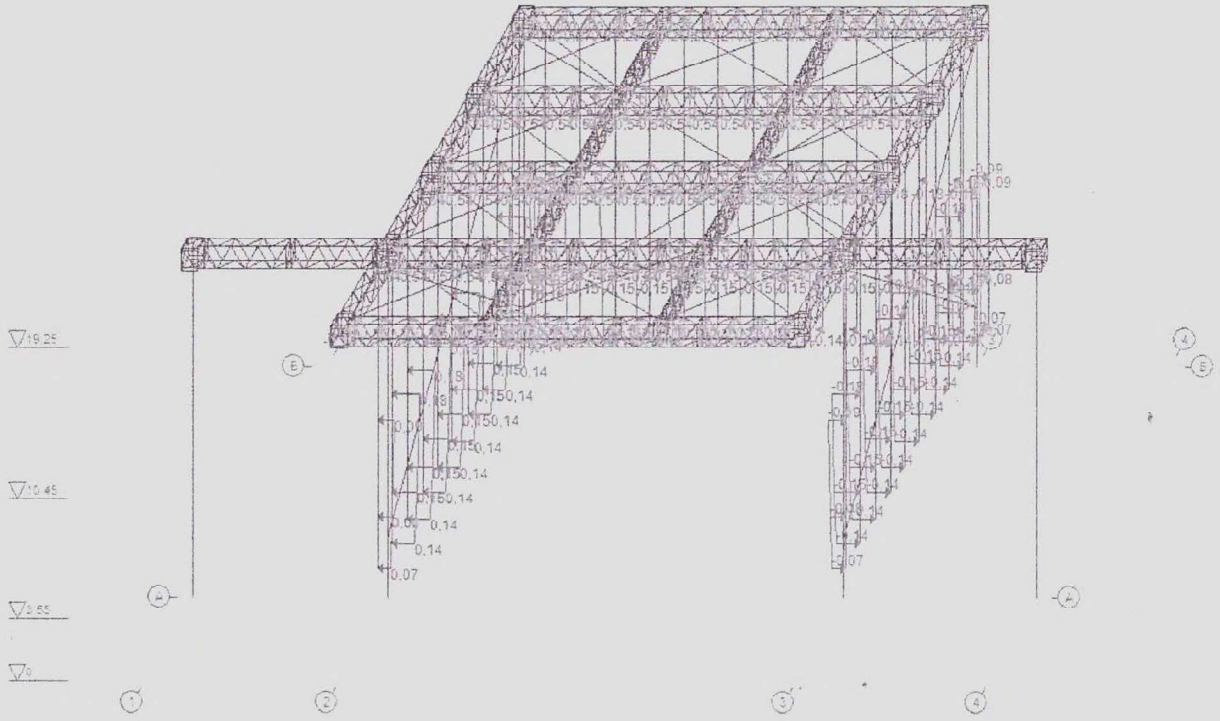
Checked by DBN V.2.6-198:2014	**Results of calculation** **Factor**	**Load-carrying capacity utilization factors**
Clause 9.2.1	strength under the action of bending moment My	0.62
Clause 9.2.1	strength under the action of bending moment Mz	0
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0.01
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.62
Clause 8.1.3	compressive stability in the plane X1, O, Y1 (X1,O, U1)	0.02
Clause 8.1.3	compressive stability in the plane X1, O Z1 (X1,O, V1)	0
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.03
Clause 10.2.9	compressive stability with bending in two planes	0.05
Cl.10.2.6-10.2.8	stability from the plane of action of the moment My at off-center compression	0.64
Clause 13.4.1	ultimate flexibility in the plane X1, O, Y1	**2.37**
Clause 13.4.1	ultimate flexibility in the plane X1, O, Z1	**1.37**

Load-carrying capacity utilization factor 2.37 is the ultimate flexibility in the plane X1, O, Y1

4.3 Calculated loads for the option W0= 37 kg/m2



The diagram of wind load deposition along letter axes (W0=37 kg/m2)



The diagram of wind load deposition along digital axes (to inside the stage) (W0=37 kg/m2)

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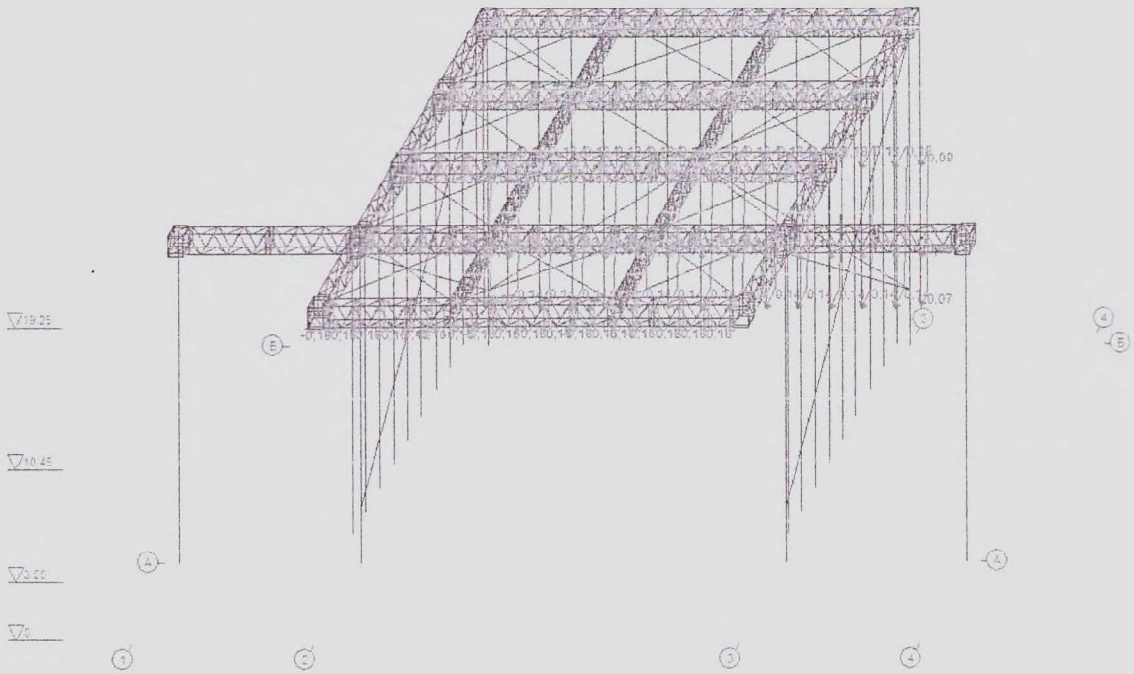
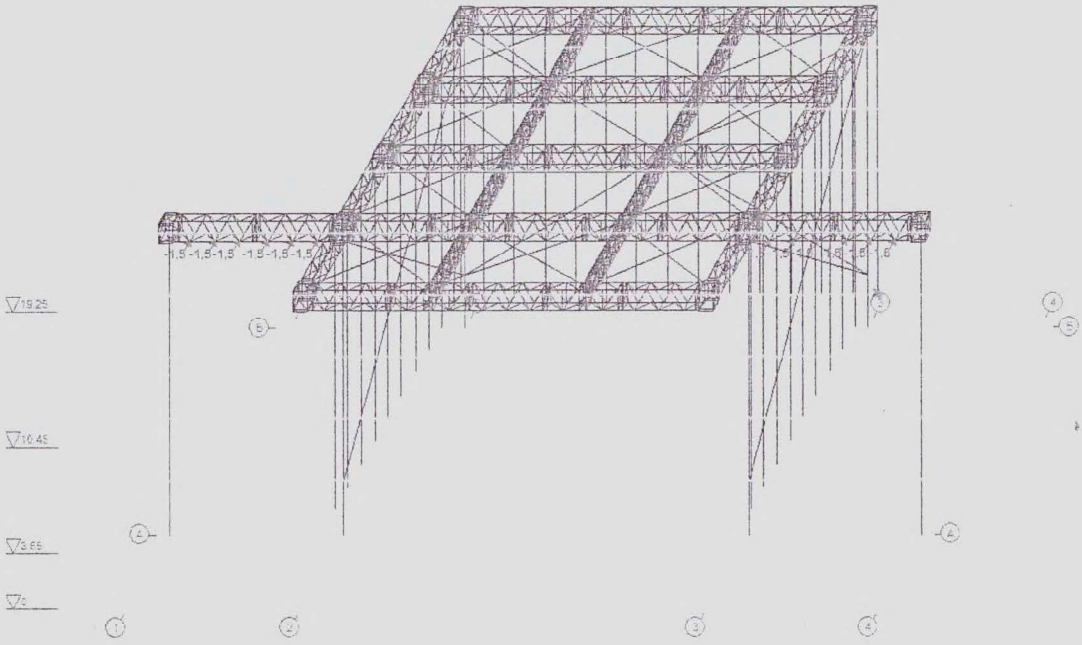


The diagram of wind load deposition along numerical axes (to the back wall of the stage)
(W0=37kg/m2)



The diagram of wind load deposition from suspended screens (W0=37kg/m2)

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Signature and date

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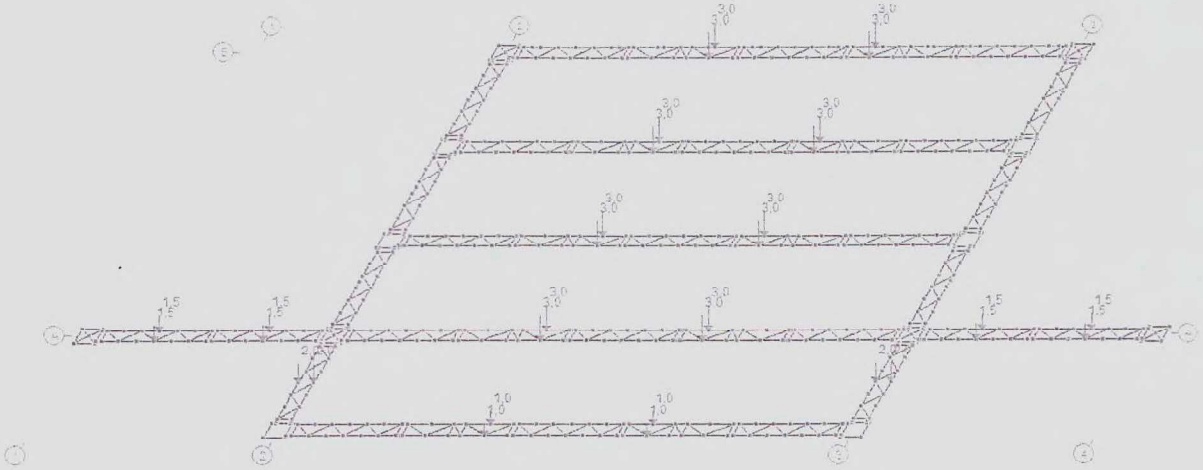
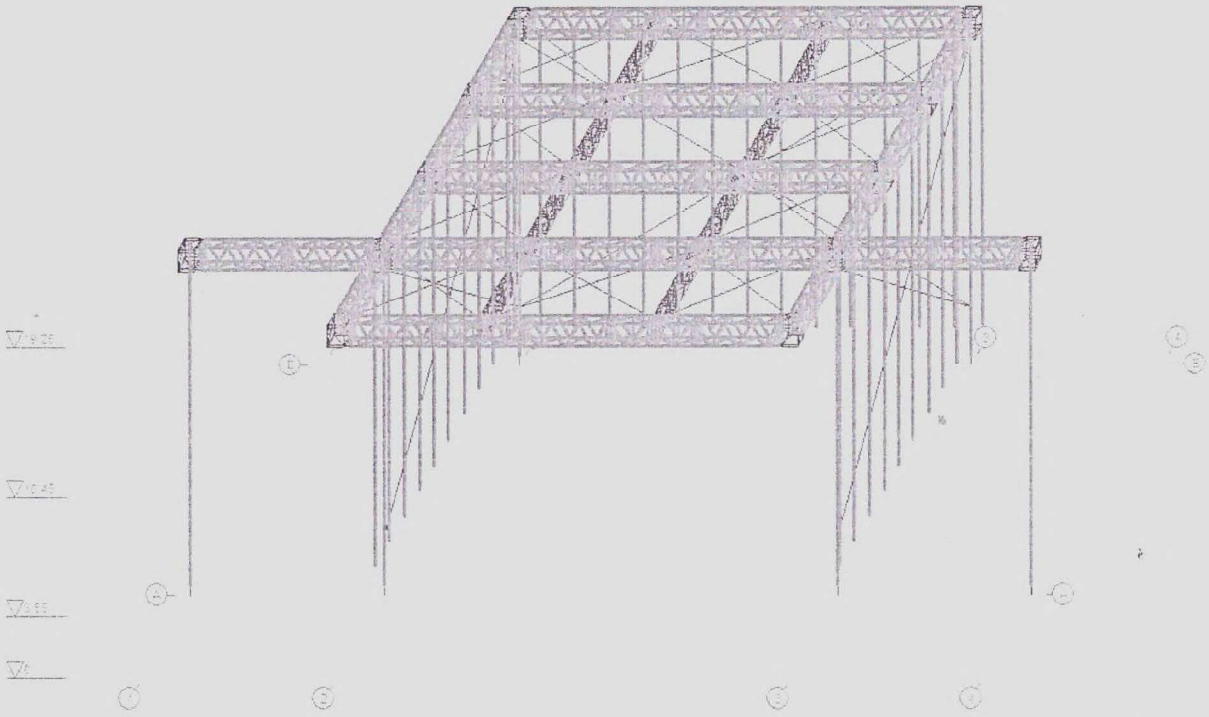


The diagram of load deposition from suspended equipment

4.4 Results of calculation for the option W0 = 37 kg/m2



General view of the structural diagram according to the calculation results for option W0=25 kg/m2

The green color on the diagram indicates the elements with load-carrying capacity utilization factors not exceeding 1.0.
The red color on the diagram indicates the elements with load-carrying capacity utilization factors exceeding 1.0.

The overall results of the calculation of the stage frame

Wind W0=37 kp/m2

№ of combination	Name of loads	Name of element	Maximum efforts N, tf	Horizontal displacements (tower top) m	Vertical movement (deflection of the trusses), m	Maximum efforts in the base of the column N1, tf
1	Own weight + suspended equipment	trusses belts	±24,0	0,005	-0,093	-43,0
		truss web	-8,1 /+8,9			
		vertical ties	+3,6			
		horizontal ties	-0,5 /+1,0			
2	Own weight + suspended equipment + wind W0 along the axis ±X	trusses belts	-18,0 /+17,0	0,009	-0,060	-29,0
		truss web	±5,0			
		vertical ties	+4,5			
		horizontal ties	+1,0 /-0,4			
3	Own weight + suspended equipment + wind W0 along the axis +Y	trusses belts	-20,0 /+24,0	0,105	-0,028	-15,0
		truss web	±8,0			
		vertical ties	+8,0 /-5,2			
		horizontal ties	+1,1			
4	Own weight + suspended equipment + wind W0 along the axis -Y	trusses belts	-34,0/+28,0	0,107	-0,088	-45,0
		truss web	±8,0			
		vertical ties	+10,0/-4,5			
		horizontal ties	+1,0 /-0,4			
5	Own weight + wind W0 along the axis ±X	trusses belts	±5	0,009	+0,015	-6,0
		truss web	±2,0			
		vertical ties	+3,2			
		horizontal ties	+1,1			
6	Own weight + wind W1 along the axis ±Y	trusses belts	±15,0	0,009	+0,066	+16,5
		truss web	±6,0			
		vertical ties	+3,0/-0,4			
		horizontal ties	+1,7			
7	Own weight + wind W1 along the axis -Y	trusses belts	±4	0,009	-0,014	-10,0
		truss web	±4,0			
		vertical ties	+3,9			
		horizontal ties	+1,0			

1.Efforts in the column base with the sign (+) means the presence of uplift.
2.Maximum allowable displacement in the column top is 110 mm.
3.Maximum allowable trusses deflection is 100 mm
4.The value of the load-carrying capacity utilization factors for each group of elements of the frame of the stage are given in the diagrams in calculations.
5.Based on the uplift value in combination 6, the weight of the necessary ballast:
- 20 t for columns in axes 2, 3 run A;
- 12 t for columns in axes 1, 4 run A; in axes 2, 3 run B.
6.Efforts in vertical ties provided for two planes of ties.

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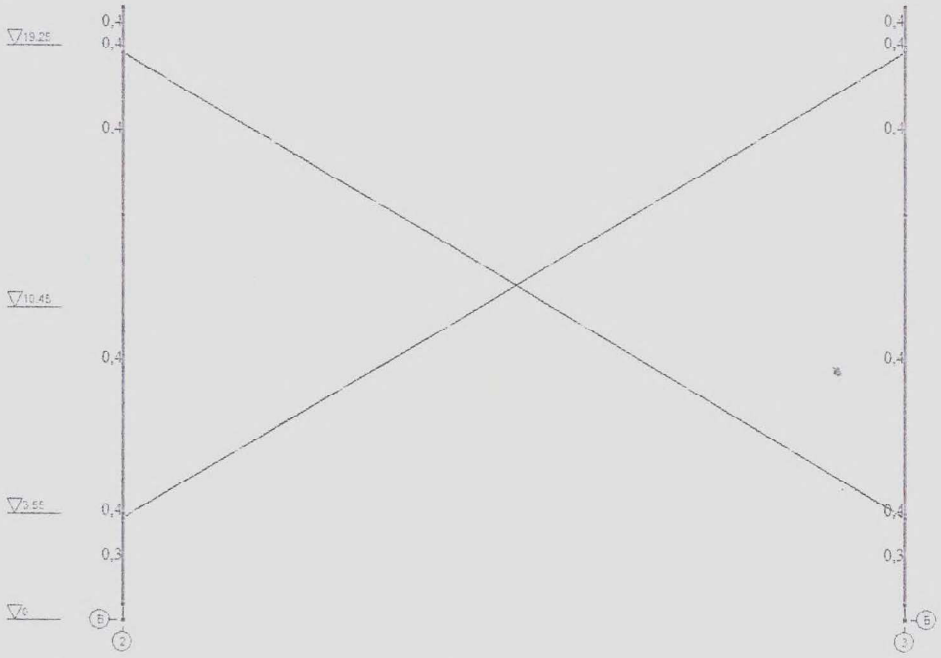
Load-carrying capacity utilization factors of columns along the axis A.
(the largest of those determined by the criteria of strength and stability)



Load-carrying capacity utilization factors of columns along the axis B.
(the largest of those determined by the criteria of strength and stability)

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Signature and date

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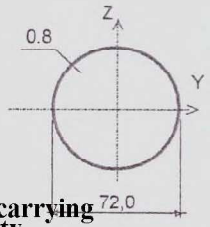
According to the results of the static verification calculation made by to the program SCAD of the spatial frame of the stage, the strength and stability of the elements for the action of the calculated load combinations are given in the following tables, where the elements load-carrying capacity usage are indicated by the factors values

Columns in axes 1 and 4. Run A. Element No. 4284

Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 200,0
Longitudinal electric-welded tubes GOST 10704-91 ⌀720x8



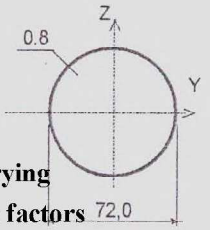
Load-carrying capacity utilization factors

Checked by DBN V.2.6-198:2014	**Results of calculation**	**Factor**
Clause 9.2.1	strength under the action of bending moment My	0.02
Clause 9.2.1	strength under the action of bending moment Mz	0.19
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.19
Clause 8.1.3	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.05
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0.02
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.04
Cl.10.2.6-10.2.8	stability from the plane of action of the moment My at off-center compression	0.02
Clause 13.4.1	ultimate flexibility in the plane X1,O, Y1	0.99
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	0.5

Load-carrying capacity utilization factor 0.99 is the ultimate flexibility in the plane X1,O, Y1.

Columns in axes 2 and 3. Run A. Element No. 4285

Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 150.0
Longitudinal electric-welded tubes GOST 10704-91 ⌀720x8

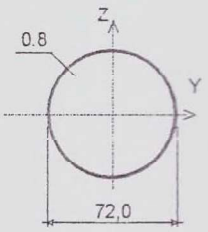


Load-carrying capacity utilization factors

Checked by DBN V.2.6-198:2014	**Results of calculation**	**Factor**
Clause 9.2.1	strength under the action of bending moment My	0.08
Clause 9.2.1	strength under the action of bending moment Mz	0.09
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.18
Clause 8.1.3	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.12
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0.13
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.2
Clause 13.4.1	ultimate flexibility in the plane X1,O, Y1	0.41
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	0.5

Load-carrying capacity utilization factor 0.5 is the ultimate flexibility in the plane X1,O, Y1.

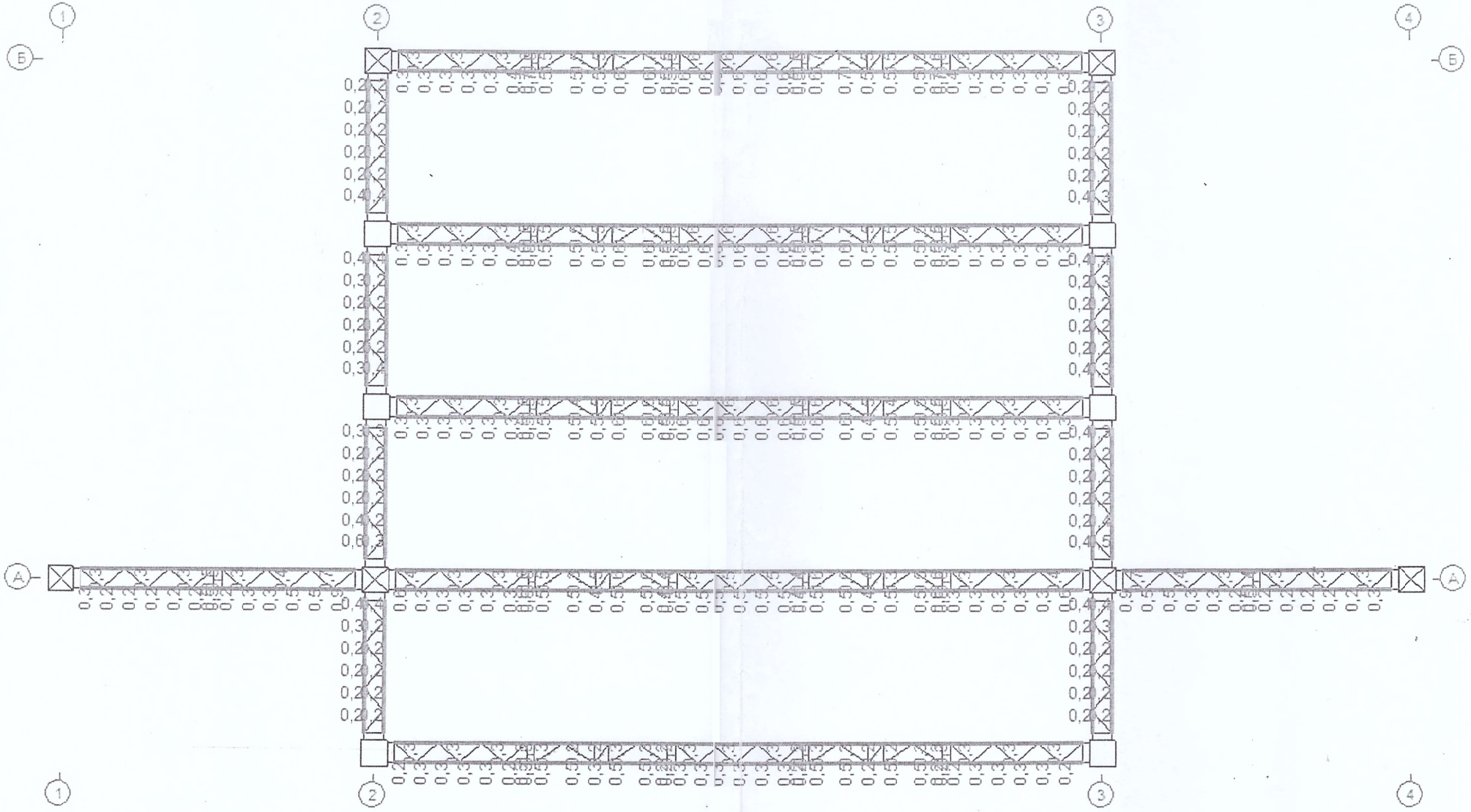
Columns in axes 2 and 3. Run B. Element No. 4288



Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 150.0
Longitudinal electric-welded tubes GOST 10704-91 ø720x8

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.18
Clause 9.2.1	strength under the action of bending moment Mz	0.1
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0.02
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.25
Clause 8.1.3	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.06
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0.06
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.19
Clause 13.4.1	ultimate flexibility in the plane X1,O, Y1	0.41
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	0.41

Load-carrying capacity utilization factor 0.41 is the ultimate flexibility in the plane X1,O, Y1.



Load-carrying capacity utilization factors of the elements of the truss upper belts
(the largest of those determined by the criteria of strength and stability)

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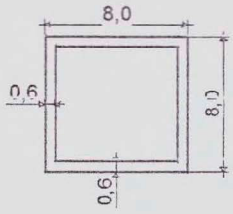
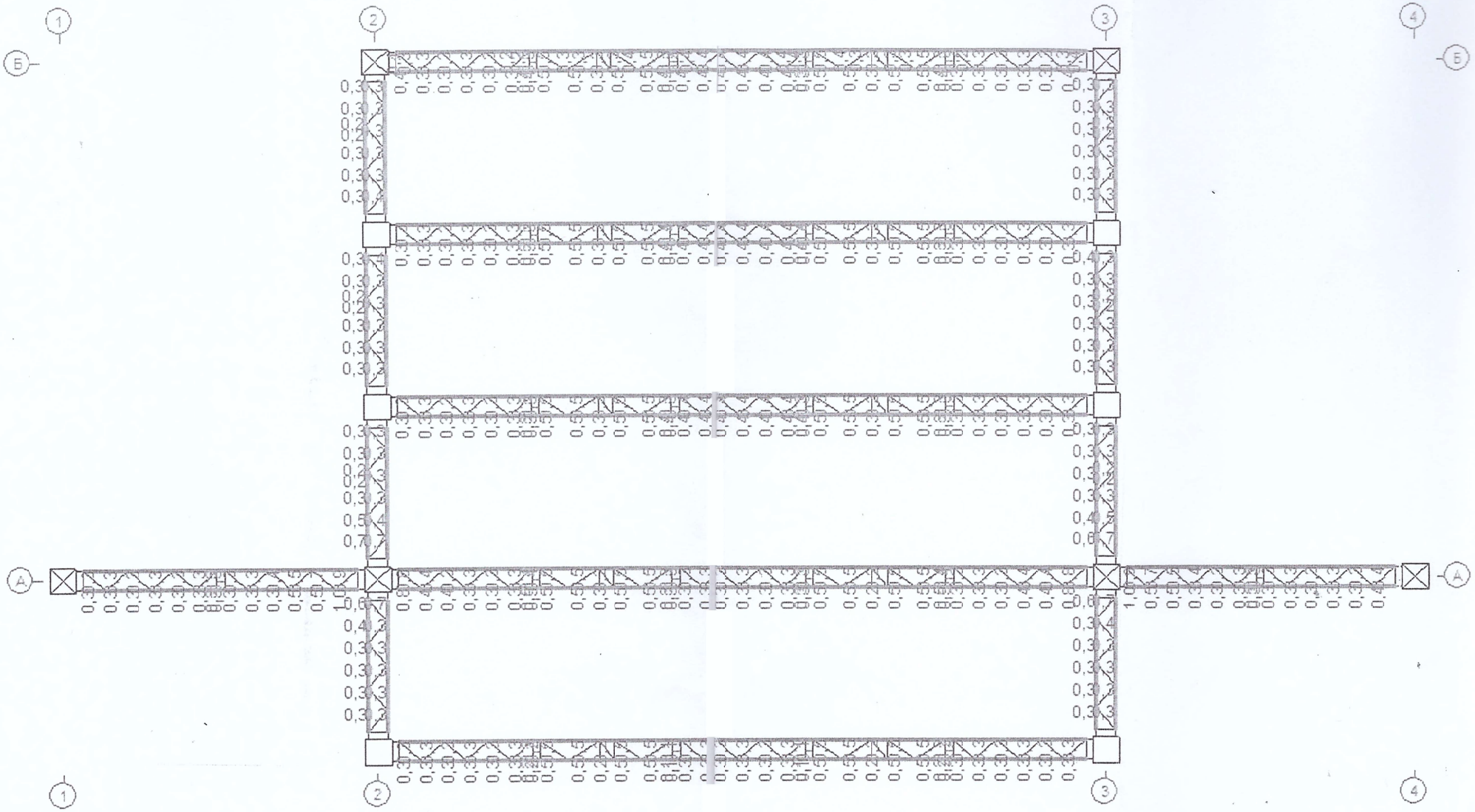
Trusses upper belt. Element No. 1770



Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 150.0

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.12
Clause 9.2.1	strength under the action of bending moment Mz	0.23
Clause 9.2.1	strength under the action of the transverse force Qy	0.03
Clause 9.2.1	strength under the action of the transverse force Qz	0.01
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.89
Clause 10.1.1	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.74
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0.62
Clause 8.13	stability in the plane of action of the moment My at off-center compression	0.62
Cl.10.2.2, 10.2.3	ultimate flexibility in the plane X1,O, Y1	0.47
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	0.17
Clause 13.4.1	stability under the action of the bending moment My	0.17

Load-carrying capacity utilization factor 0.89 is the strength under the mutual action of longitudinal force and bending moment excluding plastic.



Load-carrying capacity utilization factors of the elements of the truss lower belts
the largest of those determined by the criteria of strength and stability)

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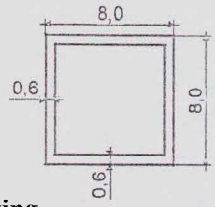
Trusses lower belt. Element No.1749

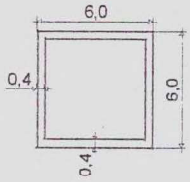


Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 150.0

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.15
Clause 9.2.1	strength under the action of bending moment Mz	0.22
Clause 9.2.1	strength under the action of the transverse force Qy	0.03
Clause 9.2.1	strength under the action of the transverse force Qz	0.02
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.99
Clause 8.1.3	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.8
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0.8
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.38
Clause 13.4.1	ultimate flexibility in the plane X1,O, Y1	0.17
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	0.17

Load-carrying capacity utilization factor 0.99 is stability in the strength under the mutual action of longitudinal force and bending moment excluding plastic.

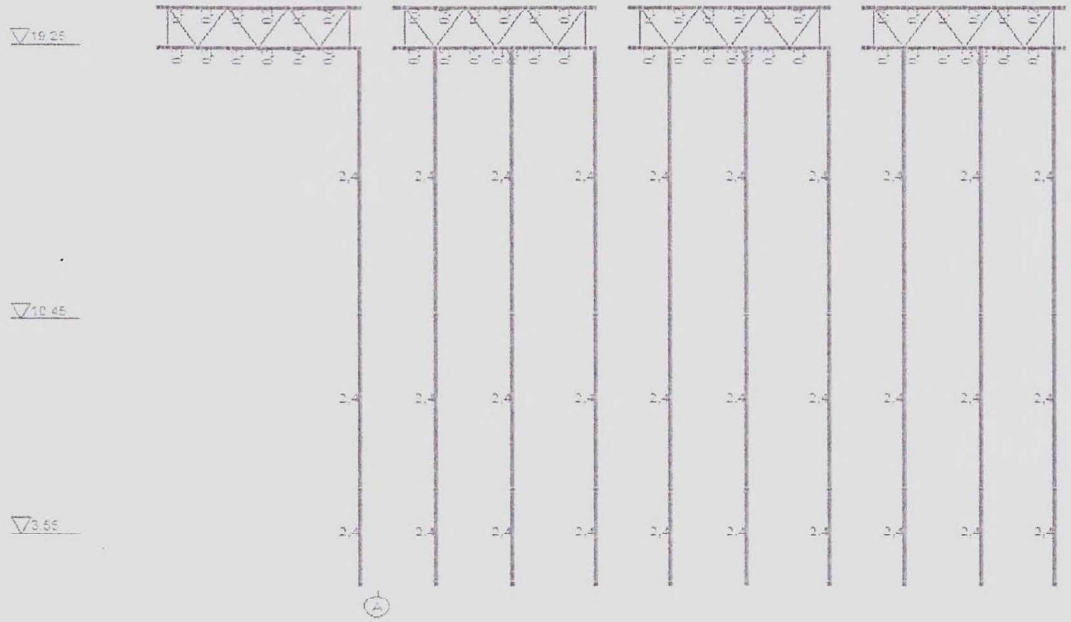
Trusses web. Element No. 1925



Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 200.0

Checked by DBN V.2.6-198:2014	Results of calculation Factor	Load-carrying capacity utilization factors
Clause 9.2.1	strength under the action of bending moment My	0.04
Clause 9.2.1	strength under the action of bending moment Mz	0.58
Clause 9.2.1	strength under the action of the transverse force Qy	0.1
Clause 9.2.1	strength under the action of the transverse force Qz	0
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.74
Clause 8.1.3	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.2
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0.2
Clause 13.4.1	ultimate flexibility in the plane X1,O, Y1	0.15
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	0.15

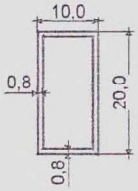
Load-carrying capacity utilization factor 0.74 is stability in the plane of action of the moment My at off-center compression.



Load-carrying capacity utilization factors of the elements of the framework structure vertical posts, (the largest of those determined by the criteria of strength and stability)

Framework structure. Element No 4322

Design resistance of steel R_y= 24,500.0 T/m^2
Specific conditions of use factor — 1.0
Ultimate flexibility -- 180.0



Results of calculation

Checked by DBN V.2.6-198:2014	**Factor**	**Load-carrying capacity utilization factors**
Clause 9.2.1	strength under the action of bending moment My	0.62
Clause 9.2.1	strength under the action of bending moment Mz	0
Clause 9.2.1	strength under the action of the transverse force Qy	0
Clause 9.2.1	strength under the action of the transverse force Qz	0.01
Clause 10.1.1	strength under the mutual action of longitudinal force and bending moment excluding plastic	0.62
Clause 8.1.3	compressive stability in the plane X1,O, Y1 (X1,O, U1)	0.02
Clause 8.1.3	compressive stability in the plane X1,O, Z1 (X1,O, V1)	0
Cl.10.2.2, 10.2.3	stability in the plane of action of the moment My at off-center compression	0.03
Cl.10.2.9	compressive stability with bending in two planes	0.05
Cl.10.2.6, 10.2.8	stability from the plane of action of the moment My at off-center compression	0.64
Clause 13.4.1	ultimate flexibility in the plane X1,O, Y1	**2.37**
Clause 13.4.1	ultimate flexibility in the plane X1,O, Z1	**1.37**

Load-carrying capacity utilization factor 2.37 is the ultimate flexibility in the plane X1,O, Y1.

5. Conclusions and recommendations

5.1 According to the results of calculations of the metal frame of the stage, the following main indicators were estimated:

- load-carrying capacity of the elements of spatial trusses;
- load-carrying capacity of the columns;
- horizontal displacement of columns tops;
- the presence of uplift in the supporting part of the columns.

5.2 According to the analysis of the performed verification calculations for the given loads, the carrying capacity of the metal frame of the stage as a whole is provided with the mandatory use of ballast on the columns supports at a distance of up to 3.0 m from the column.

Horizontal displacements do not exceed those that are permissible according to DSTU B V. 1.2-3:2006 "Deflections and displacements".

5.3 When operating facilities in open areas and on the banks of rivers or the sea, where there may be sudden changes in the direction and speed of wind pressure, in case of warning in the weather forecasts, we recommend that you urgently dismantle the awning covering and screens to reduce windage.

5.4 When installing vertical ties, it is necessary to provide their pre-tension at a force of 1.0 t and for horizontal ties of the covering-0.7 t.

5.5 During operation of the facility it is necessary during the regular inspection of structures to monitor places of fastening of the ties, the joints of the columns, the welds, the condition of anti-corrosion coatings. Perform anticorrosion protection of metal structures according to the instructions of DSTU B V. 2.6-193:2013 "Protection of metal structures against corrosion. Design requirements»;

5.6 **For a more reliable operation of the structure, we recommend installing additional covering elements or struts, which, in strong winds, will reduce the displacement and possible fluctuations of the individual columns (see. Annex A, sheet 6).**

6. Additional materials

6.1 Fundamental solution of their design with the placement of assembly joints, cross-arms design, etc. for the manufacture of frame columns are given in Annex A in the sheet 7

These solutions are not binding, but in case of changes and wishes of the customer, they need to be agreed with the performer.

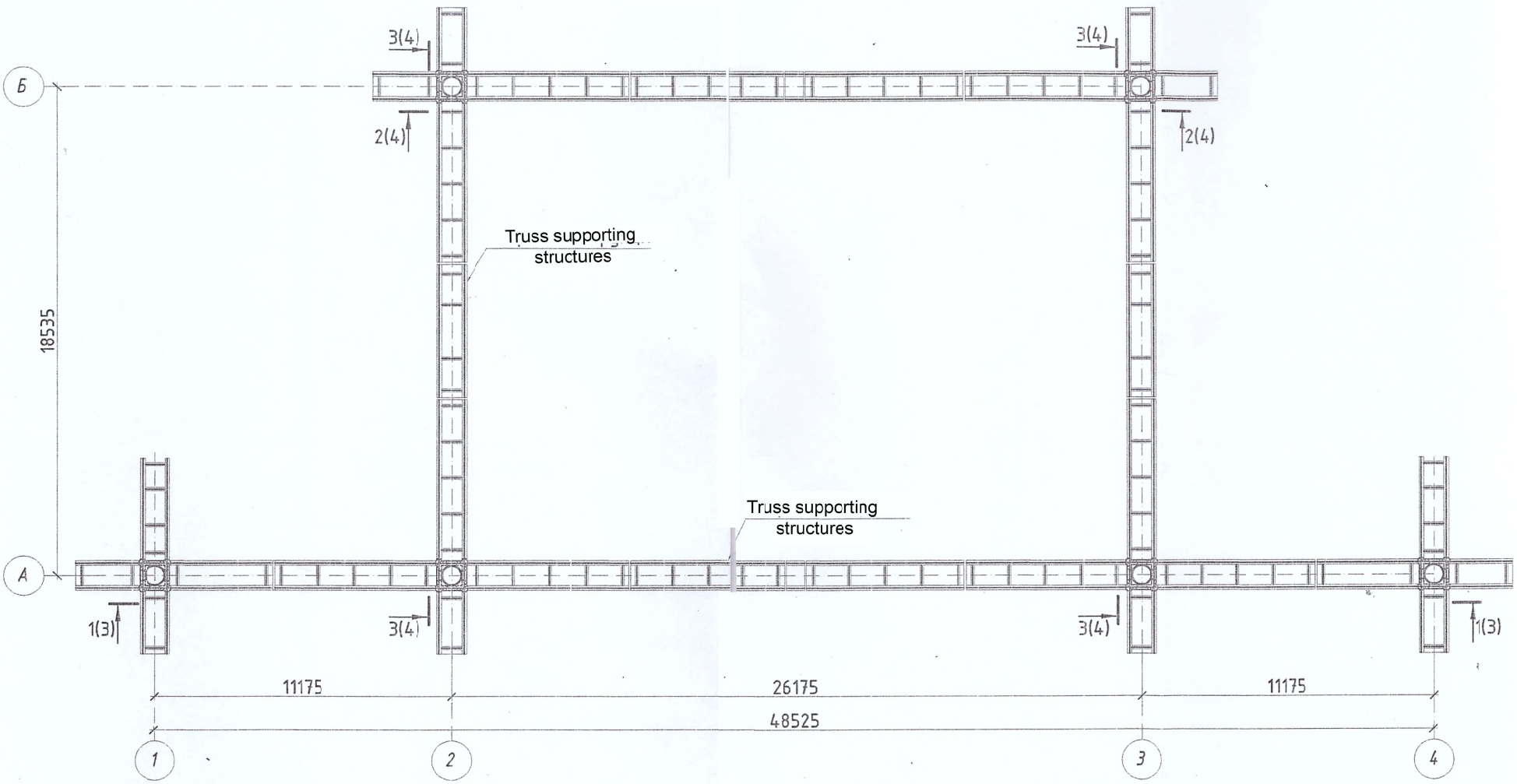
6.2 Individual elements of spatial trusses connected to each other can be used as separate "I-beams".

The ultimate loads at different spans of "beams" and schemes of loads deposition are given in Appendix B.

Annex A

Graphical representations

Layout of columns and supporting structures at the mark of +0.500



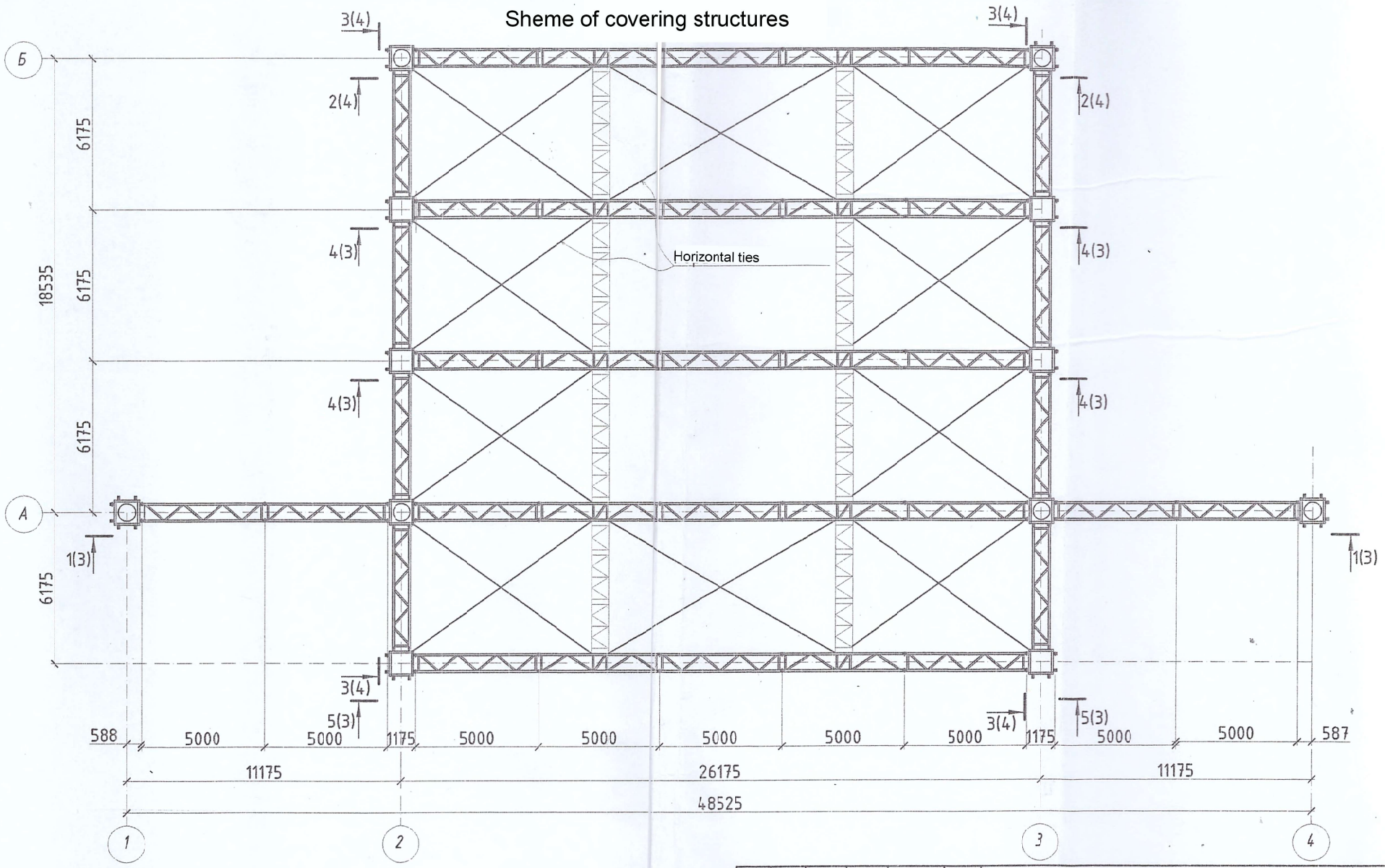
Work together with sheets 3,4

						31845-KM	
						Verification calculation of metal frame of the stage	
Cont.	Qty	Sheet	Nc.doc.	Signature	Date		
Head of the Dep.		Holubova			02.2018	Technical report	Stage: P; Sheet: 1; Tot.Sheets:
Public insp.		Kovalchuck			02.2018		
Project slr. eng.		Iliushenko			02.2018		
Head of the group		Moskalenko			02.2018	Layout of columns and supporting structures at the mark of +0,500	V. M. Shimanovsky Ukrinstalkon LLC, 2018
Checked by		Iliushenko			02.2018		
Developer		Moskalenko			02.2018		

Инв. № подл. | Подпись и дата | Взам. инв. №

A3

Sheme of covering structures



Work together with sheets 3, 4

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H. of the Dep.		Holubova			02.2018
Public insp.		Kovalchuck			02.2018
Proj.str. eng.		Iliushenko			02.2018
H. of the gr.		Moskalenko			02.2018
Checked by		Iliushenko			02.2018
Developer		Moskalenko			02.2018

31845-KM

Verification calculation of metal frame of the stage

Technical report	Stage	Sheet	Tot.sheets
	P	2	

Scheme of covering structures

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Ukrinstalkon LLC, 2018

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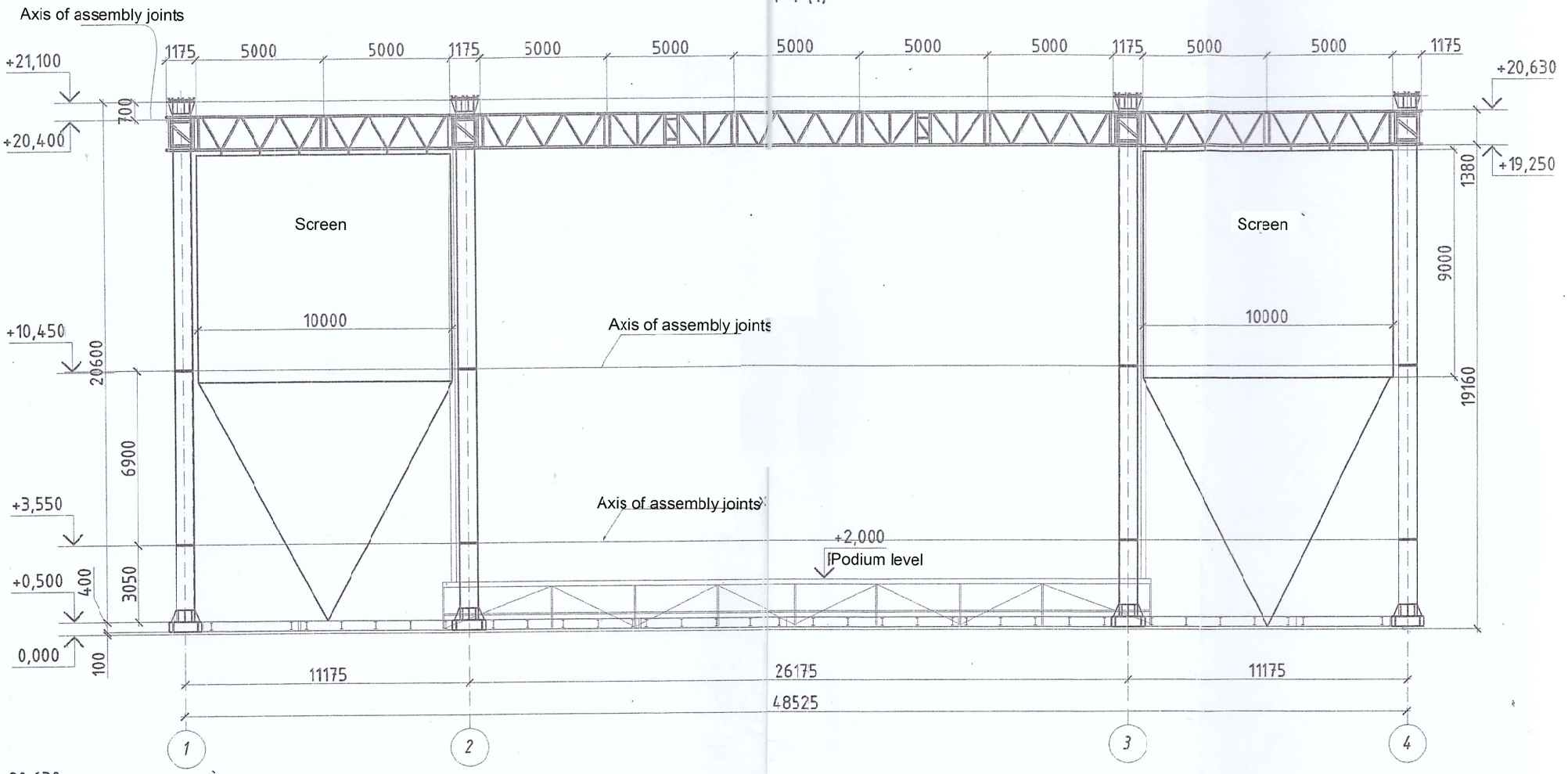
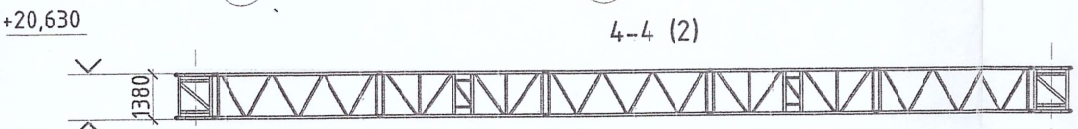
Inv No of equip

1–1 (1)



4–4 (2)



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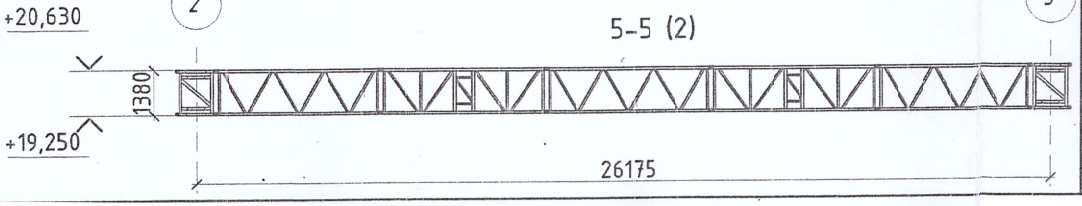

Work together with sheets 1, 2

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Public inspection		Kovalchuck			02.2018
Project str. eng.		Illushenko			02.2018
Head of the group		Moskalenkc			02.2018
Checked by		Illushenko			02.2018
Developer		Moskalenkc			02.2018

31845-KM

Verification calculation of metal frame of the stage

Technical report

Stage	Sheet	Tot.Sheets
P	3	

Section 1-1; 4-4; 5-5

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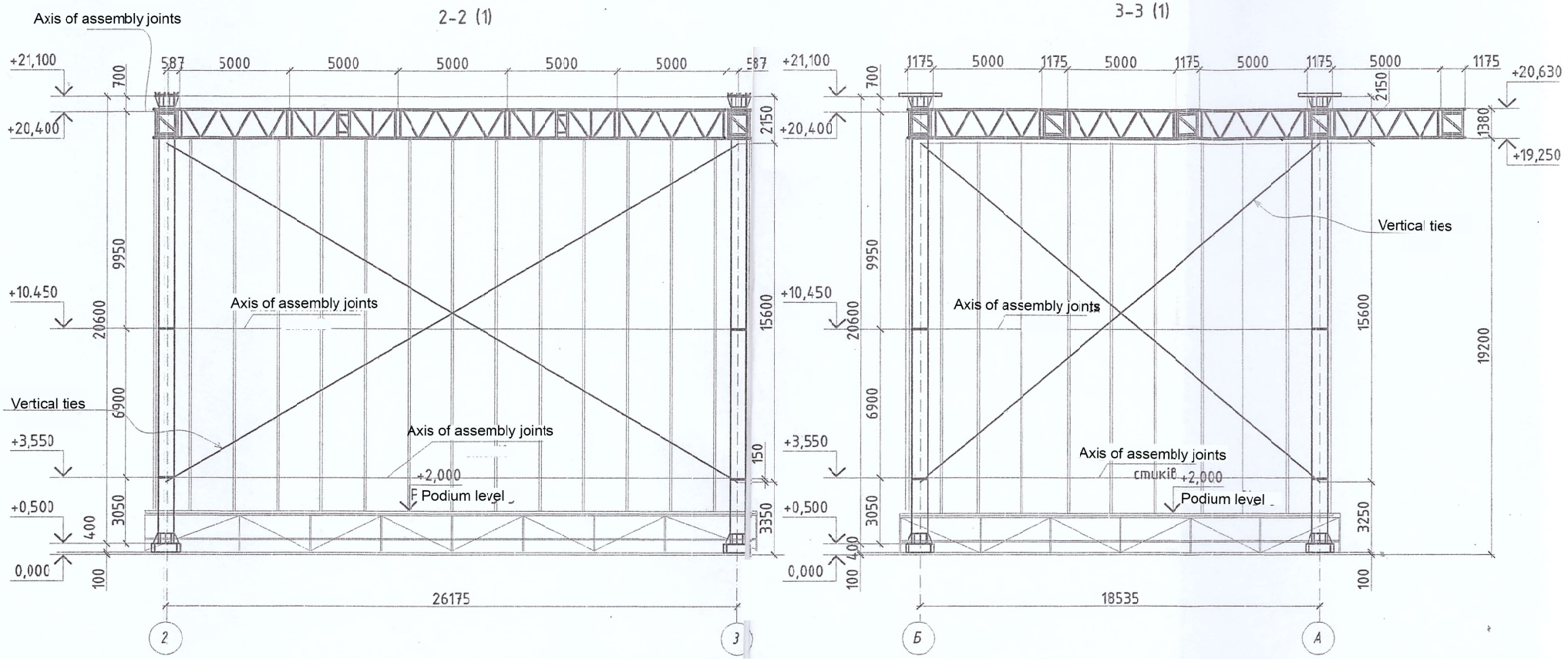

Work together with sheets 1, 2

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H. of the gr.		Mcskalenko			02.2018
Checked by		Iliushenko			02.2018
Developer		Mcskalenko			02.2018

31845-KM

Verification calculation of metal frame of the stage

Technical report	Stage	Sheet	Tot.sheets
	P	4	

Section 2-2; 3-3

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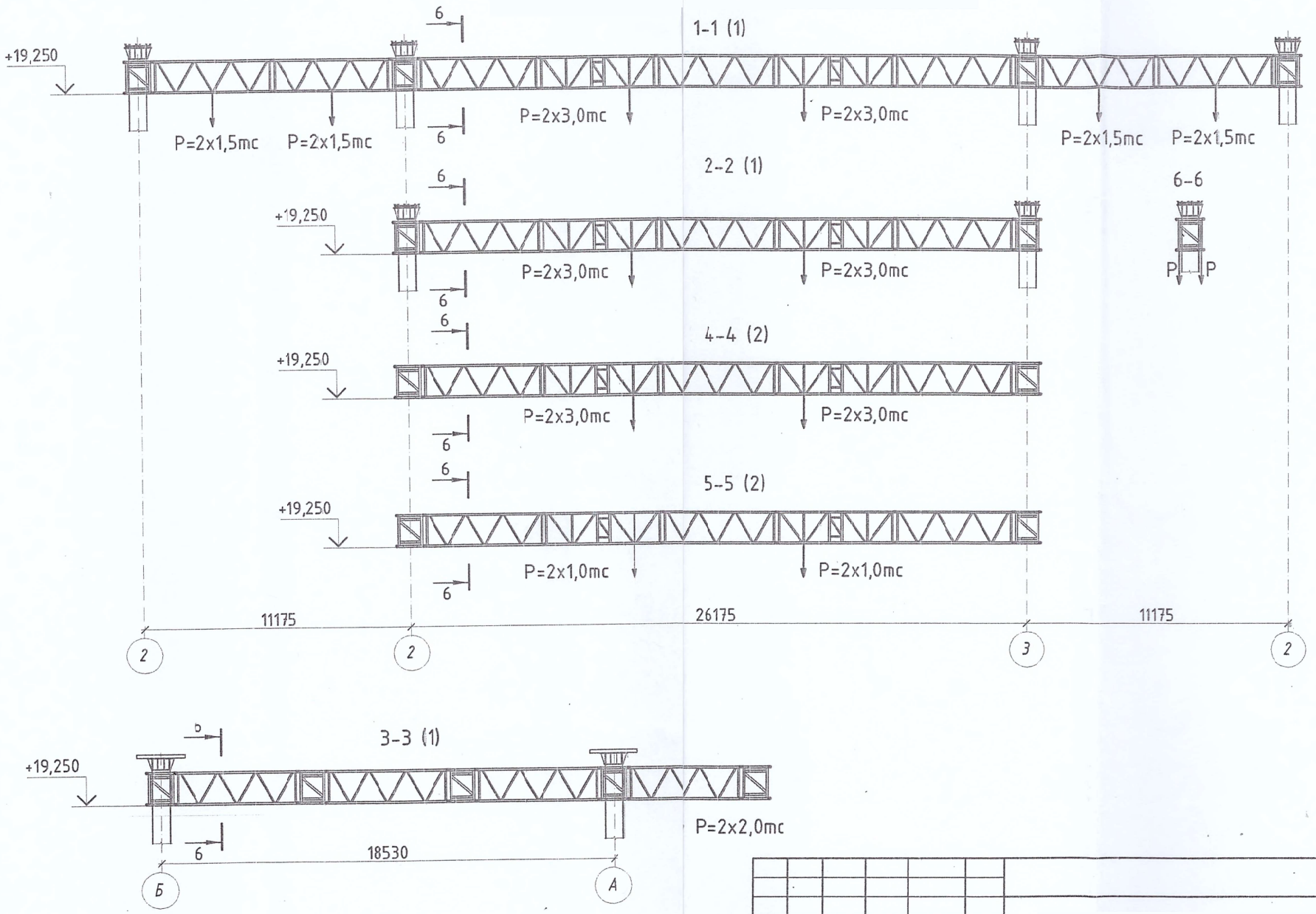
Layout of processing equipment



Work together with sheets 3, 4

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Public insp.		Kovalchuck			02.2018
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H. of the gr.		Moskalenko			02.2018
Checked by		Iliushenko			02.2018
Developer		Moskalenko			02.2018

31845-KM

Verification calculation of metal frame of the stage

Technical report	Stage	Sheet	Tot.sheets
	P	5	

Layouts of processing equipment

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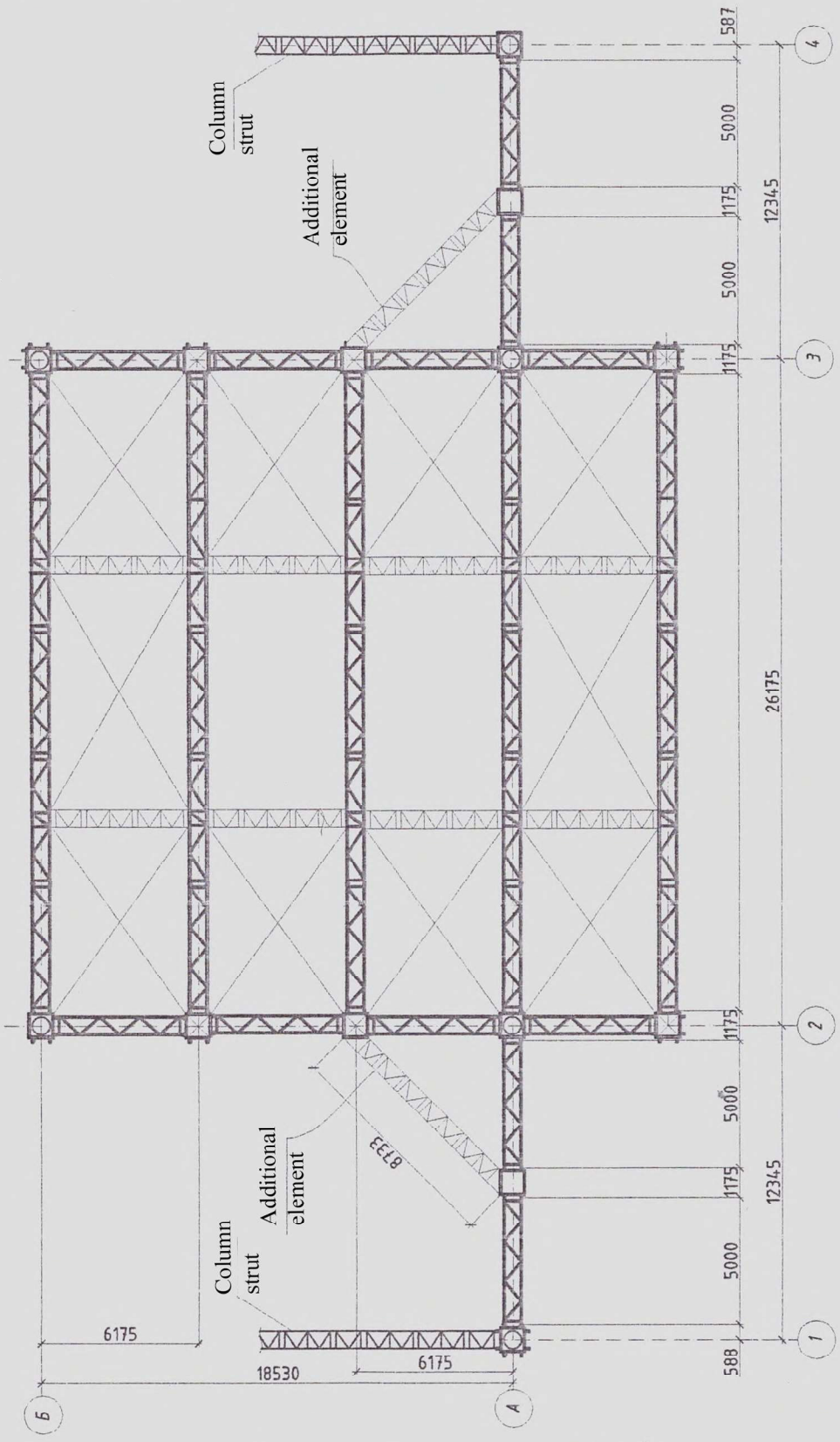
Scheme of covering structures with additional element.



						31845-KM
						Verification calculation of metal frame of the stage
Cont.	Qty	Sheet	Ndoc.	Signature	Date	
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Public ins.		Kovalchuck			02.2018	
Pr. str. engi.		Iliushenko			02.2018	
H.of the group		Moskalenko			02.2018	Scheme of covering structures with additional element.
Checked by		Iliushenko			02.2018	
Developer		Moskalenko			02.2018	

Stage	Sheet	Tot.sheets
P	6	

V. M. Shimanovsky
Ukrinstalkon LLC, 2018

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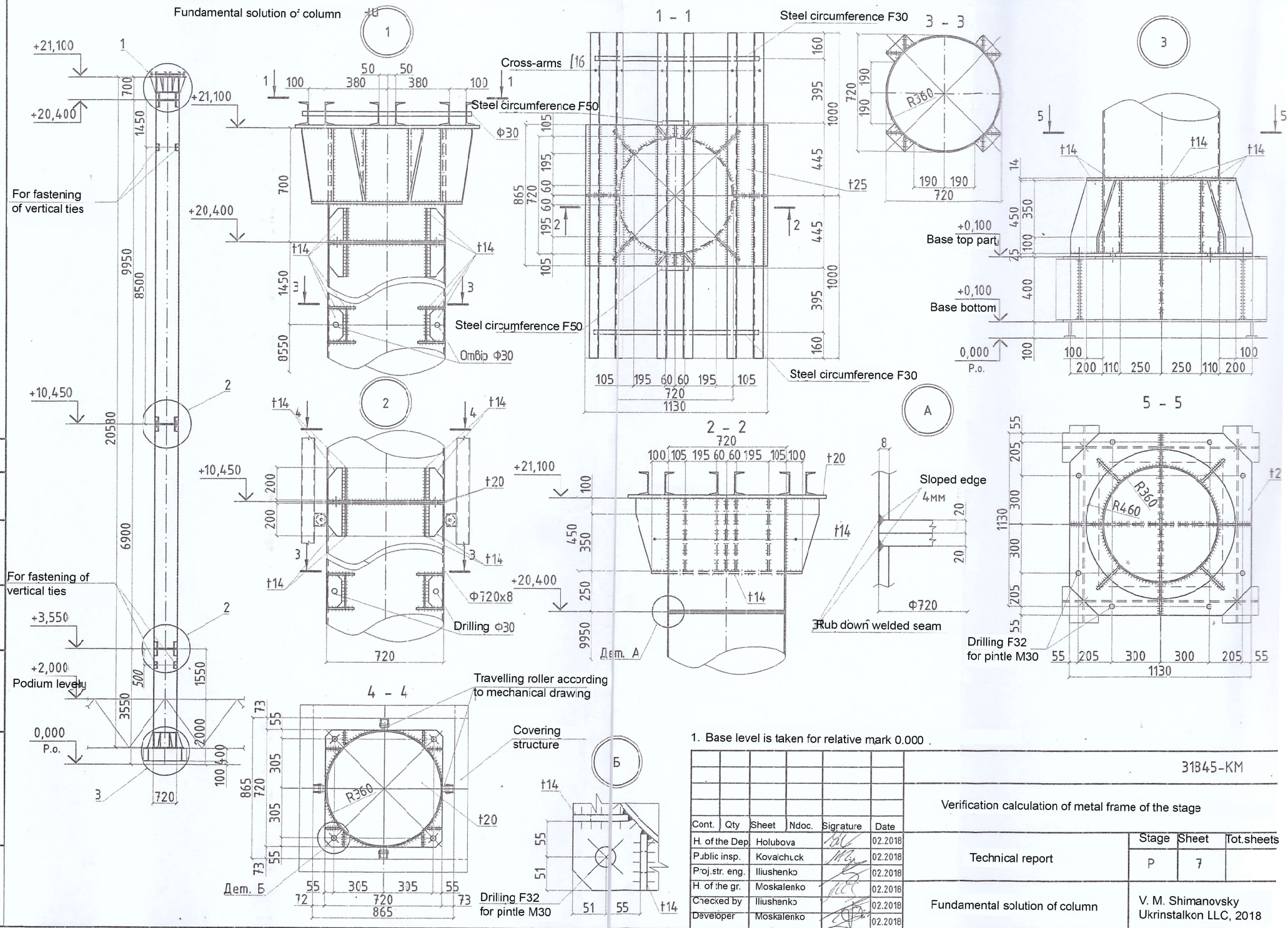
Fundamental solution of column



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Public insp.		Kovalchuck			02.2018		
Proj.str. eng.		Iliushenko			02.2018		
H. of the gr.		Moskalenko			02.2018	Fundamental solution of column	V. M. Shimanovsky Ukrinstalkon LLC, 2018
Checked by		Iliushenko			02.2018		
Developer		Moskalenko			02.2018		

Approved

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Signature and date

Inv No of equip

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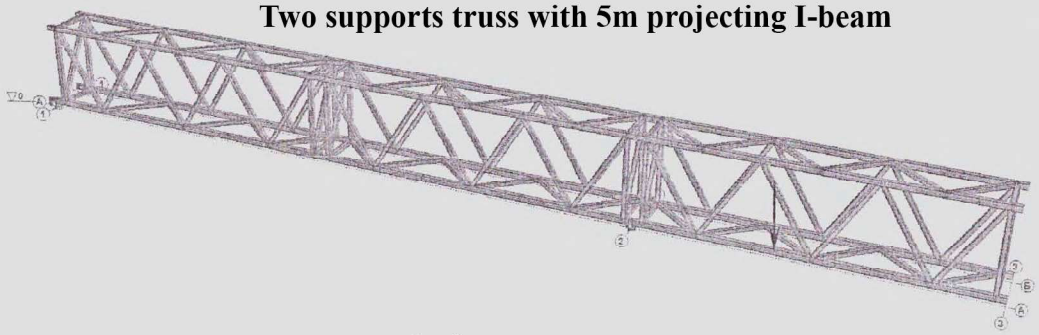
Annex B

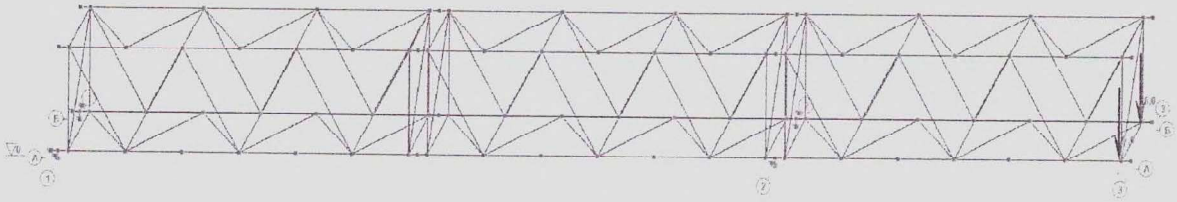
Typical modular trusses
(load options)

Table of maximum permissible loads on typical modular trusses with 5m projecting I-beam											
Option 1			Option 2			Option 3			Option 4		
ΣP	Deflection,	Efforts in truss bclts N max, tf	ΣP	Deflection,	Efforts in truss bclts N max, tf	ΣP	Deflection,	Efforts in truss bclts N max, tf	ΣP	Deflection,	Efforts in truss bclts N max, tf
	2	3	4	5	6	7	8	9	10	11	12
10	26	±19.0	12	23	±17.5	12	24	±18.0	12	19	±14.6

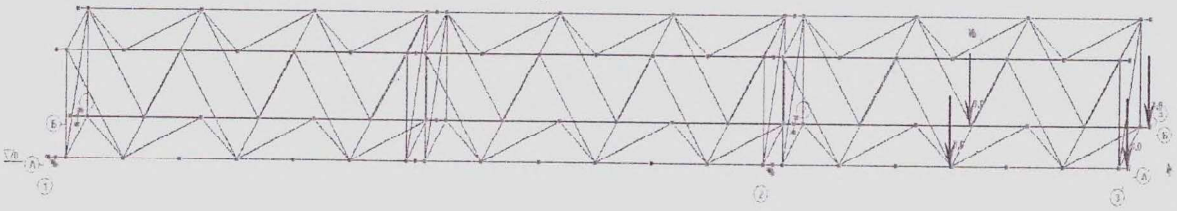
Two supports truss with 5m projecting I-beam



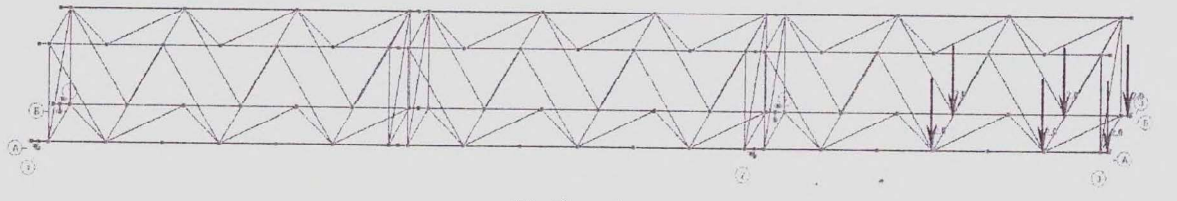
Option 1



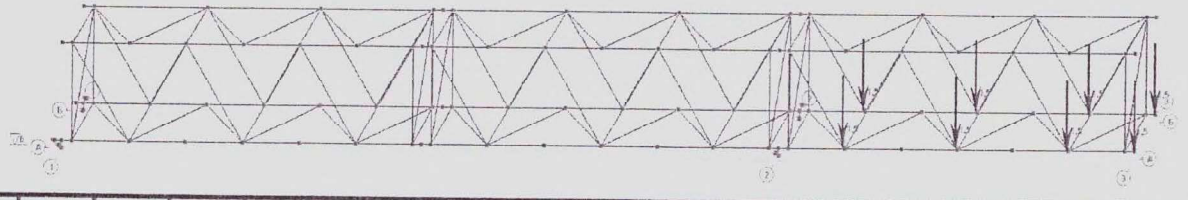
Option 2



Option 3



Option 4



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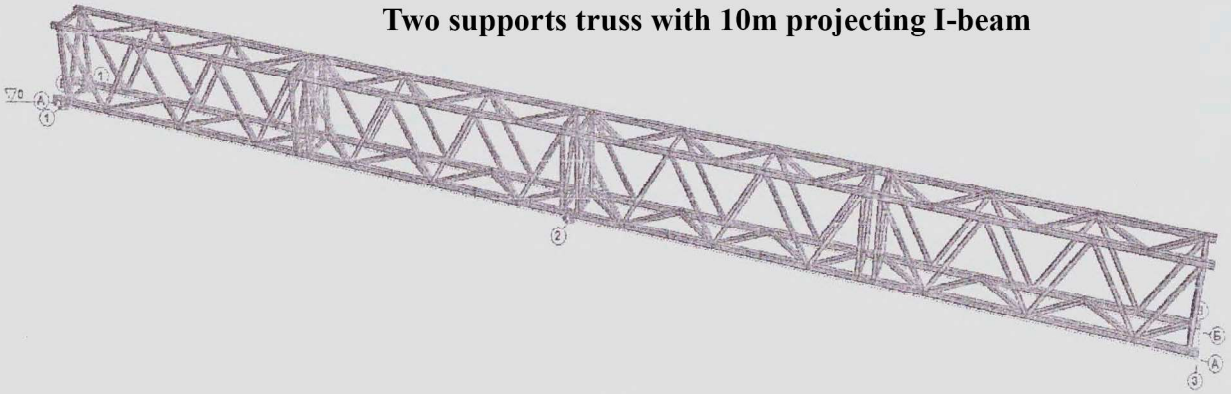
Inv. No of equip.

Content	Qty	Sheet	№ doc;	signature	Date	31845-KM	Sheet 38

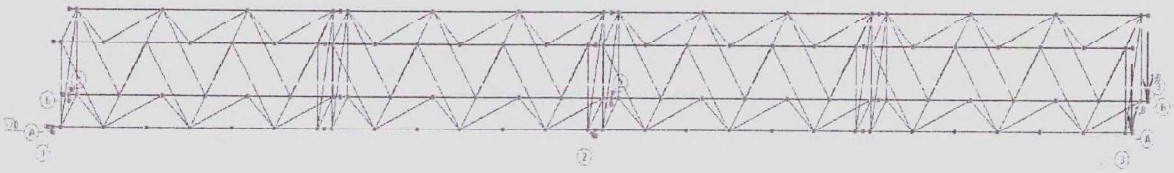
Table of maximum permissible loads on typical modular trusses with 10m projecting I-beam

Option 1			Option 2			Option 3			Option 4		
ΣP	Deflection,	Efforts in truss belts N max, tf	ΣP	Deflection,	Efforts in truss belts N max, tf	ΣP	Deflection,	Efforts in truss belts N max, tf	ΣP	Deflection,	Efforts in truss belts N max, tf
	2	3	4	5	6	7	8	9	10	11	12
3.6	50	±15.9	4.8	48	±15.9	6	48	±16.2	5.6	46	±15.5

Two supports truss with 10m projecting I-beam



Option 1



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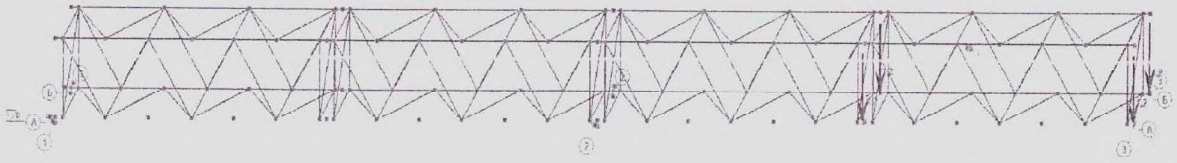
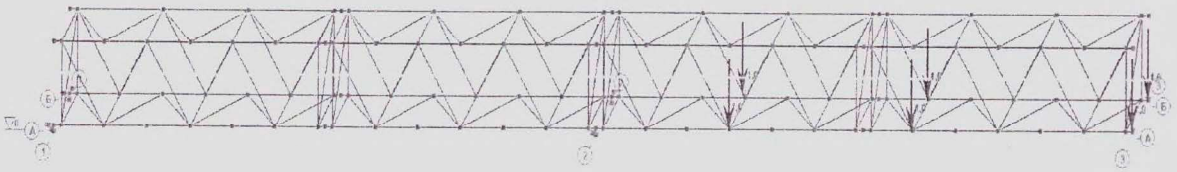
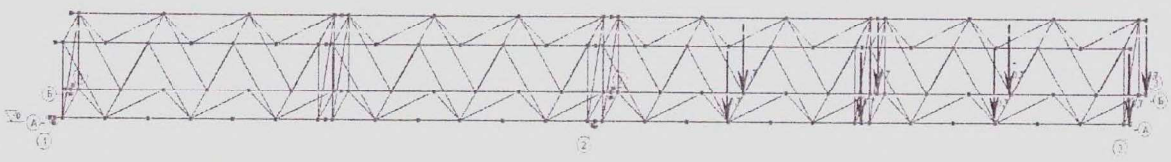


Option 3



Option 4



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Signature and date

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Content	Qty	Sheet	№ doc.	signature	Date	31845-KM	Sheet 39

Inv. No of equip.	Signature and date	Subst. No of equip.

Content | Qty | Sheet | № doc | signature | Date

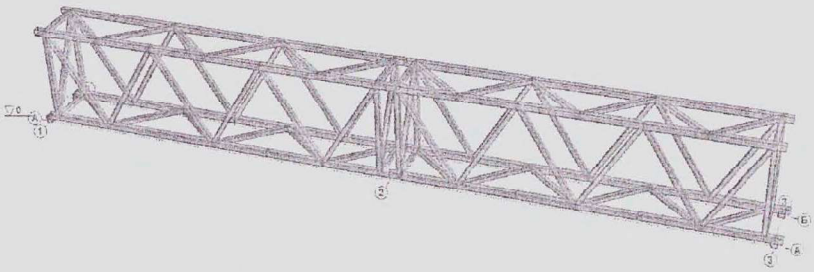
31845-KM

Sheet 40

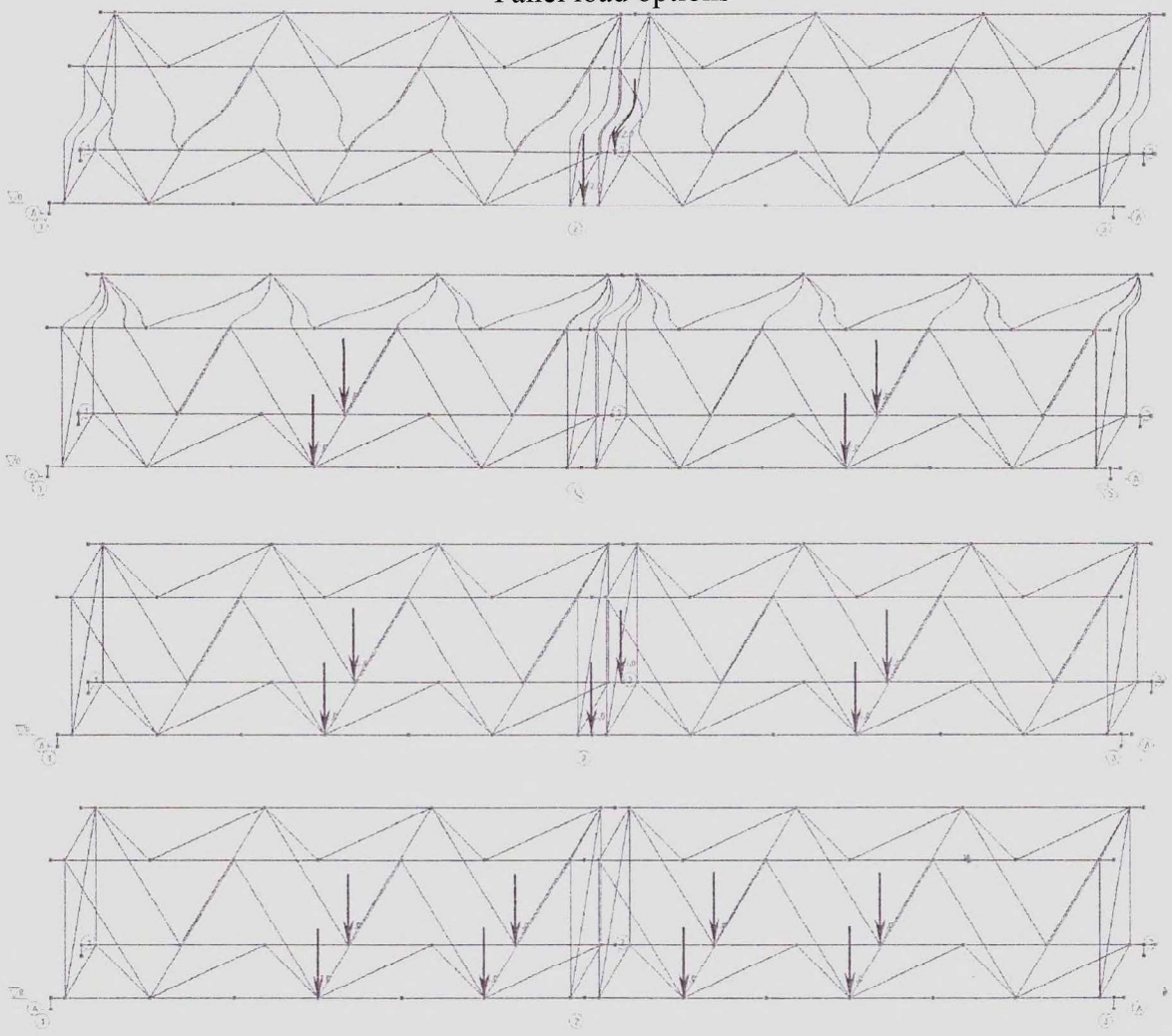
Table of maximum permissible loads on typical modular trusses with spans of 10m - 35m

Span	Panel load which divides the truss span in two equal parts			Panel load which divides the truss span in three equal parts			Panel load which divides the truss span in five equal parts			Panel load which divides the truss span in five equal parts		
	Central load (in the middle of the truss in both lower belts of the truss) ΣP (τ)	Deflection, (mm)	Efforts in truss belts N max, tf	Duplex spot load (in both lower belts of the truss) ΣP (τ)	Deflection, (mm)	Efforts in truss belts N max, tf	Three-point load (in both lower belts of the truss) ΣP (τ)	Deflection, (mm)	Efforts in truss belts N max, tf	Four - point load (in both lower belts of the truss) ΣP (τ)	Deflection, (mm)	Efforts in truss belts N max, (tf)
1	2	3	4	5	6	7	8	9	10	11	12	13
10m	24	15	±23.9	28	11	±14.6	30	14	±20.3	32	15	±21.5
15m	17	28	±25.8	24	33	±25.2	24	31	±25.4	28	31	±24.1
20m	12	43	±25.5	16	50	±25.6	18	49	±25.4	24	52	±25.6
25m	9	63	±25.2	10	62	±21.0	12	64	±22.3	12	62	±20.9
30m	6	79	±22.6	6.8	76	±18.3	7.2	75	±19.1	8	79	±19.5
35m	3	84	±17.1	4	87	±15.4	4.2	89	±16.6	4	85	±15.3

Truss 10 m



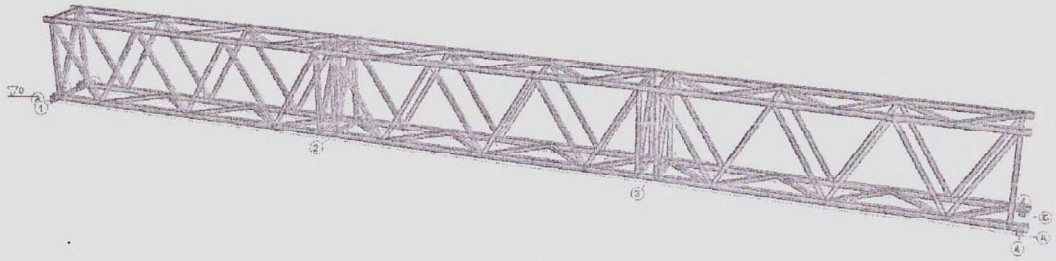
Panel load options



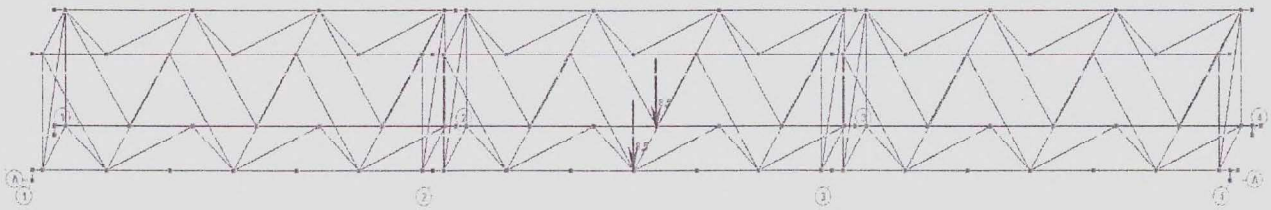
Inv. No of equip.	Signature and date	Subst. No of equip.

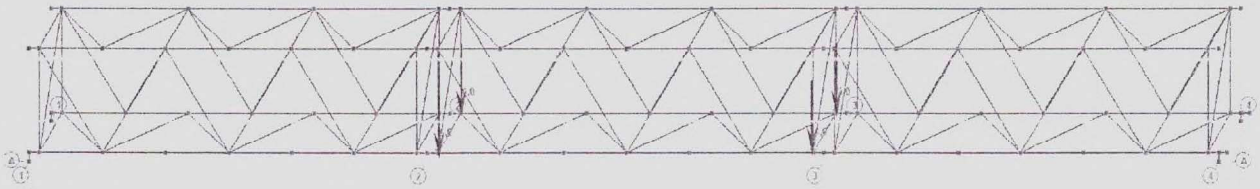
Content	Qty	Sheet	№ doc.	signature	Date	31845-KM	Sheet 41

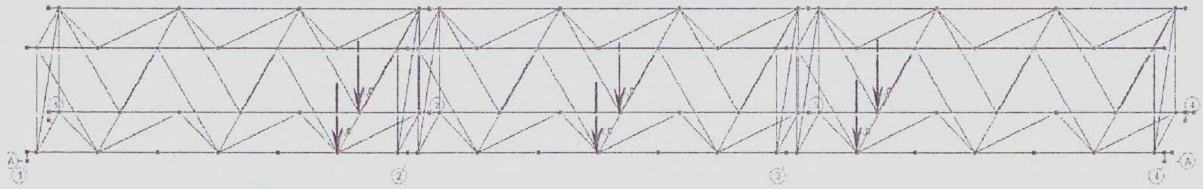
Truss 15 m

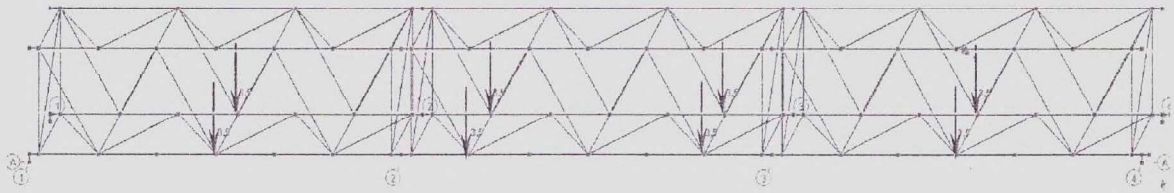


Panel load options









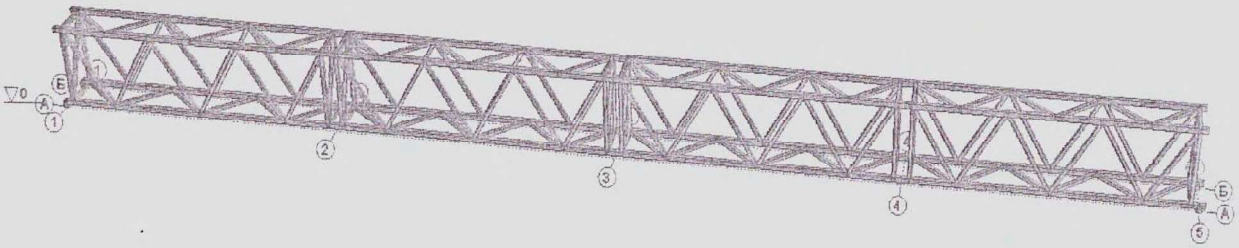
Subst. No of equip.

Signature and date

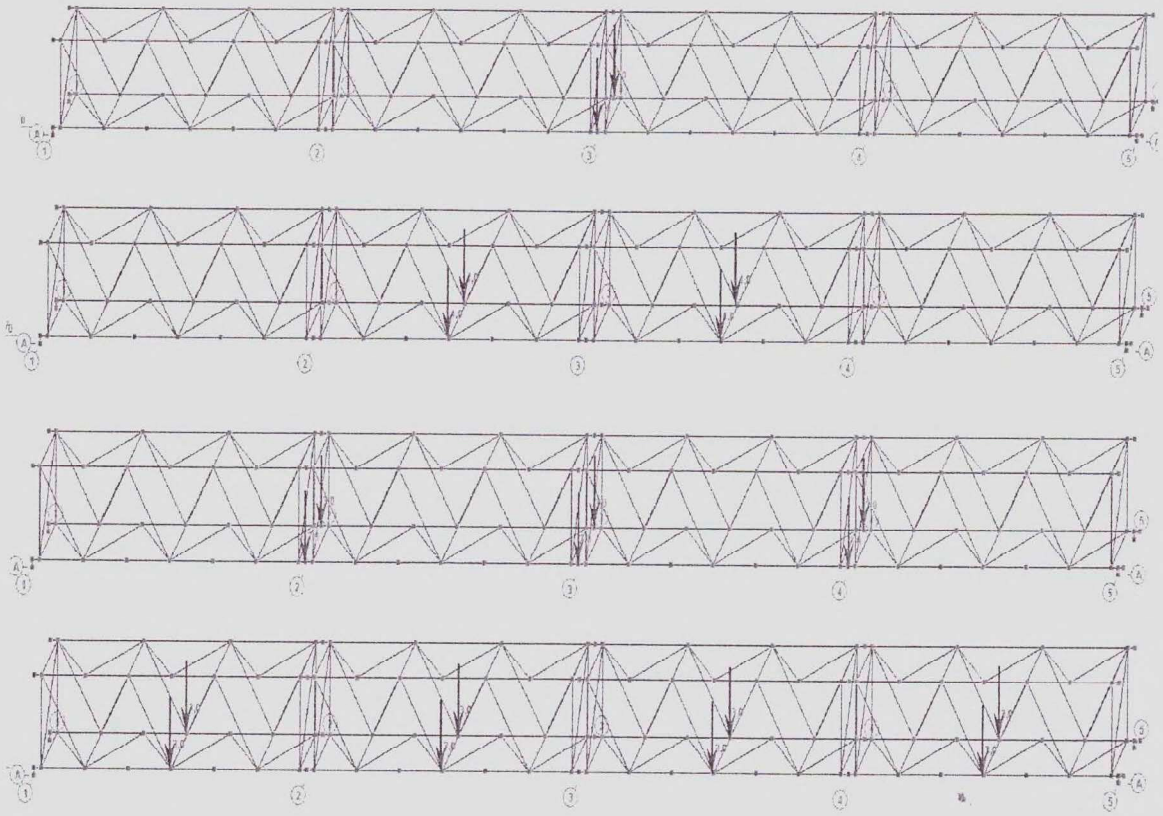
Inv. No of equip.

Content	Qty	Sheet	№ doc	signature	Date	31845-KM	Sheet 42

Truss 20 m



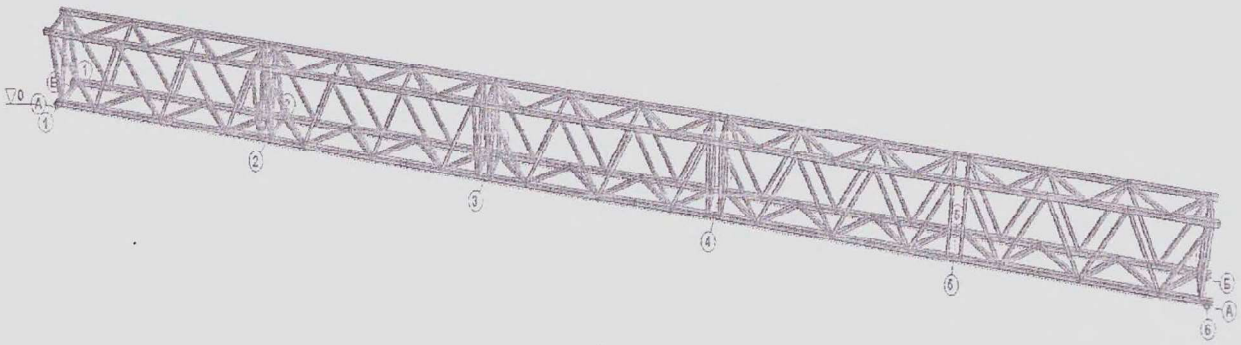
Panel load options



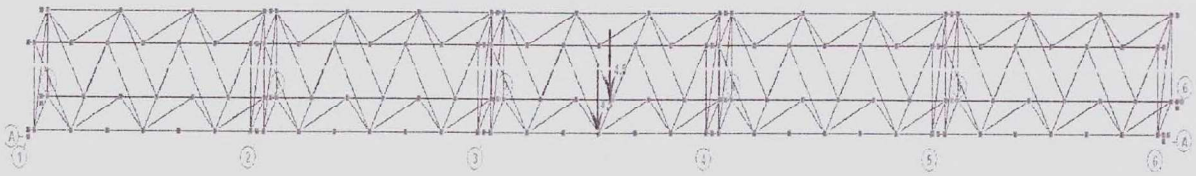
Inv. No of equip.	Signature and date	Subst. No of equip.

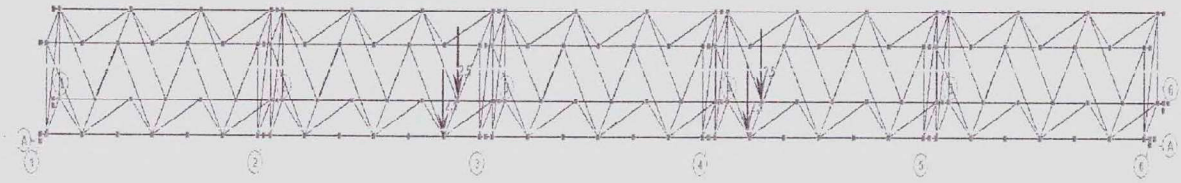
Content	Qty	Sheet	№ doc.	signature	Date	31845-KM	Sheet 43

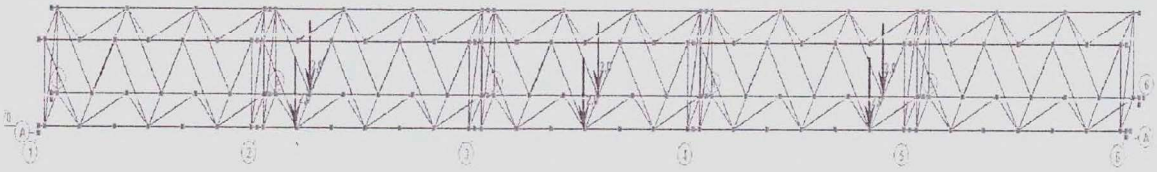
Truss 25 m

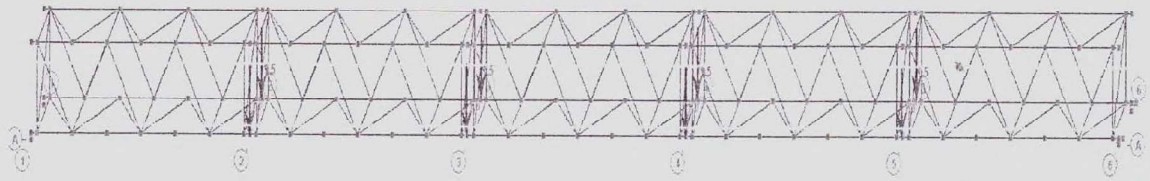


Panel load options









Inv. No of equip.	Signature and date	Subst. No of equip.

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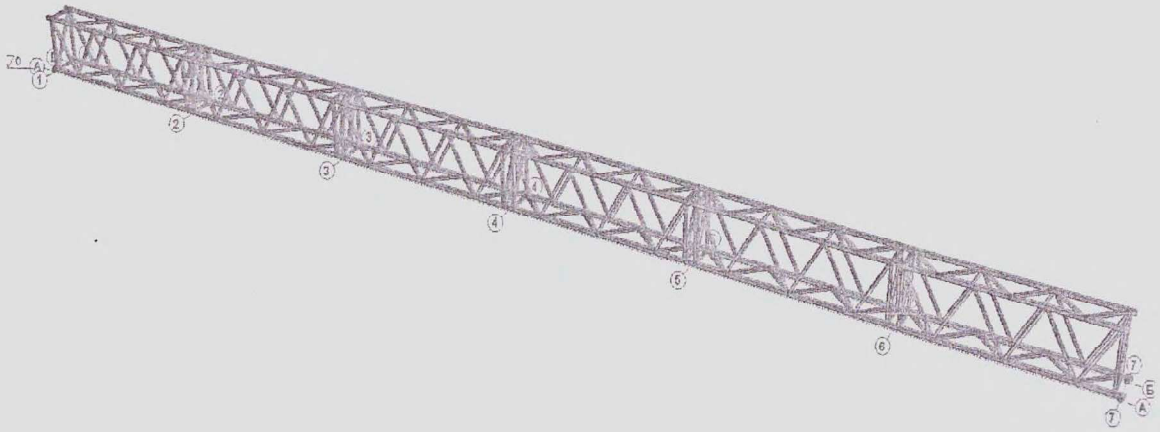
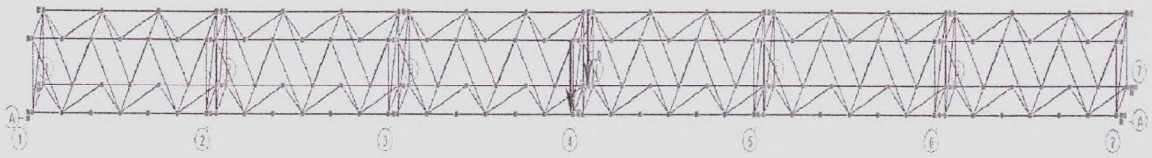
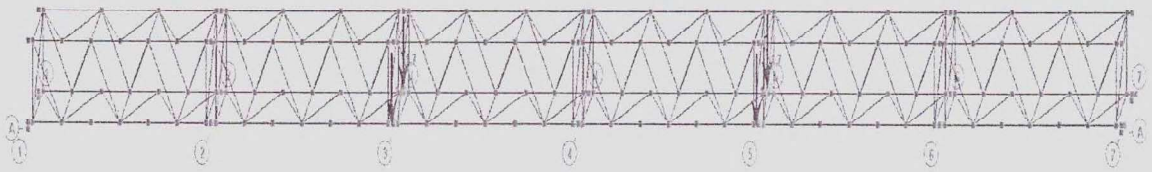
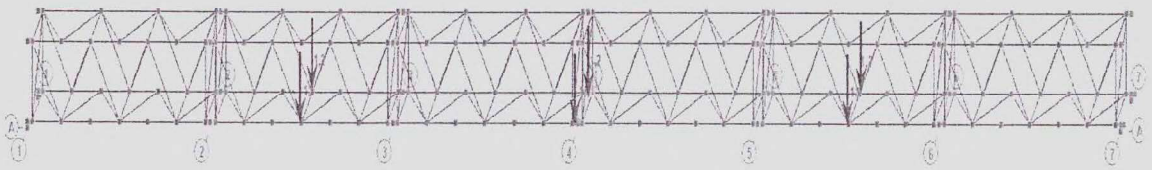
Truss 30 m

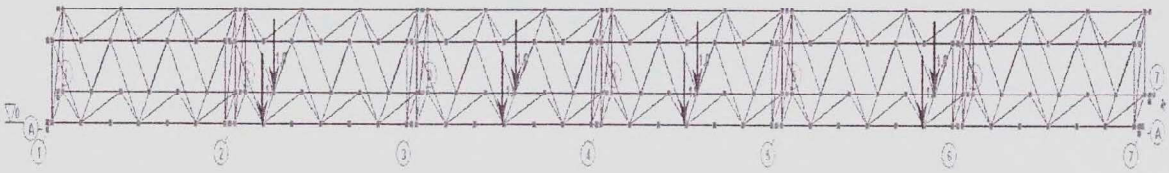


Panel load options









Subst. No of equip.

Signature and date

Inv. No of equip.

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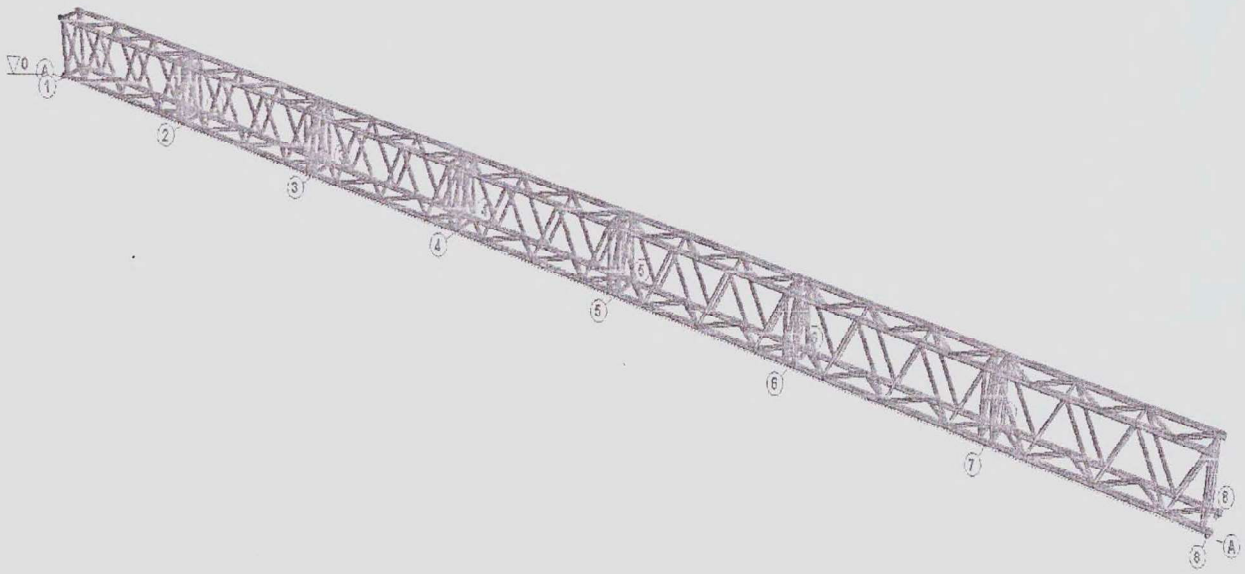
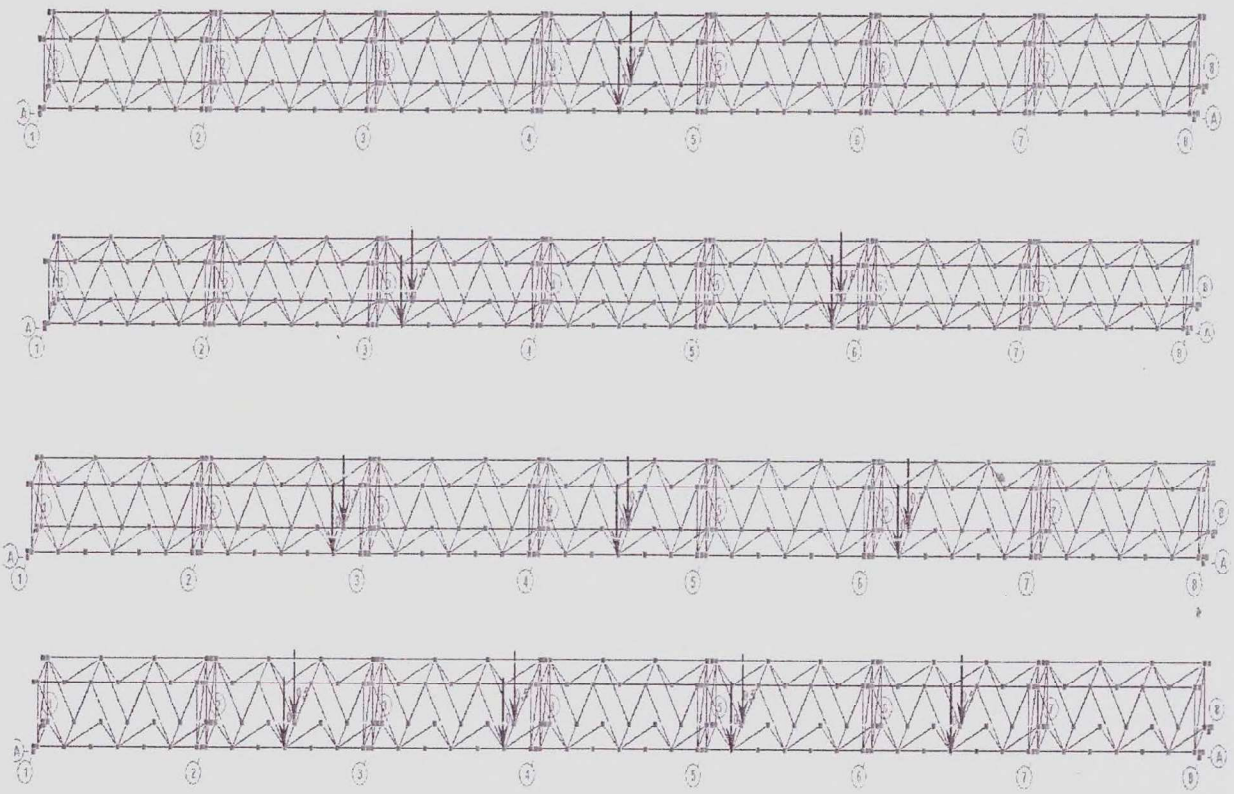
Truss 35 m



Panel load options



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Signature and date	
Inv. No of equip.	

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Annex B

Annex No1
to Agreement No. 31845
of 26 January 2018

"AGREED"
General Director of V.M. Shimanovsky Ukrainian Research and Design Institute of Steel Construction JSC
___/signature/_____Shimanovskii O. V.
"__" _____2018

"APPROVED"
Director Kushpitovsky Stanislav Evgenovych
/signature/
Seal: /illegible/
"___" _____2018

TECHNICAL SPECIFICATION

1. The main aim and purpose of the implementation of the Works

The purpose of the implementation of the Works are:

1. Performing a static calculation of a metal frame of a stage.
2. Development of technical solutions for the implementation of assembly units and connections
3. Report on scientific and technical work with conclusions and recommendations.

2. Initial data required to perform the work

At the request of the Contractor, the Customer provides project documentation with instructions for the manufacture and installation of metal structures of the stage frame. In addition. The Customer, at the request of the Contractor, provides information on the materials and technical solutions that were used in the performance of work on the installation of the frame. If necessary, in the course of work the Customer at the request of the Contractor provides additional initial data

3. Requirements for the way of implementation of the Works results

The obtained results will be used for further work to eliminate possible shortcomings.

4. The order of consideration and acceptance of the Results of Works are accepted by the Act of work performed.

5. Requirements for observance of the rights for the results of the works

The owner of the results of the Works is the Customer.

6. Requirements for the type of Scientific and technical products (Report), which is transferred to the customer after the completion of the Work under the Contract

Scientific and technical production (Report) is transferred to the Customer in 4 (four) copies on paper and 1 (one) on electronic media (in the format *pdf *dwg).

Prepared
Project structural engineer Iliushenko O.S.

Subst. No of equip.
Signature and date
Inv. No of equip.

MINISTRY OF REGIONAL DEVELOPMENT, CONSTRUCTION AND HOUSING MAINTENANCE AND UTILITIES OF UKRAINE

CERTIFICATION ARCHITECTURAL AND CONSTRUCTION COMMISSION

Series AP № 000106

QUALIFICATION CERTIFICATE OF

responsible executor of certain types of works (services), related to the creation of an object of architecture

Architect engineer

Issued on the fact that Shimanovsky Oleksandr Vitaliiovych
(Name, surname, patronymic name)

held professional certification that confirms his (her) compliance with qualification requirements in the sphere of activities related to the creation of objects of architecture, professional specialization, the required level of skill and knowledge.

Category: Architect engineer.

The qualification certificate was issued according to the decision of Certification Architectural and Construction Commission (further on Commission) from №

By decision of the Relevant section of the commission dated 22.03.2012 № 6 approved by the Presidium of the Commission 27.03.2012 № 6-ІП).

Registered in the Register of certified persons on March 29, 2012 under the number 106.

Works (services) related to the creation of architectural objects the implementation capacity of which is determined by the qualification certificate: engineering and construction design in terms of mechanical resistance and durability

Date issued 23.04.2012

Chairman (assistant chairman) of the Certification Architectural and Construction Commission — Nepomnizshchiy O.M.

Subst. No of equip. | Signature and date | Inv. No of equip.

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All-Ukrainian public organization
"Guild of designers in construction"
Limited Liability Company
"Scientific and methodical center "Engineering"

CERTIFICATE No. 00211

Architect engineer

Shimanovsky Oleksandr Vitaliiovych

from 13.06.2017 to 15.06.2017

according to Art. 17 of the Law of Ukraine "On architectural activity"
increased qualification in the direction of

Engineering and construction design in terms of mechanical resistance and durability

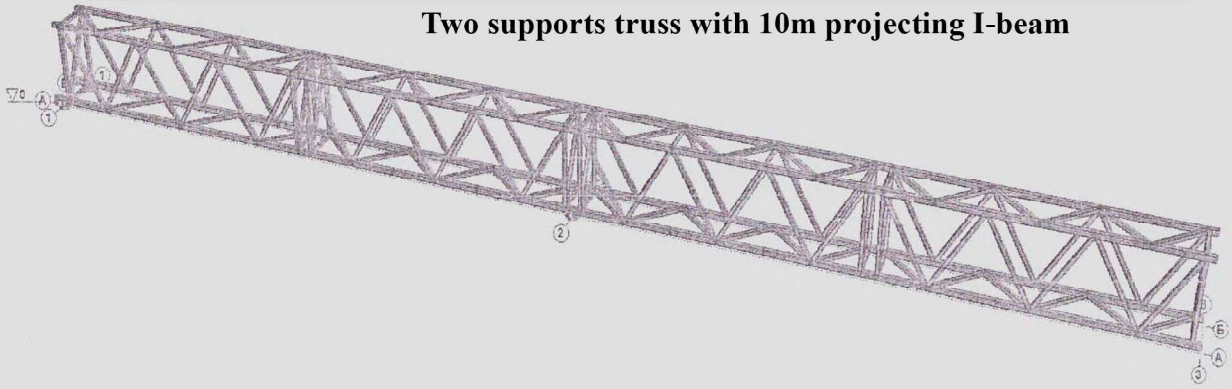
Director of SMC "Engineering" JSC — O.F. Khabensky
Executive Director of VUGiP — D.M. Kolomiets

Date issued 15.06.2017

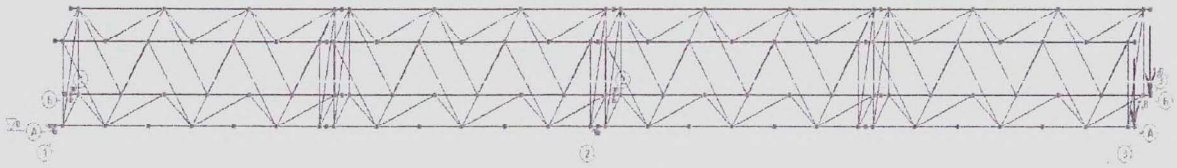
Kyiv

Table of maximum permissible loads on typical modular trusses with 10m projecting I-beam											
Option 1			Option 2			Option 3			Option 4		
ΣP	Deflection,	Efforts in truss belts N max, tf	ΣP	Deflection,	Efforts in truss belts N max, tf	ΣP	Deflection,	Efforts in truss belts N max, tf	ΣP	Deflection,	Efforts in truss belts N max, tf
	2	3	4	5	6	7	8	9	10	11	12
3.6	50	±15.9	4.8	48	±15.9	6	48	±16.2	5.6	46	±15.5

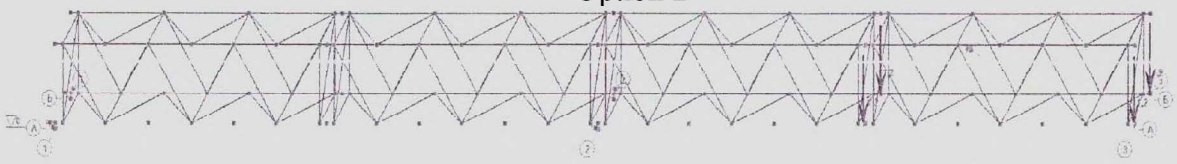
Two supports truss with 10m projecting I-beam



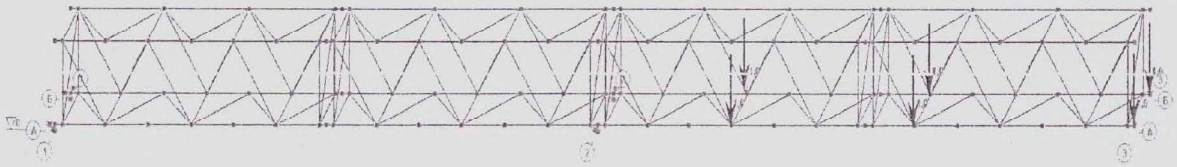
Option 1



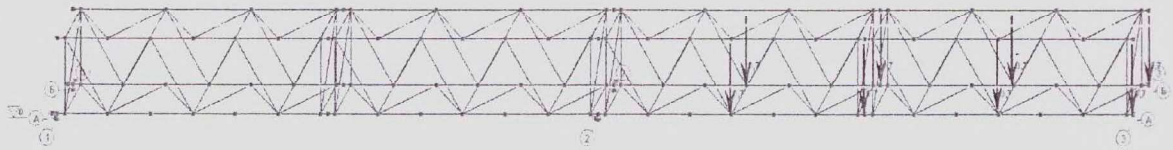
Option 2



Option 3



Option 4



Subst. No of equip.

Signature and date

Inv. No of equip.

Content	Qty	Sheet	№ doc.	Signature	Date

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