MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ARCHITECTURE, CIVIL ENGINEERING AND DESIGN
COMPUTER TECHNOLOGIES OF CONSTRUCTION DEPARTMENT

TO ADMIT TO GUARD

Head of the Department

____________O.I. Lapenko

“_____” _____________ 2020

MASTER THESIS

(EXPLANATORY NOTE)

EDUCATIONAL AND PROFESSIONAL PROGRAM:

“INDUSTRIAL AND CIVIL ENGINEERING”

Topic: “Determination of allowable flexibility of elements of high-rise tower under the influence of vortex wind load”

Performed by: student of group FACD-205ma Maslak Ihor Mykolaiovych
(student, group, last name, first name, patronymic)

Scientific adviser: Doctor of technical science, Professor, Department of computer technologies in construction, Barabash Maria Serhiivna
(academic degree, academic rank, last name, first name, patronymic)

Adviser of the chapter «Labour protection»: ___________ Konovalova O.V.
(signature) (Surname, initials)

Adviser of the chapter
«Environment protection»: ___________ Bilyk T.I.
(signature) (Surname, initials)

Design rule check: ___________ Rodchenko O.V.
(signature) (Surname, initials)

Kyiv 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АРХІТЕКТУРИ, БУДІВНИЦТВА ТА ДИЗАЙНУ
КАФЕДРА КОМП'ЮТЕРНИХ ТЕХНОЛОГІЙ БУДІВНИЦТВА

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач випускової кафедри

____________О.І. Лапенко

"_____" _____________2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ОСВІТНЬО-ПРОФЕСІЙНА ПРОГРАМА:

«ПРОМИСЛОВЕ І ЦИВІЛЬНЕ БУДІВНИЦТВО»

Тема: Визначення допустимої гнучкості елементів висотної башти під впливом вихрового вітрового навантаження

Виконавець: студент групи ФАБД-205ма Маслак Ігор Миколайович
(студент, група, прізвище, ім'я, по батькові)

Керівник: д.т.н, професор кафедри комп'ютерних технологій будівництва Барабаш Марія Сергіївна
(науковий ступінь, вчене звання, прізвище, ім'я, по батькові)

Консультант розділу «Охорона праці»: __________ Коновалова О.В.
(підпис) (ПІБ)

Консультант розділу
«Охорона навколишнього середовища»: __________ Білик Т.І.
(підпис) (ПІБ)

Нормоконтролер: __________ Родченко О.В.____
(підпис) (ПІБ)

Київ 2020

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет архітектури, будівництва та дизайну

Кафедра комп’ютерних технологій будівництва

Спеціальність: 192 «Будівництво та цивільна інженерія»

Освітньо-професійна програма: «Промислове і цивільне будівництво»

ЗАТВЕРДЖУЮ

Завідувач кафедри

___________О.І. Лапенко

«____» __________ 2020 р.

ЗАВДАННЯ

на виконання дипломної роботи

Маслака Ігора Миколайовича

(П.І.Б. випускника)

1. Тема роботи «Визначення допустимої гнучкості елементів висотної башти під впливом вихрового вітрового навантаження»

затверджена наказом ректора від «_10_» ____11____ 2020 р. №___2251___/_ст.

2. Термін виконання роботи: з 05.10.2020 по 21.12.2020

3. Вихідні дані роботи: місце будівництва – смт. Кодра, промислова будівля, інженерно-геологічні вишукування, 2-й вітровий та 5-й сніговий райони згідно ДБН «Навантаження і впливи», ІІ-й клас відповідальності споруд.

4. Зміст пояснювальної записки: Аналітичний огляд літератури за темою роботи, наукова частина, архітектурна частина (та графічний матеріал), конструктивна частина, охорона праці, охорона довкілля.

5. Перелік обов’язкового ілюстративного матеріалу: таблиці, рисунки, діаграми, графіки, слайди - 6, креслення архітектурної та розрахункової частини - 6.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Аналітичний огляд	08.10.2020	
2	Наукова частина	09.11.2020	
3	Архітектурна частина	09.11.2020	
4	Конструктивна частина	18.11.2020	
5	Основи та фундаменти	08.12.2020	
6	Охорона праці	24.11.2020	
7	Охорона довкілля	09.12.2020	
8	Оформлення пояснювальної записки	17.12.2020	

7. Консультація з окремих розділів:

Назва розділу	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Аналітичний огляд	Професор кафедри комп'ютерних технологій будівництва Барабаш М.С..		
Наукова частина	Професор кафедри комп'ютерних технологій будівництва Барабаш М.С..		
Архітектурна частина	Професор кафедри комп'ютерних технологій будівництва Барабаш М.С..		
Конструктивна частина	Професор кафедри комп'ютерних технологій будівництва Барабаш М.С..		
Основи та фундаменти	Професор кафедри комп'ютерних технологій будівництва Барабаш М.С..		
Охорона праці	Коновалова О.В.		

Охорона навколишнього середовища	Білик Т.І.		

8. Дата видачі завдання: «_05_» _____10_____ 2020 р.

Керівник дипломної роботи: _____________ Барабаш М.С.

(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____________ Маслак І.М.

(підпис випускника) (П.І.Б.)

Abstract

Key terms:

Vortex excitation, ultimate flexibility, dynamic component of wind load, wind pressure, natural oscillation frequency.

The purpose of the work is to:

In the study of the effect of Eddy wind pressure on the elements of a high-rise tower. Determination of the permissible flexibility of structural elements under the influence of wind pressure. Plotting the dependence of the relative lengths of structural elements on the wind flow rate for four types of design schemes for flexible structural elements.

Work tasks:

Determine the conditions for interaction of flexible tower structural elements with the dynamic component of the wind load (Eddy excitation). Determination of the critical wind velocity that causes aeroelastic oscillation of Eddy excitation. Description of the natural oscillation frequency of a flexible structural element of a high-rise tower. Calculation of the permissible value of the relative length of structural elements, at which the calculation for Eddy excitation can not be performed. Calculation of the permissible flexibility of Tower structural elements. Investigation of the need to assess the fatigue life of flexible structural elements both during design and during operation and reconstruction. Evaluate the design decisions made and anticipate possible defects, develop new design solutions to eliminate them.

Scientific novelty of the work:

Investigation of the possibility of vortex excitation from the action of a vortex wind load, which consists in checking the possibility of occurrence of one of the types of aeroelastic instability using approximate criteria that allow determining the corresponding value of the critical wind speed and the cross-section dimensions of structural elements. Analysis of the calculation of flexible tower structural elements under the action of an air flow such as Eddy excitation.

Content

INTRODUCTION

Engineering structures, such as high-rise buildings, towers, masts for various purposes, smoke and ventilation pipes, due to the importance of their height, specific purpose, structural and spatial planning design, are unique objects that require an individual responsible approach to design. A significant effect in reducing their material consumption and cost can be achieved by using modern composite materials and structures.

High-rise structures are the most impressive and remarkable architectural and engineering structures. They are often famous symbols that make the world's cities easily recognizable. An area with a high-rise building or structure is an important feature of the city, it is a sought-after item of European financial capitals, successfully implemented in development strategies in New York, London, Frankfurt and other cities.

Designing high-rise structures is a challenging task for architects and engineers. One of the problems that occurs when increasing altitude is the importance of wind exposure.

The largest share of effort in the structures of exhaust towers is caused by wind load. Wind load on a structure is a consequence of the pressure of moving air masses on it, as on an obstacle.

As the height of the structure increases, the calculation of structures for the impact of wind loads becomes a priority, especially in regions with a low risk of an earthquake. In addition to static wind loads that increase with altitude, dynamic impact values dramatically affect the structure and can often dominate design. The dynamic component of wind load (wind pulsation) that affects high-rise structures can cause resonance of high-rise structures, which increases wind-induced loads and can affect the well-being of people in the structure, especially on the upper parts of the structure. The higher the structure, the greater the resonant vibrations.

The research on this topic was conducted by me on the example of a metal exhaust tower with a height of 100 meters. This tower is part of an industrial building of a glass factory.

Smoke and ventilation pipes and their load – bearing towers in industrial enterprises are complex, expensive high-rise engineering structures that are exposed to significant force and wind impacts, as well as aggressive high-temperature gases moving inside the pipe. Smoke and ventilation pipes of industrial enterprises (power plants, metallurgical, petrochemical, gas processing and other plants) are the final link of technological processes, and their decommissioning leads to the shutdown of all production.

Significant defects and damage received during operation lead to the destruction of chimneys and load-bearing towers. This can lead to serious consequences for production and personnel, for the life support of the population in the event of shutdown of vital industries, for example, thermal power plants in winter.

Industrial metal pipes are divided into smoke and ventilation pipes. Chimneys are designed to remove flue gases from fuel combustion in fire heating units (boilers, furnaces, etc.). Ventilation pipes are designed to remove harmful gas-air mixtures that occur during technological processes in reactors, apparatuses and installations of the chemical industry

Depending on the placement of flues, industrial pipes are made with underground, above-ground and aboveground flue entries.

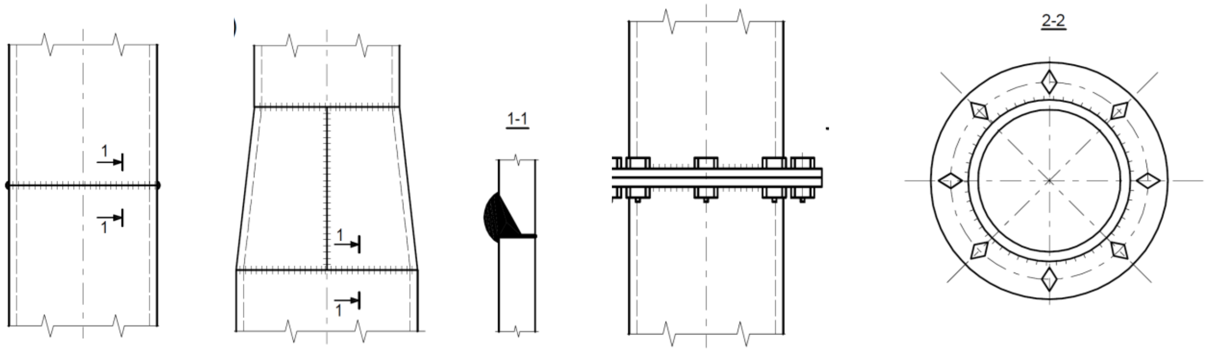
In the upper part of the trunk of modern pipes, spiral structures made of a metal strip are provided – interceptors that reduce the vibrations of the pipe and improve its aerodynamic characteristics, creating an upward flow of air along its outer surface and stabilizing the release of flue gases.

At high heights of metal smoke and ventilation pipes (40m or more), load-bearing metal lattice towers are constructed around them. The gas outlet metal pipe is suspended from a lattice tower or supported on its own foundation. The metal lattice tower takes the load from the tower's own weight (sometimes from the pipe), from the wind impact on the pipe trunk transmitted to the tower at the junction with it, as well as climatic conditions and technological temperature influences. At the junction of the pipe trunk and the load bearing tower is provided with freedom of temperature deformations of the pipe in the vertical direction. The pipe trunk takes its own weight in the area between the suspensions, the wind load between the attachment points from the plane on the load-bearing tower, the force from the flue gas temperature.

CHAPTER 1
ANALYTICAL REVIEW

The experience of examining high-altitude smoke and exhaust structures has shown that the most common structural form is a steel load-bearing lattice tower with a gas outlet trunk located inside it.

Smoke and ventilation pipes in a load-bearing metal tower are used in a wide range of heights and diameters under various operating conditions. The height of metal towers of smoke and ventilation pipes reaches 180 m or more.



a) b) c)

Fig. 1.1 Design solutions for metal chimney assemblies:

a) factory welded joint of the chimney trunk elements; b) factory welded joint of the cylindrical and conical parts of the chimney trunk; c) flanged connection of the pipe trunk elements.

The overall dimensions of the load-bearing metal tower are determined by the technological parameters and are set by the design assignment. These parameters include: geometric dimensions of the barrel (diameter and the mark of the top of the pipe), the number of gas outlet shafts, the mark of the upper service area, the mark of the entry of gas outlets into the tower, the dimensions of the tower at the base from the conditions of its placement on the master plan.

Metal towers of smoke and ventilation pipes are classified according to their structural, geometric and technological characteristics:

- according to the geometric outline of the tower in the plan – trihedral, tetrahedral and polyhedral (fig. 1.4, 1.5);

a) b) c)

Fig. 1.2 Support units of metal chimneys:

a) support unit of the metal chimney of the Machine Shop of the metallurgical plant;

b) support unit of the chimney of the «Південнобузька» compressor station;

c) support unit of the chimney of the open-hearth shop of the metallurgical plant.

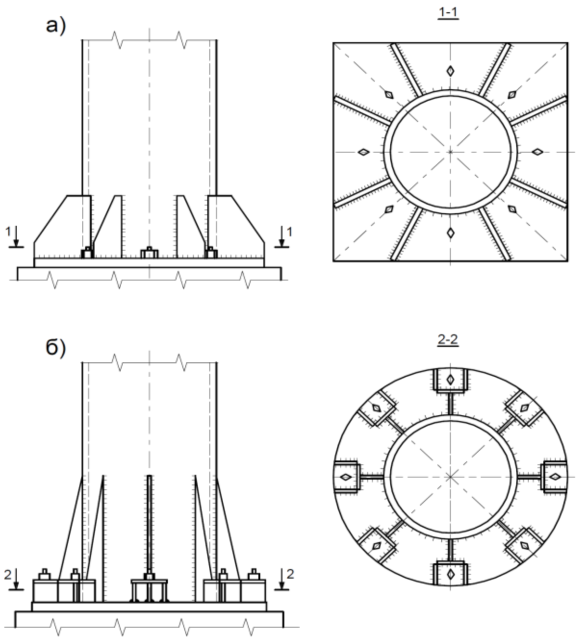
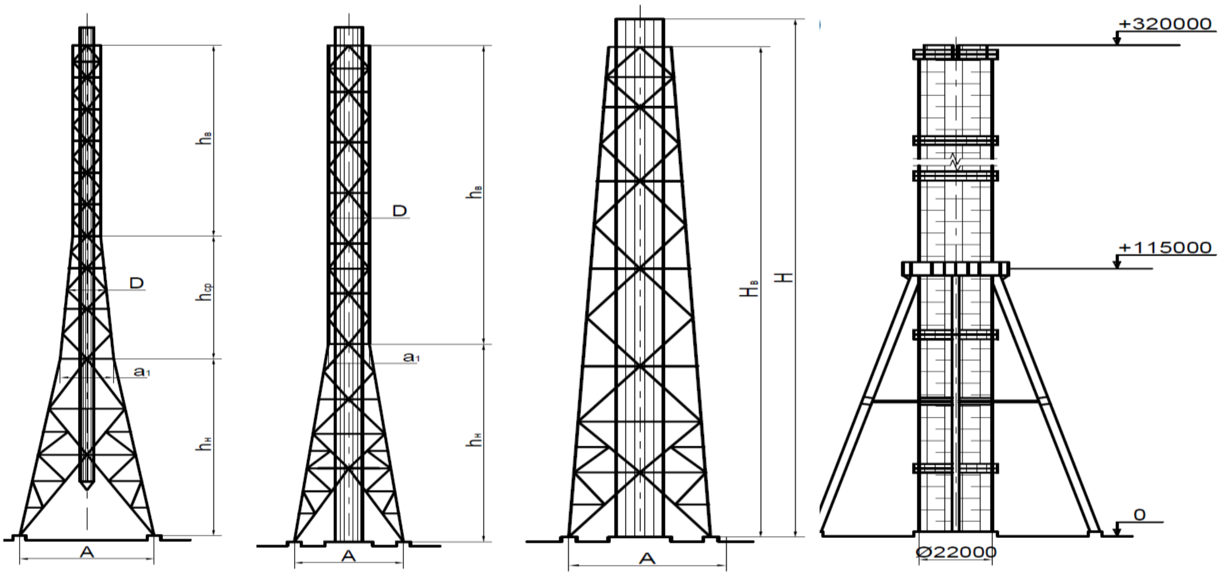


Fig. 1.3 Design of supporting units of metal chimneys: a) anchor bolts are attached to the base plate of the column base; b) anchor bolts are attached to the column base through ribs and traverse.

- according to the outline of metal towers in height – without a fracture, with one fracture or with two fractures in height (fig. 1.4, 1.5);

a) b) c) d)

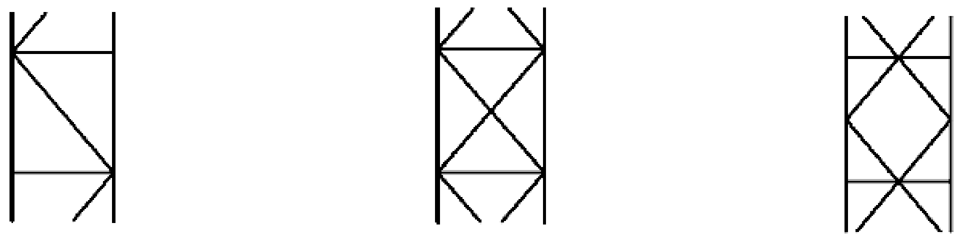
Fig. 1.4 General types of metal towers:
a) metal tower with a height of 150 m of the ammonia shop of the chemical plant;
b) towers with a height of 120 m of the nitric acid shop of the chemical plant;
c) metal tower with a height of 80 m of the ammonia shop of the chemical plant;
d) metal tower with a height of 30 m of the pipe rolling shop of the metallurgical plant.



а) б) в) г)

Fig. 1.5 Types of metal tower silhouettes:
a) a tower with two fractures in height; b) a tower with one fracture in height; c) a tower without a fracture in height; d) a multi-barrel pipe in a load-bearing shell.

- according to the scheme of a slanted grid – triangular with racks, cross, rhombic (fig. 1.6);

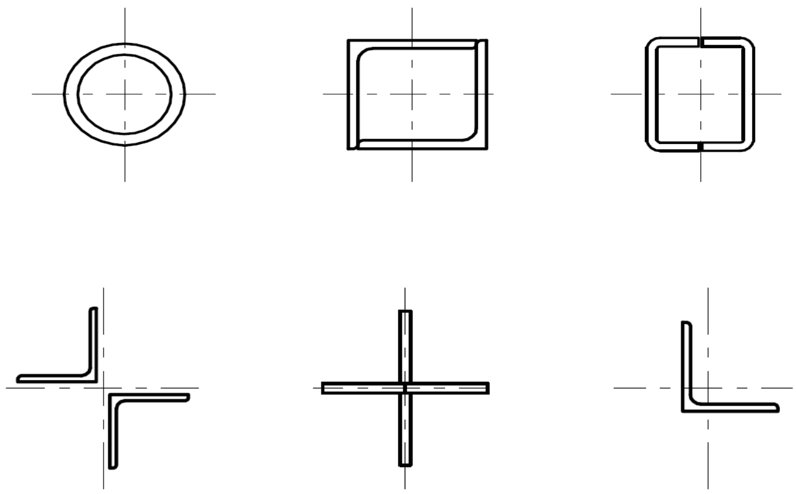


a) b) c)

Fig. 1.6 Basic schemes of Tower grilles:

a) triangular with spacers; b) Cross; c) rhombic.

- by the type of cross – sections of belts, braces, and struts-elements of an open or closed Tower profile (fig. 1.7);



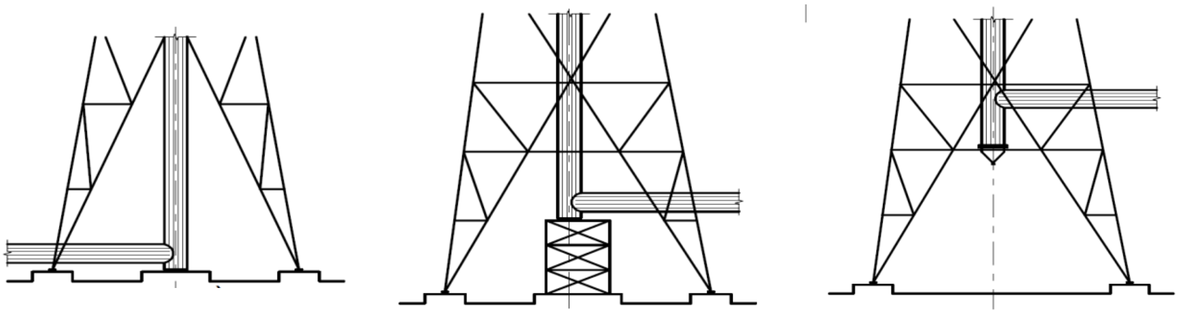
a)

b)

Figure 1.7 Types of cross-sections of Tower elements:

a) closed profiles; b) Open profiles.

- according to the support of the gas outlet shaft – on a separately installed foundation, on a tower, or on a special support (fig. 1.8).



a) b) c)

Figure 1.8 Gas outlet barrel support diagrams:

a) on an independent foundation; b) on a special support; c) on the diaphragm of the tower.

For exhaust towers up to 200 m high, the most common are three-sided and four-sided load-bearing towers in plan.

Comparing trihedral and tetrahedral towers, we note that trihedral towers do not need special diaphragms to ensure the contour remains unchanged, have fewer basic elements, and are less sensitive to uneven precipitation. The disadvantages of three-sided towers include wider faces compared to four-sided ones (1.5 times wider) due to the placement of the gas outlet shaft (fig. 1.9), the complexity of the interface nodes of structural elements associated with the location of the faces at an angle 60^0.

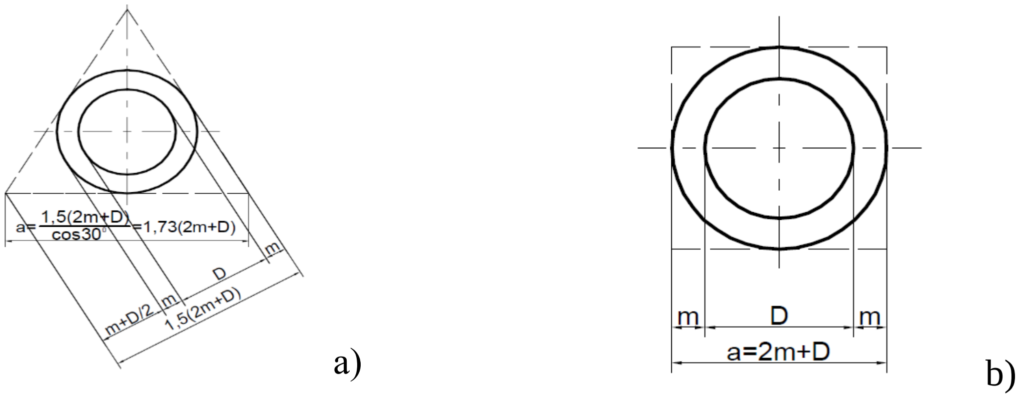


Figure 1.9 Layout of the gas outlet barrel:

a) in three-sided towers;

b) in tetrahedral towers.

From an aesthetic point of view, the absence of mutually perpendicular planes of symmetry of three-sided towers leads to the fact that when looking at the tower from the side parallel to one of the faces, it seems asymmetric, and up close it seems that it "falls".

Given all this, for exhaust towers with a single gas outlet barrel, it is more expedient to use tetrahedral towers.

Three-sided towers are widely used in the construction of radio and television towers, for which the decisive load is the impact of high - speed wind pressure directly on the tower, and the wind load on the equipment is insignificant.

Metal consumption for the manufacture of such three-sided Towers is 10-15% less than for four-sided ones [1].

Towers with two face fractures in height are characterized by the largest number of mounting elements. At the same time, the silhouette of a tower with two face fractures is closest to the configuration of a rod of equal resistance, which ensures relative constancy of forces over the entire height of the pyramidal parts of the tower and leads to a reduction in steel consumption.

The scheme of towers with a constant slope of belts is characterized by a smoother increase in forces in the belts and a relatively lower height in the upper part of the tower. Such towers without belt fractures, with enlarged elements and fewer nodal connections are more often used when operating structures in conditions of increased aggressiveness of the environment.

The survey revealed some ratios of the main dimensions of exhaust towers, which determine the choice of their silhouette. The main sizes include: H_0 – tower height, $H_{пор}$ – height of the portal (lower tier), $h_н$ – height of the lower part of the tower, $h_в$ – height of the upper part of the pipe, $h_{ср}$ – height of the middle part of the pipe, A – width of the tower base, a_1 – tower width at the fracture level, H – gas outlet barrel height, D – diameter of the gas outlet barrel.

For structures with a height of less than 80 m, in all cases it is recommended to use towers without fractures of the faces in height.

The grid scheme is determined by the need for Belt decoupling and the flexibility of the elements of the grid itself. In the examined metal towers, three schemes of Tower lattices were found: triangular with spacers, Cross, and rhombic (fig. 1.6).

The choice of the tower grid type is determined by the overall dimensions of the structure and specific operating conditions. With a high tower height and a high height of the gas outlet shaft, the rhombic grid device prevails. And in conditions of increased aggressiveness of the external environment, a sparse triangular grid is most often used (with an increase in Belt panels), with Tower elements made of pipes.

For high-rise tower-type structures, the main design load is the effect of wind flow on the pipe and supporting structures of the tower. Therefore, the type of cross-sections of elements of high-rise structures is of particular importance, since the size and shape of the profiles largely depends on the amount of wind load on the structure.

The main share of wind load in exhaust towers occurs from wind pressure on the exhaust shaft. But the type of cross-section of the tower elements also significantly affects the amount of wind load and, as a result, the forces in the tower. Also, in a highly aggressive environment, their corrosion wear Depends on the type of cross-sections of the elements.

The main types of cross sections of load bearing elements of the surveyed towers there are closed profiles (such as pipes, box sections made of rolled corners and bent channels) and open profiles – cross sections made of two corners or welded from three sheets, single corners (fig. 1.7).

Elements of exhaust towers made of pipes are made of rolled or electro – welded pipes, as well as with large diameters (over 600 mm) - from pipes obtained by rolling rolled products. Tubular cross-sections best meet the requirements for exhaust Tower elements. Elements of the tower made of pipes are equal in all directions, have minimal resistance to wind flow, as well as the smallest external surface, which helps to improve the operational qualities of the structure, especially in the presence of aggressive impurities in the air.

Box-shaped elements are made of rolled corners and thin – walled (10-12 mm thick) bent channels. In terms of aerodynamic characteristics and corrosion resistance, they are significantly inferior to tubular elements. Also, structural changes in the metal that occur at the bending point negatively affect the operation of elements in conditions of alternating dynamic wind influences.

Cross-section elements are widely used in exhaust Tower elements because of their ease of manufacture. Cross-section elements are formed by rolling corners or made of sheet steel by welding.

Analysis of the long-term operation of the cross-section types discussed above allows us to conclude that the most rational type of cross-section for Tower elements is the tubular cross-section.

As noted earlier, the vertical load from the weight of the gas outlet shaft can be transmitted in one of three ways: to an independent foundation, to a special support located inside the tower, and to one of the tower diaphragms (fig. 1.8, 1.10).

In order to maximize the unloading of the load-bearing tower from the weight of the gas outlet barrel, it is better to support the gas outlet barrel on an independent foundation. For the period of installation and repair of the gas outlet barrel, it is possible to hang it from the upper diaphragm. The forces caused in the grid by such a suspension are removed by installing additional struts.

Stiffening diaphragms play an important role in ensuring transverse rigidity in the horizontal plane of the tower. To do this, they must be geometrically unchanged. Also, stiffening diaphragms are used at various marks of the tower as platforms for servicing the structure during Operation. The most complex in its scheme is the lower diaphragm, especially if the gas outlet barrel rests on it (fig. 1.8 V). To perceive the load from the gas outlet barrel, the cross-sections of the diaphragm elements are significantly increased compared to other diaphragms [1].

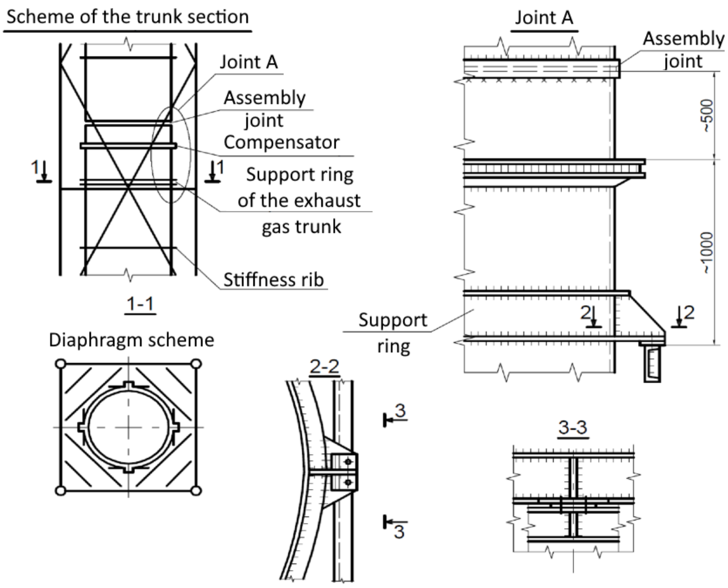
For bending elements of diaphragms, rolling channels and I-beams are used, and for large vertical loads on the diaphragm beams (the support of the gas outlet barrel), welded I-beams are used. Compressed elements of diaphragms are made of the same cross – section as Tower elements-tubular, box-shaped or cross-shaped.

To transfer the load from the gas outlet shaft to the supporting structures of the tower, such support schemes are used that are compatible (fig. 1.10) or separately transmit horizontal and vertical force impacts (fig. 1.11).

The gas outlet barrel is under constant action of horizontal and vertical forces. Wind horizontal loads acting on the gas outlet shaft are transmitted to the tower in the plane of the diaphragms, while special design measures ensure free vertical movement of the pipe relative to the tower. When the gas outlet barrel is supported on each diaphragm and the connected transmission from the barrel to the tower of horizontal and vertical loads, temperature movements are extinguished by installing special expansion joints near the support unit of each section of the gas outlet barrel (fig. 1.10). If the trunk rests completely on the diaphragm in the lower part of the structure and transmits a vertical load to it, then horizontal forces are transmitted in the planes of the tower's diaphragms through special sliding stops (fig. 1.11).

Welded connection of belt elements is carried out in factory and installation conditions. Factory connections of exhaust Tower elements are made only by welding. The connection of belts made of pipes of the same diameter in the factory is carried out by end-to-end welding on the remaining substrate (fig. 1.12 a).

Elements of belts of different diameters are connected by end-to-end welding through a special conical insert (fig. 1.12 B) or by inserting a pipe of a smaller diameter and a cross embedded in it into a pipe of a larger diameter (fig. 1.12 c).



a)

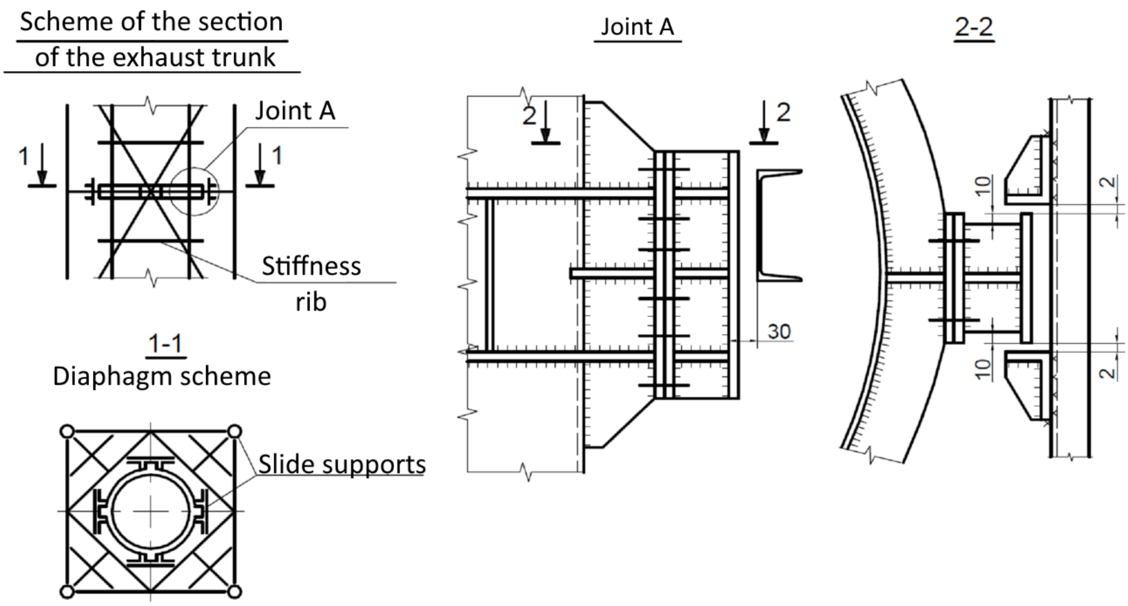
b)

Figure 1.10 Support of a gas outlet barrel with a combined transmission of vertical and horizontal forces:

a) structural solutions of the Pipe Support Unit and expansion joint installation;
b) Tower elements and a chimney compensator with a height of 90 m.

Factory Connection of belts made of pipes of different diameters through a conical insert is advisable for high forces and with significant element diameters (800-1400 mm). However, if the thickness of the joined elements is relatively small ($\delta/R \leq 1/00$), such a joint, which is a combination of thin-walled shells of various shapes, needs additional testing for local stability and edge effect. To reduce the edge effect and stress concentration, the length of the conical insert should reach such dimensions that the slope of the cone is 1/5-1/7 of the larger diameter of the joined elements. Both elements at the junction with the conical insert are reinforced with thickened cuffs [1].

a)



b)

Figure 1.11 Horizontal load transfer unit using sliding supports:
a) design of the horizontal load transmission unit;
b) a node for transmitting wind load from the pipe to the tower.

When the barrel rests on the lower diaphragm of the tower, it is important to observe such gaps between the sliding supports and the structures of the diaphragms that will allow the free development of temperature deformations along the height of the pipe and the transfer of wind loads from the pipe to the tower (fig. 1.16)

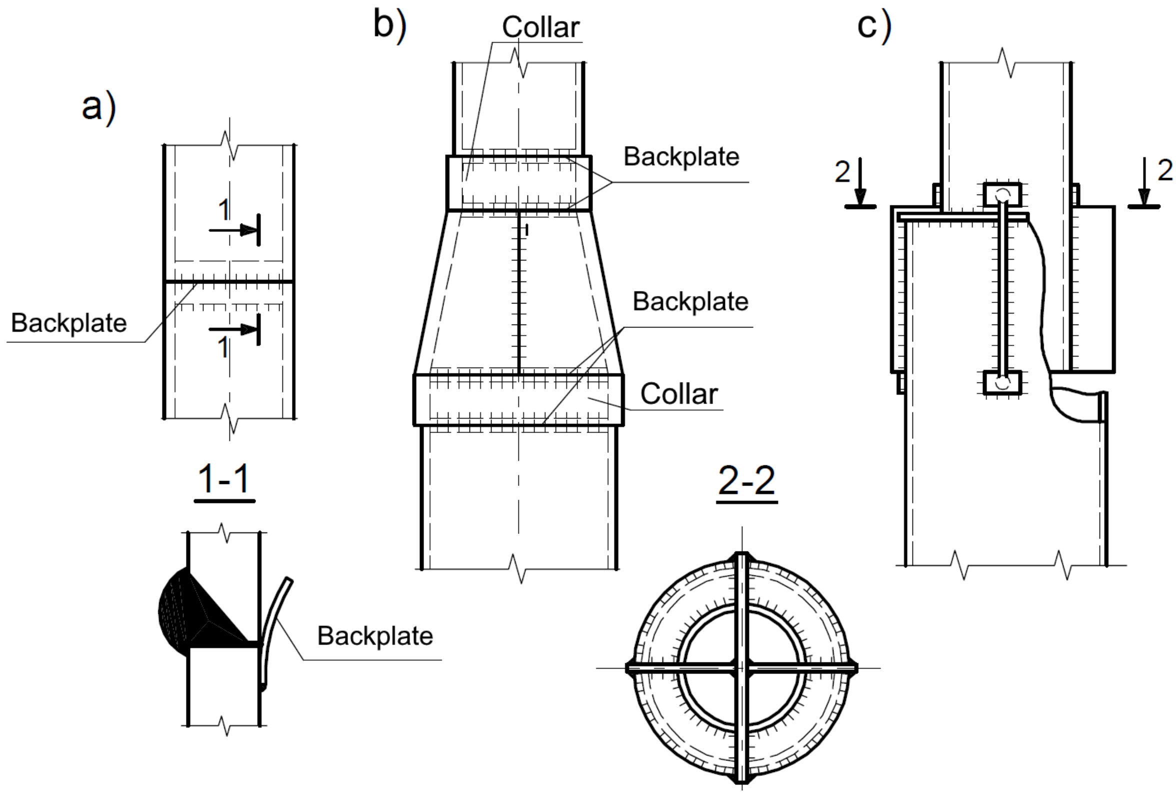


Figure 1.12 Factory connections of metal chimney elements:

a) end-to-end on the remaining substrate; b) end-to-end through a conical insert; c) using a cross embedded in the pipe.

Changing the cross-section along the length of the belts is carried out either by changing the size of the cross-section, or its thickness.

When mounting welding of belt elements to each other a close connection is used through a mortise welded cross (fig. 1.13 b), end-to-end connection through a mortise welded cross on high-strength bolts (fig. 1.13 c), connection by means of corner pads on welding or high-strength bolts (fig. 1.13 d). Flanged connections of belts of load-bearing metal towers for pipe sections are widely used (fig. 1.13 a, 1.13). However, it should be taken into account that with significant tensile forces in the tower belts, fatigue cracks may appear in such connections in the near-seam zone of the flange-pipe interface, the development of which, over a long service life under dynamic load conditions, will lead to the destruction of the connection.

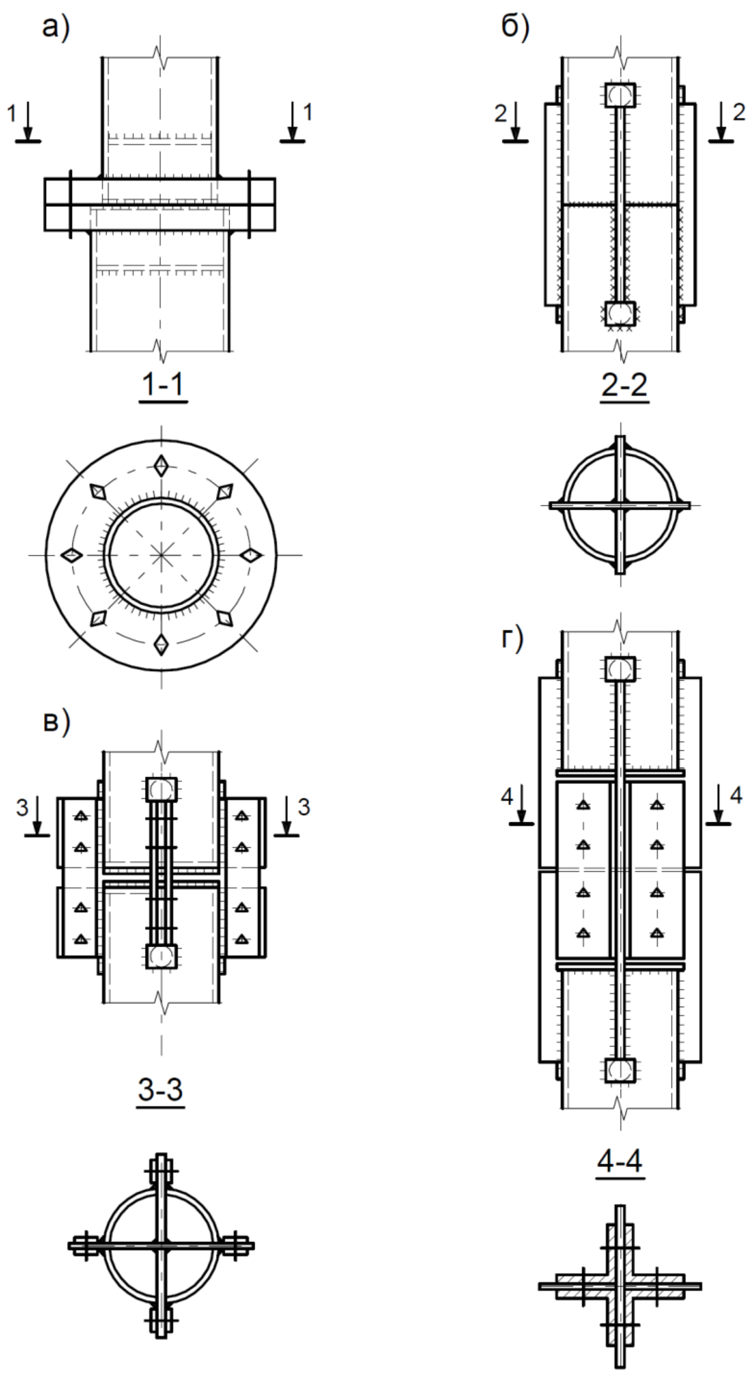


Figure 1.13 Design solutions for pipe mounting connections:

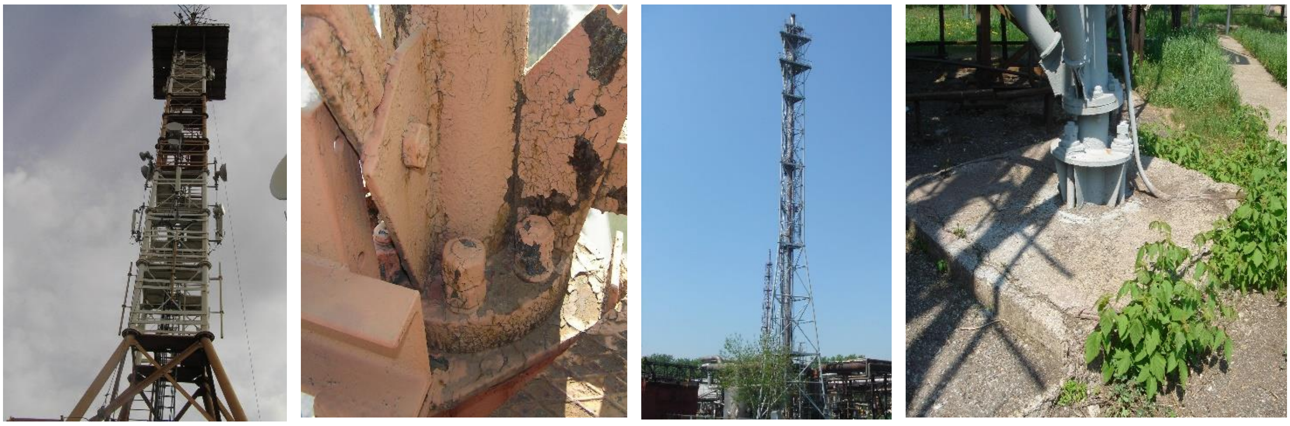
a) flanged connection;

b) end-to-end connection through the embedded cross;

c) end-to-end connection through a mortise cross on high-strength bolts;

d) connection of corner linings.

In lattice load-bearing towers, the flanged joints are usually connected to the center of the grid attachment point (fig. 1.14 a, 1.14 b). The practice of designing exhaust Towers has shown that it is advisable to place the mounting joint of belts outside the interface points with the grid, at a height of 1-1.5 m above the level of the diaphragm. The difference in the diameters of pipes connected on flanges should not exceed 50 mm.



a) b) c) d)

Figure 1.14 Metal towers with flanged belt connections:

a) metal tower with a height of 32 m on the roof of the «Держпром» building in Kharkiv;

b) flanged interface unit for Tower belt elements;

c) metal tower with a height of 80 m of the torch chimney;

d) flanged junction of the tower belt with the foundation.

For cross profile belts consisting of two corners connecting elements

with different thicknesses, they are often connected to the factory joint, and changes in cross – section size-to the installation joint.

For cross profile belts consisting of two corners connecting elements

with different thicknesses, they are often connected to the factory joint, and changes in cross – section size-to the installation Joint.

In practice, factory connections on the corner linings of load-bearing Tower belts are rare (for low towers).

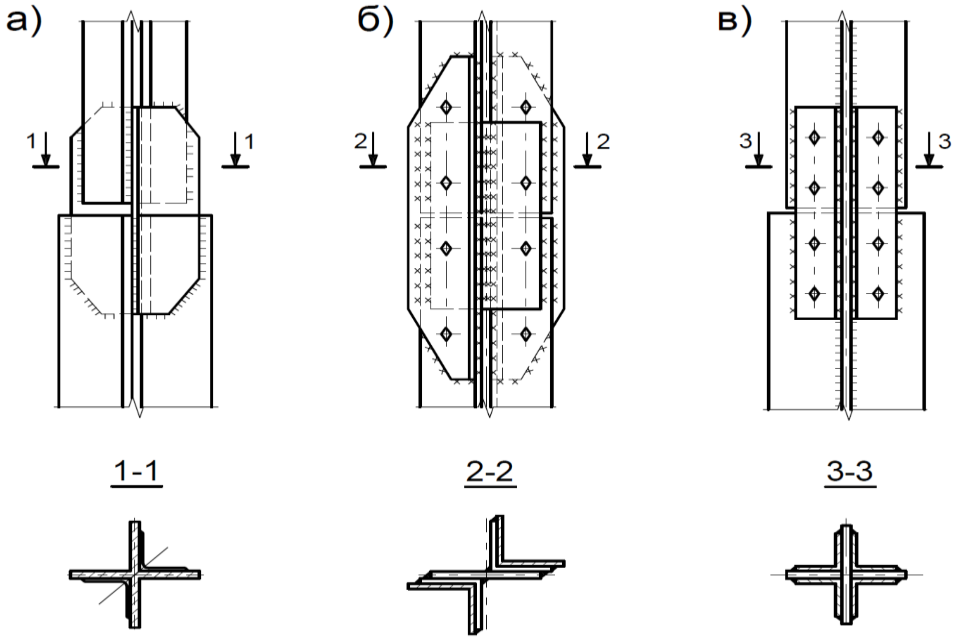


Figure 1.15 Design solutions for factory and installation applications connections of cross section elements:

a) factory joint on corner pads;

b) cross-section mounting joint made of corners;

c) cross-section mounting joint made of sheet steel.

The places where the tower belts break during the transition from the pyramidal part to the Prismatic part are responsible and rather complex nodes. The most common design of pipe break units in practice is shown in Fig. 1.16.

One of the most important nodes of the tower is the support node. Normal and cutting forces are transmitted to the foundation through the tower's support unit. Depending on the direction of the wind flow, the normal force may be compressive or tensile. The compressive force is transmitted to the foundation through the base plate, and the tensile force is perceived by the anchor bolts. Fixing the tetrahedral tower on the foundation is carried out by four support nodes, in each of which one tower Belt and two braces of adjacent faces converge.

The clearest transfer of forces and rational manufacturing conditions for the support unit can be achieved by installing the base plate perpendicular to the belt axis, and anchors parallel to it (fig. 1.17).

This solution is the most reliable and most common design solution for the construction of high-height towers with belts and braces of tubular cross-section.

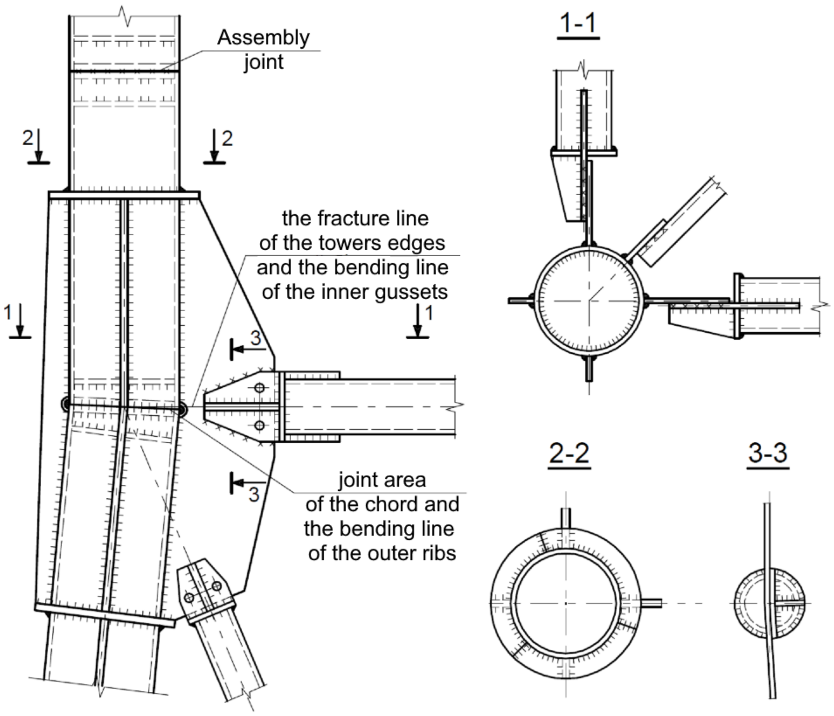


Figure 1.16 Belt fracture node made of pipes connected end-to-end

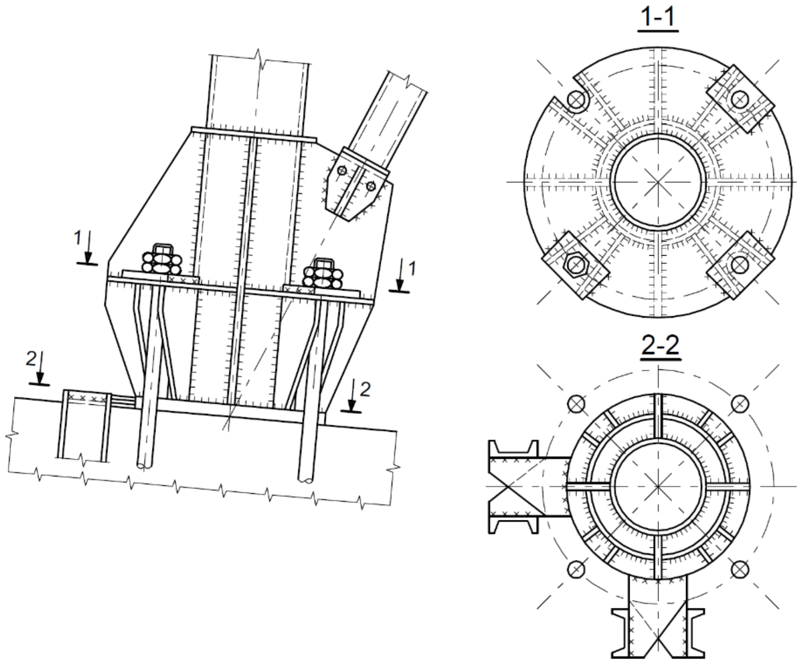


Figure 1.17 Tower support unit with tubular cross-section elements with four anchor bolts

Horizontal immobility of the support unit is provided by special embedded elements connected to the base plate by a "spur".

The transfer of forces from the Belt and braces to the elements of the support unit is carried out through a system of ribs and traverse. Ribs located in the plane of the tower faces are also shapes for fixing support braces.

CHAPTER 2
SCIENTIFIC RESEARCH

2.1. Aerodynamic research

In world practice, research institutes calculate and check high-rise structures for wind loads in a wind tunnel.

Large - scale testing of models in a wind tunnel with a boundary layer is the most reliable way to test the various effects that the wind has on a building with a high - rise building. Model tests are usually carried out on a small scale (in the range of 1:300 — 1:500) in order to obtain reliable turbulence modeling and an adequate representation of the surrounding buildings. Design wind loads are usually determined by measuring wind load fluctuations at the base using high-frequency strain gauges, or by simultaneously measuring surface pressure fluctuations over the entire surface of the structure using multi-point scanning. The possibility of using a particular measuring technique depends mainly on the geometric dimensions and shape of the model being tested.

Currently, construction aerodynamics laboratories in different countries operate a large number of installations. These installations were borrowed from aviation laboratories, so a significant number of the two main types of wind tunnels of direct-flow and closed configurations are still in operation. Because the construction industry does not have enough financial resources, like aviation, and, as a rule, the type and configuration of the pipe is dictated by the size of the houses or premises in which it will be placed. A distinctive feature of construction pipes is the relatively long length of the working part, which is necessary for modeling the surface boundary layer of the atmosphere.

When designing buildings and structures, a strong wind, which is slightly affected by thermal stratification, is the most important. This is why the flow is usually an isothermal boundary layer, which is modeled by a thermally neutral atmospheric boundary layer. Wind tunnels designed to create this type of flow are classified as boundary layer wind tunnels. Acceptable boundary layer modeling in short working sections for low structures is more difficult to achieve.

The efficiency of using wind tunnels was the beginning of a number of studies by domestic scientists, such as S. G. Kuznetsov, V. N. Vasilev, V. F. Mushchakov, O. V. Atamanchuk, I. S. Kholopov, as well as foreign authors Yu.V. Nemirovsky, G. M. Richardson, T. Lavson, Zhao Yin Wang, etc.

The possibility of using such pipes in domestic practice is described in scientific works and articles by the rector of the Donbass National ASAPRemy of construction and architecture E. V. Gorokhova.

The construction aerodynamics Laboratory of the Department of metal structures of the Donbass National Academy of construction and architecture is an organization that conducts research, testing and provides advice on wind impacts for architectural and construction companies in the design of wind-sensitive structures, especially for high-rise structures. This was achieved by combining direct experience in creating specific projects and investing in research.

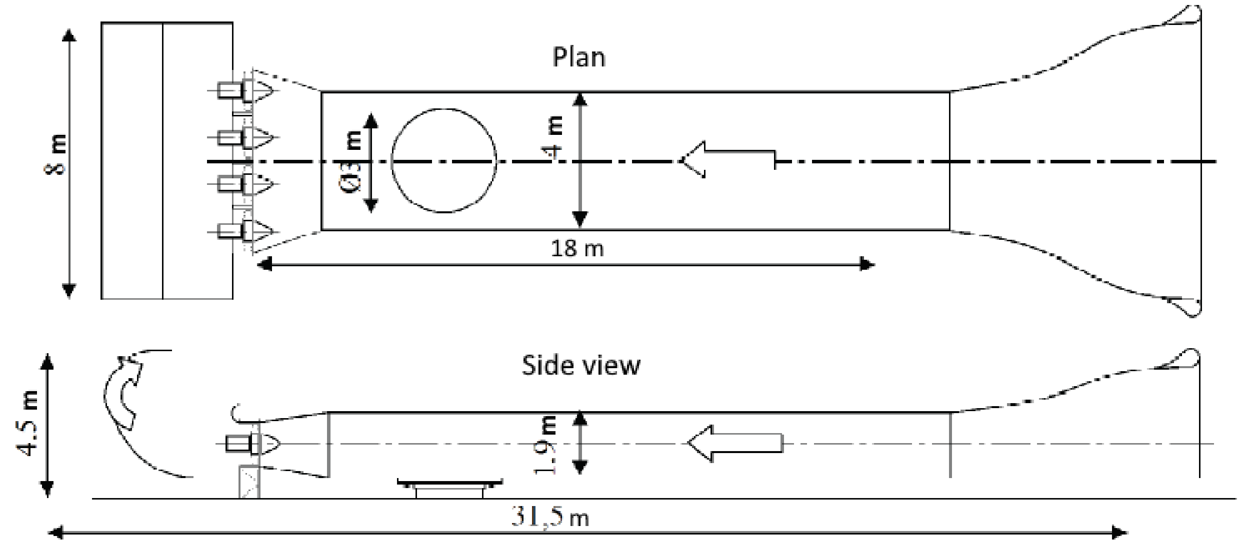


Fig. 2.1 Wind tunnel diagram.

In the works of E. V. Gorokhov, the project of a wind tunnel with a boundary layer of the atmosphere implemented at the Donbass National ASAPRemy of construction and architecture is presented to determine the assessment of the features of atmospheric wind, which are used to solve various technical problems and test high-rise structures [2].

In the modern regulatory literature, there is no data on the aerodynamics of pipe packages. At the same time, the aerodynamic coefficients of pipes in the package differ from the aerodynamic coefficients of single cylinders. The first major work in this direction can be considered the work of A.V. Atamanchuk, who, together with I. S. Kholopov, conducted research on the calculation of high-rise structures for wind load in various software packages and compared them with the results in a wind tunnel. But access to pipes is not always possible, and therefore in his works there is often a method for calculating high-rise towers for pulsating wind load. In contrast to the accepted normative calculation method, the proposed method allows taking into account not only the contribution of own forms, but also the correlation between own forms. The issue of summing the reaction by its own forms is considered. The results of calculations of the exhaust tower for pulsating wind load, according to the standard method and the author's methodology, are presented. In his works, the problem of wrapping a package of flue cylinders to wind load using the control volume method is solved. The values of aerodynamic coefficients for the cylinders of the exhaust pipe package and tower construction pipes are given [3].

Solving problems of turbulent fluid flows allows us to obtain satisfactory data, thus simulating the behaviour of real turbulent flows. Turbulence models describe a system of additional equations (and related algebraic relations and a set of constants) that are solved together with the Navier-Stokes equation.

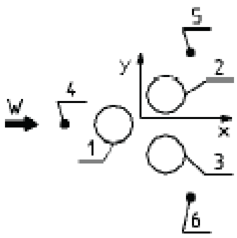
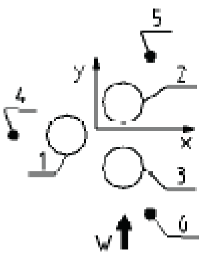
The blowing of the package at three angles of attack by the wind flow was simulated 0, 90° i 180°.

The results of the longitudinal and transverse aerodynamic coefficients of individual cylinders of the flue package and the structure are presented in Table. 2.1.

As an example, calculations of a three-sided exhaust tower with three flues are performed [3].

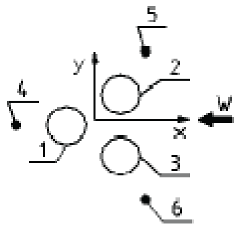
Calculations were performed using two methods for determining the wind load and the reaction of the structure to the pulsation wind impact. The first method is based on the regulatory methodology of the snip. The wind load according to the first method is determined taking into account the aerodynamic coefficients presented in Appendix 4 [4]. The second method is the method of the authors of the study from the algorithm proposed above. The wind load using the second method is determined taking into account the aerodynamic coefficients obtained by the authors of the study in the Lira-SAPR program.

Table 2.1 Aerodynamic coefficients

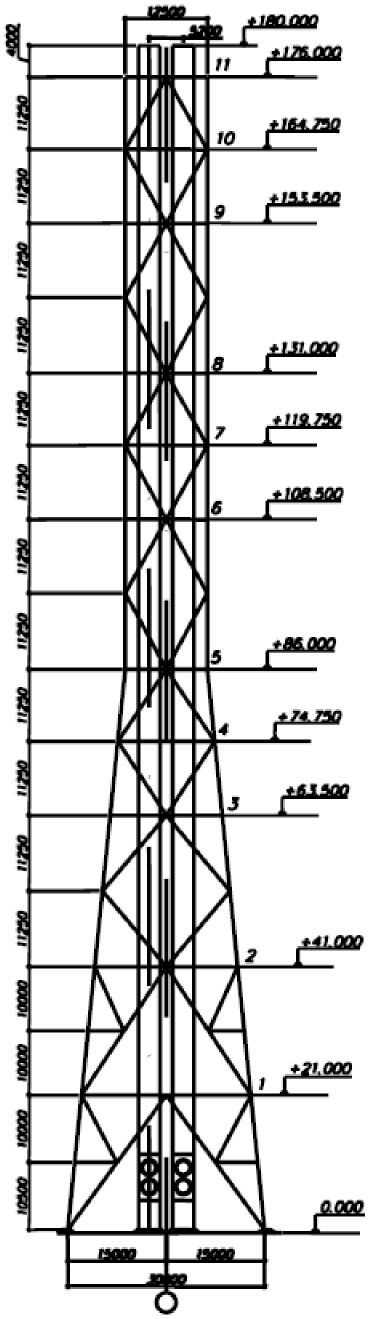
№	Angle of attack by wind flow	Diameter of tower subconstruction pipes	Aerodynamic coefficients	
			C_x	C_y
1	Angle of attack 0° 	Without tower subconstruction	$C_{x1}=0,28$ $C_{x2}=0,36$ $C_{x3}=0,36$	$C_{y1}=0$ $C_{y2}=0$ $C_{y3}=0$
		diam. 1220 mm	$C_{x1}=0,24$ $C_{x2}=0,45$ $C_{x3}=0,45$ $C_{x4}=0,11$ $C_{x5}=0,39$ $C_{x6}=0,39$	$C_{y1}=0$ $C_{y2}=0,24$ $C_{y3}=-0,24$ $C_{y4}=0$ $C_{y5}=0,1$ $C_{y6}=-0,1$
		diam. 1020 mm	$C_{x1}=0,24$ $C_{x2}=0,42$ $C_{x3}=0,42$ $C_{x4}=0,13$ $C_{x5}=0,48$ $C_{x6}=0,48$	$C_{y1}=0$ $C_{y2}=0,27$ $C_{y3}=-0,27$ $C_{y4}=0$ $C_{y5}=0,07$ $C_{y6}=-0,07$
		diam. 720 mm	$C_{x1}=0,24$ $C_{x2}=0,38$ $C_{x3}=0,38$ $C_{x4}=0,18$ $C_{x5}=0,62$ $C_{x6}=0,62$	$C_{y1}=0$ $C_{y2}=0,24$ $C_{y3}=-0,24$ $C_{y4}=0$ $C_{y5}=0,05$ $C_{y6}=-0,05$
2	Angle of attack 90° 	Without tower subconstruction	$C_{x1}=0,07$ $C_{x2}=-0,35$ $C_{x3}=0,12$	$C_{y1}=0,41$ $C_{y2}=0,16$ $C_{y3}=0,4$
		diam. 1220 mm	$C_{x1}=0,15$ $C_{x2}=-0,38$ $C_{x3}=0,2$ $C_{x4}=-0,22$ $C_{x5}=-0,04$ $C_{x6}=0,03$	$C_{y1}=0,49$ $C_{y2}=0,18$ $C_{y3}=0,33$ $C_{y4}=0,6$ $C_{y5}=0,37$ $C_{y6}=0,59$
		diam. 1020 mm	$C_{x1}=0,13$ $C_{x2}=-0,36$ $C_{x3}=0,18$ $C_{x4}=-0,22$ $C_{x5}=-0,04$ $C_{x6}=0,03$	$C_{y1}=0,47$ $C_{y2}=0,17$ $C_{y3}=0,35$ $C_{y4}=0,63$ $C_{y5}=0,42$ $C_{y6}=0,57$

		diam. 720 mm	C_{x1}=0,13 C_{x2}=-0,36 C_{x3}=0,18 C_{x4}=-0,22 C_{x5}=-0,04 C_{x6}=0,03	C_{y1}=0,47 C_{y2}=0,17 C_{y3}=0,35 C_{y4}=0,63 C_{y5}=0,42 C_{y6}=0,57

Table 2.1 Aerodynamic coefficients

№	Angle of attack by wind flow	Diameter of tower subconstruction pipes	Aerodynamic coefficients	
			C_x	C_y
3	Angle of attack 180° 	Without tower subconstruction	C_{x1}=-0,14 C_{x2}=-0,49 C_{x3}=-0,49	C_{y1}=0 C_{y2}=-0,16 C_{y3}=0,16
		diam. 1220 mm	C_{x1}=-0,11 C_{x2}=-0,44 C_{x3}=-0,44 C_{x4}=-0,17 C_{x5}=-0,85 C_{x6}=-0,85	C_{y1}=0 C_{y2}=-0,14 C_{y3}=0,14 C_{y4}=0 C_{y5}=0,1 C_{y6}=0,1
		diam. 1020 mm	C_{x1}=-0,12 C_{x2}=-0,46 C_{x3}=-0,46 C_{x4}=-0,17 C_{x5}=-0,82 C_{x6}=-0,82	C_{y1}=0 C_{y2}=-0,15 C_{y3}=0,15 C_{y4}=0 C_{y5}=0,1 C_{y6}=-0,1
		diam. 720 mm	C_{x1}=-0,13 C_{x2}=-0,48 C_{x3}=-0,48 C_{x4}=-0,17 C_{x5}=-0,82 C_{x6}=-0,82	C_{y1}=0 C_{y2}=-0,15 C_{y3}=0,15 C_{y4}=0 C_{y5}=0,1 C_{y6}=-0,1

The forms of natural vibrations of the tower blowing were determined in the Lira-SAPR, while the spatial scheme was modelled. The tower was divided into 11 sections. The masses of the sections were concentrated in the tower posts, and the mass of the flues — in the place of support — the diaphragms. The first six forms of natural vibrations were taken into account. The wind on the tower was set at three angles of attack 0, 90° i 180, as shown in Fig. 2.2.



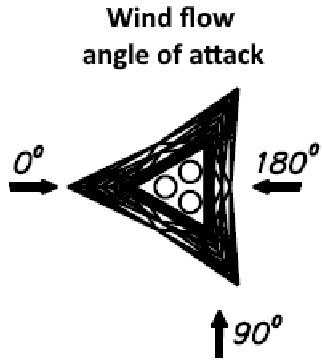


Fig. 2.2 Architectural interchange of the exhaust tower and angles of attack by wind flow.

Based on the results of calculations, the values of the maximum Tower displacements from the pulsating wind load were obtained according to DBN [4] method and according to the method proposed by the authors of the study. The obtained data were summarized in Table 2.2. summation of the reaction from dynamic wind influence by the forms of natural vibrations was carried out both by Formula (2.1) and by Formula (2.2). $X = X_{стат} + X_{динам} = X_{стат} + \sqrt{\sum_{j=1}^{r} X^{2}_{c.форми}}$

(2.1)

where, r — number of custom forms taken into account , X — reaction value.

In some cases, for calculations of structures with a dense frequency spectrum, it is necessary to take into account not only the contribution of natural waveforms, but also the contribution of mutual correlations between the shapes. The SNiP does not take into account mutual correlation by the forms of natural fluctuations. In the regulatory literature and DBN [4], the coefficients of dynamism and correlations of wind speed pulsations in space are given for the 1st form of natural vibrations, and for other forms these coefficients are equal to one.

$$X = X_{стат} + X_{динам} = X_{стат} + \sqrt{\sum_{S=1}^{r}\sum_{l=1}^{r} X_{S} \cdot X_{l\cdot}\mu_{Sl}} \qquad (2.2)$$

The formula (2.2) - summation of calculated forces by waveforms, proposed by the authors of the study, differs from formula (2.2) [5].

Table 2.2 Maximum displacements of the top point of the tower in (mm)

Wind angle of attack	№ own forms	Frequency of overhead vibrations (Hz)	According to DBN [4] Lira		According to the author's program [2]	
			Axis X	Axis У	Axis X	Axis У
1	2	3	4	5	6	7
0°	1	0,45	570	0	884.4	67.5
	2	0.45	-570	0	561.1	-106.9
	3	1.29	0	0	0	-12.4
	4	1.55	-22.1	0	31.1	1.4
	5	1.55	-22.1	0	10.5	-4.2
	6	2.55	0	0	0	0
	Total formula (1)		807	0	1048	127
	Total formula (2)		-	-	1446	42
90°	1	0.45	0	523.3	94.6	500
	2	0.45	0	523.3	144.6	836
	3	1.29	0	8.4	0	22
	4	1.55	0	-19.5		9
	5	1.55	0	19.5	5	29
	6	2.55	0	1	0	2
	Total formula (1)		0	741	173	975
	Total formula (2)		-	-	240	1337
180°	1	0,45	512,7	0	868.7	59
	2	0.45	-512,7	0	548.7	-78.7
	3	1.29	0	0	0	-13.1
	4	1.55	-19.1	0	29.7	1
	5	1.55	-19.1	0	10.2	-3.4
	6	2.55	0	0	0	2.7

	Total formula (1)	726	0	1028	99
	Total formula (2)	-	-	1418	24

A significant contribution to the development of methods for calculating tower-type structures for wind load is the developed model for dynamic calculation of tower-type structures for wind load by Yu.V. Nemirovsky. In his work, it is indicated that the structure is modelled by a flat cantilever inhomogeneous rod of variable cross-section with intermediate elastic-pliable bonds, which, along with distributed ones, also carry discrete masses with three degrees of will concentrated in the reduction centers at the boundaries *n* calculated sections (fig., b). A rod made up of s_n it has a symmetrical structure, which in cross-section is characterized by equidistant (see fig. , c) or concentric (fig., d) boundaries of stripped layers with arbitrary binding in the coordinate system *xyz* to the reference plane $y = 0$. Geometric axis of the rod *x* formed by the intersection of the power line $z = 0$ and the reference plane [6].

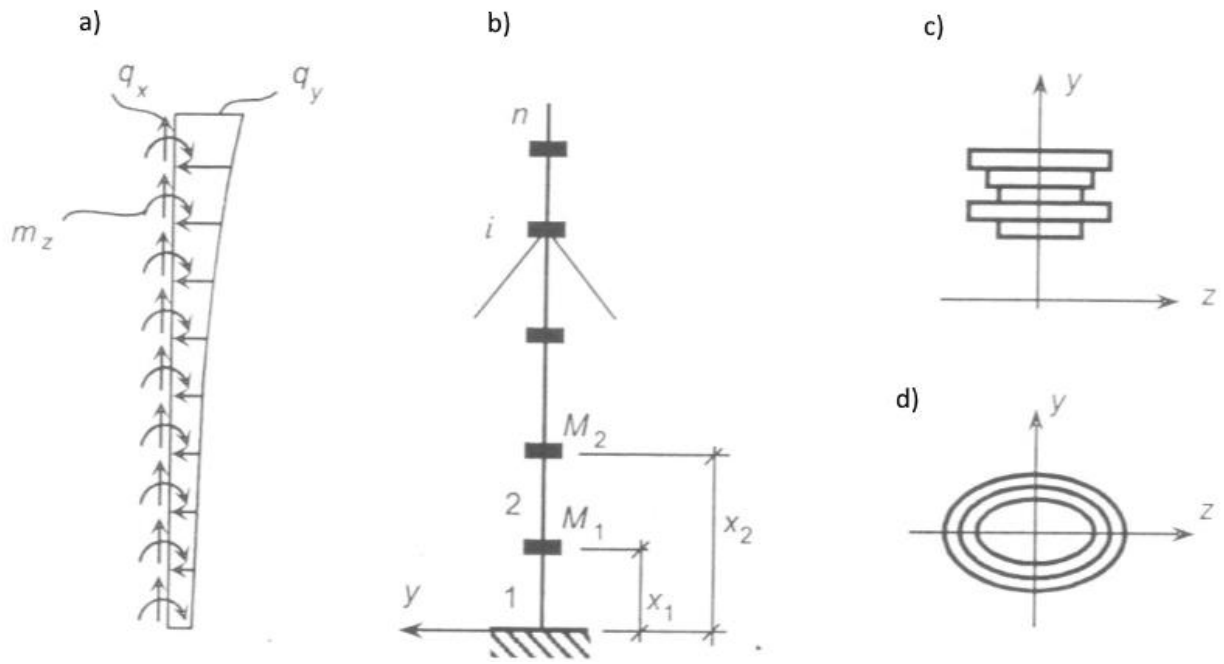


Fig.2.3 Design schemes of loads (a), rod (b), cross-sections (c, d).

2.2. Features of wind load

When studying the motion of liquids or gases and their interaction with solid or elastic bodies, aerohydromechanics considers liquids or gases as continuous media. If at any point in the space occupied by the flow of a liquid or gas, the pressure, density, flow rate and its direction do not change over time, then the motion is characterized as established. The motion of a liquid or gas is controlled by the well-known laws of conservation of mass and conservation of energy, from which the main equations of aerodynamics follow: the Continuity equation and the Bernoulli energy equation.

On the surface of bodies flowing around the air flow, a thin layer of inhibited gas is formed - the boundary layer. Its thickness depends on the shape of the surface, its roughness and determines the creation of a drag force. The friction force of the flow on the surface of the body is determined by the structure of the boundary layer and the physical processes occurring in it. If the boundary layer is vigorously mixed particles in the transverse flow direction and the entire boundary layer is randomly swirled, then it is called turbulent.

Consider the surface aerodynamic forces acting on an arbitrary body when it is surrounded by an air flow (fig. 2.4).

According to the basic theorem of mechanics, these forces can be reduced to one resultant force and one resulting moment **M**, which are called the total aerodynamic force and the total aerodynamic moment, respectively.

In the aerodynamics of building structures, a high-speed coordinate system is adopted, reduced to the flow velocity vector, which has axes ***x, y, z*** (see fig. 2.5). In general, the incoming flow forms a certain angle α with a plane ***xOz - angle of attack, and some angle with a plane xOy - sliding angle.*** Projections of vectors of total aerodynamic force $\vec{R}$ and the total aerodynamic moment **M** in the accepted coordinate system will be:

- drag force ***X;***
- lifting force ***Y***;
- lateral (transverse) force ***Z;***
- roll moment M_x;
- yaw moment (longitudinal moment) M_y.

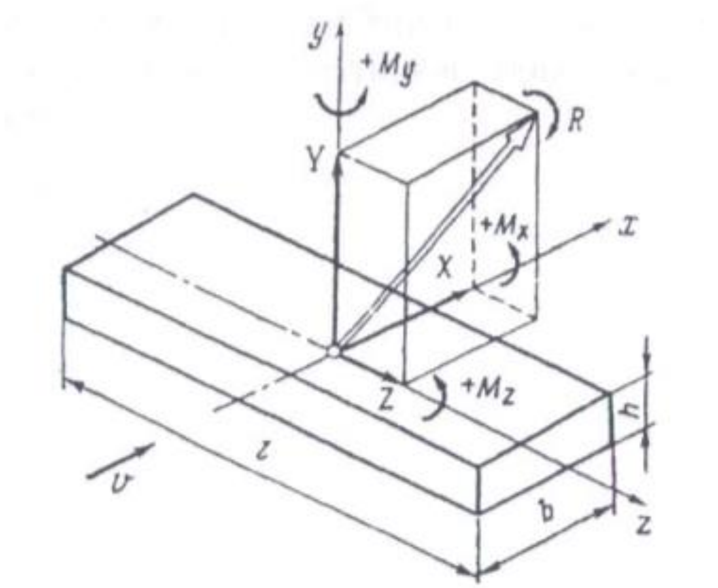


Fig.2.4. Structural element in the air flow and the scheme of aerodynamic forces acting on it

Their positive directions are shown in Fig. 2.4.the cross - section of a body streamlined by the wind flow is called the midel Section, its height h is called the midel, width **b** is called the chord, and the length of the body **l** is called the elongation. If **l/b>20 and l / h>20**, then in aerodynamics it is assumed that the body has an infinite elongation.

According to aerohydrodynamic theory the total resistance of a body to wind flow

$$R = \frac{1}{2}\rho V^2 c_R S \tag{2.3}$$

where, ρ - air density; ***V*** - incoming flow rate; S – mid-section area; c_R – coefficient of total aerodynamic force. Considering a dimensionless coefficient c_R as a vector that coincides in direction with the vector of the total aerodynamic force $\vec{R}$, you can represent its projection on the axis ***x, y, z*** in the form of c_x, c_y, c_z accordingly. These coefficients, also dimensionless, have names in aerodynamics: c_x - drag force; c_y - lifting force; c_z - lateral force. Similarly, in aerodynamics, the concepts of coefficients are introduced: roll moment m_x**;** the yaw moment m_y and moment of pitch m_z**.**

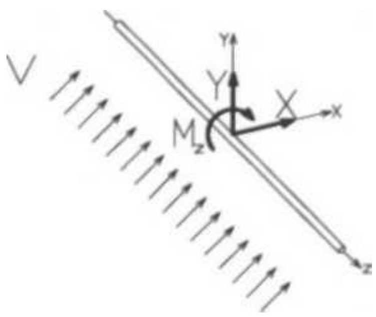
An important physical fact follows from the above formula (2.3): all aerodynamic forces and moment contain the parameter

$$w_0 = \frac{1}{2}\rho V^2 \tag{2.4}$$

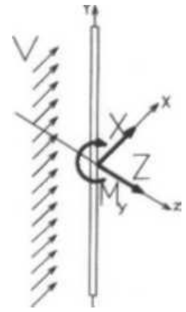
which is called **velocity head** (wind pressure). This parameter is proportional to the square of the speed and, therefore, determines the kinematic effect of wind on structures.

For most real structures, some aerodynamic forces or moments can be ignored either because of their smallness compared to others, or because of the significant hardness of structures in the direction of action of these forces or moments. So, for example:

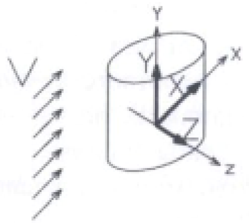
- for extended structures three aerodynamic parameters are essential ***X, Y***, M_z**;**

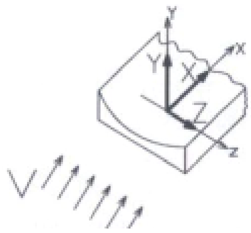


- for high - rise structures-parameters ***X, Z,*** $\boldsymbol{M_y}$;



- for spatial structures (tanks, membrane coatings, domes, etc.) - parameters ***X, Y*, *Z.***





Aerodynamic coefficients $c_x, c_y, c_z, m_x, m_y, m_z$ they are characterized by the aerodynamic qualities of structural elements when they interact with the wind flow. The numerical values of the coefficients (therefore, aerodynamic forces and moments) depend on seven main factors: the speed, direction of the wind and the degree of its turbulence; the geometric dimensions and shape of the cross-section; the degree of roughness of its surface and orientation relative to the direction of the wind flow. A special feature of the wind load is its pulsating nature, the specifics of atmospheric turbulence of the wind flow. Spectral analysis of wind flow turbulence in the surface layer of the atmosphere established the maxima of the ripple spectrum of the horizontal component of wind speed, shown in Fig. 2.5.

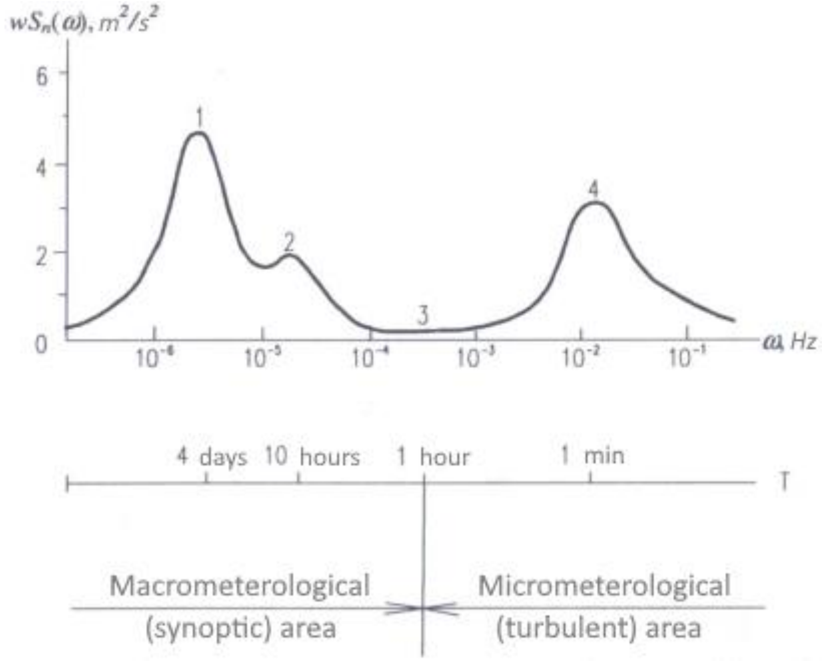


Fig. 2.5 Van der Hoeven Spectrum:

$wS_n(\omega)$ - total energy of the spectrum; ω - ripple frequency (T-ripple period) of the longitudinal component of wind speed;

1 - area of a large-scale baric system;

2 - the same applies to the daily cycle of solar energy;

3 - same as the center of the spectral minimum;

4 - the same applies to turbulence caused by the underlying surface.

The Van der Hoeven spectrum explains the presence of dynamic wind ripple effects along with static wind action. As can be seen from fig. 2.5, a wide region of the minimum spectrum divides it into two regions - synoptic and turbulent, which causes the wind load as the sum of two components: static with a frequency close to zero, and dynamic with a frequency of 0.02 Hz (a period of 50 s). In the general case of wind impact on structural elements, the wind direction has a certain gradient, making up an angle (angle of attack) with a horizontal density. The ascending flow corresponds to a positive value, and the descending flow corresponds to a negative value of the angle of attack. Numerous studies have made it possible to obtain dependence (fig. 2.6), which indicates an increase in the wind flow gradient (angle of attack α) with a decrease in the flow rate [5].

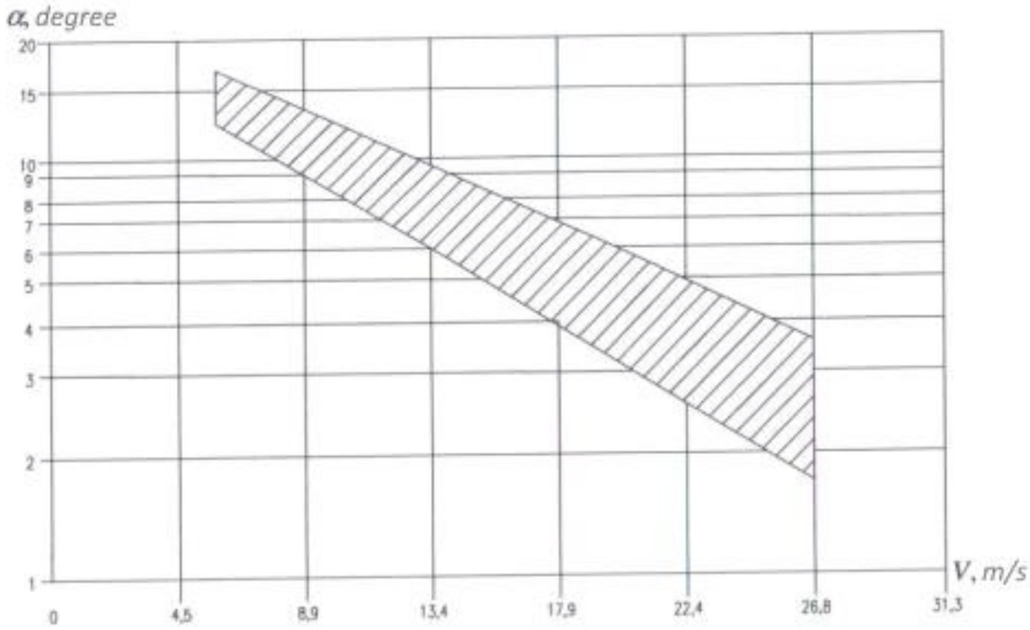


Fig. 2.6. Change in the wind flow gradient in the surface layer of the atmosphere

Analysis of the vertical component of wind flow velocity along with the pattern $\alpha(V)$ it also detects the dependence of maximum angles of attack on the focal time based on the Panovsky - McCormick spectrum of instantaneous values of the angle of attack (fig. 2.7). Solid lines show theoretical dependences calculated at three different values of the average wind speed for the density of the vertical component of the wind flow. Experimental values for average wind flow velocity $V = 10 м/с$ marked with a dashed line.

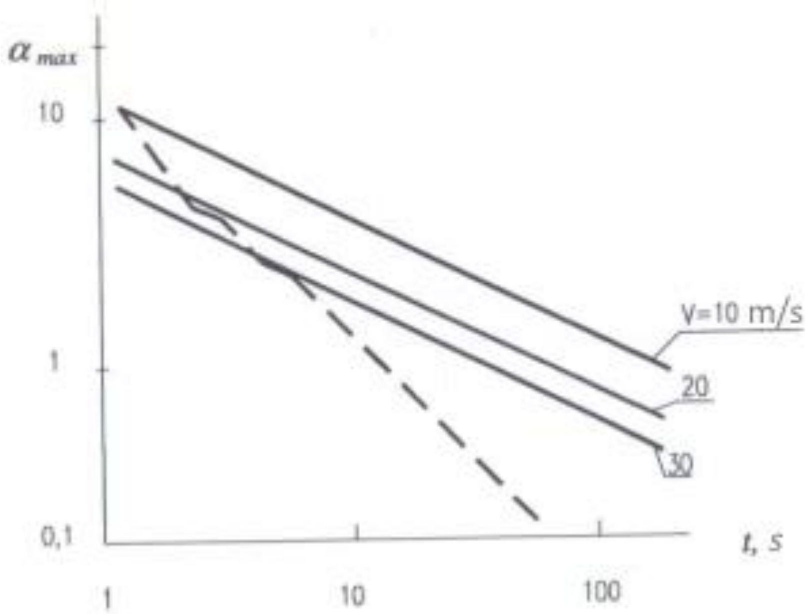


Fig. 2.7. Influence of the determination time on the value of the maximum wind flow gradient

When discussing wind impacts on building structures, you should pay attention to such an atmospheric phenomenon as a tornado. A tornado is an intense small-scale vortex that causes the strongest winds. However, the probability of their occurrence in any particular area in comparison with other experimental winds (storm, hurricane) is low.

Long-term climate changes can change attitudes towards rationing a certain class of structures. In countries with a real probability of tornadoes, it is generally accepted that the cost of building structures that can withstand the effects of tornadoes should be significantly higher than the cost of estimated damage caused by tornadoes. Expected losses are defined as the products of the amount of losses and the probability of their occurrence. The nature of tornado impacts is determined by three main factors:

- wind pressure of the air flow;

- the impact caused by a change in the atmospheric pressure field when a tornado passes over structures;

- strike forces of flying objects captured by a passing tornado.

2.3. Interaction of flexible structural elements with wind flow

Analysis of the van der Hoeven spectrum indicates two possible types of interaction of structural elements with wind flow: static and dynamic. In static interaction, the wind flow is considered uniform and incompressible [5]. In this case, the wind load, in turn, is considered as a combination:

- normal pressure, centred according to a certain law applied to the upper surface of a structural element or structure as a whole;

- friction forces directed tangentially to the outer surface and related to the area of its horizontal or vertical projection.

Dynamic impact generates non-stationary loads in the form of instantaneous local or instantaneous total (accumulated over the entire surface of the element) pressure. In this case, the dynamic response depends on the nature of non-stationary aerodynamic forces and can be: random fluctuations along the flow in the natural frequency spectrum of structures or one of the aeroelastic phenomena of a bending (across the flow) or torsional shape.

The standard value of the average pressure time is determined by the averaging time interval. It is generally accepted that stable values can be obtained by choosing this interval equal to 15c for wind tunnel studies and 8-15 minutes in full-scale conditions, which is quite enough to obtain representative estimates of average wind speeds.

Non-stationary loads contain both drag force ripples caused by wind speed ripples, and periodic aerodynamic forces caused by the nature of the flow around structures.

Thus, the three types of structural reactions to wind impacts described above indicate the trinity of wind action on building structures.

2.4. Permissible flexibility of structural elements

When flexible structural elements interact with the air flow if the condition is met

$$V_{кр} < V_p \qquad (2.5)$$

aeroelastic instability of the vortex excitation type may occur. This instability is accompanied by intense cross-flow self-oscillations. Critical speed $V_{кр}$, what causes the aeroelastic oscillation of the vortex excitation is determined by the well - known formula:

$$V_{кр} = fd / Sh \qquad (2.6)$$

where d - the characteristic cross-sectional size of a flexible element, such as the diameter; f - natural oscillation frequency of the element; Sh - Struhal number; $V_p -$ estimated wind speed.

Inequality

$$V_{кр} > V_p \qquad (2.7)$$

the inverse of inequality (2.5) is adequate to the condition that this type of instability cannot occur.

Own frequencies f_j for $j-$th, the vibration tones of a flexible element are described by the expression:

$$f_j = \frac{1}{2\pi} \frac{\alpha_j^2}{l^2} \sqrt{\frac{EJ}{m}\left(1 \pm \frac{N}{N_э}\right)} \qquad (2.8)$$

where ***m*** - wt.; ***J*** - the moment of inertia of an element is determined by the dependencies:

$$m = F\rho_0 \, , J = i^2 F \, , \; J / m = i^2 / \rho_0 \tag{2.9}$$

$l, \; F \, , i^2 , \rho_0 , \; E$ - length, cross-sectional area, radius of inertia, density and modulus of elasticity of the element material, respectively; α_j - frequency coefficient that depends on the boundary conditions and sequence number $j -$th, waveforms of the element; N - longitudinal force in the rod; $N_Э$ - Euler's critical force.

The " + "sign corresponds to the longitudinal tensile forces, and the" - " sign corresponds to the compressive forces.

Substitute expressions (2.6), (2.8), and (2.9) into inequality (2.7):

$$V_p = \frac{1}{2\pi} \frac{\alpha_j^2 id}{l^2 Sh} \sqrt{\frac{E}{\rho_0}\left(1 \pm \frac{N}{N_Э}\right)} \tag{2.10}$$

From here we find acceptable values of the relative length l / d elements for which Eddy disturbance calculations cannot be performed:

$$\frac{l^2}{d} < \frac{1}{2\pi} \frac{\alpha_j^2 i}{ShV_p} \sqrt{\frac{E}{\rho_0}\left(1 \pm \frac{N}{N_Э}\right)} \tag{2.11}$$

Between the relative length l / d elements and their flexibility there is a connection:

$$\lambda = k \frac{l}{d} \text{, where } k = м \frac{d}{i} \tag{2.12}$$

Thus, based on (2.11) and (2.12), we can also obtain the maximum permissible flexibility of the elements:

$$(\lambda)^2 < \frac{1}{2\pi}\frac{\alpha_j^2 d\mu}{iShV_p}\sqrt{\frac{E}{\rho_0}\left(1\pm\frac{N}{N_Э}\right)} \tag{2.13}$$

Expressions (2.11) and (2.13) for acceptable relative length values l/d and flexibility λ structural elements can be represented in a different form:

$$\frac{l}{d} < \frac{A_j}{\sqrt{V_p}}\sqrt[4]{\left(1\pm\frac{N}{N_Э}\right)}; \quad \lambda < \frac{B_j}{\sqrt{V_p}}\sqrt[4]{\left(1\pm\frac{N}{N_Э}\right)}; \tag{2.14}$$

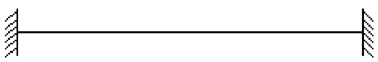
if you enter the following symbols:

$$A_j = \alpha_j\sqrt{\frac{i}{2\pi dSh}\sqrt{\frac{E}{\rho_0}}}; \quad B_j = \alpha_j\mu\sqrt{\frac{d}{2\pi iSh}\sqrt{\frac{E}{\rho_0}}}; \tag{2.15}$$

etc. $A_j = \frac{i}{d\mu}B_j;$

The most typical design schemes of flexible structural elements and their corresponding frequency coefficient values α_j for the first tone of vibrations, they are shown in Table. 2.3.

Table 2.3. Design schemes of flexible structural elements

	Розрахункова схема елемента	Частотний коефіцієнт α_j	Коефіцієнт розрахункової довжини μ
I		4,73	0,5

In Fig.2.8 families of graphs of the dependence of the limits of acceptable values are shown l/d from the speed of the wind flow *V*.

They can be easily transformed into limits of acceptable flexibility values by entering a multiplier $B_1/A_1 = \mu d/i$

If conditions (2.11) and (2.13) or, respectively, (2.14) cannot be satisfied, the calculations of structural elements for Vortex excitation must be supplemented with an endurance test using the formula:

$$\sigma_{max} \le \alpha R_v \gamma_v \qquad (2.16)$$

where is the parameter α depends on the estimated number of load cycles; R_v - calculated fatigue resistance; γ_v, - coefficient that depends on the type of stress-strain state and the parameter of dynamic stress asymmetry.

So, with an estimated durability of 20 years, it is recommended to take the number of cycles $n = 3{,}9 \cdot 10^6$. Corresponding parameter value α exactly $\alpha = 0{,}77$.

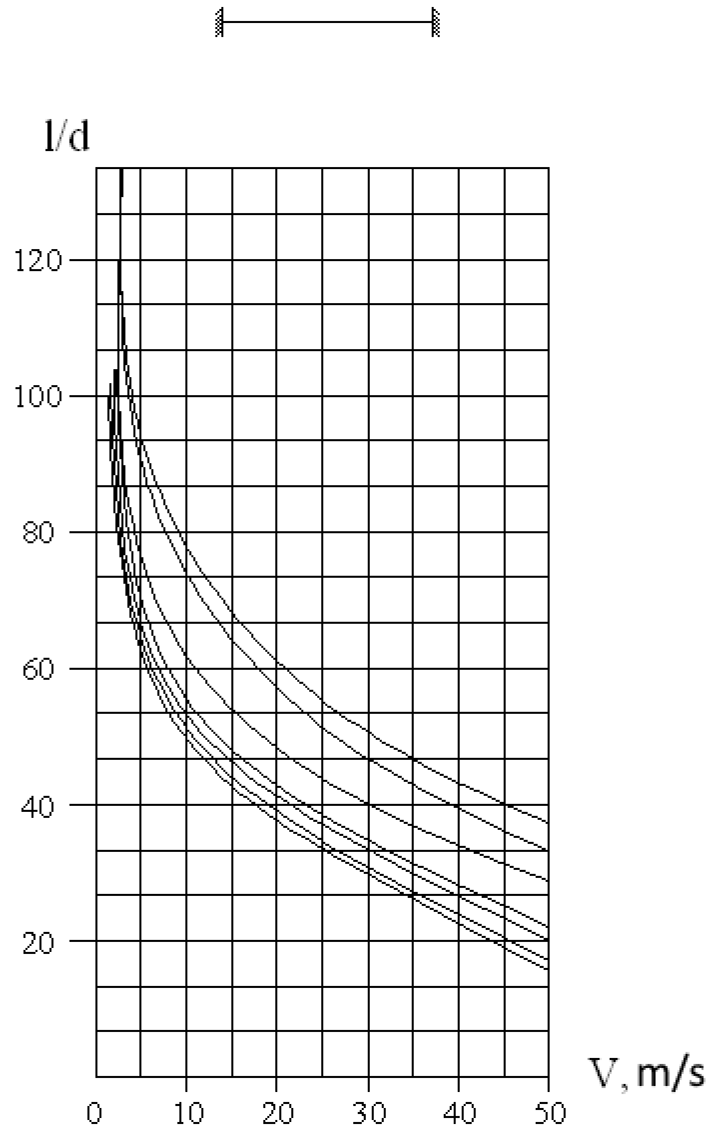


Fig. 2.8. dependence of the relative length l/d on the wind flow velocity V for four types of design schemes of elements with different types of cross-section

2.5. Resource fatigue estimates

No less important is the need to assess the fatigue life of flexible structural elements both during design, and during operation and reconstruction. This assessment can be performed using the formula:

$$t = nT_j / p, \text{ c} \qquad (2.17)$$

where ***n*** - number of load cycles, depending on the responsibility of the element

($n = 2 \cdot 10^6 - 4 \cdot 10^6$), $T_j = l / f_j$ - the period of natural vibrations of the element (it is equal to the period of aeroelastic self-oscillations of the vortex excitation);

p - probability of the most unfavourable values of wind flow parameters.

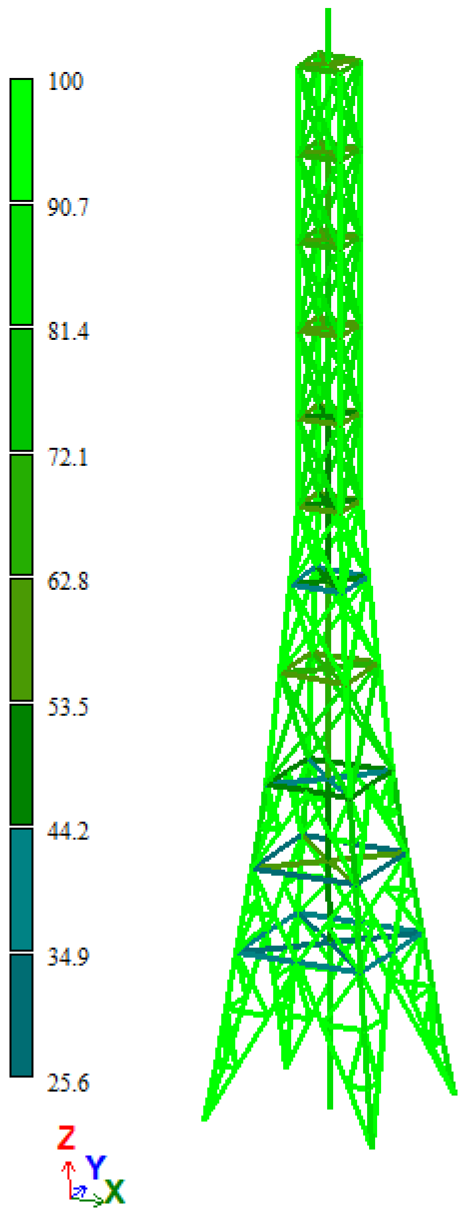
The parameters included in formula (2.17) are specified in accordance with the technological requirements of operation and data from long-term meteorological observations that characterize the climatic features of the object (Meteorological micro district).

2.6. Calculation of acceptable flexibility

So we calculate the horizontal element of the exhaust tower for flexibility at a height of 40 m. (Fig.2.9).

According to the calculation data, in the Lira-SAPR PC and STK-SAPR, this element is channel 10.

Design option:Variant 1
Analysis by DCL:ДБН В.1.2 - 2:2006_1 (DBN B.2.6-198:2014)



Mosaic results. Selected cross sections: check for serviceability limit state (SLS)

The flexibility of an element is determined by a well-known formula:

$$\lambda_1 = \mu \frac{l}{i}$$

where $\mu -$ coefficient of the calculated length, which depends on the attachment. Since all elements of the tower are fixed rigidly, therefore $\mu = 0.5$

$l-$ element length, $l = 6.4м$

$i-$ radius of inertia of the element, $i = 40мм$

$$\lambda_1 = \mu \frac{l}{i} = 0.5 \frac{640}{40} = 80$$

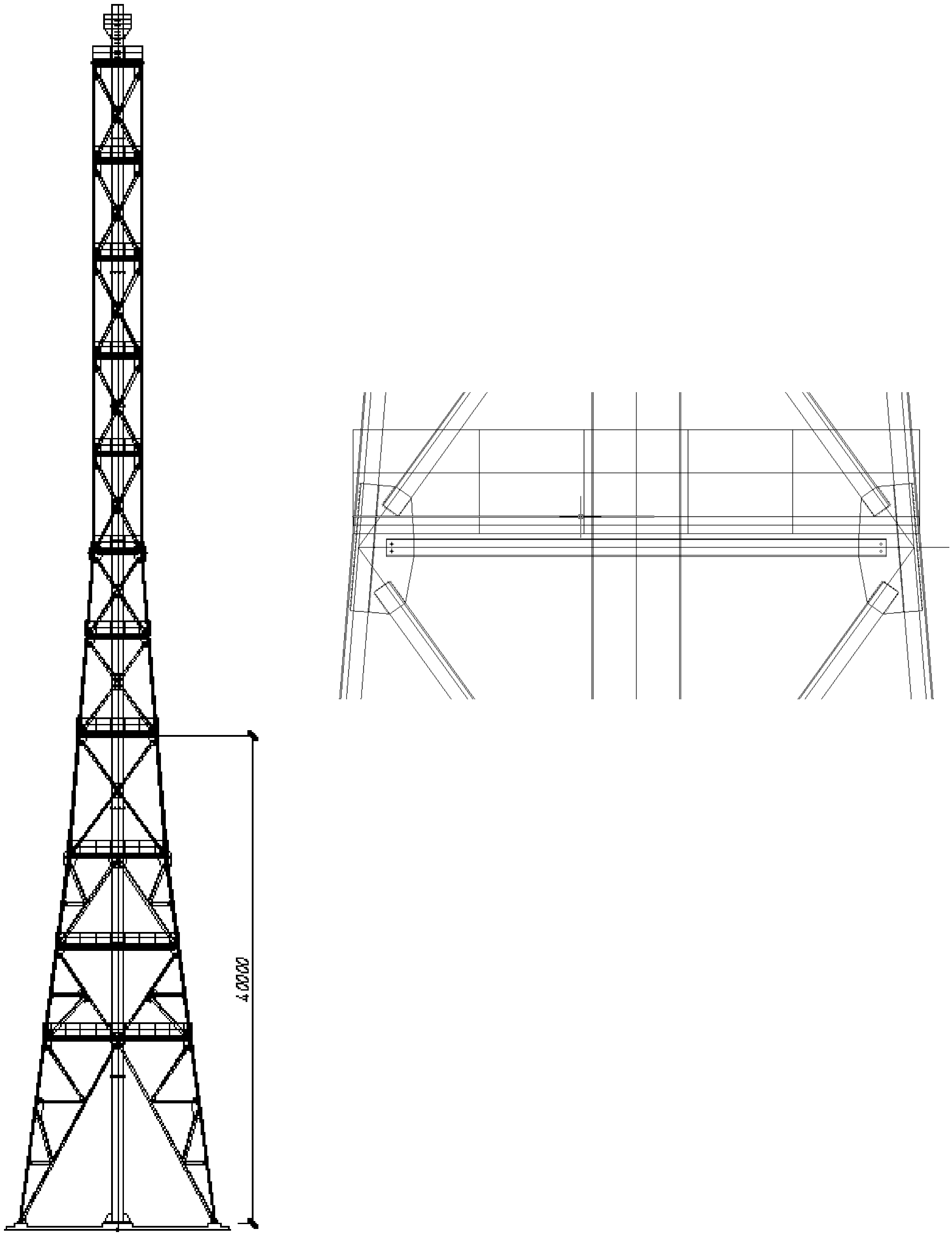


Fig.2.9. 100 m high exhaust tower

And now we perform the calculation using the formula (2.13):

$$(\lambda)^2 < \frac{1}{2\pi}\frac{\alpha_j^2 d\mu}{iShV_p}\sqrt{\frac{E}{\rho_0}\left(1 \pm \frac{N}{N_Э}\right)}$$

where $\alpha_j = 4.73$ according to the table 2.3

$$\frac{i}{d} = \frac{1}{0.3}$$

$Sh = 0.145 -$ Struhal number

$\mu = 0.5 -$ coefficient of the calculated length, which depends on the attachment.

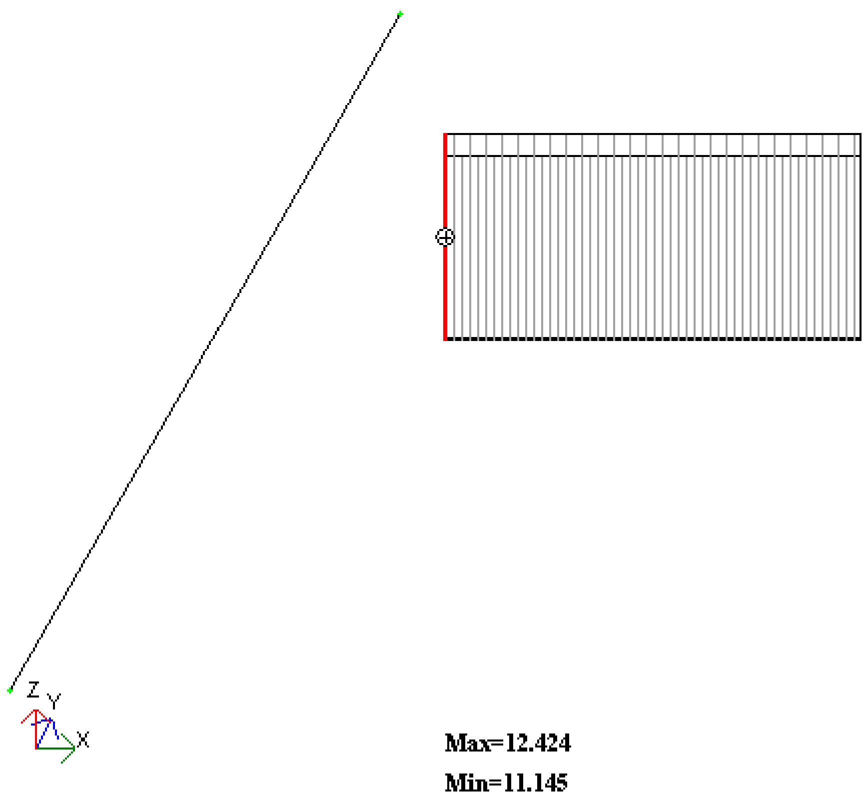
$V_p = 45кг/м^2 -$ estimated wind speed.

$N_Э -$ Euler's critical force.

$$N_Э = \frac{\pi^2 EI}{(\mu l)^2} = \frac{3.14^2 \cdot 2 \cdot 10^6 \cdot 174}{(0.5 \cdot 640)^2} = 0.034 \cdot 10^6 кг = 34$$ т.

$N -$ longitudinal force in the element.

Diagram N, Tf



$$(\lambda)^2 < \frac{1}{2\cdot 3.14}\frac{4.73^2\cdot 0.5^2\cdot 5123.475}{0.3\cdot 0.145\cdot 45}\sqrt{\left(1+\frac{12.424}{34}\right)} = 2723.94$$

$$\lambda = \sqrt{2723.94} = 52.2$$

Compare the obtained values:

$$\lambda = 52.2 < \lambda_1 = 80$$

Conclusion:

This calculation has shown that with the same length and radius of inertia of the element, the flexibility of (λ) much less flexibility (λ_1) this method. And the lower the flexibility of the element, the better its strength is ensured.

CHAPTER 3
ARCHITECTURAL PART

3.1 General information

The architecture of buildings and structures is an artificially created spatial environment in which all the life processes of society and individuals take place – work, everyday life, communication, social and cultural services, recreation, and so on. In terms of material implementation, architecture relies on construction equipment, as a material environment – reflects the social conditions of society, as art – is able to create a deep emotional impact.

Architectural design of buildings and structures and their complexes is carried out in accordance with functional requirements, physical laws and laws of architectural aesthetics to ensure the architectural and artistic expressiveness of the building. Architecture organically combines functional, structural and aesthetic features. The means of architecture are space and an artificially created architectural environment, which in buildings has the forms of structural shells that protect people from the negative effects of the external environment. Requirements for architectural objects include a large number of components: the functional purpose of the structure, its aesthetic significance, structural solution, materials of structural elements, technology and construction conditions, as well as interaction with the environment. Architectural works include buildings, individual fragments of Urban Development and the spatial organization of cities as a whole, engineering structures, as well as external landscaping structures. Architecture forms the material environment of people's life in accordance with the material, technical and economic capabilities of society and its needs.

In accordance with modern requirements for the design of the construction part of industrial enterprises, the textbooks provide information [7].

3.2 General requirements for buildings and their elements.

Any building and engineering structure must meet the following requirements: functional feasibility, structural reliability, sanitary and technical requirements, taking into account natural, climatic and local conditions, architectural and artistic expressiveness and cost-effectiveness of construction and operation.

The requirements of functional feasibility of a design solution are the maximum compliance of the building's premises with the functional processes for which it is intended. Any building is a financially organized environment for a person to carry out various processes: life, everyday life, work, recreation, and so on.

The structural reliability of a building is ensured by its strength, vertical stability, spatial rigidity, durability and fire resistance. The building must reliably protect people and equipment from adverse force and non-force impacts.

Reliability is the ability of structures, buildings and structures to perform specified functions flawlessly during the estimated period of operation: to guarantee the safety and comfort of people living or working in buildings and structures, to ensure a given technological process, normal operation of machines and equipment during the designed service life. Currently, reliability is characterized by two coefficients: the ratio of the actual service life of buildings without major repairs to the projected service life; the ratio of theoretical operating costs to actual ones for the period before major repairs.

The reliability of structures, buildings and structures is ensured by the quality of raw materials, the manufacture of structures, the performance of design and construction and installation works, the implementation of protective measures in accordance with the degree of aggressiveness of the environment, the culture of operation of buildings, timely repair work. The reliability of buildings increases if the overall strength, spatial rigidity and stability of buildings are ensured, with an increase in the strength of the connection of structures and their elements.

Strength is the ability to perceive force loads and impacts without destruction and significant residual deformations.

Stability is the ability to maintain balance from tipping over or shifting under power loads and impacts.

3.3. Master plan

The project provides for the construction of an experimental workshop of household utensils with an administrative building built into the warehouse and an attached metal exhaust tower that diverts past cleaning, but retains a certain degree of aggressiveness.

The area of the building plot is 5.93 ha

Built – up area-22876 sq.m.

The terrain of the site is calm, the absolute mark is 160.0 m in the Baltic elevation system.

3.4 Initial design data

Place of construction of the building – c. Kodra.

The project was developed in accordance with the climatic conditions of the construction site:

- standard snow load for the V snow area [4];

- high-speed wind pressure for wind zone II [4];
- estimated temperature of the coldest five-year plan minus 6˚C (provision 0,92) [8], the humidity zone is normal [9].

The reliability coefficient for its intended purpose is assumed to be 0.95; which corresponds to the II Class of responsibility of buildings and structures (rules for taking into account the degree of responsibility of buildings and structures in the design of structures) [10].

3.5 General characteristics of the construction site

The design of the building of the «Kodryansky glass factory» in the village of Kodra was carried out by the association «УкрНДІагропроект» c. Kyiv.

The working project provided for the commissioning of a complex of buildings « Kodryansky glass factory » one turn.

For the relative mark “0,000” an absolute mark is accepted 160,000 in the Baltic coordinate system. The depth of freezing of the soil is 1.2 m. the soil is not aggressive; the terrain of the site is calm. Climatic conditions according to design data (according to regulatory data of 2006): wind pressure – 35 kg/m^2; snow load - 70 kg/m^2; estimated winter air temperature - 6°C. According to current regulatory data the snow load is 114 kg/m^2; wind load 75 kg/m^2 [4].

The total area of the production shop is 6012m^2, built-up area 7109 m^2, the construction volume is 47930 m^3.

On the territory of the enterprise there is a main one-story building with built-in service rooms of a 2-storey administrative building; an exhaust Tower with a height of 100m. and 5.4 m in plan. An exhaust Tower is a tower-type structure characterized by a clear separation of engineering and technological functions, consisting of a steel supporting structure and one or more gas outlet shafts. The supporting structure, as a rule, is a lattice tower, and the gas outlet trunk is an element of technological communications.

The building is designed as a glass production building. It is divided into two halls – a product processing area and a furnace hall.

According to the classification, the building is industrial, industrial with an administrative and household building. The building belongs to the II capital group, II degree of fire resistance, II class of buildings.

The production shop is built according to the frame structural system, as a complete frame, according to the frame-connected structural scheme. The building is heated. The terrain of the construction site is calm.

3.5.1 Characteristics of the experimental shop of household utensils

The projected building is functionally divided into two zones and has built-in office and utility rooms. The building is a one-story, rectangular building with dimensions in the axes of 138x24 M and a height to the bottom of the rafter structures of the coating of 6.6 M and 12.0 m.

Service completion in axes 1-2, A-D is designed with 2-storey dimensions in the plan of 6x24m. the height of the floors is 3.0 m.

Metal columns of the I-beam frame located in axes 1-18 have a height of 6.6 M. and in axes 18-24 there are two-branch metal columns of I-beam cross-section with a height of 12 m. the columns have a rigid fixation in the cups.

Along the digital axes in the lower part of the building, metal triangular trusses are placed on columns. And in the High part, polygonal farms are nested.

At the top of metal trusses, a roof is arranged along a profile metal sheet.

The foundations are made of monolithic reinforced concrete. The lower mark is -1.8 m and -4.8 m.

The exterior walls are made of factory-made sandwich panels filled with mineral wool slabs 100 mm thick.

The roof is rolled, with a low slope and internal drainage. Mineral wool insulation, double-layer [11].

3.5.2 Administrative and household building

An administrative building is a two-story building and is a built-in or attached structure to a warehouse building.

According to its functional load, the administrative building provides the complex with premises for shop employees, men's and women's changing rooms, showers and bathrooms for shop employees and the administrative building.

The level of the clean floor of the warehouse is taken as 0.000. The clean floor level on the second floor is +3,000.

The structural structure of the building is brick on a cement-sand mortar. The exterior walls are brick with a thickness of 380 mm, the interior walls are brick-380 mm. The partitions are made of 125mm brick. The foundation is ribbon with support on glasses. The floor is made of reinforced concrete hollow slabs [11].

The exterior walls are additionally insulated with Rockwool basalt wool slabs. Window and exterior door blocks are made of metal-plastic profile with three-chamber double-glazed windows. The building belongs to the II degree of fire resistance [12].

3.5.3 Exhaust tower

The exhaust tower is 100m high and 5.4 m in plan. The exhaust tower is a tower-type structure characterized by a clear separation of engineering and technological functions. It consists of a steel supporting structure and one or more gas outlet shafts. The supporting structure, as a rule, is a lattice tower, and the gas outlet trunk is an element of technological communications.

The gas outlet barrel is a metal pipe with a diameter of 1020 mm.

Silhouette of a lattice tower with one belt fracture in height. The tower grilles are assumed to be cross-shaped. The cross-section of elements consists of corners. The basis for the value of stiffness diaphragms is made by platforms necessary for servicing the structure during its operation. There are seven such platforms located on this tower. Climbing on them is carried out on a metal ladder.

3.6 Building finishing

Exterior decoration of the building – galvanized painted trapezoidal sheet of blue and white colour. Internal finishing of the composition – White galvanized trapezoidal sheet.

Exterior decoration of the building – galvanized painted trapezoidal sheet of blue and white color. Internal finishing of the composition – White galvanized trapezoidal sheet.

Finishing of bathrooms and showers – ceramic tiles.

3.7 Fire prevention measures

According to the regulations [12], [13], the project provides for the following fire prevention measures:

- the project provides for a one story structure of the 2nd degree of fire resistance;
- instead of fire walls, to solve architectural and planning solutions, the project provides for the use of automatic drencher curtains;
- increase the fire resistance of metal columns up to 2 hours due to facing with 4 layers of fire resistant drywall;
- increase in fire resistance to 0.75 hours. metal beams of coating “overlap, elms due to coating with a flame retardant mixture " Endotherm HT-150”;
- installation of smoke extraction shafts on the roof of the structure;
- application of non-flammable insulation materials for exterior walls and roofs;
- the total width of evacuation exits is provided at the rate of 1 m of exit width for 165 people for houses of the 2nd degree of fire resistance;
- for the evacuation of people from the second floor, ordinary stairwells of type 1 are provided;
- the width of the staircases is assumed to be 1.2 m;
- bowing marches of stairs does not exceed 1:2;
- stairwells are provided with natural light and have access directly to the outside;
- the width of the doors at the exit of stairwells is assumed to be at least the width of the flight of stairs;
- along the perimeter of the structure, with the exception of the main facade, external fire escapes are provided at a distance of no more than 150 m from each other;
- corridor width accepted 1,8 m;
- doors on escape routes open in the direction of exits from the structure;

- the height of doors on escape routes is not less than 2.1 m;
- evacuation exits are provided from each room with more than 50 people;
- a circular detour for fire trucks is designed around the structure at a distance of 5 m from the walls of the complex.

Conclusion

Building is made of special frame system, columns, beams and trusses are made from steel. The experimental shop of household utensils is a one-story, rectangular building with dimensions in the axes of 138x24 m and a height to the bottom of the rafter structures of the coating of 6.6 m and 12.0 m. An administrative building is a two-story building and is a built-in or attached structure to a warehouse building. Floor height equals to 3 m. The exhaust tower is 100 m height and 5.4 m in plan. Fire prevention measures have been made. The total area of the production shop is 6012 m2, built-up area 7109 m2, the construction volume is 47930 m3.

CHAPTER 4
DESIGN AND CALCULATION PART

4.1 Calculation of the cross frame of the experimental shop

4.1.1. Collecting loads

4.1.1.1 Constant load

The surface load from the mass of the coating is determined in tabular form.

Table 4.1 Load from the mass of coating structures

Roof element	Standard load, kN/m2	Load reliability factor, γ_f	Design load, kN/m2
Protective layer of gravel sunk into bitumen mastic $t = 10$мм, $\gamma = 2000$kg/m^3	0,2	1,3	0,26
Waterproofing (4 layers of bituminous felt)	0,16	1,3	0,21
Insulation: rigid mineral wool boards ($t = 100$мм, $\rho = 200$kg/m^3)	0,2	1,3	0,26
Vapour barrier (one layer of parchment)	0,05	1,3	0,06
Steel profiled flooring	0,08	1,05	0,08
Through purlins	0,09	1,05	0,1
Through crossbars (trusses)	0,30	1,05	0,31
Knitting on the surface	0,05	1,05	0,05
Total	$g_n = 1{,}13$	–	$g = 1{,}33$

3 taking into account the reliability coefficient for its intended purpose $\gamma_n =$ 0,95	$g_n = 1{,}07$	–	$g_{m,\text{пок}} = 1{,}26$

The linear load on the crossbar of the frame along the axis 3 is determined by the formula: $g_{m,n} = (\frac{g_{m,no\text{к}}}{cos\,\alpha} + g_{m,\text{р}} + g_{m,\text{в}} + g_{m,\text{п.л.}} + g_{m,\text{к.л.}}) \cdot B \cdot \gamma_n$, where $\cos\alpha = 1$

$$g_{m,\text{р}} = 0{,}25kN/m^2; g_{m,\text{в}} = 0{,}05kN/m^2; g_{m,\text{к.л.}} = 0{,}1kN/m^2; g_{m,\text{л.п.}} = 0{,}412kN/m^2.$$

$$g_{m,n} = (\frac{1{,}26}{1} + 0{,}25 + 0{,}05 + 0{,}1 + 0{,}412) \cdot 12 \cdot 0{,}95 = 23{,}62(kN/m)$$

The pressure on the column from the constant load on the crossbars is determined by the formula:

$$F_{\text{ф.п.}} = g_{m,n} \cdot l/2 = 23{,}62 \cdot \frac{24}{2} = 283{,}44kN$$

Concentrated moment applied to the top of the column from the constant load on the crossbars:

$M_{\text{ф.п.}} = F_{\text{ф.п.}} \cdot e_{\text{ф}}$, where $e_{\text{ф}}$- load eccentricity (distance from the center of the truss support unit to the geometric axis of the upper part of the column).

$$e_{\text{ф}} = 250 + 10 = 260mm = 0{,}26m$$

$$M_{\text{ф.п}} = 283{,}44 \cdot 0{,}26 = 73{,}69kN \cdot m$$

Load from the step column's own weight:

$F_k = g_k \cdot \frac{H_{\text{кол}}}{20} \cdot \text{B} \cdot \frac{l}{2} \cdot \gamma_{fm} \cdot \gamma_n$, where g_k- characteristic value of a uniformly distributed load from the column's own weight.

$$g_k = 0{,}5kN/m^2$$

$$H_{кол} = l_1 + l_2 = 11150 + 6250 = 17400\,mm,\gamma_{fm} = 1{,}05;\ \gamma_n = 0{,}95$$

$$F_k = 0{,}5 \cdot \frac{17{,}4}{20} \cdot 12 \cdot \frac{24}{2} \cdot 1{,}05 \cdot 0{,}95 = 62{,}48kN$$

Load from the mass of the lower and upper parts of the column respectively:

$$F_{k1} = 0{,}8F_k = 0{,}8 \cdot 62{,}48 = 49{,}98kN$$

$$F_{k2} = 0{,}2F_k = 0{,}2 \cdot 62{,}48 = 12{,}5kN$$

Load from the mass of walls and window frames with glazing in the lower and upper parts respectively:

$$F_{cm1} = \left[g_{cm}\left(H_H - H_{pB1}\right)\gamma_{fm,cm} + g_{pB1}H_{pB1}\gamma_{fm,pB}\right] \cdot B \cdot \gamma_n$$

$$F_{cm2} = \left[g_{cm}\left(H_B - H_{pB2}\right)\gamma_{fm,cm} + g_{pB2}H_{pB2}\gamma_{fm,pB}\right] \cdot B \cdot \gamma_n$$

From the cross-section we determine:

$$H_{pB1} = 6m;\ H_{pB2} = 2{,}4m$$

$$H_H = 10800mm = 10{,}8m$$

$$H_B = 8700mm = 8{,}7m$$

$g_{cm}, g_{pв}$ - characteristic value from the surface mass of walls and window frames with glazing, respectively (respectively $2kN/m^2$ та $0{,}35kN/m^2$).

$\gamma_{fm,cm}, \gamma_{fm,pв}$ - reliability coefficient based on the maximum value of the load from the mass of the wall and the mass of window frames with glazing (1.2 and 1.1, respectively).

We have:

$$F_{cm1} = [2(10,8 - 6)1,2 + 0,35 \cdot 6 \cdot 1,1] \cdot 12 \cdot 0,95 = 135,77kN$$

$$F_{cm2} = [2(8,7 - 2,4)1,2 + 0,35 \cdot 2,4 \cdot 1,1] \cdot 12 \cdot 0,95 = 182,9kN$$

4.1.1.2 Snow load

In static calculation according to design schemes with a conditional solid crossbar, the load from snow, as well as from its own weight, is taken evenly distributed along the length of the span and determined by the formula:

$$S_{m,s} = \gamma_{fm} S_0 C$$

where γ_{fm} – reliability coefficient based on the snow load limit value. We accept $\gamma_{fm} = 1.14$;

S0 – the characteristic value of the snow load (in Pa), determined according to ДБН В.1.2-2:2006; S0 = 1.6 kPa.

C – coefficient determined by the formula:

$$C = \mu \cdot C_e \cdot C_{alt} = 1 \cdot 0,8 \cdot 1 = 0,8$$

where μ – coefficient of transition from the weight of snow cover on the ground surface to the snow load on the roof, which is equal to $\mu = 1$ at $\alpha \le 25^0$ $\mu = 0$ at $\alpha > 60^0$;

C_e – coefficient that takes into account the operating mode of the roof. C_e =0,8 [4];

C_{alt} – coefficient of geographical altitude determined by the formulas

C_{alt} = 1,4H + 0,3 (at H$\geq$0,5 *km*); C_{alt} = 1 (at H<0,5 *km*).

The design load per 1m^2 of the horizontal projection of the coating is determined by the formula:

$$S_{m,s} = 1{,}14 \cdot 1{,}6 \cdot 0{,}8 = 1{,}19 kN/m^2,$$

Calculated evenly distributed load on the crossbar, taking into account γ_n=0.95

$$q_s = S_m \cdot B \cdot \gamma_n = 1{,}19 \cdot 12 \cdot 0{,}95 kN$$

Pressure on the column from snow load:

$$F_{\text{ф},s} = q_{m,s} \cdot \frac{l}{2} = 13{,}57 \cdot 12 = 162{,}84 kN.$$

Concentrated moment due to the displacement of the upper and lower axes:

$$M_{\text{ф},s} = F_{\text{ф},s} \cdot e_{\text{ф}} = 162{,}84 \cdot 0{,}26 = 43{,}394 kN \cdot m$$

4.1.1.3 Wind load

The wind load increases with increasing height, but to simplify the calculation, it is replaced with an equivalent (in terms of torque in the support section of the frame riser) evenly distributed, applied to the frame riser. The maximum design uniformly distributed load from the active pressure and suction in this work is determined accordingly by the formulas (in the absence of a longitudinal half-timbered structure):

$$q_w = \gamma_n \cdot W_m \cdot B$$

$$q'_w = q_w \cdot C'_{aer}/C_{aer}$$

Maximum design value of wind load W_m we determine by the formula:

$$W_m = \gamma_{fm} \cdot W_0 \cdot c$$

where γ_{fm} – reliability coefficient based on the maximum design value of wind load (for 100 years - 1,14);

W_0 – characteristic value of wind pressure (for Kyiv -450 Pa=0,45 kN);

The coefficient C is determined by the formula

$C = C_{aer} \cdot C_h \cdot C_{alt} \cdot C_{rel} \cdot C_{dir} \cdot C_d$

where C_{aer} – aerodynamic coefficient, variable value;

C_h – building height coefficient, C_h = 1,259;

C_{alt} – geographical elevation coefficient, C_{alt} = 1;

C_{rel} – terrain coefficient; C_{rel} = 1;

C_{dir} – direction coefficient; C_{dir} = 1;

C_d – dynamism coefficient. C_d = 0,9;

Aerodynamic coefficients are accepted $C_{aer} = 0{,}6$ for passive loading; $C_{aer} = 0{,}8$ for active load [4].

$C = 0{,}8 \cdot 1{,}259 \cdot 0{,}9 = 0{,}906$

$W_m = 1{,}14 \cdot 0{,}45 \cdot 0{,}906 = 0{,}444 kN/m^2$

We find the value of the maximum calculated uniformly distributed load:

$q_w = 0{,}95 \cdot 0{,}444 \cdot 12 = 5{,}06 kN/m$

For suction:

$$q'_w = 5{,}06 \cdot \frac{0{,}6}{0{,}8} = 3{,}795 kN/m$$

The wind load acting at a height from the bottom of the truss to the highest point of the lamp is applied to the transverse frame at the level of the crossbar of the frame in the form of a force from the active pressure and a force from the suction. The force from the active pressure is calculated by the formula:

$F_w = \frac{(k'_{2-3} - k''_{2-3})}{2} H_{Ш} \cdot \gamma_{fm} \cdot W_0 \cdot C_{aer} \cdot C_d \cdot B \cdot \gamma_n$, where

$k'_{2-3}; k''_{2-3}$- ordinates of the coefficient plot C_h, which are determined according to the drawing depending on the ordinate $k_1; k_2$, which correspond to the height above the Earth's surface of 10, 20 M and are equal to 1.2 and 1.55 for Type II terrain [4].

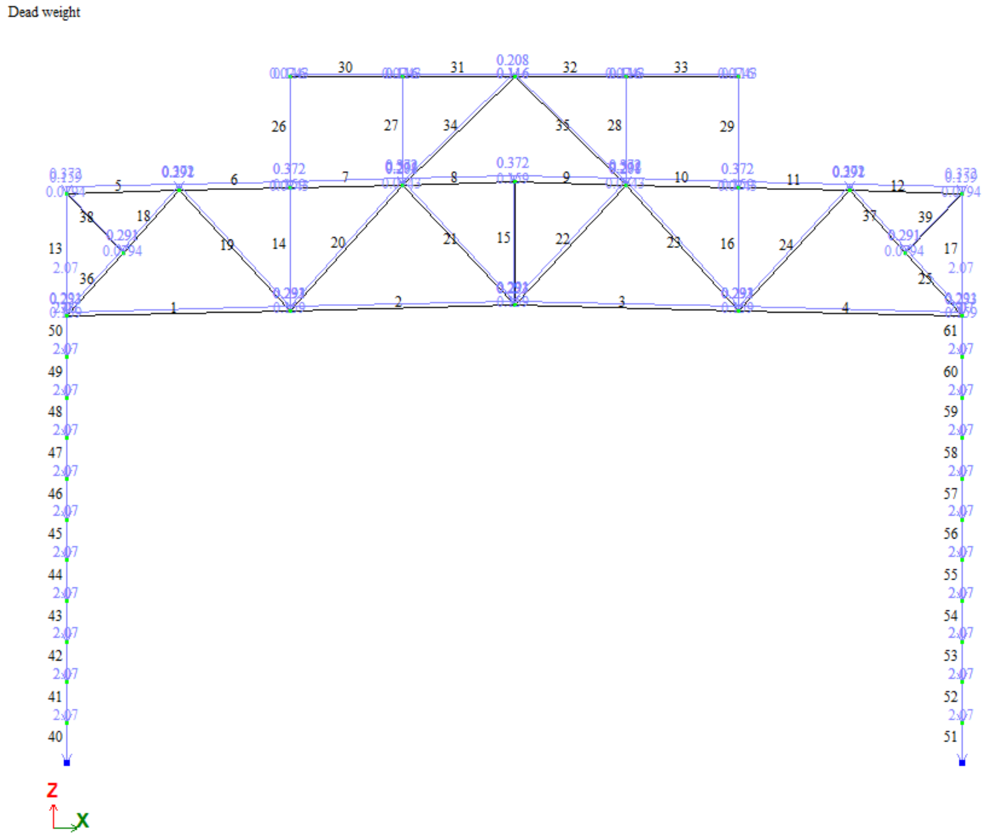


Fig. 4.1 Dead weight

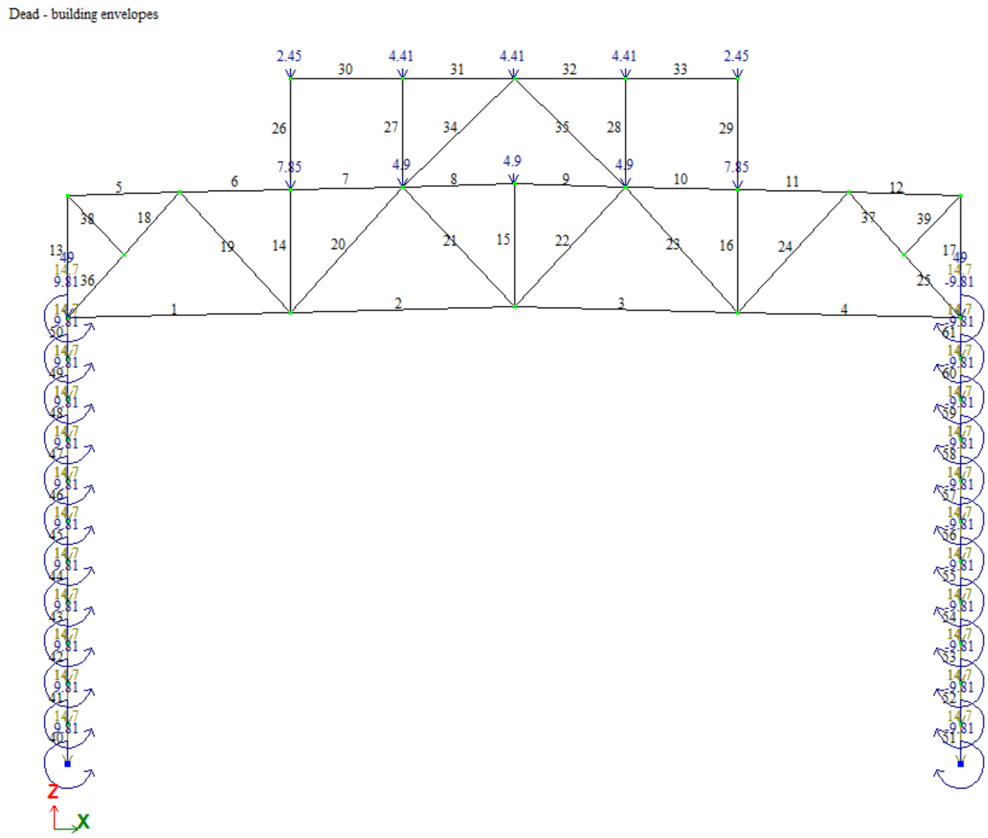


Fig. 4.2 Enclosing structures

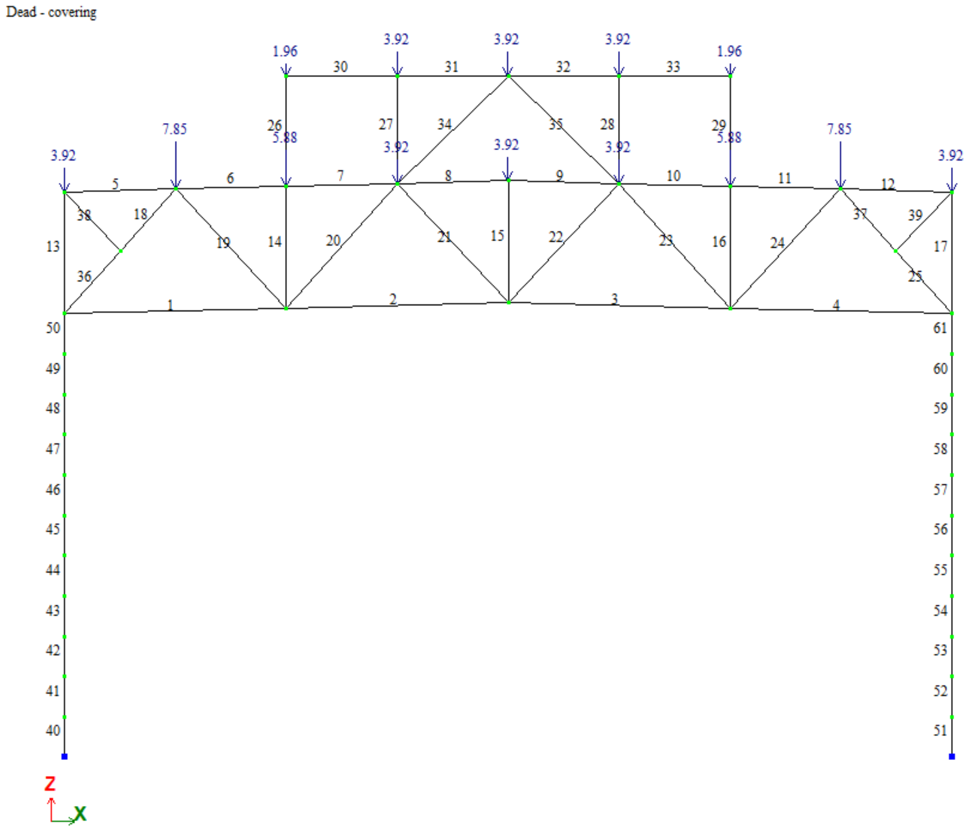


Fig. 4.3 Roof

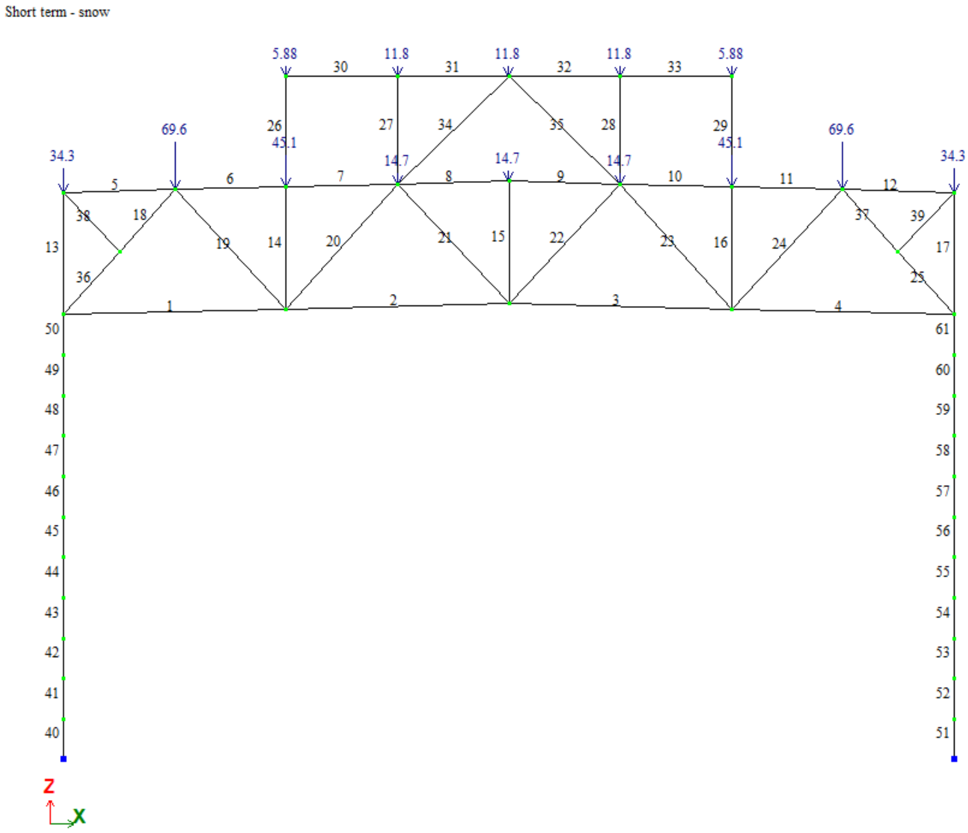


Fig. 4.4 Snow

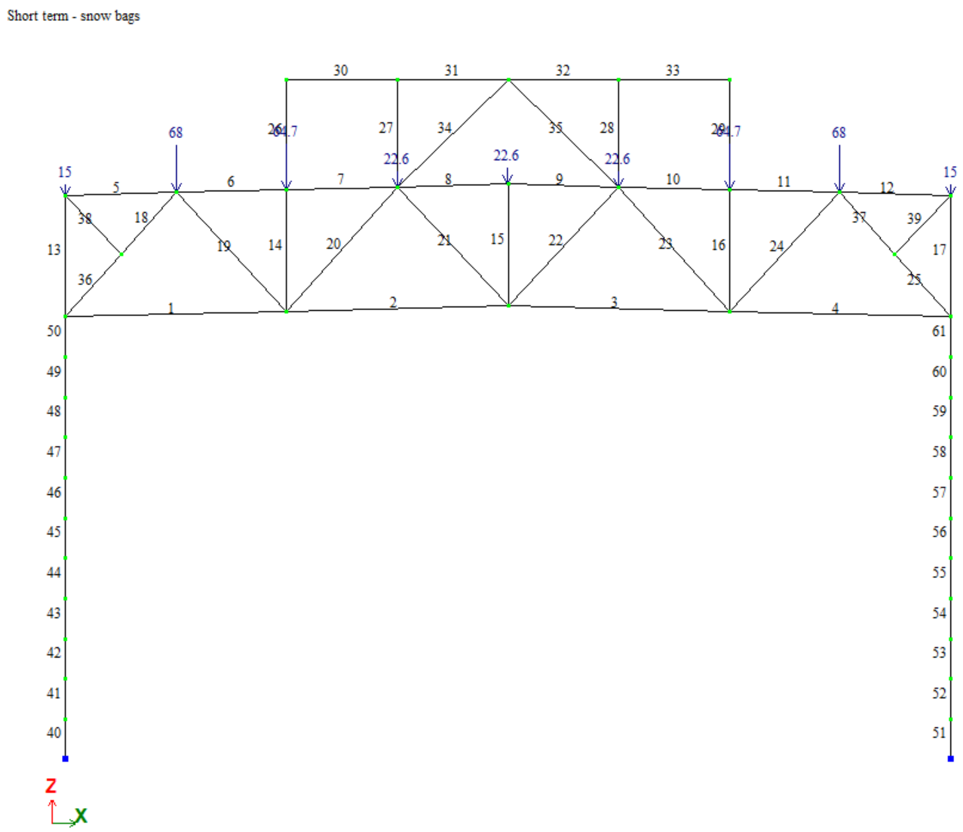


Fig. 4.5 Snow bags

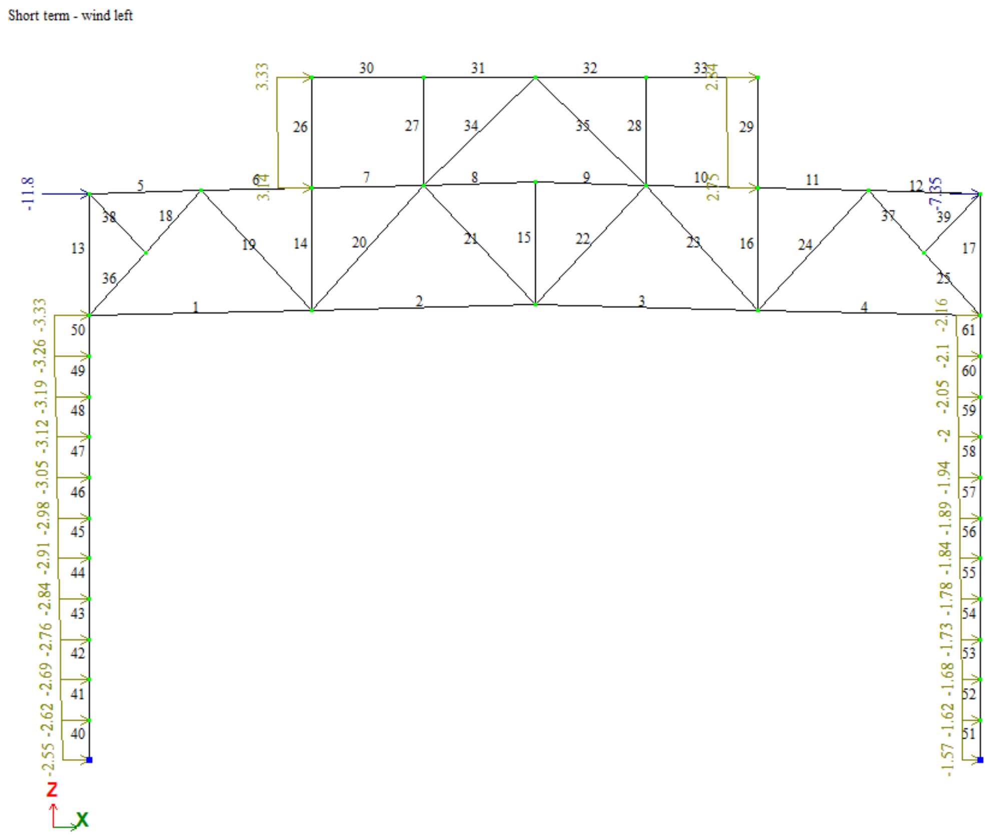


Fig. 4.6 Wind (left)

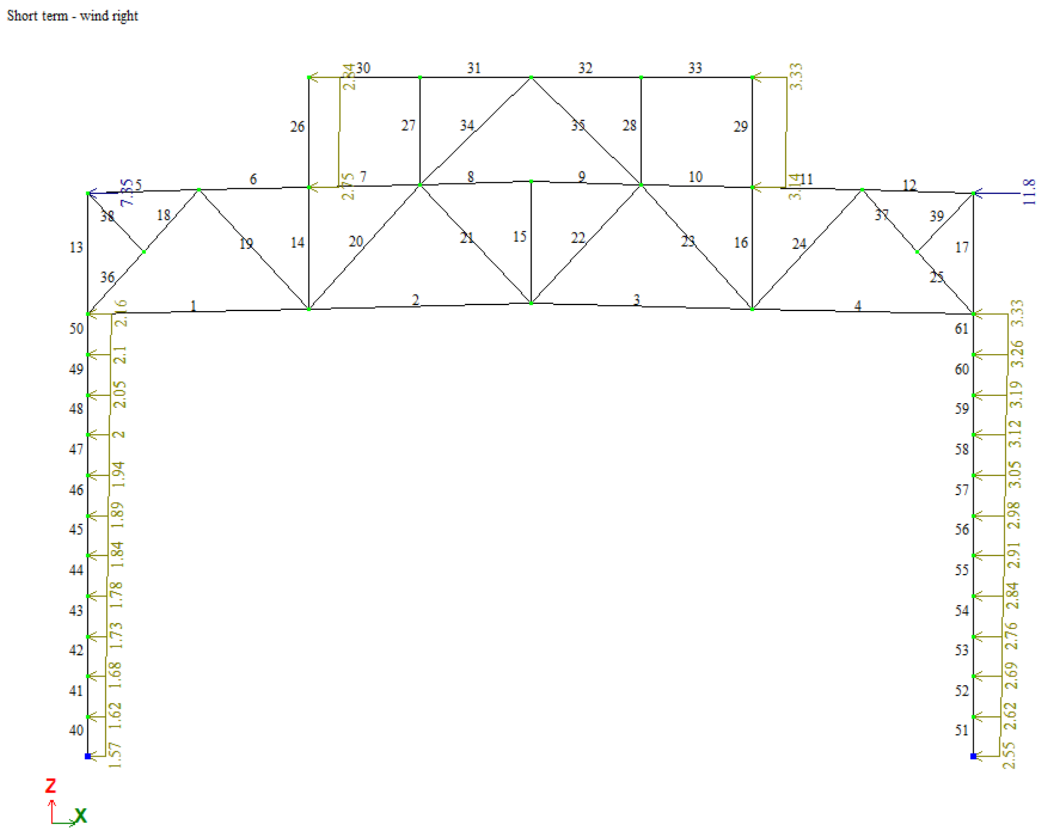


Fig. 4.7 Wind (right)

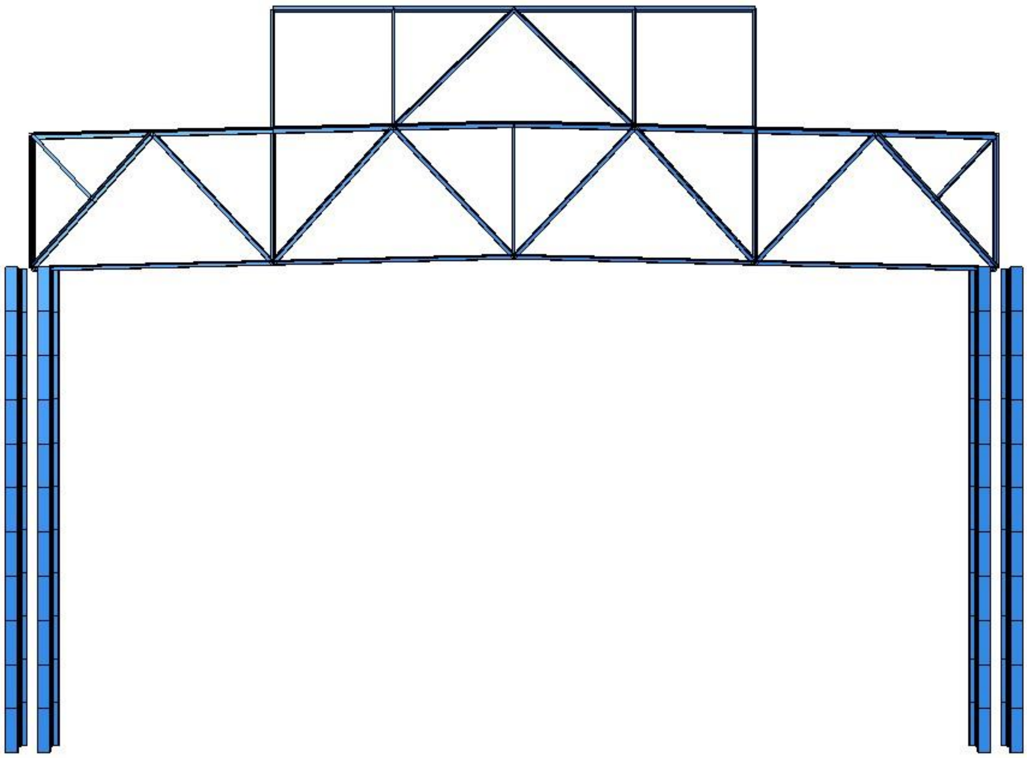


Fig. 4.8 Spatial view

4.1.2 Calculation results

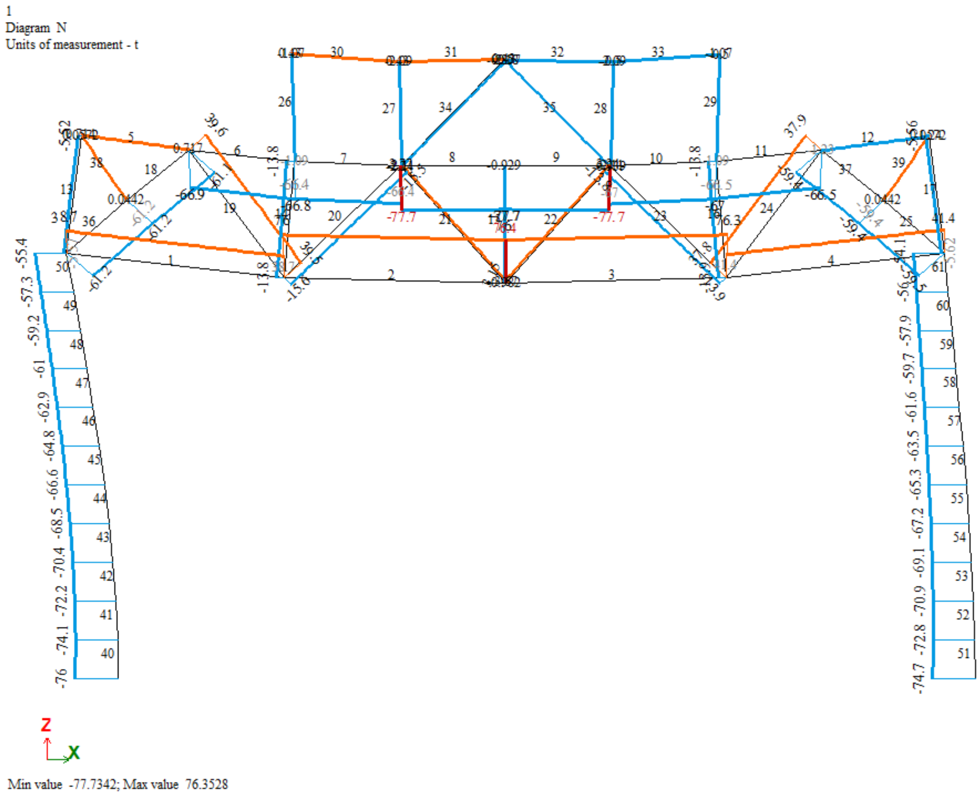


Fig. 4.9 plot N from RSN

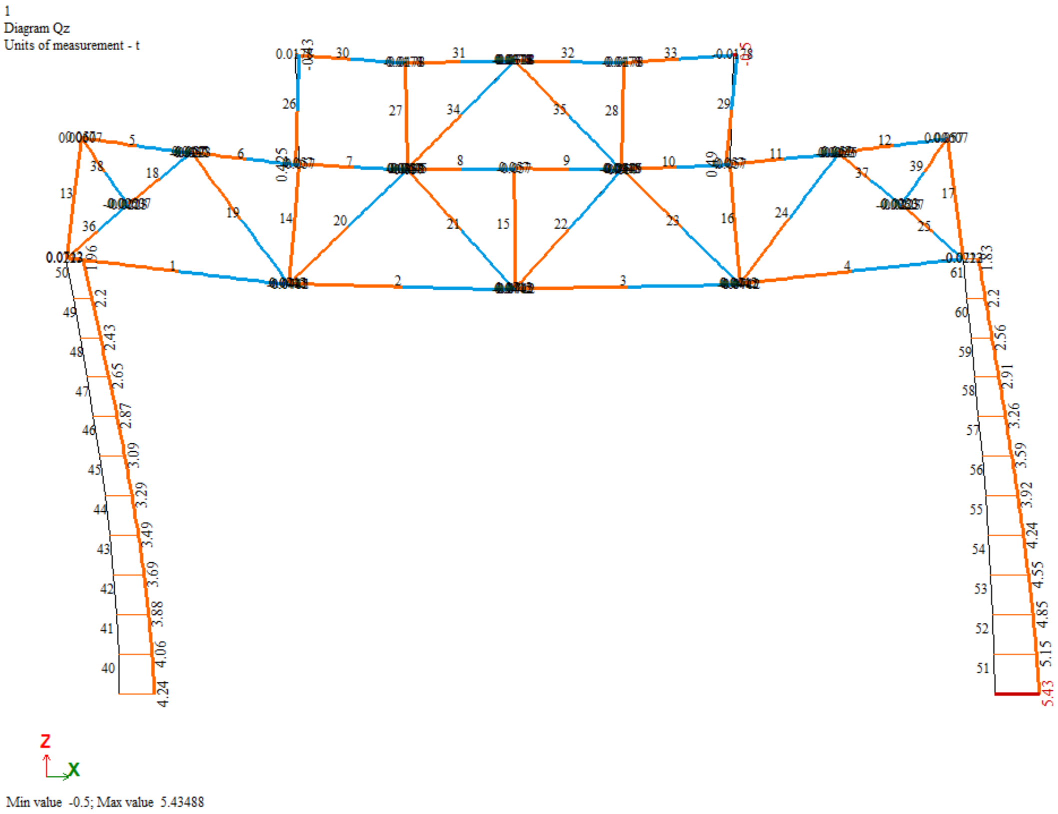


Fig. 4.10 plot Q from RSN

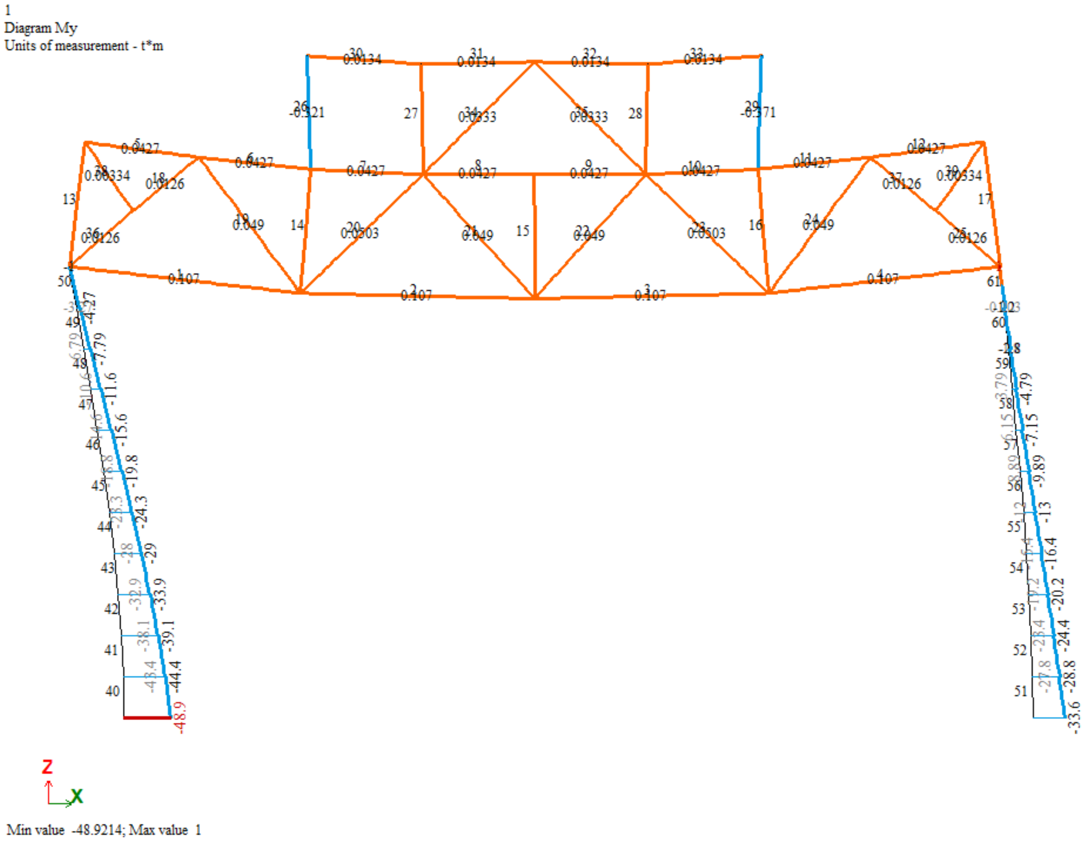


Fig. 4.11 plot M from RSN

4.2 Checking the calculation of truss elements

4.2.1 Calculation results in the Lira-SAPR

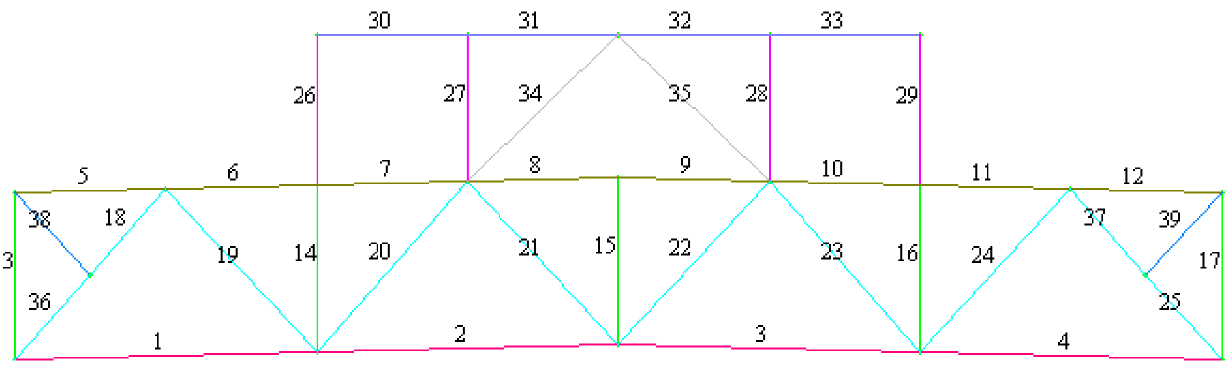


Fig. 4.12 Numbering of farm elements

Table 4.2 calculation results

№ Rods	Rod force	Dimensions of corner joints, mm		Notes	Selected cross-section
		obushka	pera		
1	42,44	250	110	**Lower belt (Н. П.)**	**2∟100x10**
2	**82,12**				
5	0,71	250	110	**Upper belt (В. П.)**	**2∟140x9**
6	-73,52				
7	-73,59				
8	**-85,63**				
13	-6,14	50	30	**Racks (C)**	**2∟90x6**
14	**-15,24**				
15	-1,23				
38	0,063	110	60	**Crossbar (P3)**	**2∟100x10**
18	**-66,26**				
19	42,57				
20	-16,17				
21	3,8				

4.2.2 Selection of the cross-section of truss bars.

The cross section of the lower belt is selected according to the maximum force

$N_2 = 821{,}2kN$

$A_{тр} = \frac{N}{R_y \cdot \gamma_c} = \frac{821{,}1}{24{,}5 \cdot 0{,}95} = 35{,}28cm^2$,

We accept 2∟100x10, $A_1 = 19{,}24cm^2$,

$A = 19{,}24 \cdot 2 = 38{,}48cm^2$

$I_{x1} = I_{y1} = 178{,}95cm^4$, z0=2,83cm,

$I_y = 2I_{y1} + 2 \cdot A \cdot z_0^2 = 2 \cdot 178{,}95 + 2 \cdot 19{,}24 \cdot 2{,}83^2 = 666{,}08cm$

$I_x = 2I_{x1} = 2 \cdot 178{,}95 = 357{,}9cm$

$$i_y = \sqrt{\frac{I_y}{A_n}} == \sqrt{\frac{666{,}08}{38{,}48}} = 4{,}16cm$$

$$i_x = \sqrt{\frac{I_x}{A_n}} == \sqrt{\frac{357{,}9}{38{,}48}} = 3{,}05cm$$

Checking the cross-section:

$$\lambda_x = \frac{L_x}{i_x} = \frac{600}{3.05} = 196.7 < 400$$

$$\lambda_y = \frac{L_y}{i_y} = \frac{600}{4.16} = 144.2 < 400$$

$\sigma_{max} = \frac{N_{max}}{A_n} < R_y \cdot \gamma_c;$

$$\sigma_{max} = \frac{830,11}{38,48} = 21,57 < 24 \cdot 0,95 = 22,8MPa.$$

Steel C245 with the value of the calculated resistance Ry= 245MPa. It can be concluded from the results obtained that the radius of inertia relative to the X-axis will not change for paired identical corners, and will be minimal. So in further calculations we will use the range data for i_x [14].

The cross section of the upper belt is selected according to the maximum force

$$N_8 = -856,3kN.$$

$$A_{\text{тр}} = \frac{N}{\phi \cdot R_y \cdot \gamma_c} = \frac{856,3}{0,582 \cdot 24,5 \cdot 0,95} = 63,21cm^2,$$

where $\lambda = 100 \to \phi = 0,582$.

We accept 2∟140x12, $A_1 = 32,49cm^2$,

$$A = 32,49 \cdot 2 = 64,98cm^2\ ,\ i_x = 4,31cm$$

Checking the cross-section:

$$\lambda_x = \frac{L_x}{i_x} = \frac{300}{4,31} = 69,6 < 100 \to \phi_x = 0,8025$$

$$\sigma_{max} = \frac{N_{max}}{\varphi_x A_n} < R_y \cdot \gamma_c;$$

$$\sigma_{max} = \frac{-856,3}{0,8025 \cdot 69,6} = 15,33 < 24 \cdot 0,95 = 22,8MPa.$$

The cross section of the rack is selected according to the maximum force [15].

$$\boldsymbol{N_{28} = -152,4kN.}$$

$A_{\text{тр}} = \frac{\boldsymbol{N}}{\boldsymbol{\phi \cdot R_y \cdot \gamma_c}} = \frac{\mathbf{152{,}4}}{\mathbf{0{,}276 \cdot 24{,}5 \cdot 0{,}95}} = \mathbf{23,72}\boldsymbol{cm^2}$**,**

where $\lambda = 150 \rightarrow \phi = 0{,}276$.

We accept 2∟90x7, $A_1 = 12.3cm^2$,

$A = 12{,}3 \cdot 2 = 24{,}6cm^2$, $i_x = 2{,}77cm$

Checking the cross-section:

$L_x = 0{,}8 \cdot 225 = 180 \quad \lambda_x = \frac{L_x}{i_x} = \frac{180}{2{,}77} = 64.98 < 150 \rightarrow \phi_x = 0{,}6438$

$\sigma_{max} = \frac{N_{max}}{\varphi_x A_n} < R_y \cdot \gamma_c;$

$\sigma_{max} = \frac{152{,}4}{0{,}6438 \cdot 24{,}6} = 9{,}62 < 24 \cdot 0{,}95 = 22{,}8MPa.$

The cross section of the braces is selected by force

$N = -662{,}6kN:$

$A_{\text{тр}} = \frac{N}{R_y \cdot \gamma_c} = \frac{662{,}6}{24{,}5 \cdot 0{,}95} = 28.46cm^2,$

We accept 2∟100x8, $A_1 = 15{,}5cm^2$**,**

$A = 1955 \cdot 2 = 31cm^2 , \quad i_x = 3{,}07cm$

Checking the cross-section:

$L_x = 0{,}8 \cdot 370 = 296$

$$\lambda_x = \frac{L_x}{i_x} = \frac{296}{3.07} = 96.4 < 120 \rightarrow \phi_x = 0{,}419$$

$\sigma_{max} = \frac{N_{max}}{\varphi_x A_n} < R_y \cdot \gamma_c;$

$$\sigma_{max} = \frac{662,6}{0,419 \cdot 31} = 14,45 < 24 \cdot 0,95 = 22,8MPa$$

4.3 Calculation of a metal exhaust tower

4.3.1 Output data:

Brief description of chimney designs

The height of the chimney with a diameter of d=1020 mm is H=100 meters.

In order to ensure the overall stability and strength of the pipe trunk structures, they are equipped with a load-bearing steel frame from 0.000 to 95,000 meters.

The frame of the structure is a four-sided prism with a height of 95.0 meters with two fractures earlier in height.

The spatial load-bearing frame is equipped with stiffening diaphragms, which are used as. To climb to the level of viewing platforms, the project provides vertical stairs with height fences.

Grid elements are located in the plane of the faces of the spatial frame:

- belt - from the channels of the corners;
- spacers-from single corners;
- braces-from single corners.

4.3.2 Calculation of chimney frame structures

Mass collection for calculations of the ripple component of the wind load was carried out during the design with the following load reliability coefficients:

- dead weight of structures ……………………………….1,1;
- mass of technological equipment ………………………1,1.

2 wind district – 450 Pa [4].

In static calculations of the chimney frame, the connections of elements in the nodes were assumed to be rigid.

Calculations of the frame were made for the first (in terms of strength) and second (in terms of deformations) limit states.

According to the first limit state, calculations were made for design loads, and according to the second state, for standard loads.

When calculating metal structures, the following combinations of loads were taken into account:

- calculated weight (net weight) of metal structures and technological equipment, as well as calculated wind impact taking into account the ripple component;
- estimated mass (net weight) of metal structures and technological equipment, estimated mass of ice deposits, as well as 25 percent of the calculated wind impact without taking into account the pulsation component;
- standard weight (net weight) of metal structures and technological equipment, as well as standard wind impact, taking into account the pulsation component.

Wind directions for support calculations were taken:

- on the facade;
- in the plane of one of the side faces of the structure.

Structural calculations are performed according to the Certified program for calculating building structures of the Lira-SAPR [16].

The design loads on the tower structures were determined according to the calculation and design standards. at the same time, the calculation was made for its own weight, wind, snow, and a combination of these loads.

Loads on the design scheme are set as separate loads and include:

- constant loads: net weight of structures and payload (Fig. 5.14);
- temporary load: wind load (Fig. 5.15);
- snow load (Fig. 5.18).

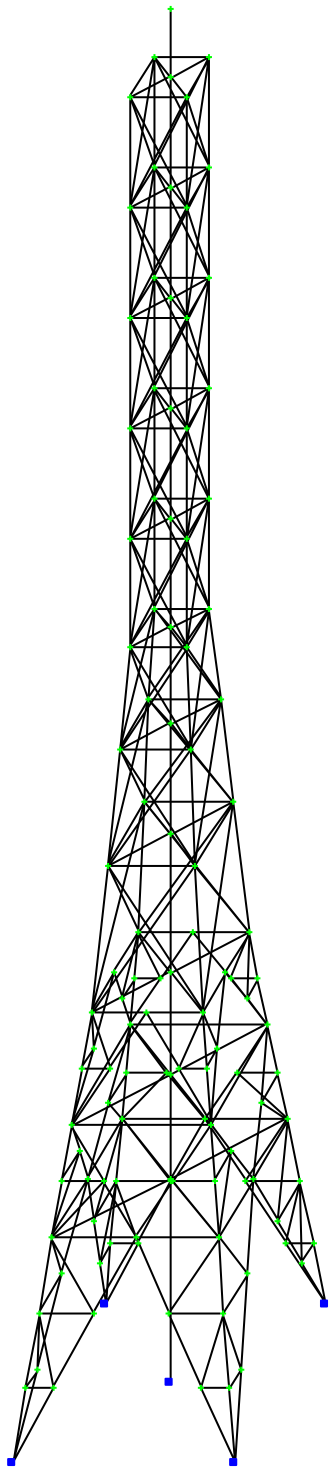


Fig. 4.13 general view of the tower in the Lira-SAPR

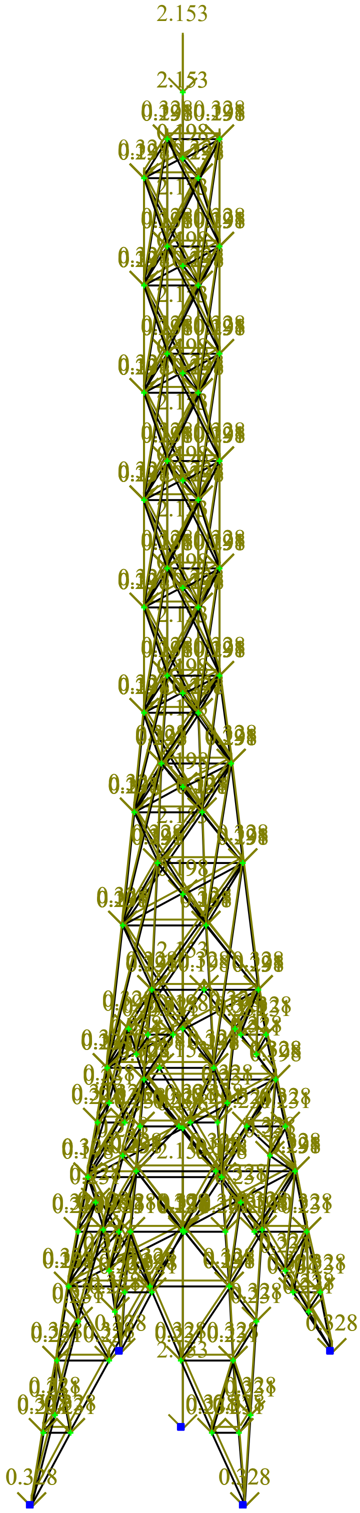


Fig. 4.14 Loading 1. net weight of the tower in the Lira-SAPR

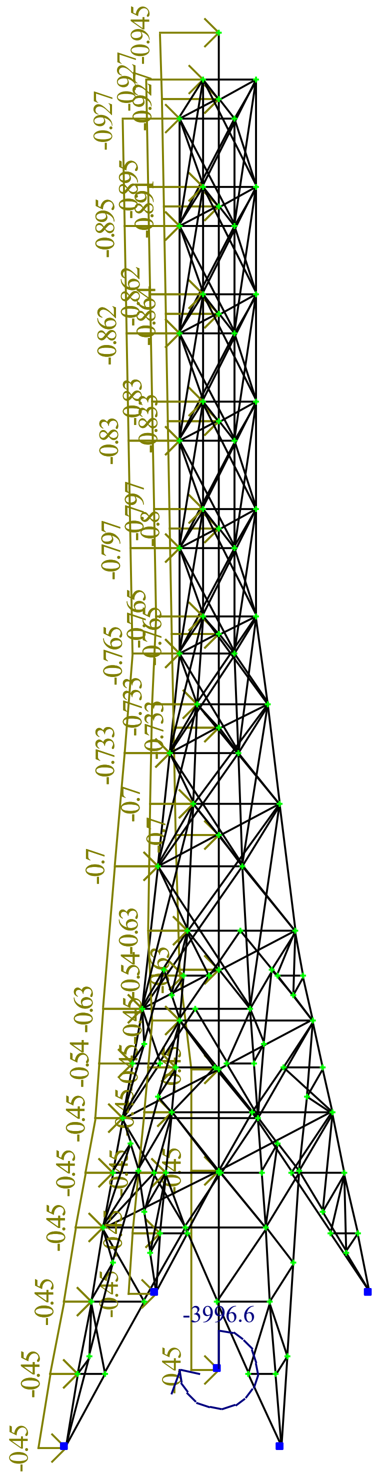


Fig. 4.15 Loading 2. Wind load on the tower in the Lira-SAPR

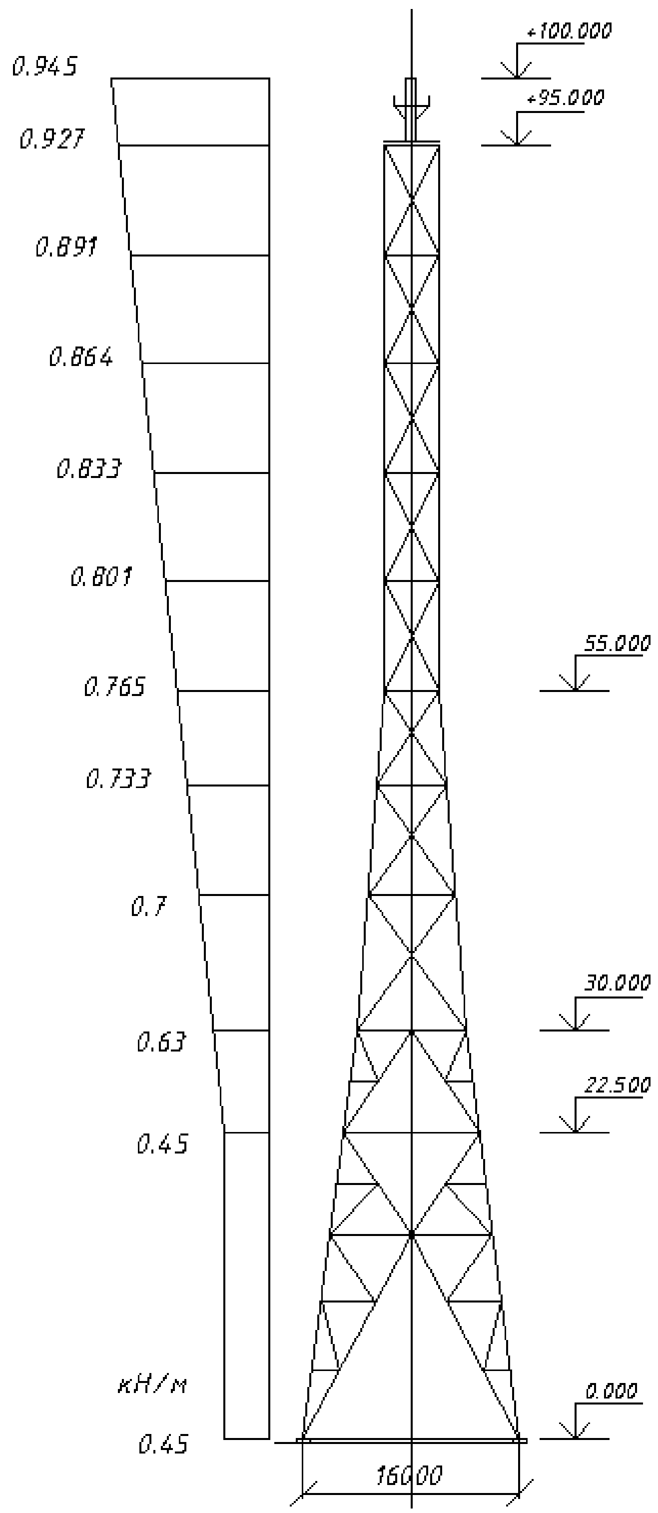


Fig. 4.16 Wind load on the tower

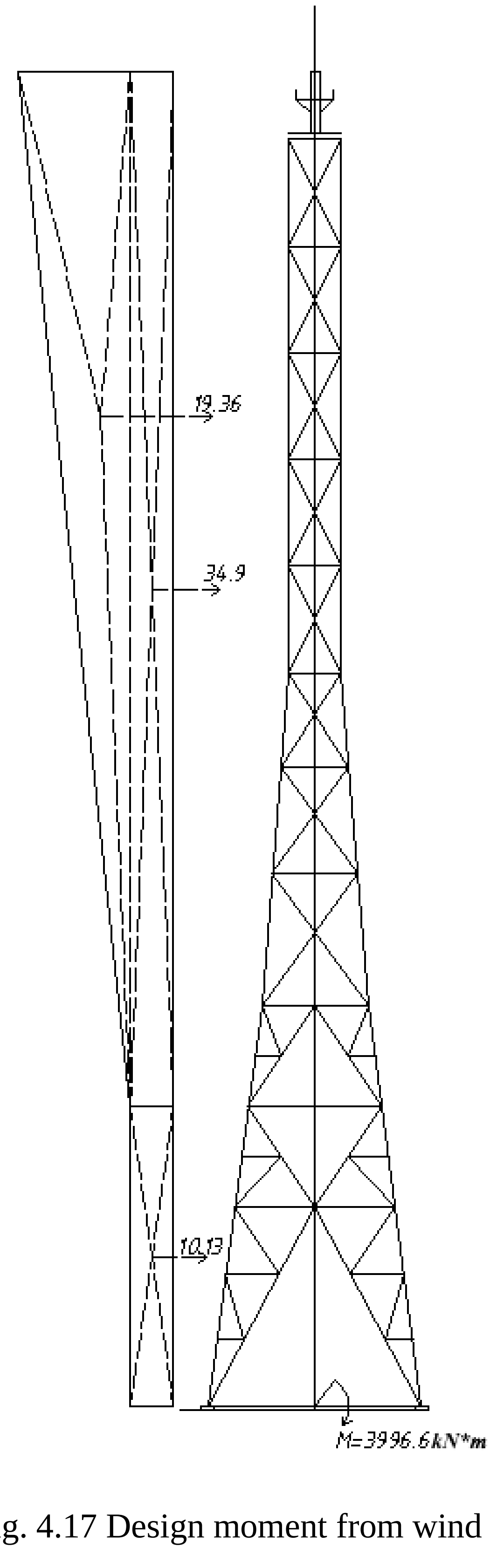


Fig. 4.17 Design moment from wind load

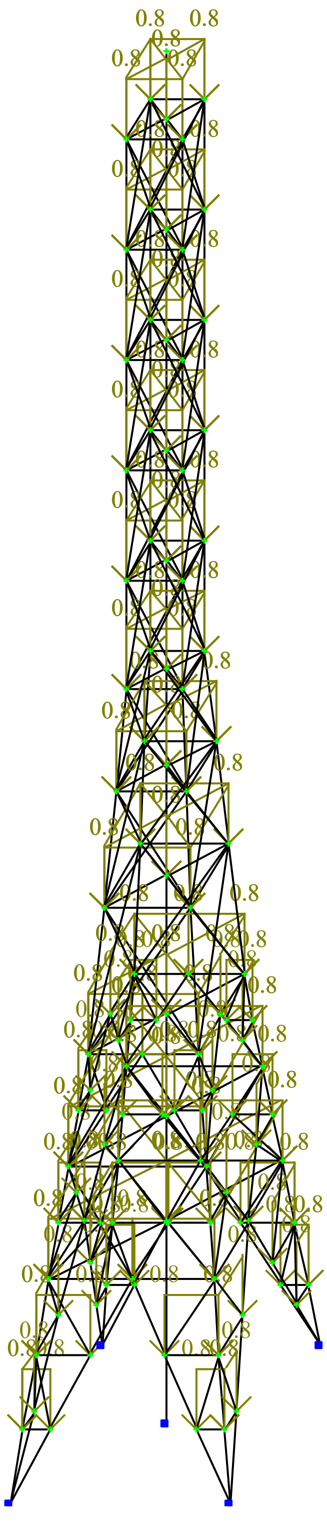


Fig. 4.18 Loading 3. Snow load on the tower in the Lira-SAPR

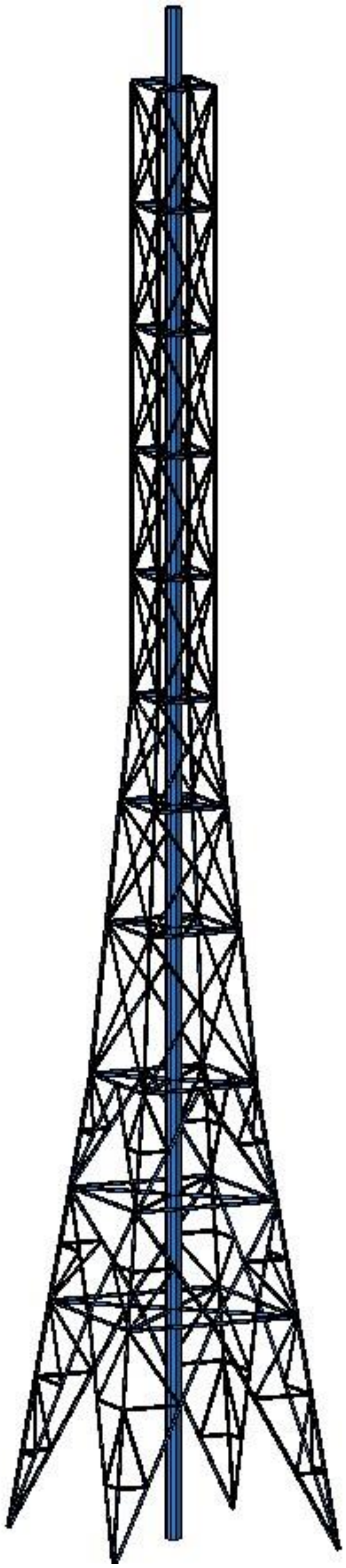


Fig. 4.19 Spatial model of the tower

Calculation results

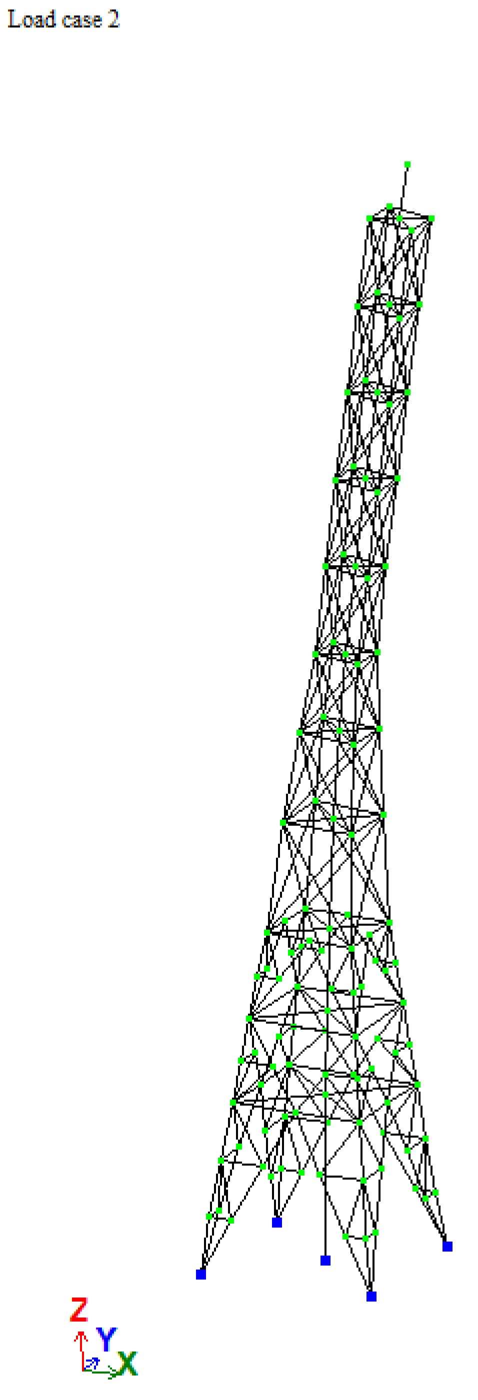


Fig. 4.20 Loss of stability

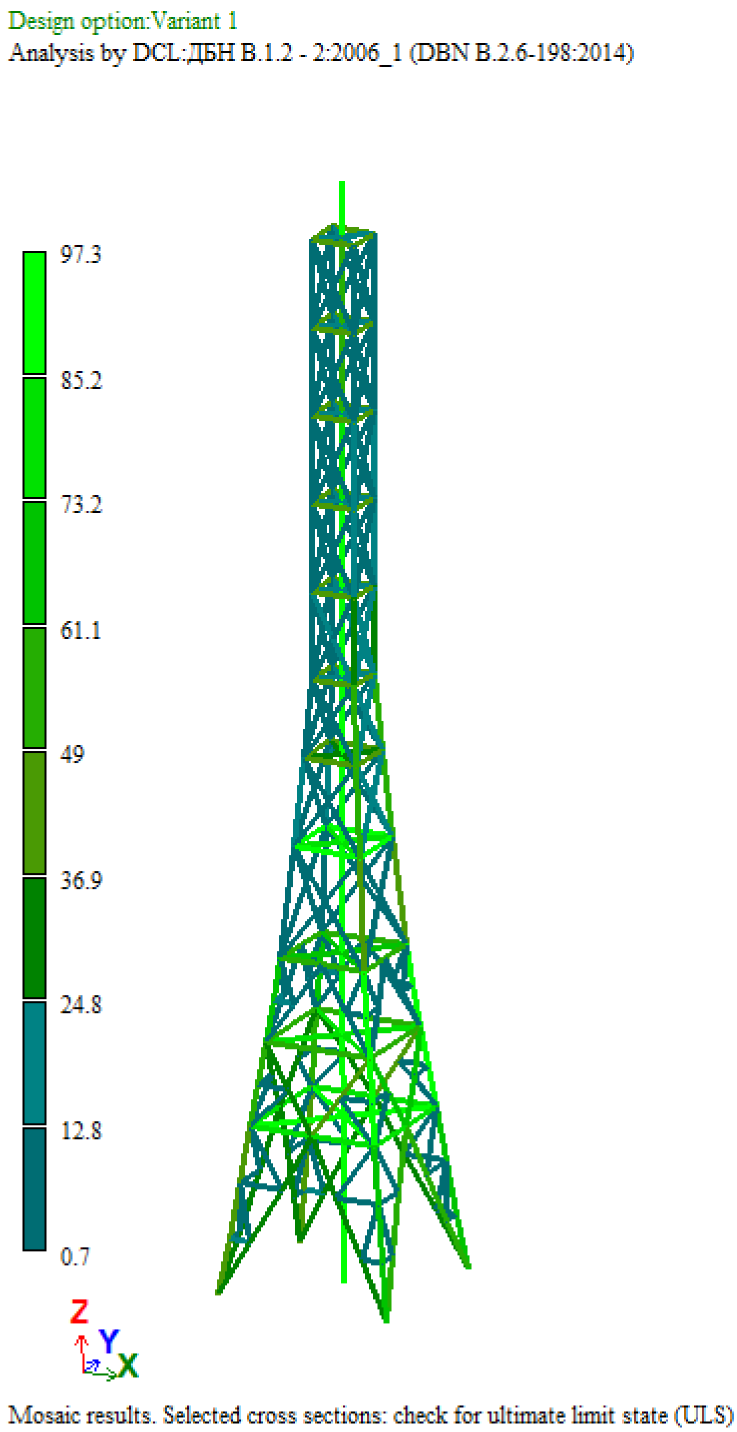


Fig. 4.21 1st limit state. RSN calculation

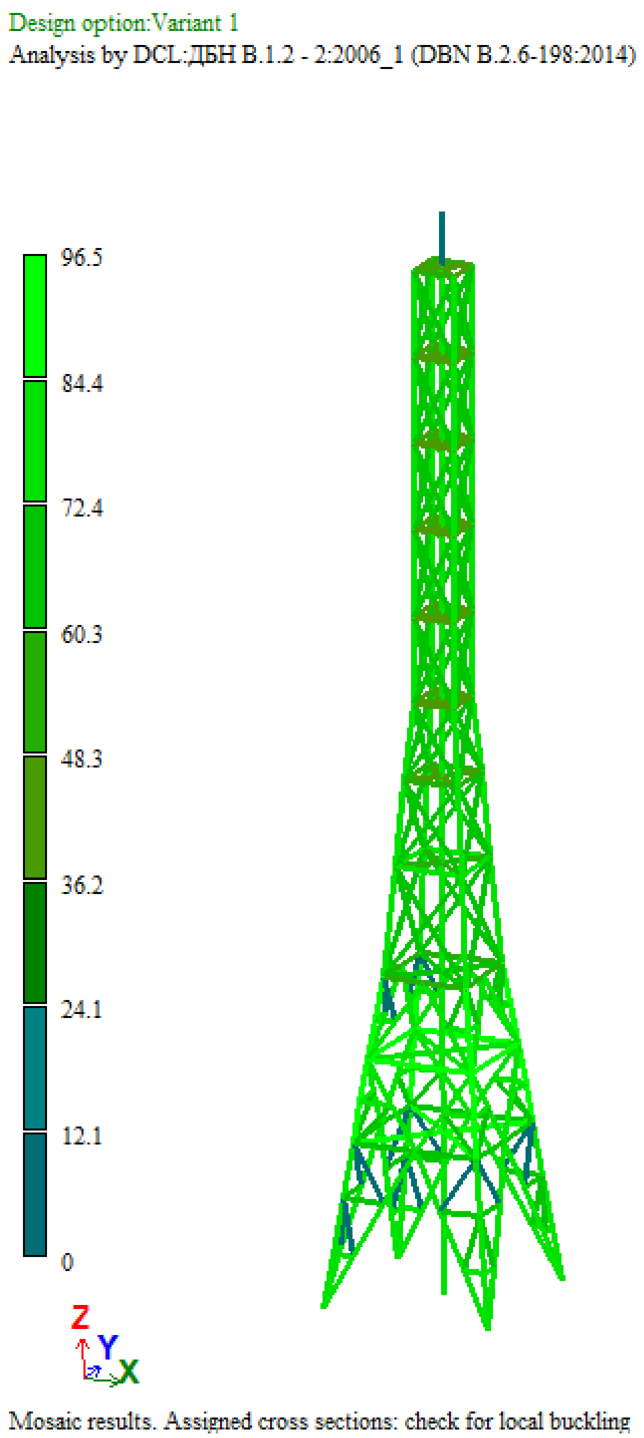


Fig. 4.22 local sustainability. RSN calculation

Selection of tower elements

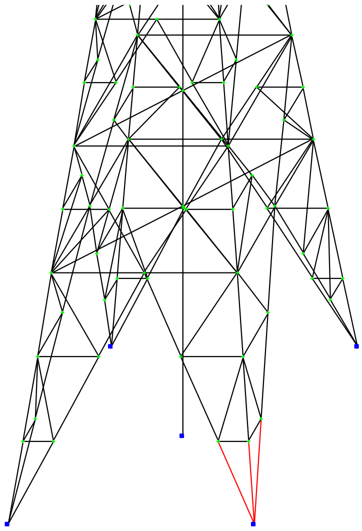


Fig. 4.23 Selection of tower racks

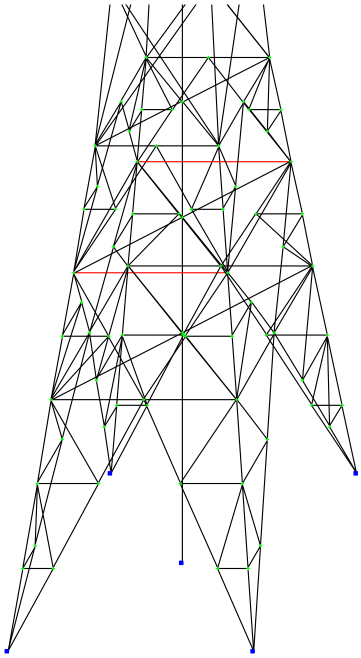


Fig. 4.23 Selection of tower crossbars

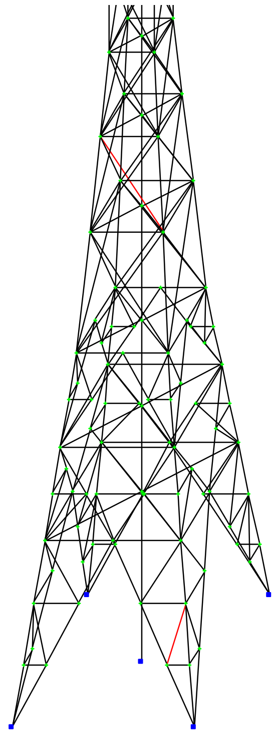


Fig. 4.23 Selection of tower braces

The results are shown in the tables 4.3, 4.4, 4.5.

Table 4.3 Selection of tower racks

Trusses

Element	SN	Group	Batten Step, m	Note	Utilization Percentage of Truss Load-Carrying Capacity in Sections, %										Element Length, m
					nml	BY1	BZ1	rY1	rZ1	WB	FB	ULS	SLS	LB	
Section: 2. Angle 180 x 180 x 11															
Shape: 180 x 180 x 11; ГОСТ 8509-86															
Steel: ВСт3кп2-1; ТУ 14-1-3023-80															
File: Angle with parallel flanges															
27			Selected: 2. Angle 200 x 200 x 12												
			Shape: 200 x 200 x 12; ГОСТ 8509-86												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
27	1		0.00		25	69	45	84	60	0	69	69	84	69	5.09
27	2		0.00		25	68	45	84	60	0	69	68	84	69	5.09
74			Selected: 2. Angle 160 x 160 x 12												
			Shape: 160 x 160 x 10; ГОСТ 8509-86												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
74	1		0.00		8	30	18	98	70	0	69	30	98	69	5.71
74	2		0.00		8	30	18	98	70	0	69	30	98	69	5.71
219			Selected: 2. Angle 180 x 180 x 10												
			Shape: 180 x 180 x 10; ГОСТ 8509-86												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
219	1		0.00		13	51	30	99	69	0	54	51	99	54	5.71
219	2		0.00		13	51	30	99	69	0	54	51	99	54	5.71

Table 4.4 selection of tower crossbars

Beams and Girders

Element	SN	Group	Stiffener Step, m	Fib min	Utilization Percentage of Beam Load-Carrying Capacity in Sections, %										Element Length, m
					nml	shr	eql	BB	dfl	WB	FB	ULS	SLS	LB	
Section: 5. Channel 20															
Shape: 20; GOST 8278-83															
Steel: ВСт3кп2-1; ТУ 14-1-3023-80															
File: SHvellery stal`nye gnutye ravnopolochnye (GOST 8278-83)															
41			Section: 5. Channel 16												
			Shape: 16; GOST 8240-72												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
41	1		0.00	0.34	18	2	15	56	0	30	41	56	0	41	10.00
41	2		0.00	0.34	18	2	15	56	0	30	41	56	0	41	10.00
142			Section: 5. Channel 16												
			Shape: 16; GOST 8240-72												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
142	1		0.00	0.34	18	2	15	56	0	30	41	56	0	41	10.00
142	2		0.00	0.34	18	2	15	56	0	30	41	56	0	41	10.00

Table 4.5 Selection of tower braces

Trusses

Element	SN	Group	Batten Step, m	Note	Utilization Percentage of Truss Load-Carrying Capacity in Sections, %										Element Length, m
					nml	BY1	BZ1	rY1	rZ1	WB	FB	ULS	SLS	LB	
Section: 3. Angle 140 x 140 x 10															
Shape: 140 x 140 x 10; ГОСТ 8509-86															
Steel: ВСт3кп2-1; ТУ 14-1-3023-80															
File: Angle with parallel flanges															
77			Selected: 3. Angle 140 x 140 x 9												
			Shape: 140 x 140 x 9; ГОСТ 8509-86												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
77	1		0.00		0	2	1	94	65	0	67	2	94	67	5.22
77	2		0.00		0	2	1	94	65	0	67	2	94	67	5.22
101			Section: 3. Angle 150 x 150 x 10												
			Shape: 150 x 150 x 10; ГОСТ 8509-86												
			Steel: ВСт3кп2-1; ТУ 14-1-3023-80												
101	1		0.00		2	3	2	89	64	0	74	3	89	74	8.94
101	2		0.00		2	4	2	89	64	0	74	4	89	74	8.94

Conclusion

Strength and stability of all construction parts have been provided.

CHAPTER 5

BASE AND FOUNDATIONS

5.1 Calculation of the foundation for the frame column.

Output data:

N=82,85t

M=62,752tm

Q=5,4t

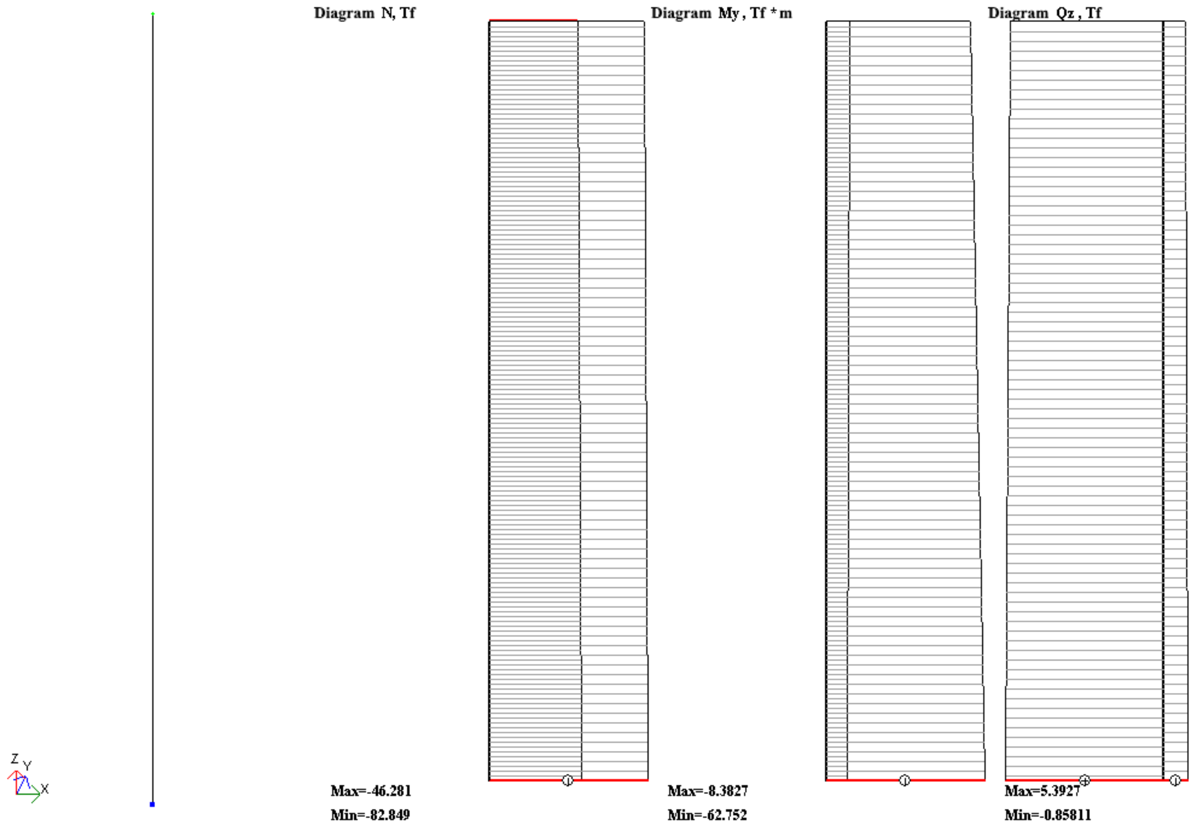


Table 5.1 Initial data of the geological section

Layer number	Layer thickness, m	Name	$\gamma, \frac{kN}{m^3}$	$\gamma_s, \frac{kN}{m^3}$	ω	S_r	E_{II}, MPa	R_0, kPa	ϕ_{II}, degr	c_{II}, kPa
1	0.3	Vegetation layer	14.1	-	-	-	-	-	-	-
2	2.85	Fine sand of medium density	18.2	26.9	0.12	0.49	25	300	31	2
3	3.1	Sand of med. size, med. density (e=0.65)	20	26.6	0.24	0.98	30	400	35	-
4	2.8	Soft-plastic loam (I_L=0.6, e=0.75)	19.4	27	0.26	0.94	12	220	18	25
5	6.0	Refractory clay (I_L=0,5; e =0,26)	19.2	27.3	0.32	0.99	27	250	16	36

Determining the size of the foundation

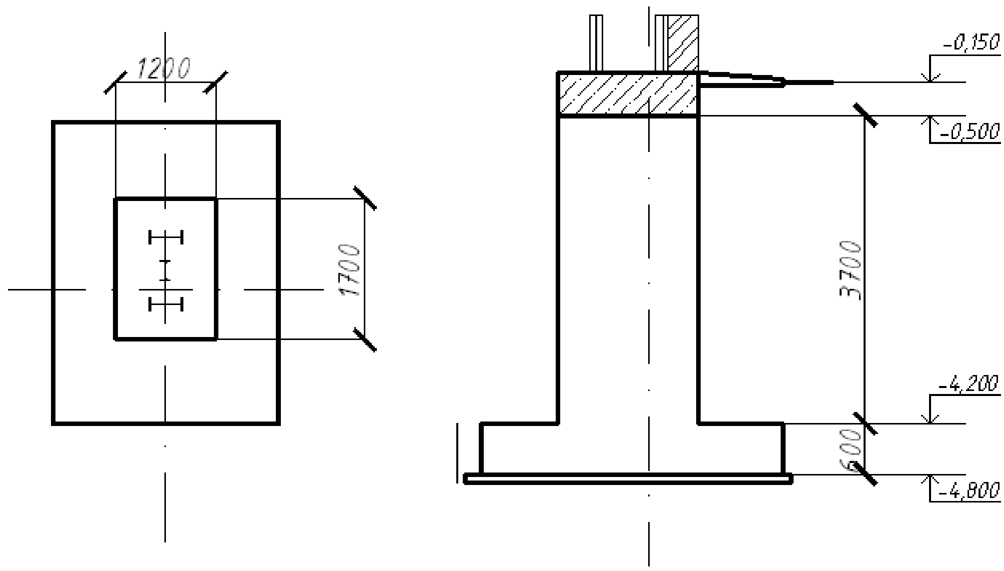


Fig.6.1 initial dimensions of the foundation

5.1.1 Determining the dimensions of the foundation sole:

The area of the foundation sole in the plan is determined by the formula:

$$F = \frac{N}{R^H - y_{cp}H}$$

where $N -$ standard load on the foundation;

$R^H -$ standard pressure under the foundation sole;

$y_{cp} -$ average weight of the foundation and soil on the edge.

$H -$ foundation depth from ground level, m.

$$F = \frac{82.85}{22.0 - 2.66 \cdot 4.3} = 7.5m^2$$

Taking into account the effect of the moment, we increase the area of the foundation by 20% [17].

$$F = 9m^2$$

$$b = \sqrt{F} = \sqrt{9} = 3m$$

Structurally, we accept one side of the foundation plate of 3.6 M. Then

$a = \frac{F}{b} = \frac{9}{3.6} = 2.5m$, structurally, we accept 2.7 m.

5.1.2 Determining the cross-sectional area of the reinforcement:

The cross sectional area of the reinforcement in one direction is determined by the formula for reinforcement A400C $R_0 = 4000kg/cm^2$

$$F_a = \frac{M}{R_0 \cdot 0.9 \cdot h}$$

where $M -$ bending moment;

$h -$ foundation sole height, cm.

$$F_a = \frac{6275200}{4000 \cdot 0.9 \cdot 60} = 29cm^2$$

We accept 14 Ø16 A400C.

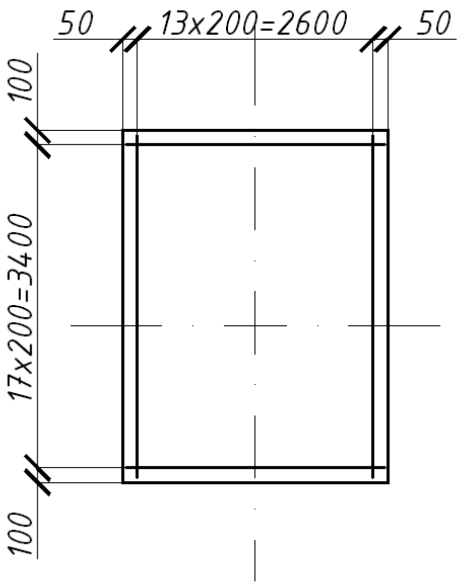


Fig.5.2 Foundation sole reinforcement scheme

5.2 Calculation of the pile foundation for a tower

5.2.1. Output data:

Cross-section column 50x60см;

Load on the upper edge of the foundation:

$$N_{II} = 184{,}5kN; \mathrm{M_{II}} = 14{,}21kN \cdot m; Q = 0{,}05kN$$

Standard soil freezing depth – 160 cm;

Vertical terrain layout – cutting by 0.15 m

Table 5.2 initial data of the geological section

№ of layer	Layer thickness, m	Name	$\gamma, \frac{kN}{m^3}$	$\gamma_s, \frac{kN}{m^3}$	ω	S_r	E_{II}, MPa	R_0, kPa	ϕ_{II}, $degr$	c_{II}, kPa
1	0.3	Vegetation layer	14.1	-	-	-	-	-	-	-
2	2.85	Fine sand of medium density	18.2	26.9	0.12	0.49	25	300	31	2
3	3.1	Sand of med. size, med. density (e=0.65)	20	26.6	0.24	0.98	30	400	35	-
4	2.8	Soft-plastic loam (I_L=0.6, e=0.75)	19.4	27	0.26	0.94	12	220	18	25
5	6.0	Refractory clay (I_L=0,5; e =0,26)	19.2	27.3	0.32	0.99	27	250	16	36

For design reasons, we assign the depth of sealing the grillage sole from the Planning Assessment d_f=1,5m.

We accept for design driven prismatic piles without prestressed reinforcement. The length of the pile is assigned based on engineering and geological conditions, immersing the lower end in the ground with a sufficiently high design resistance to a depth of at least 1÷1,5м. As a base, we take hard-plastic clay. Choose piles with a length of 6 m, pile brand-C6-30.

1. Grillage height

$h_p = h_0 + 0.25 = 0.1 + 0.25 = 0.35m(min)$ де $h_0 = 0.1m$- height of the pile insertion into the grillage

We accept the height of the grillage from the design conditions $h_p = 0.6m$

2. Load-bearing capacity of a single hanging pile on the ground

$$F_d = \gamma_c \left(\gamma_{CR} \cdot R \cdot A + U \sum_{i=1}^{n} \gamma_{cf} \cdot f_i \cdot h_i \right)$$

where $\gamma_c -$ coefficient of working conditions of the pile in the ground, accepted $\gamma_c = 1.0$;

$\gamma_{cR}, \gamma_{cf} -$ coefficients of soil working conditions under the lower end and on the side surface of the pile, respectively, taking into account the influence of the pile immersion method. In this example $\gamma_{cR} = 1{,}0; \gamma_{cf} = 1{,}0$, because we assume that immersion by driving solid piles is performed by a hammer;

$R -$ calculated ground resistance under the lower end of the pile, in this example *R* = *f*(*H*=10,2 м; *IL*=0,5) = 1500 kPa;

A – the area of support on the ground of the pile, taken from the Gross cross-sectional area of the pile or from the cross-sectional area of the camouflage expansion by its largest diameter or from the area of the pile-shell net, $A = 0,3^2 = 0{,}09m^2$;

$u -$ external perimeter of the pile cross-section, $u = 4 \cdot 0{,}3 = 1{,}2$;

$f_i -$ calculated resistance of the i-th soil layer of the base on the side surface of the pile, kPa;

$h_i -$ thickness of the first layer of soil in contact with the side surface, m.

To determine the calculated friction resistance on the side surface of the pile f_i, each layer of soil is divided into layers of height *h* no more than 2,0m.(Рис.6.3)

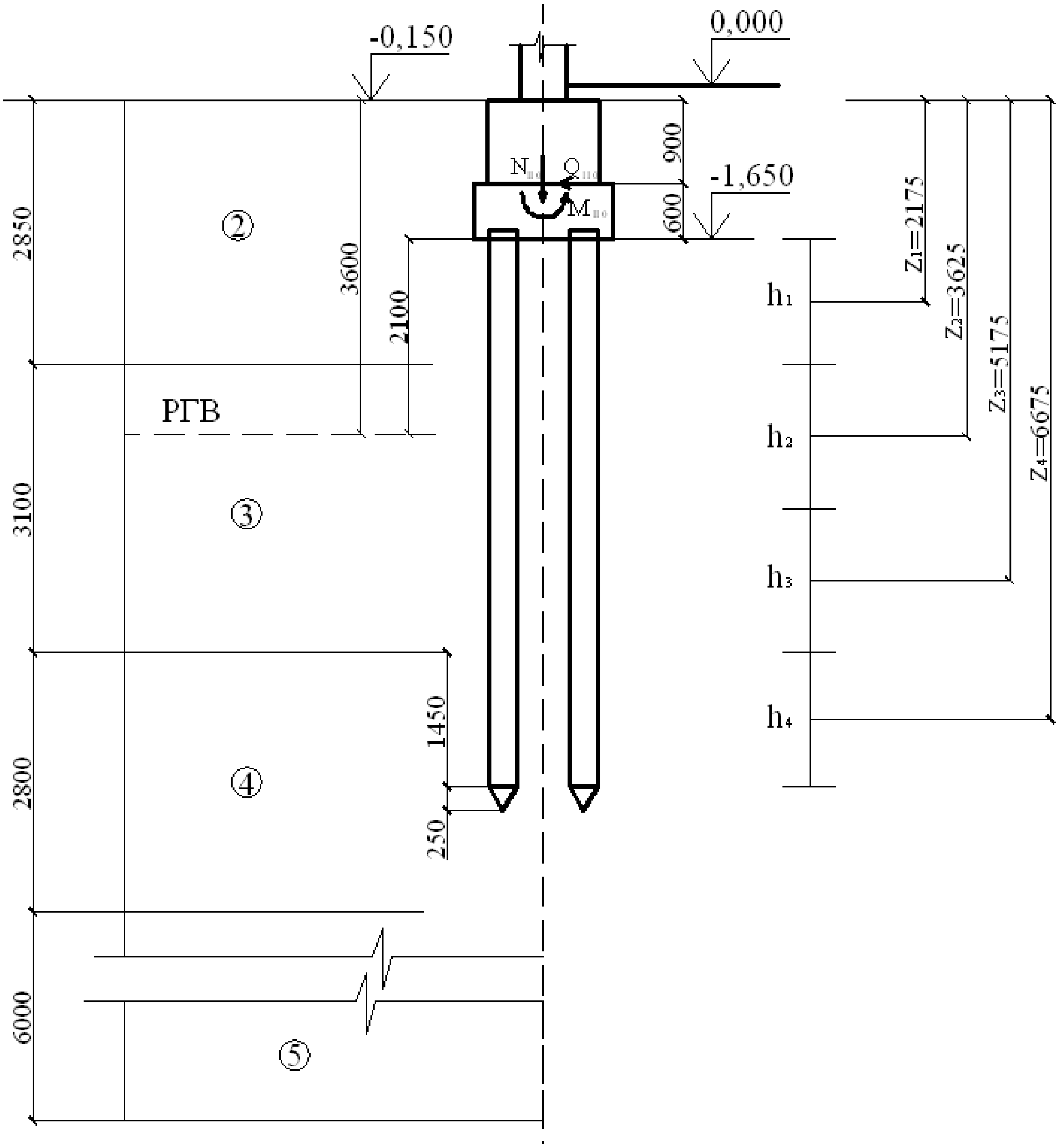


Fig. 5.3 Scheme for determining the depth of friction support

Friction resistance at depth:

$Z_1 = 2.175 \Rightarrow f_1 = 0.031MPa \quad h_1 = 1.35m$

$Z_2 = 3.625 \Rightarrow f_2 = 0.0512MPa \quad h_2 = 1.5m$

$Z_3 = 5.175 \Rightarrow f_3 = 0.056MPa \quad h_3 = 1.5m$

$Z_4 = 6.675 \Rightarrow f_4 = 0.0184MPa \quad h_4 = 1.45m$

$$F_d = 1 \cdot \left[1 \cdot 1500 \cdot 0.09^2 + 1.2 \cdot 1.0 \cdot \begin{pmatrix} 31 \cdot 1.35 + 1.55 \cdot (51.2 + 56) + \\ +18.4 \cdot 1.45 \end{pmatrix}\right] =$$
$$= 293.8kPa \cdot m^2 = 293.8kN$$

4. Permissible design load:

$$N = \frac{F_d}{\gamma_к} = \frac{293.8}{1.4} = 209.86kN$$

where γ_k=1.4 – coefficient that takes into account the method of obtaining calculated loads, in our case using the formula.

5. Finding the required number of piles:

$$n_0 = \frac{\gamma_к \cdot N_{OI}}{Fd - \gamma_f \cdot a^2 \cdot d_p \cdot \gamma_m} = \frac{1.4 \cdot 221.4}{293.8 - 1.15 \cdot 1 \cdot 1.6 \cdot 20} = 1.2$$

where γ_f=1.15 – load reliability factor

$a = (3\ldots6)b = 4 \cdot b = 4 \cdot 0.25 = 1m$ step piles

where γ_m=0.02*MPa* – calculated cellular value of the specific gravity of the soil and grillage

$N_{OI} = N_{OII} \cdot \gamma_s = 184.5 \cdot 1.2 = 221.4kN,$

where γ_s=1.1 – load reliability factor

Taking into account the off-center load, we increase the number of piles by 20-25%

$$n = 1.2\ldots1.25 \cdot n_0 = 1.24 \cdot 1.1 \approx 2.0$$

According to the design requirements we accept 4 piles for the support;

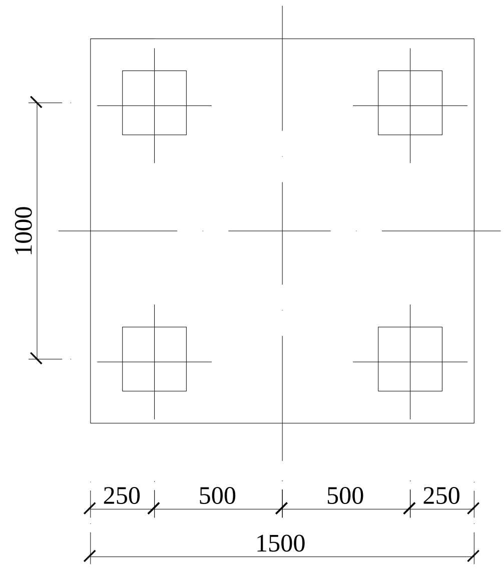


Fig. 5.4 Pile layout

6. We determine the load that falls on one pile:

$$N = \frac{\left(N_{OI} + N_{PI} + N_{\Pi I} + N_{\text{гр}I}\right)}{n} \pm \frac{M_x \cdot y}{\sum_{i=1}^{n} {y_i}^2} \pm \frac{M_y \cdot x}{\sum_{i=1}^{n} {x_i}^2}$$

$N_{\Pi I}$ - load from the subcolumn own weight

$N_{\Pi II} = 0{,}9m^3 \cdot 2500kg/m^3 = 2250kg = 2.25kN$

$N_{\Pi I} = N_{\Pi II} \cdot \gamma_c = 2.25 \cdot 1.1 = 2.475kN$

$N_{PII} = \gamma_p \cdot V_p = 0.025 \cdot 0.6 \cdot 1.5 \cdot 1 = 0.0023MN$; $N_{\text{pI}} = 1.1 \cdot 2.3kN = 2.5kN$;

$N_{\text{гр}II} = 0.019 \cdot 1.0 \left(\frac{1.5-1.0}{2}\right) \cdot 1.8 = 0.0086MN$; $N_{\text{грI}} = 1.1 \cdot 8.6kN = 9.5kN$;

M_x, M_y- calculated moments relative to the main central axes of the foundation sole:

$M_{IIy} = M_y \cdot \gamma_f + Q_y \cdot d \cdot \gamma_f = 14.21 \cdot 1.1 = 15.63kN \cdot m$

Х=У=0.5 м

$\sum_{i=1}^{n} y_i{}^2, \sum_{i=1}^{n} x_i{}^2$, - total value of distances from the axes of all piles to the central axis of the grillage

$$\sum_{i=1}^{n} y_i{}^2 = \sum_{i=1}^{n} x_i{}^2 = 4 \cdot 0.5^2 = 1$$

$$N = \frac{221{,}4+2{,}5+2{,}475+9{,}5}{4} \pm \frac{15{,}63 \cdot 0.5}{1} = 66{,}8kN;$$

7. Let's check that the calculation conditions for the 1st group of limit states are met $N_{max} = 66.8kN$

1) $N < \frac{F_d}{\gamma_c}$; $\quad 66{,}8 < \frac{293{,}8}{1.4} = 209{,}86kN$;

The condition is met, so the foundation is designed correctly.

5.2.2. Calculation for the 2nd group of limit states

1. Determine the focal angle of internal friction of the base, which is cut by the pile:

$$\alpha_{\text{ср}} = \frac{1}{4} \cdot \left(\frac{\phi_{1II} \cdot l_1 + \phi_{2II} \cdot l_2 + \phi_{3II} \cdot l_3}{l_1 + l_2 + l_3}\right) =$$

$$= \frac{1}{4} \cdot \left(\frac{31 \cdot 1.35 + 35 \cdot 3.1 + 18 \cdot 1.45}{1.35 + 3.1 + 1.45}\right) = 7.5°$$

2. Determine the width of the conditional foundation:

$$b_y = b_{piles} + b_{\text{м.п.}} + 2 \cdot \text{a} = 0.3 + 1.0 + 2(6.15 \cdot tag7.5°) = 2.9m$$

3. Find the weight of the soil of the conditional volume.

$$N_{\text{грII}} = \sum_{i=1}^{n} \gamma_{\text{i}} \cdot V_i = 18.2 \cdot 2.85(2.9^2 - 1.5^2) + 20 \cdot 3.1 \cdot 2.9^2 +$$

$+19.4 \cdot 1.7 \cdot 2.9^2 = 1118.3kN$

4. Find the average pressure under the sole of the conditional foundation;

5. $N = \frac{(N_{OII}+N_{PII}+N_{\Pi II}+N_{\text{гр}II})}{A_y} \pm \frac{M_x}{W_y} \pm \frac{M_y}{W_x}$

$N_{II} = 184{,}5kN; \mathrm{M_{II}} = 14{,}21kN \cdot m; Q = 0{,}05kN$

$N_{\Pi I}$- load from the subcolumns own weight

$N_{\Pi II} = 0{,}9m^3 \cdot 2500kg/m^3 = 2250kg = 2.25kN$

$N_{PII} = \gamma_p \cdot V_p = 0.025 \cdot 0.6 \cdot 1.5 \cdot 1 = 2.3kN;$

$$N_{\text{грII}} = \sum_{i=1}^{n} \gamma_{\text{i}} \cdot V_i = 1118.3kN$$

$$M_x = M_{IIx} + Q_{IIx} \cdot H = 14{,}21 \cdot 1.1 + 0.05 \cdot 7.4 = 16kN$$

$$M_y = M_{IIy} + Q_{IIy} \cdot H = 14{,}21 \cdot 1.1 + 0.05 \cdot 7.4 = 16kN$$

$$W_y = W_x = \frac{b_y \cdot {b_y}^2}{6} = \frac{2.9 \cdot 2.9^2}{6} = 4.07m^3$$

$$N = \frac{(184{,}5 + 2{,}3 + 2{,}25 + 1118{,}3)}{2.9^2} \pm \left(\frac{16}{4.07}\right)^2 = 171kN$$

6. Find the calculated resistance of the soil of the base in which the conditional foundation lies:

$$R = \frac{\gamma_{c1} \cdot \gamma_{c2}}{k} \cdot \left[M_\gamma \cdot k_z \cdot b \cdot \gamma_{ii} + M_q \cdot d_1 \cdot \gamma'_{II} + \left(M_q - 1\right) \cdot d_b \cdot \gamma'_{II} + M_{\text{c}} \cdot C_{II}\right];$$

$$R = \frac{1.0 \cdot 1.0}{1} \cdot [0.43 \cdot 1 \cdot 2.9 \cdot 19.4 + 2.73 \cdot 7.8 \cdot 18 + 5.31 \cdot 25] = 540.23kN;$$

$\gamma_{c1} = 1.0$ (medium-sized sand)

$\gamma_{c2} = 1.0$ (a building with a flexible design scheme)

$k = 1$ engineering data obtained experimentally (according to СНиП)

$\phi = 18^O \Rightarrow M_\gamma = 0.43; M_q = 2.73; M_c = 5.31;\ d_1 = 7.8m$

7. Let's check that the calculation conditions for the 2nd group of limit states are met

1) $N_{max} = 171kN \leq 1.2R = 1.2 \cdot 540.23 = 648.3kN$

The conditions are met, so the foundation is designed correctly.

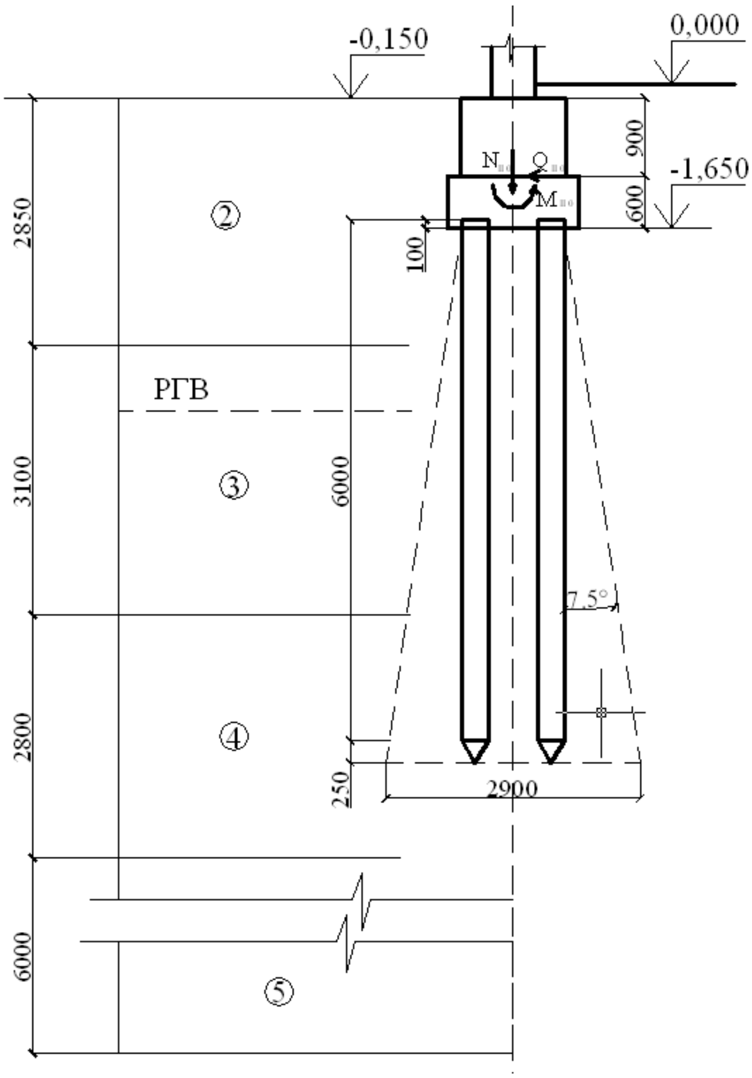


Fig.5.5 Angle detection scheme α

5.2.3. Grillage calculation

Grillage under the column is usually designed as bending elements with single reinforcement in the form of a grid, which is laid on the pile heads. The height of such a grillage should ensure the perception of the transverse forces of its inclined sections due to the resistance of concrete. Therefore, its height will be checked under the following conditions:

1) to push through the column

2) to push through the most remote pile

3) on the transverse force in inclined sections.

The use of a subcolumn, which leads to a combination of the column structure with piles, eliminates the need to check the first two conditions.

1. Checking the grillage height for transverse force in inclined sections. Required condition: $\sum_{i=1}^{n} N_{pi} \leq Q \quad Q = m \cdot b \cdot h_0 \cdot R_{bt}$, where

N_{pi}- maximum load on the pile located behind each inclined section

m –coefficient that depends on the ratio $\frac{h_0}{c}$

c – distance from the face of the column to the face of the pile, c=0,05 m

h_0 – distance from the top face of the grillage to the center of the reinforcement

R_{bt} - calculated resistance of concrete to axial tension

b - grillage width

We calculate a monolithic grillage with a height of 60 cm made of concrete class B20 ($R_{bt} = 1.2MPa$) and reinforcement Ø 12 A 400 C ($R_s = 365MPa$)

$h_0 = 60 - 15 - 1 = 44cm$, where 1см - reinforcement

$$\frac{h_0}{c} = \frac{44}{5} = 8.8 \Rightarrow m = 2.5$$

$$Q = 2.5 \cdot 1.5 \cdot 0.44 \cdot 1200 = 1980kN$$

$N_{pi} = 66.8kN$

$$\sum_{i=1}^{n} N_{pi} = 2 \cdot 66.8 = 133.6kN \leq Q = 1980kN$$

The condition is met, so the height of the concrete is sufficient to perceive these loads.

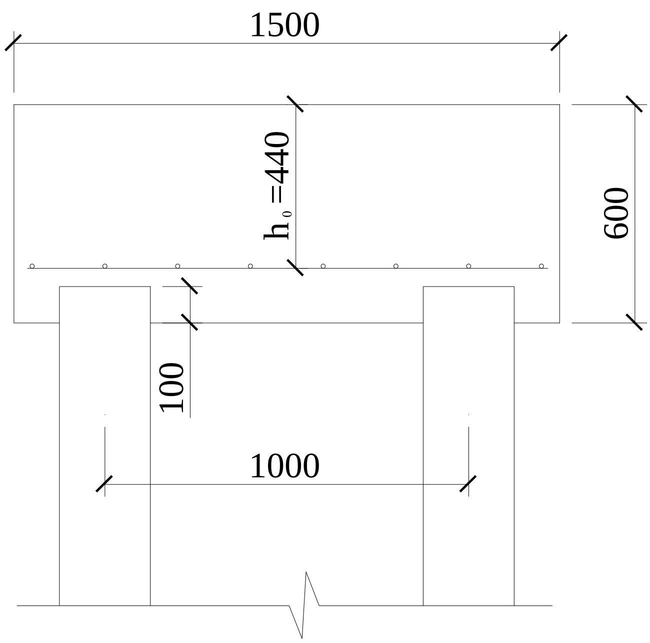


Fig. 5.6 Scheme for determining the height of reinforcement occurrence

5.2.4. Calculation of grillage reinforcement

Since the loads (moments) acting on the grillage both in the longitudinal and transverse directions are the same, the reinforcement will also be equivalent.

$A_s = \frac{M}{0.9 \cdot R_s \cdot h_0}$ $\quad M = \frac{\sum N_{pi} \cdot l}{\mathrm{x}}$, where

l –distance from the wall face to the pile axis $l = 0.2m$;

x – крок паль x=1 m

$$M = \frac{\sum N_{pi} \cdot l}{\text{x}} = \frac{(66.8 \cdot 0.2 + 66.8 \cdot 0.2)}{1} = 26.72 kN \cdot m$$

$$A_s = \frac{26.72 \cdot 10^3}{0.9 \cdot 365 \cdot 44} = 1.85 cm^2$$

We accept 5 Ø 12 A400C on 1 m. p. grillage, both in the longitudinal and transverse directions.

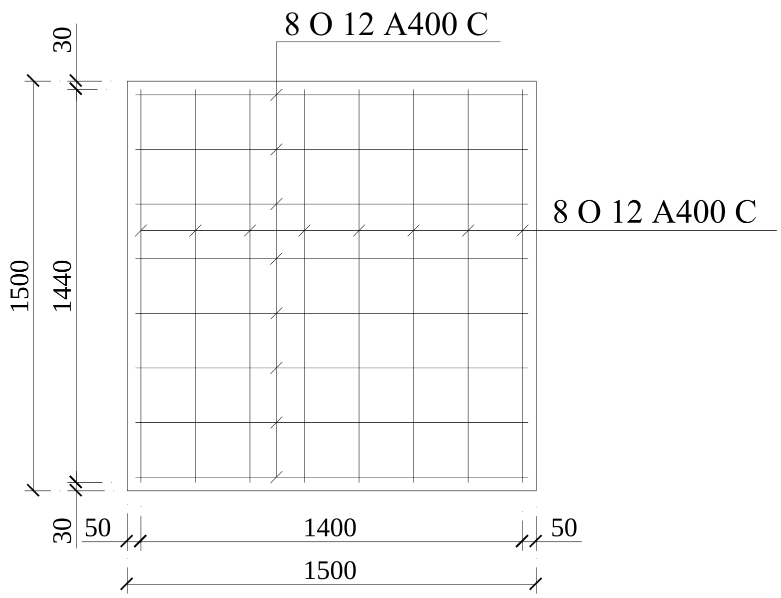


Fig. 5.7 Grillage reinforcement scheme

5.3 Calculation of the retaining wall.

We set the dimensions:

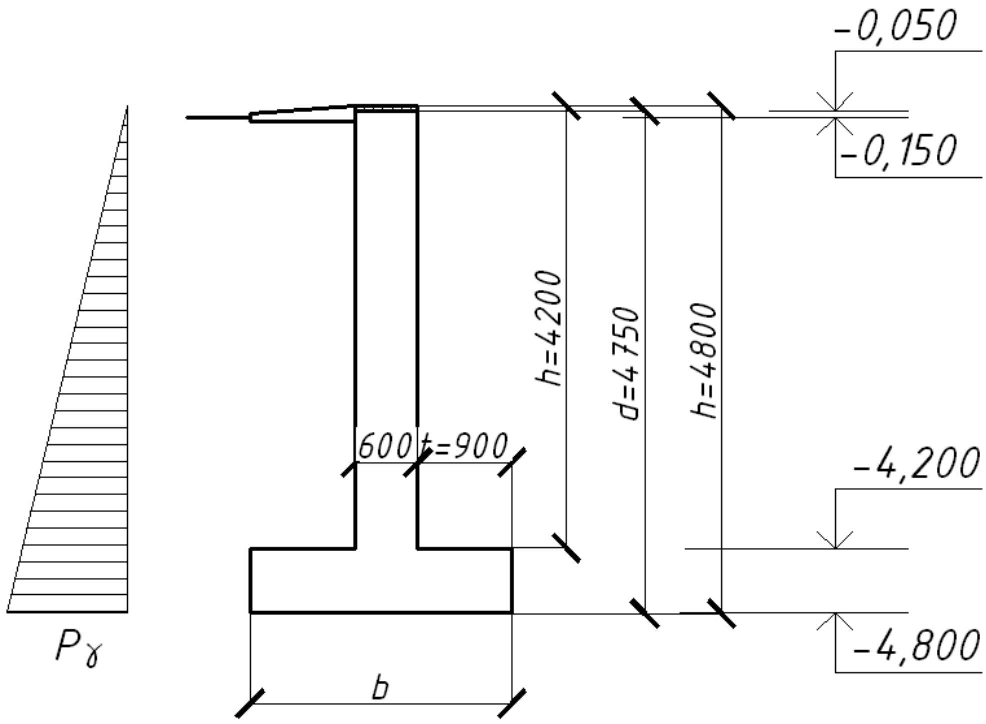


Fig. 5.8 Initial data

Characteristics of the base soil-loam:

$\gamma^{н} = 18.8\frac{kN}{m^3}$, $\phi_{II} = 21^0$, $c_I = 4kPa$, $E_I = 13MPa$.

Backfill soil characteristics-fine sand:

$\gamma_I = 16{,}5\frac{kN}{m^3}$, $\phi_I = 25^0$, $c_I = 0kPa$.

Calculated characteristics of the base soil:

$\gamma_I = 1{,}05 \cdot \gamma^{н} = 1{,}05 \cdot 18.8 = 19{,}74\frac{kN}{m^3}$,

$\phi_I = \phi^H/1{,}1 = 21^0/1{,}1 = 19{,}1^0$

Calculated characteristics of backfill soil:

$$\gamma_I' = 0{,}95 \cdot \gamma_{\mathrm{I}} = 0{,}95 \cdot 19{,}74 = 18{,}75 \frac{kN}{m^3},$$

$$\phi_I' = \phi_{\mathrm{I}}/1{,}1 = 19,1^0/1{,}1 = 17,2^0$$

We determine the coefficient of horizontal soil pressure by the formula:

$$\lambda = tg^2\left(45^0 - \frac{\phi_{\mathrm{I}}}{2}\right) K_\rho = tg^2\left(45^0 - \frac{17.2}{2}\right) \cdot 1 = 0.54;$$

where: K_ρ – coef., which takes into account the slope of the backfill soil surface.

Horizontal soil pressure intensity:

$$P_\gamma = 1.15 \cdot \gamma_I' \cdot h_0 \cdot \lambda \cdot K_c = 1.15 \cdot 18.75 \cdot 4.2 \cdot 0.54 \cdot 1 = 48.9kPa;$$

where: $K_c -$ coef., which takes into account seismic (for 7 points - $K_c = 1$)

We find the value of the bending moment m in the wall:

$$M = P_\gamma \cdot \frac{h_0^2}{6} = 48.9 \cdot \frac{4.2^2}{6} = 143.76kN \cdot m;$$

Finding the value of the shear force:

$$F_{AS} = P_\gamma \cdot \frac{h}{2} = 48.9 \cdot \frac{4.2}{2} = 143.76kPa \cdot m$$

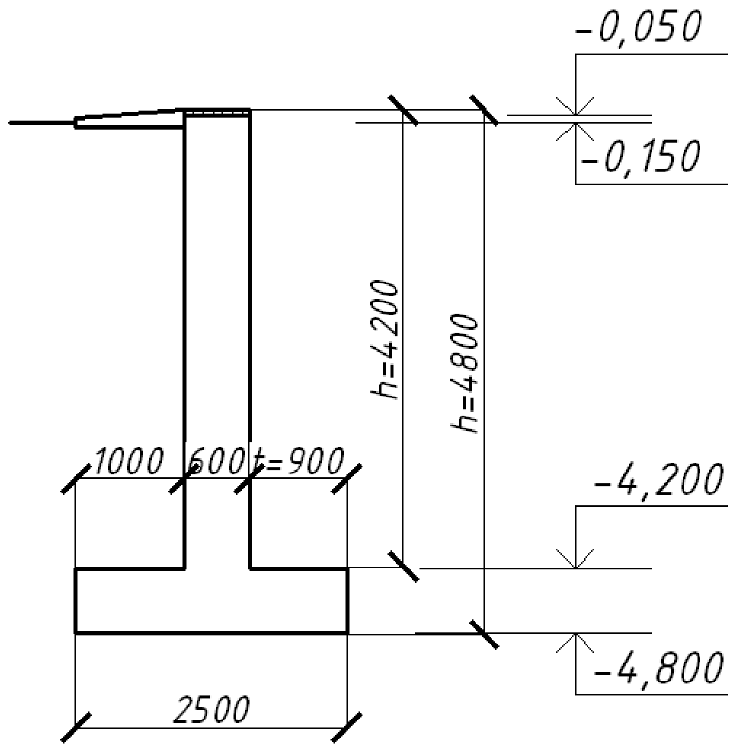
We determine the width of the sole using the formula:

$$b = \frac{1.2 \cdot F_{AS} + t[18 \cdot (h-d)]tg\phi_I - 9(d^2 + \lambda \cdot h^2 \cdot tg\rho)}{18 \cdot h \cdot tg\phi_I + C_I} =$$

$$= \frac{1.2 \cdot 117.36 + 0.9[18 \cdot (4.8 - 4.75)]tg19.1^0 - 9(4.75^2 + 0.54 \cdot 4.8^2 \cdot 0)}{18 \cdot 4.8 \cdot tg19.1^0 + 0} =$$

$$= 2.4m$$

We accept it constructively $b = 2.5m$



Conclusion

The bearing capacity of foundations is full enough to provide strength and stability of the building.

CHAPTER 6
LABOR PROTECTION

6.1 Analysis of harmful and dangerous production factors

Workplace— it is fixed by a separate employee of the spatial zone, equipped with means of labor necessary for the performance of certain work.

The organization of the workplace should help maximize the effectiveness of the labor process and be a worthy person. It determines the worker's productivity and quality. Organization of the workplace - a system of measures for its specialization, equipment with the necessary means and objects of labor, their placement in the workplace, its external design and the creation of proper working conditions. The specific content of these activities is determined by the nature and specialization of the workplace, its type and value in the production process.

The main directions in the organization of workplaces are:

- effective placement of equipment, equipment, work items;

- rational specialization;

- lighting of the working area;

- service;

- conditions for safe and high-performance work.

The level of organization of work at a specific workplace also depends on the quality of its service. Service of the workplace provides timely provision of all that is necessary, including maintenance (adjustment, regulation, repair); regular supply of the necessary types of energy, information and consumables; equipment quality control, transport and maintenance (cleaning, cleaning of equipment, etc.).

Service jobs are provided by the following functions: preparatory, informational, industrial, instrumental, debugging, power, control, etc. Progress in job service systems consists in switching from next service, that is, servicing the call from the place of stopping production to a scientifically based standard planning preventive service.

According to [18] the installer is affected by the following dangerous and harmful production factors:

1. Moving machines and mechanisms; moving parts of production equipment
2. The increased dustiness and gassiness of air of a working zone
3. Increased noise in the workspace
4. Increased voltage in the electrical circuit, the short circuit of which can occur through the human body
5. Increased or decreased air temperature of the working area
6. Lack or absence of natural light
7. Location of the workplace at a significant height relative to the ground (floor).

All the above-mentioned risk factors in their manifestations have significant adverse effects on the health and even on the lives of personnel. The high level of occupational injuries reduces productivity and can lead to disability workers (temporary and / or permanent) and even be the cause of the death. Therefore, minimizing the adverse effects and risks to the life and health of the worker is an integral part of the production process. It has been proved that, with regular training and safety checks, occupational injuries are significantly reduced. Therefore, this part of the production process is important for conducting a production process with high efficiency.

6.1.1 The increased dustiness and gassiness of air of a working zone

During the building construction assembling process, dustiness and gas pollution arises. This is due to the result of the operation of machines and the use of building materials. A dust concentration of 18 mg / m3, according to app. 2 [19] is permitted in the construction area. When exceeding the limit value, personal protective equipment is used. In the area of increased air pollution completely eliminate or minimize the number of workers.

6.1.2 Location of the workplace at a significant height relative to the ground (floor)

During the building construction erection process, the workplace may be at a considerable height relative to the ground. To ensure safety at work at altitude, it is necessary to follow the "Rules of occupational safety while performing work at altitude" [20].

6.1.3 Moving machines and mechanisms; moving parts of production equipment

Moving machines and mechanisms; moving parts of production equipment – according to [21], are assembling crane and works, which are related to moving and assembling steel structures.

In the process of installation works are used various types of machines and mechanisms (automobile pneumatic wheel cranes, trucks, boom and cable lifts, etc.). Only persons who have undergone special training and have been certified to operate (or service) this machine are allowed to work with them. When working near a machine or mechanism, you must adhere strictly to the rules, safety precautions and to know and comply with the instructions for operating the machine, which must be in the workplace. Mobile machines (mortar pumps, compressors, mixers, etc.)

should be installed on level ground and then fixed with stretch marks or put under their wheels. All moving parts of machinery and machinery must be enclosed with enclosures and the working area around the machine enclosed.

Before starting the machine after installation or repair, it must be carefully inspected and checked to make sure that it does not leave any spare parts or mounting tools that could fall into its moving parts during operation and cause an accident. It is strictly forbidden to leave the machine running unattended, or to adjust or lubricate it during operation.

6.2. Measures to reduce the impact of harmful and dangerous production factors.

6.2.1 Air normalizing in working area

The section deals with measures that ensure the health of the employee and safe and harmful working conditions in the workplace. Normalization of air in the working area measures and means of prevention of air pollution in the working zone:

• removal of harmful substances in technological processes, replacing them with less harmful substances;

• improvement of technological processes and equipment;

• automation and remote control of technology. processes;

• sealing of production equipment, work of technological equipment under degreasing, localization of harmful emissions due to local ventilation, etc. the means;

• normal functioning of heating systems, general ventilation, air conditioning, emission control;

• Preliminary and periodic medical examinations of workers working in hazardous conditions, preventive nutrition, and observance of rules of personal hygiene;

• control of the content of harmful substances in the air of the working zone;

• use of personal protective equipment.

Ventilation - removing air from the room and replacing it with fresh, if necessary, treated air. Ventilation creates conditions for the air environment, favorable for the health and well-being of a person, meeting the requirements of the technological process.

By way of moving air, ventilation is divided into two types: natural; mechanical

By way of organization of air exchange ventilation can be: local; commonplace.

According to the principle of ventilation, the equipment is divided into:

1) Exhaust in (general and local);

2) it is tributary local (air showers, oases, curtains) and general.

Air conditioning is the creation and automatic support in the premises regardless of the external conditions of the constituents or variables in the corresponding program of microclimate parameters, which are most suitable for a person and the normal passage of the technological process.

The basic principle of the air balance of the building is that the volume entering the building of the outside should correspond to the volume of air coming out of it. Ideally, the amount of external air supplied through ventilation and air conditioning systems in the building should exceed the amount of outlet air to provide some excess pressure inside the building. This prevents uncontrolled infiltration of the outside air at the inputs and outlets.

Multiplicity of air exchange is an indicator that shows how many times an hour indoor air changes.

Given the release of carbon dioxide by the person at rest, the researchers calculated that the minimum amount of ventilation per person in the living space should be not less than 30 m3 per 1 hour. The optimal air condition conditions for a person are provided at a volume of ventilation of 80-120 m3 / h.

6.2.2 Rules when working at high-level.

The most significant from mentioned factors is location of work place at high elevation above the ground. It is necessary to provide calculation of strength and stability of trestle works.

Let's primarily accept following data: trestle works dimensions L = 200 cm, e = 100 cm, e $_2$= 30 cm, h = 200 cm; longitudinal braces are from tube 42,3 x 3,2 m; W = 3,6 cm^2; post is from tube 48 x 3,5 м; F = 5 cm^2, W = 5,44 cm^2, i = 1,57 cm, e = 7 cm; tubes are from steel Ст.3, [22], [σ]= 2100 kgf/cm^2, E = 2x10^6 kgf/cm^2.

Loadings: distributed q = 200 kgf/cm^2, concentrated P = 200 kgf, maximal on post $P_п$ = 1200 kgf.

Check of longitudinal bracing.

Loading P_A equals:

$P_A = Pe_1 / e$, P_A = 200 x 70/100 = 140 kgf.

Maximal bending moment in longitudinal bracing:

$M_{мах} = P_A / 2 \cdot L / 2$, $M_{мах}$ = 140/2 x 200/2 = 7000 kgf*cm.

$\sigma_{пс} = M_{мах} / W$,$\sigma_{пс}$ = 7000/3,6 = 1944 kgf/cm^2.

Strength of longitudinal bracing is provided as:

$\sigma_{пс}$ = 1944 < [σ] = 2100 kgf/cm^2.

Check of post

Maximal bending moment in post is

$M^{мах} = P_2 э = P_3 э = P_A э$, $M^{мах}$ = 140 x 7 = 980 kgf*cm.

Maximal tension:

$\sigma_{вс} = P_п / F + M^{мах} / W$,$\sigma_{вс}$ = 1200/5 + 980/5,44 = 240 + 180 = 420 kgf/cm^2,

Which is lower than [σ] = 2100 kgf/cm^2, i.e. strength of post is provided.

Check of post stability:

Flexibility of post is λ = 1 x 200/1,57 = 127.

Conditional flexibility is $\lambda_{у} = \lambda\sqrt{[\sigma]/E}$, $\lambda_{у} = 127\sqrt{2100/2\cdot 10^6} = 4{,}1$

Relative eccentricity m = 7 x 5/5,44 = 6,4.

Reduced relative eccentricity m_{ef} = 1,05 x 6,4~7,0.

If $\lambda_{у}$ = 4,1 and m_{ef} = 7 then $\varphi_e \approx 0{,}13$.

Stability of post is provided:

$P_{п} / \varphi_e F \le [\sigma]\gamma_{c}$, 1200/0,13 x 5 = 1846 < [2100] x 0,95 = 1995 kgf/cm^2.

Check of decking:

Moment of resistance of pine board by ДСТУ EN 336:2003, for example, with dimensions b = 50cm and t = 2cm, is equal:

$W_{н} = 50\cdot 2^2/6 = 33{,}3$ cm^3.

Maximal tension:

$\sigma_{н} = M_{н}/W_{н} = P_{А}e_2/bt^2/6$,

$\sigma_{н}$ =140 x 30/33,3=126 kgf/cm^2< [σ] = 150 kgf/cm^2,

that means strength of decking is provided.

Check of trestle works fixation to wall: force of dowel push at dimensions d=3cm, e = 4cm on the wall from brick ($\sigma_{см}$ = 50 kgf/cm^2)

N = 50 x 3 x 4 = 600 kgf.

Force of dowel pulling with two tabs from the wall with friction coefficient f=0,35:

Q = f*z*N, Q = 0,35*2*600 = 420 kgf.

Parameters of screw with average diameter $d_{ср}$ =10,8mm, step S = 1,75mm, half of screw's profile angle β=30° and friction coefficient $f_{р}$ = 0,25 are defined:

$tg\,\alpha = S/\pi d_{ср}$, α =arc tg(1,75/3,14 x 10,8) = 2°56';

$tg\,\rho = f_{р}/\cos\beta$, β=arc tg(0,25/cos 30°) = 16°4'.

Optimal bending moment at screw nut 5cm:

$M_{кр} = Qd_{ср} / 2tg(\alpha + \rho)$, $M_{кр}$ = 420 x 10,8/2 tg(2°56' + 16°4') = 84 kgf*cm.

At screw's arm length 10cm effort doesn't exceed 9 kgf that is quite acceptable. Calculation proves correctness of chosen parameters for dowels fixation to wall.

When trestle works are not effective tipping bridge is used.

6.3 Instruction on labor protection for a manual welder.

6.3.1. General safety requirements.

6.3.1.1. Age limit for welding works is 18 years. A welder should be educated, should have passed medical examination, checking their knowledge, after holding introductory instruction at the workplace. They should have qualification certificate for safety measures at least II, when working in closed containers - at least III.

6.3.1.2. Workers that have the term of safety measures expired are not allowed to perform welding processes; women are not allowed to work in closed containers.

A welder has to:

- Perform only the work committed to him by the foreman or the team leader and according to which he had been instructed on safety work measures;
- Follows the rules of internal work order. It is not allowed to take and also to be at the territory of construction site in a state of alcoholic, drug or toxic intoxication. It is allowed to smoke only in places specially allocated for that.
- Use protective clothing and protective means, regardless of the type of work he has to use protective helmet at the construction site;
- Be able to render first medical aid to an injured person;
- Follow hygienic rules;

- Tell the administration about any malfunctions of instruments, machines and equipment.

The main harmful and dangerous factors during a welding process are:

- electrical arch radiation, that can lead to an eye disease;
- striking with electrical current;
- intoxication with nitrogen oxides and also such disease as black-lung disease caused by the pollution of the welder's working zone with harmful vapors, gases and dust;
- body burns if touching the welded wares and structures.

Manual welder should be given:

- canvas suit;
- underwear;
- leather boots or kersey boots;
- canvas gloves;
- dielectric gloves;
- galoshes;
- protective helmet.

When working in winter outside additionally should be given:

- cotton jacket with heat insulation;
- cotton pants with heat insulation;
- winter gloves;
- felted boots;
- galoshes over the felted boots;
- cap comforter.

Among the individual protection means there should be an erection belt. During the exploitation process the belt should be tested every 6 months for tension by a statical force equal to 400 kg with correspondent marking. The belt is daily examined by a welder before starting welding.

To protect head from mechanical injury and striking with electrical current it is necessary to use protection helmets.

Eyes should be protected with protection glasses (screens).

To protect oneself from dust it is necessary to use respirators of types: ТБ-1", "Лепесток-5, 40, 200", and also "Астра-2", "Кама-200", "Снежок".

Requirements for fire and explosion safety:

- Workers performing electrical welding works should know the practical rules of using the primary fire fighting means;
- Welder’s workplace should be free from flammable matters and materials;
- Electrical welding bug should be properly grounded;
- Places where welding works are to be performed should be located at a distance not less that 5 m from combustible matters and 10 m from explosive matters.
- It is prohibited to leave the welding bug switched on during a break and after finishing works;

In not following the requirements of the instruction a worker will bear responsibility according to the present legislation.

6.3.2. Safety requirements before starting the works.

Before starting manual welding a worker should:

- Check for the presence of protective clothing and protective shoes and other means of individual protection;
- Get the task form a foreman (team leader) and acquaint with safe work execution order;

- Check the workability of all instruments. In case of malfunction repair or replace it;
- Check the workability, reliability of junctions, the presence of mechanical damages of equipment according to the requirements of the rules on technical exploitation of welding equipment and the cable;
- Check for the presence and operability of the welding bug.

6.3.3. Safety requirements during the welding works performance

During electrical welding at rainy weather, snowfall a workplace should be equipped with a canopy.

The performance of welding works at high altitude, from trestles or scaffolding is allowed if all conditions preventing the falling of workers, ignition of wooden flooring and constructions, the contact of the welding bug and metal structures are provided.

It isn’t allowed for people to be in the zone of possible molten metal falling.

The places where welding works are to be performed should be located at least 5 m from inflammable materials and 10 m from explosive materials.

Hands, clothing and shoes should always be dry.

When switching wires it is necessary to use canvas gloves.

Welder’s workplace should be fenced with portable or stationary fences (shields or screens).

Welding elements over the places of other works performance is allowed only in case of presence the graph of combined works and the absence of people in a dangerous zone.

Jointing the welding cables should be performed only by means of pressing, welding or soldering.

Welded metal structures, details, knots should be properly grounded.

Workplaces located at a distance over 1.3 m above the ground level should be fenced.

When working at high elevations it is necessary to use the protection erection belt.

Places of welding works performance should have appropriate illumination, as temporary illumination sources there should be used special lighters.

During the welding works and after their completion the knife switches should be locked.

Moving the welding cables and installations should be performed after their disconnection from the network.

As a portable lighting source a lighter having voltage of 12 V should be used.

6.3.4. Safety requirements after finishing work

It is necessary to switch off the welding bug, switch off and lock the knife switch.

Put into order everything at the workplace.

Surrender the instruments to the closet.

Convolve in a coil the welding cable and put it to the proper place

Put into order the protective clothing and boots.

Perform the sanitary procedures.

6.3.5. Safety requirements in emergency situations

At accidents it is necessary instantly remove the accident source, take measures on the first aid to the victims and tell the foreman (team leader) and, if that doesn’t threaten human life, keep the situation.

Accidental situations at a construction site during electrical welding works can happen for the following reasons:

- Storing flammable matters close to the welding works performance;
- Plugging more than one aggregate to the starting device.

CHAPTER 7
ENVIRONMENTAL PROTECTION

7.1 Analysis of the building's impact on the environment during its construction and exploitation

7.1.1. Environmental hazard of glass factory during its construction

During construction, the ecosystem is destroyed and an artificial system for human life is created in its place. How acceptable it will be for a person who is part of an ecosystem rather than a man-made environment will depend on the art of the architect and builder not to upset the balance in the natural environment, ensuring its sustainability, harmoniously combining buildings and structures with natural ecosystem components. It has become a frequent phenomenon when a person in a place artificially created by architects and builders feels ecological discomfort.

Construction is a clear example of anthropogenic activity, which often has a serious negative impact not only on individual components of the environment and their conservation, but also on the resilience of ecosystems as a whole.

Today, one of the main tasks in construction is the accounting and analysis of all anthropogenic pressures on the environment and the assessment of actions on it to preserve and maintain ecological balance. There is a high level of air, water and soil pollution at construction sites, which ultimately leads to a decrease in biodiversity. This occurs at all stages: during the design and survey work, when arranging roads and quarries, directly when performing work on the construction site. Therefore, the issue of the impact of construction projects on the environment is extremely important.

All types of impact of construction on the environment can be classified according to the following environmental characteristics: removal from the environment and bringing into the environment. Sources of impact on ecosystems during construction are: new material objects located on the construction site;

elements of the main and auxiliary technologies, the functioning of which is the cause of landscape change and environmental pollution; facilities whose life cycle is associated with construction or operation in the future. All these actions affect the resilience of ecosystems and reduce the quality of the environment, either directly or indirectly.

The main sources of pollution during construction works are: drilling and blasting, construction of ditches and trenches, deforestation and shrubs, damage to the soil layer and washing away contaminants from the construction site, the formation of construction waste dumps and more.

Construction creates an additional environmental burden and causes deterioration of human health. Already built buildings also have a negative impact on the environment: the terrain changes, the vegetation changes, artificial plantings are replaced by artificial ones.

In addition to the negative effect on vegetation and soil, the consolidated object changes the conditions of insolation. Buildings shade the territory, the mode of evaporation of moisture changes.

The object of the planned activity belongs to the second category of activities and objects that can have a significant impact on the environment and are subject to environmental impact assessment in accordance with [23].

Probable consequences for the environment, including the population:

– emissions of pollutants into the atmosphere from stationary sources, the calculated and actually measured surface concentrations of which should not exceed the values of maximum permissible concentrations (MPC), and mobile sources of pollution, namely emissions from road, rail transport and industrial equipment;

– there is no impact on the aquatic environment during the construction of the facilities;

– during operation: water supply - from an artesian well;

– disturbance (destruction) of soils during construction (transformation of soil layers), movement of vehicles, vibrations from production processes, which can be intensified under the influence of natural factors - wind, rain flows, etc.;

– acoustic pollution, the estimated maximum permissible level of which in residential buildings should not exceed the permissible noise level in populated areas;

– on the social environment - the creation of new jobs, promoting the development of small and medium-sized businesses, filling the budgets of various levels, the development of district infrastructure.

The land plots, which are considered in the detailed plan, are located outside the objects and territories of the nature reserve fund, and therefore, no impact is expected. In the process of construction and operation of the enterprise there are various risks of environmental impact. In my project, the biggest impact on the environment is the impact on the atmosphere.

Information is taken from [23], [24] and [25].

7.1.2. Environmental hazard of glass factory during its exploitation

Sources of environmental impact during the operation of the facility are:

experimental shop:

- glass furnace (glassmaking process, natural gas combustion products);

As a source of atmospheric pollution, the object is characterized by the following emissions: nitrogen dioxide, carbon monoxide, soda ash (sodium carbonate), sulphate dust (sodium sulphate), sulphur dioxide, inorganic dust (SiO_2 <20%), inorganic dust (SiO_2 >70%), aluminium oxide.

Aspiration systems are provided to capture dust and harmful substances from technological equipment AC, filters «Wamgroup». For the removal of harmful pollutants, an exhaust pipe is provided, which ensures organized removal and dispersion of emissions in the atmosphere. Excess heat is removed by means of aeration lights placed on the roof.

In auxiliary industrial premises, local exhaust ventilation systems are provided to localize harmful emissions from technological processes.

Experimental shop with dosing and mixing Department

Release of pollutants due to technological processes:

- gaseous and freeze-dried substances of thermal decomposition of charge components during glassmaking and substances formed during fuel combustion;
- dust the charge when loading into the glass furnace.

Emissions from fuel combustion in a glass furnace are removed through an exhaust pipe (table 7.1).

Charge dust is removed through the pipe when the glass furnace is loaded.

The following harmful substances are released into the atmosphere: nitrogen dioxide, carbon monoxide, soda ash (sodium carbonate), sulphate dust (sodium sulphate), sulphur dioxide.

DZV is equipped with an aspiration system of the charge preparation line, charge dust is captured and returned to the technological process, and there are no emissions into the atmosphere.

Table 7.1 Characteristics of emission sources

Characteristics of emission sources										Characteristics of harmful substances			
Number on the plan	Name (pipe, Lantern etc.)	Height, m	Diameter, m	Coordinates on map-diagram		Parameters of the gas-air mixture at the outlet of the emission source			Duration of work, Hour / year	Name	Code	Ejection power	
				X,m	Y,m	Volume, m^3/c	Tempera	Speed, m/c				g/s	t/year
Experimental shop													
2	Pipe	45,0	0,6	935	1070	1,43	130	5,1	8760	Sodium carbonate	155	0,17	5,38
										Sodium sulphate	158	0,073	2,3
										Sulphur dioxide	330	0,206	6,49
										Nitrogen dioxide	301	0,133	4,2
										Carbon monoxide	337	0,015	0,47
Dosing and mixing Department. AC-1 system (elevators, screen-screen, silos)													
3	Filter	22,0	0,1x0,15	109	975	0,25	20	16	424,1	Sodium carbonate	155	0,00125	0,0019
4	Filter	22,0	0,1x0,15	110	974	0,25	20	16	424,1	Sodium carbonate	155	0,00125	0,0019
5	Filter	22,0	0,1x0,15	110	978	0,25	20	16	72,3	Aluminium oxide	101	0,00125	0,00033
6	Filter	22,0	0,1x0,15	109	980	0,25	20	16	328,7	Inorganic dust	2909	0,00125	0,00148
										(SiO_2 <20%)			
7	Filter	22,0	0,1x0,15	110	977	0,25	20	16	20,9	Sodium sulphate	158	0,00125	0,00009
8	Filter	4,0	0,1x0,15	113	960	2,1	20		1253	Inorganic dust	2907	0,004	0,018

This emission capacity must not exceed the maximum permissible concentration (MPC). We compare the results from the experimental shop and the remote control in Table. 7.2.

Table. 7.2 Approved maximum permissible emission

Name of the pollutant	**Maximum permissible concentration according to MPC, г/м^3**	**Approved maximum permissible emission**	
		g/m^3	**g/s**
1	**2**	**3**	**4**
Sodium carbonate	0,22	0,217	0,1725
Sodium sulfate	0,3	0,093	0,07425
Sulfur dioxide	0,5	0,26	0,206
Nitrogen dioxide	0,085	0,067	0,133
Carbon monoxide	0.1	0,019	0,015
Aluminum oxide	0,01	0,00157	0,00125
Inorganic dust	0,5	0,00157	0,00125
(SiO_2 <20%)			
Inorganic dust	0,15	0,005	0,004
(SiO_2 >70%)			

Thus, the maximum permissible emissions (ZGDV):

$$ZGDV = \frac{SV \cdot D}{P} < GDK$$

де ZGD – approved maximum permissible emission; SV – second outliers, g/s (see table. 10.1); D – machine operation time in 1 day, s. (accepted, 8 hours working day); P – area of the construction site - 22876 m^2.

7.1.3. Emissions of pollutants into the atmosphere from motor transport

The project provides for two open parking lots on the construction site: for passenger cars (7 PCs.) with gasoline engines and trucks of large and especially large load capacity with diesel engines (2 PCs.).

Emissions of harmful substances from vehicles are determined in accordance with [26]. the calculations take into account the influence of the driving mode (speed) and specific emissions of harmful substances depending on the age of the fleet and its technical condition.

Calculations are defined by the formulas:

- for calculating annual emissions:

$$Mj = 10^{-6} \sum_{i=1}^{n} g_{ji} \cdot L \cdot A_i \cdot K_e \cdot D$$

where: Mj – ejection mass j – pollutant, t;

n – number of transport types (petrol, diesel);

g_{ji} – specific emissions j – pollutants in one car i– type based on the age and technical condition of the park for the billing year, g / km;

K_e – coefficient that takes into account the influence of the driving mode (vehicle speed);

D – number of working days per year, 365 days;

L – conditional mileage of one transport unit per cycle across the territory;

A_i – number of vehicles moving around the territory;

- to calculate the maximum second outliers:

$$Mj = 10^{-3} \sum_{i=1}^{n} \frac{g_{ji} \cdot L \cdot A \cdot Ke}{t_{в} \cdot 3{,}6}$$

where:

Mj – ejection mass, j – pollutants, g / s;

g_{ji} ; L ; A ; Ke – similar values given above;

$t_{в}$ - vehicle release or return time (cycle time), H.

The initial data for calculating harmful emissions from cars are shown in Table 7.3 a, and the calculated data are shown in Table 7.3 b.

Table 7.3 a

Name	Output data								
	Operational quantity, PCs	Conditional mileage of one car, km	Cycle time, H	Driving mode coefficient			Specific emissions of harmful substances, g / km		
				CO	CH	NOx	CO	CH	NOx
1	2	3	4	5	6	7	8	9	10
Open parking lots									
Parking (POS. 9 for GP)									
Passenger cars with gasoline engines:									
- entrance	7	0,25	8	1,4	1,2	1,0	20,8	1,3	0,63
- check-out	7	0,7	8	1,4	1,2	1,0	20,8	1,3	0,63
Parking (POS. 10 for GP)									
Large and especially heavy duty trucks with diesel engines:									
- entrance	2	0,15	8	1,4	1,2	1,0	17,0	7,7	6,8
- check-out	2	0,4	8	1,4	1,2	1,0	17,0	7,7	6,8

Table 7.3 b

Name	Calculation results					
	Second ejection, g / s			**Annual emissions, t / year**		
	CO	**CH**	**NOx**	**CO**	**CH**	**NOx**
1	2	3	4	5	6	7
Open parking lots						
Parking (POS. 9 for GP)						
Passenger cars with gasoline engines	0,0056	0,0003	0,000136	0,054	0,003	0,00114
Parking (POS. 10 for GP)						
Large and especially heavy duty trucks with diesel engines	0,0007	0,00026	0,0002	0,0095	0,004	0,003
Together:	**0,0063**	**0,00056**	**0,0002**	**0,0149**	**0,007**	**0,00414**

The conclusion:

$$CO = \frac{SV \cdot D}{P} = \frac{0{,}0063 \cdot 3600 \cdot 8}{22876} = 0{,}008\, g / m^2 < GDR = 1 g / m^2$$

$$CH = \frac{0{,}0018 \cdot 3600 \cdot 8}{22876} = 0{,}007\, g / m^2 < GDR = 0{,}07\, g / m^2$$

$$NO_X = \frac{0{,}0002 \cdot 3600 \cdot 8}{22876} = 0{,}0025\, g / m^2 < GDR = 0{,}06\, g / m^2$$

where SV – second outliers, g/s (see table. 10.3); D – operating time of machines and mechanisms for 1 day, s. (it is assumed that the mechanisms will work 8 hours a day); P – area of the construction site - 22876 m^2.

7.2 Methods and means of protecting the environment from the influence of man-made factors

The project provides for the implementation of construction and installation works in accordance with [25].

In order to reduce the negative impact of construction production on the environment the project provides for the following measures:

- minimization of construction and installation time;
- minimizing the duration of zero-cycle work in order to prevent wind and water erosion of the soil;
- protection of trees and other green spaces surrounded by construction sites that may be damaged by vehicles (installation of temporary fences, protective shields, etc.);
- prevention of soil contamination with fuel and lubricants;
- cleaning the construction site of construction debris in quantity and taking it to landfill;
- irrigation of all roads and road-type sites in summer;
- use of modern environmentally friendly technologies, materials and mechanisms in construction;
- all mechanisms operating on the construction site with internal combustion engines must be tested for exhaust gas toxicity.

7.2.1 Measures to prevent water pollution

In order to reduce the negative impact of pollutants the project provides for the following measures:

- domestic wastewater is diverted to the domestic sewer network; after which it is treated at existing wastewater treatment plants;
- industrial effluents from the experimental workshop are subject to treatment at local sewage treatment plants (sump), diverted to the domestic sewer network, and then treated at existing sewage treatment plants;

- industrial effluents from the dining room are diverted through a grease trap to the domestic sewer network, after which they are treated at existing wastewater treatment plants;
- industrial effluents from the boiler house are diverted through the cooler to the domestic sewer network, after which they are treated at existing wastewater treatment plants;
- to save the consumption of drinking water, which is consumed for cooling the technological equipment of the experimental dinnerware shop, a reverse water supply system is provided;
- treated and decontaminated water after treatment plants is diverted to existing filtration ponds, where water is further treated by natural hydrobiocenosis and higher aquatic plants in natural conditions;
- surface wastewater from the territory of the enterprise is subject to treatment at the designed treatment facilities, after which the treated water is collected in a tank, overflow from the tank is discharged into a storage pond, and then these treated water is used for irrigation of the territory;
- temporary roads are being paved hard on the construction site and in two parking lots.

7.2.2 Measures to prevent contamination of flora and fauna

There are no vegetable soils on the site, the top layer of soil is represented by sand with admixtures of construction debris, part of the site is paved.

At the moment, there are no green spaces on the site.

In order to ensure normal sanitary and hygienic conditions and microclimate at the site, the project provides for measures for landscaping and landscaping of the territory after construction is completed.

Groups of trees and shrubs are planted on territories that are free from development and driveways, and flower beds are created from perennials with the addition of plant soil. An assortment of green spaces from the local flora.

For the collection of solid waste (construction waste, food waste, cloth, plasmas, etc.), there is a platform equipped with containers for temporary storage and further their removal for recycling.

Conclusion:

According to the data obtained in clause 7.1.2, we note that emissions of harmful substances from the experimental shop and the dosing and mixing department, taking into account their dispersion in the atmosphere, do not create a surface concentration of harmful substances that will exceed the maximum permissible concentration.

According to the data obtained in clause 7.1.3, we note that emissions of harmful substances from construction vehicles at a construction site, taking into account their dispersion in the atmosphere, do not create a surface concentration of harmful substances that will exceed the maximum permissible concentration.

The project provides for a set of measures that do not pose a threat to the health and comfort level of the population living in the adjacent territories – the levels of air pollution are acceptable, the impact on Water Resources is within regulatory requirements. In addition, its implementation will have a positive impact on the social environment, partially solve the problems of unemployment by creating new jobs.

List of references used in this section:

1. ДБН А.2.2-1-2003 „ Composition and content of environmental impact assessment materials (EIA) in the design and construction of enterprises, buildings and structures”;

2. ДСП 173 « State sanitary rules for planning and building localities »;
3. ДБН Б.2.2-12:2018 « Planning and development of territories »;
4. ВНТП-СГіП-46-16.96 « Automobile transport enterprises and motor transport enterprises of the agro-industrial complex of Ukraine »;
5. ДБН В.1.2-8:2008 « Basic requirements for buildings and structures. Safety of human life and health and environmental protection ».

REFERENCES

1. «Надійність металевих димових і вентиляційних труб та їх несучих веж». Автореферат.– Яровий С.М.. - 2018.
2. «Експериментальні аеродинамічні характеристики перерізів багатогранних гнутих стійок». Є.В. Горохов, В.М. Василев С.Г., С.Г. Кузнецов, І.М. Гаранжа, Е.А. Лозинський. - 2010 р.
3. «Вітрові навантаження на елементи тригранних башт і пакети витяжних труб». О.В. Атаманчук, І.С. Холопов, Д.Д. Чернишев. - 2007
4. ДБН В.1.2-2:2006. Система забезпечення надійності та безпеки будівельних об'єктів. Навантаження та впливи. Норми проектування.
5. «Руководство по расчету зданий и сооружений на действие ветра» Москва Стройиздат, 1978.
6. «Динамический расчет сооружений башенного типа на ветровую нагрузку». Мищенко А.В., Немировский Ю.В. - 2009.
7. СНиП 2.09.03-85. Сооружения промышленных предприятий
8. ДСТУ-Н Б В.1.1-27:2010. Будівельна кліматологія.
9. ДБН В.2.6-31:2016. Теплова ізоляція будівель.
10. ДСТУ-Н Б В.1.2-16:2013. Визначення класу наслідків (відповідальності) та категорії складності об'єктів будівництва.
11. «Архітектура будівель та споруд. Книга 1. Основи проектування: Підручник.» - К.: Кондор, - 2011 р.
12. ДБН В1.1-7:2016. Пожежна безпека об'єктів будівництва. Загальні вимоги.
13. СНиП 2.11.01-85*. Складские здания
14. ДБН В.2.6-198:2014. Сталеві конструкції. Норми проектування.
15. «Металеві конструкції. 2-е видання. Підручник». О.О. Нілов, В.О. Пермяков, О.В. Шимановський, С.І. Білик, Л.І. Лавріненко, І.Д. Бєлов, В.О. Володимирський.
16. «Программные комплексы САПФИР и ЛИРА-САПР – основа отечественных ВІМ-технологий». /Укладачі: Барабаш М. С., Медведенко Д. В., Палиенко О. И.
17. ДБН В.2.1-10:2009. Об'єкти будівництва та промислова продукція будівельного призначення. Основи та фундаменти будинків і споруд. Основи та фундаменти споруд. Основні положення проектування.
18. ГОСТ 12.0.003-74 Небезпечні та шкідливі виробничі фактори. Класифікація
19. ГОСТ 12.1.005-88 Загальні санітарно-гігієнічні вимоги до повітря робочої зони
20. НПАОП 0.00-1.15-07 Правила охорони праці під час виконання робіт на висоті

21. ОСТ 6-28-012-86 Роботи вантажно-розвантажувальні. Загальні вимоги безпеки (НПАОП 63.11-7.01-86)
22. ДСТУ 2651:2005 (ГОСТ 380-2005) Сталь вуглецева звичайної якості. Марки. Зміна № 1
23. ст. 3 Закону України "Про оцінку впливу на довкілля"
24. ДБН В.1.2-8:2008. Основні вимоги до будівель і споруд. Безпека життя і здоров’я людини та захист навколишнього природного середовища.
25. ДБН А.2.2-1:2003. Склад і зміст матеріалів оцінки впливів на навколишнє середовище (ОВНС) при проектуванні і будівництві підприємств будинків і споруд.
26. ВНТП-СГіП-46-16.96 Підприємства автомобільного транспорту і автотранспорті підприємства АПК України
27. ДБН А.2.1-1:2014. Вишукування, проектування і територіальна діяльність. Вишукування. Інженерні вишукування для будівництва.
28. ДБН В.1.2-14:2018. Загальні принципи забезпечення надійності та конструктивної безпеки будівель і споруд.
29. ДБН В.1.1-45:2017. Будівлі і споруди в складних інженерно-геологічних умовах. Загальні положення.
30. ДБН А.3.2-2:2009. Охорона праці і промислова безпека у будівництві.
31. ДСТУ Б В.2.8-43:2011. Огородження інвентарні будівельних майданчиків та ділянок виконання будівельно-монтажних робіт.
32. ДСТУ 3789:2015. Пожежна безпека. Піноутворювачі загального призначення для гасіння пожеж. Загальні технічні вимоги і методи випробовування.
33. НАПБ А.01.001-2014. Правила пожежної безпеки в Україні.
34. Кодекс цивільного захисту України від 02.10.2012 №5403-VI.
35. ДСТУ Б В.1.2-3:2006. Система забезпечення надійності та безпеки будівельних об’єктів. Прогини і переміщення. Вимоги проектування.
36. «Расчет сооружений на сейсмические воздействия и ветровую нагрузку с пульсационной составляющей»: учеб. пособие / А. Н. Куликов ; Волгогр. гос. архит.-строит. ун-т ;.
37. «Архитектурные конструкции. Книга 2. Архитектурные конструкции многоэтажных зданий» - Дыховичный Ю.А., Казбек-Казиев З.А., Даумова Р.И. – 2005.

APPENDIX A