Lecture Notes in Civil Engineering

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Proceedings of the 4th International Conference on Building Innovations

ICBI 2022

Springer

Lecture Notes in Civil Engineering

Volume 299

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ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-3-031-17384-4 ISBN 978-3-031-17385-1 (eBook)
https://doi.org/10.1007/978-3-031-17385-1

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The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Abbreviations

CDPSs	Computer data processing systems
CGS	Credit guarantee schemes
Composite-PSD	Composite plastic stress distribution (about method)
Composite-SC	Composite strain compatibility (about method)
CPSIED	Computer processing systems integer economic data
FE	Finite element
FEM	Finite element method
FIs	Financial institutions
GDP	Gross domestic product
ICT	Information and communication technologies
IDS	Intrusion detection system
IPS	Intrusion prevention system
IT	Information technologies
LAN	Local area network
MA	Machine arithmetic
MCGF	«Mortgage and Credit Guarantee Fund of the Republic of Azerbaijan»
PC	Personal computer
PCG	Partial Credit Guarantee Schemes
PD	Probability of default
RC	Reinforced concrete
SCE	Soil-cement element
SCP	Soil-cement pile
SMEs	Small and medium sized enterprises
SRC	Steel-reinforced concrete
SSS	Stress-strain state
WAN	Wide area network

Constructions and Building Materials. Structural Mechanics

Design Features of Polypropylene Heating Mats and Prospects Their Applying

Samira Akbarova and Alina Zyhun

Abstract Despite the abundance of fuel and energy resources, Azerbaijan is currently grappling with the issue of how to use them rationally. Buildings and structures spend the most part of the final energy- 45%, and heating systems utilize the most energy in buildings (21% of 45%), highlighting the enormous potential for improving the energy efficiency of buildings, particularly the heating system. Low-temperature radiant heating, or the transfer of heat energy through radiation, is efficient and energy-saving heating system. Radiant heating is a viable replacement for convection heating. The design elements of a ceiling heating system employing polypropylene heating mats are discussed in this study, a method for calculating and developing this system, as well as the benefits of application and barriers to use in Azerbaijan. Polypropylene heating mats will save nearly twice as much energy for heating buildings as standard convection heating systems. Polypropylene heating mats also have certain unique characteristics in terms of comfort, energy efficiency, and ergonomics. Further research in this direction will remove the current roadblocks.

Keywords Radiant heating systems · Polypropylene heating mats · Radiation heat transfer · Energy efficient buildings · Surface design temperature of the mats

1 Introduction

Despite the sufficiency of fuel and energy resources, the problem of their rational use is currently relevant in Azerbaijan. Most of the country's final energy consumption comes from the construction industry, so improving the energy-saving and energy efficiency of buildings requires optimal innovative solutions [1]. Energy consumption

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_1

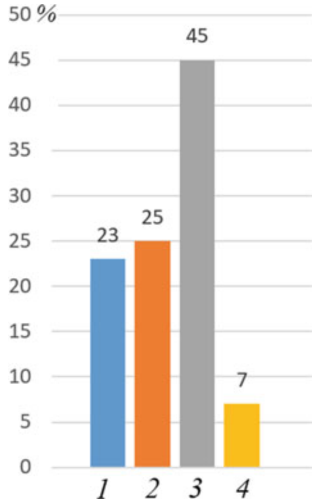

Fig. 1 Major energy consumers in Azerbaijan: 1–buildings, 2–industry, 3–transportation, 4–others [2]

between the main sectors in Azerbaijan is shown in Fig. 1. As can be seen from the graph, buildings and structures are the main energy consumers and the largest amount of energy consumed in buildings is used by heating systems–21% from 45% [2], which emphasizes the huge potential for increasing the energy efficiency of buildings, and in particular heating systems.

Traditional convective heating systems have been shown in practice to be ineffective in heating certain types of buildings, such as [3, 4]:

- premise for occasional and short-term use;
- premise with partially used area;
- premise with significant height;
- premise away from heating networks and boiler houses.

Radiant heating, or the transmission of thermal energy through radiation, is the most efficient and cost-effective method in these situations [5]. A successful alternative to airborne heating and hydronic convective heating is the radiant hydronic heating system [6]. Heating with polypropylene heating mats (PHM) is one type of radiant heating. Heating and cooling are both possible with polypropylene heating mats. They are quite popular in Europe as well as the rest of the world. Unfortunately, in Azerbaijan, this is not the case. The main reason for this is the lack of knowledge of the physical principle of the process of space heating by utilizing of heating mats in local climatic conditions [6, 7] and the lack of experience in their use.

The main reasons for the lack of practice in using these systems are:

- the lack of sufficient information regarding their characteristics;
- necessity of a specific methodology for calculating the need for thermal energy for heating [8];
- necessity engineering justifications for the best options for mats‘ layouts and so on.

Designing radiant heating with polypropylene mats is more difficult than convective heating since many factors must be taken into account that affects the thermal comfort of a person in the thermal comfort zone. And besides, the existing methods for determining the heat demand for space heating are not suitable for designing radiant heating systems. The use of this heating system is indicated and more widely considered in [9–11].

The design elements of a ceiling heating system employing polypropylene heating mats are discussed in this study, as well as a method for calculating this system is proposed, as well as the benefits of application and barriers to use in Azerbaijan are analyzed.

2 Methods and Materials

2.1 Design Features of the Polypropylene Heating Mats

To assess the technical parameters of the heating system with polypropylene heating mats it is necessary to [12]:

- compute the total heat load;
- explore the radiant energy distribution over the surfaces of the objects in the premise;
- calculate the number of mats.

Figure 2 shows the major parts of a heating system with polypropylene mats. It is a low-temperature system, where the water has a temperature of 35–55 °C. As a heat generator can be used heat pumps, condensing boilers, wood pellet boilers, and so forth. The main principle of operation of such a heating system is to transfer heat to surrounding structures and objects by radiation [13, 14]. It should be noted that ceiling heating using polypropylene mats makes it possible to achieve a comfortable and even microclimate in the premise (Fig. 3), saving up to 40% of energy at similar temperature conditions to traditional heating by radiators. Air temperature distribution in the premise for ceiling heating with PHM is close to an ideal one.

2.2 Calculation Example of the Radiant Heating System with Polypropylene Mats

The calculation of this system includes the determination of the heat transfer power of the mats [17–22]. Baku has his first experience of using polypropylene mats in the classroom of the university. In this room, the outer wall with windows of a large area faces north. It is necessary to calculate the area of mats for a given room and analyze the efficiency of the heating system.

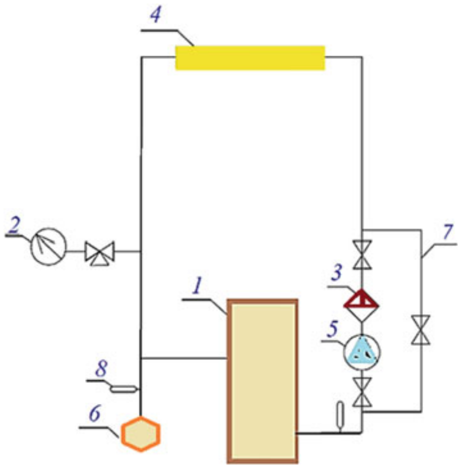

Fig. 2 Functional parts of radiant heating system: 1–boiler- heat generator; 2–hot water meter; 3–filter; 4–polypropylene heating mat on the ceiling; 5–circulation pump; 6–expansion tank; 7–bypass; 8–thermometer [15]

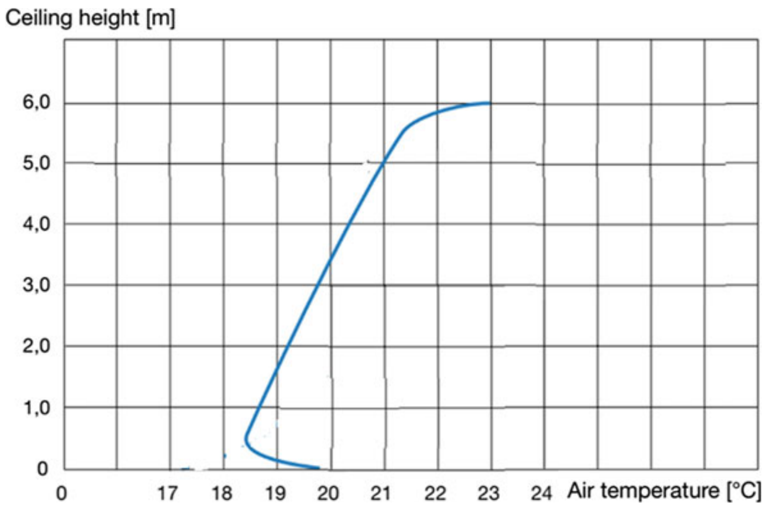

Fig. 3 Vertical air temperature profile for ceiling heating with polypropylene heating mats [16]

Description of the research object. The room is furnished with tables and chairs. In the upper part of the outer wall facing north, there are windows with a large area. Under the windows, there are two sectional aluminum radiators. Polypropylene mats are installed on the ceiling. When heating the premises, heated water from the centralized boiler house is supplied through the heat exchanger to the radiator heating system, then from the nearest radiator, the heated water enters the distribution manifolds of heating mats. Heat is transferred to the room due to radiant heat exchange, so a comfortable microclimate is created in the room. The following input data of polypropylene heating mats are assumed (Table 1). Tables 2 and 3 show the geometric dimensions of the classroom and the design indicators of indoor air and climate properly.

The average temperature of the internal surfaces of external structures of the building is determined by the formula [17]:

Table 1 Main geometric and thermal-technical characteristics of polypropylene heating mats

Input data	Indicators	Values and unit of measurement
Geometric dimensions of mats and their emission factors	Capillary diameter	3.4 mm
	Capillary thickness	0.55 mm
	Diameter of supply and return water collectors	20 mm
	The thickness of supply and return water collectors	2.0 mm
	Distance between capillary tubes	20 mm
	Emission factor for walls	0.9
	Emission factor for windows	0.94
	Emission factor for ceiling mats	0.95
	Installation height of mats	4.5 m
Thermal characteristics of mats	The temperature of the supplied heated water	34–50 °C
	Temperature of the return warm water temperature	25–28 °C
	For these temperatures the thermal power of the system according to the manufacturer's catalog	$52-70\,\frac{W}{m^2}$

Table 2 The geometric dimensions of the classroom

No	Indicators	Unit of measurement and values
1	Length	L = 5.7 m
2	Width	H = 4.5 m
3	Height	H = 4.5 m
4	Ceiling and floor area	27.65 m^2
5	Area of the windows on the outer wall, oriented to the north	$F_w = 3.0 \times 1.5 = 4.5\ m^2$

Table 3 The design indicators of indoor air and climate [7]

No	Indicators	Unit of measurement and values
1	Design air temperature in the classroom	20 °C
2	Average temperature of the coldest five-day period (with a probability of 0.92)	$t_{out} = -4$ °C
3	Average temperature of the heating period	$t_{out.\ av.} = 5.1$ °C
4	Duration of the heating period for Baku	z = 112 days
5	Average wind speed for a heating period with an average daily air temperature ≤8 °C	v = 9.5 m / s
6	Humidity regime in premises for Baku	Normal

$$T_R^o = \frac{\sum (F_{i.s.} \cdot T_{i.s.})}{\sum F_{i.s.}},\ ^\circ\mathrm{C} \tag{1}$$

$T_{i.s.}$–temperature of internal surfaces of the external walls and windows, °C;
$F_{i.s.}$–surface area of external walls and windows, m^2.
The required area of polypropylene mats is calculated by the formula [15]:

$$F_m = \frac{\left(T_R^R - T_R^o\right)}{T_m - T_R^R} \cdot \sum F_{i.s.} \tag{2}$$

T_R^R–air radiant temperature in the room with heating mats can be defined according to Fig. 3;
$\sum F_{i.s.}$–the total surface area of the internal structures, m^2;
T_m–average temperature on the surface of the mats facing the room, °C;
T_R^o–radiant air temperature in the room, °C.
Design parameters for the heating system of the studied classroom concerning Eq. (1) are given in Table 4 (Fig. 4).

Table 4 Estimated parameters for the heating system of the studied classroom

Structure name	Internal surface temperature of the room structures, $T_{i.s.}$°C	Surface area of structures, $F_{i.s.}$ m^2	$T_{i.s.} \cdot F_{i.s.}$
Internal walls	18	66.15	1190.7
2 windows	11	4.55	50.05
External wall	16	21.15	338.4
Ceiling	20	27.65	553
Floor	17	27.65	470.05
		Σ147.15	Σ2602.2

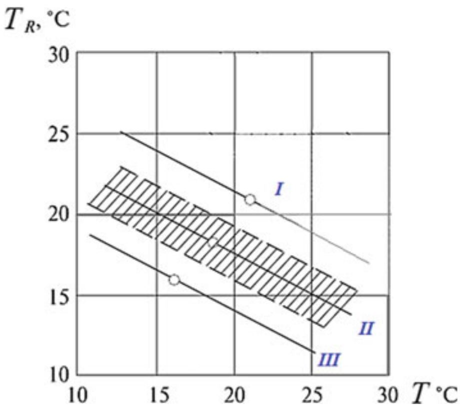

Fig. 4 Dependence radiant air temperature on room air temperature due to kind of the human activity: I–light work, II–moderate work, III–hard physical work [18]

3 Results

According to Eq. (1) and by using indicators from Table 4 the radiation temperature of the room air is calculated:

$$T_R^o = \frac{\sum (T_{i.s.} \cdot F_{i.s.})}{\sum T_{i.s.}} = \frac{2602.2}{147.15} = 17.68^\circ\text{C} \tag{3}$$

According to Fig. 3 it should be determined the radiant air temperature taking into account that the air temperature of the premise must satisfy the condition [15] (Table 5).

$$T_R^R < T_{air} \tag{4}$$

The required area of polypropylene heating mats for a given premise can be used by Eq. 2:

Table 5 Estimated parameters for the heating system of the studied classroom

No	Design parameters	Designation	Indicators
1	Average temperature on the surface of the mats facing the room	$T_m^{'}$	34-39 °C
2	Air radiant temperature in the room with heating mats according to Fig. 3	T_R^R	19.5 °C
3	Total surface area of the internal structures	$\sum F_{i.s.}$	147.15 m^2
4	Surface design temperature of the mats facing the room	T_m	36.5 °C
5	Radiant air temperature in the room	T_R^o	17.68 °C

$$F_m = \frac{(19.5 - 17.68)}{36.5 - 19.5} \cdot 147.15 = 15.8\ \text{m}^2 \quad (5)$$

According to the calculations, the required area of the heating mats is less than the actual area of the ceiling:

$$15.8 < 27.65\ \text{m}^2 \quad (6)$$

It means, that for heating this premise using heating mats is sufficient.

4 Discussion

The results of calculations correlate with the conclusions of papers [11–16], therefore, the proposed method for calculating a radiant heating system using polypropylene heating mats can be recommended for practical use.

The distinguishing features of modern radiant heating systems regarding their comfort, energy efficiency, and ergonomics are as follows:

- they are a low-temperature heating system;
- they can be used for a round of the year
- they can be used for both heating and cooling;
- heating mats have a laconic design;
- heating mats are easily combined with a lot of finishing materials;
- they do not occupy a lot of space;
- they do not have problems during redevelopment;
- they operate in a silent regime;
- temperature distribution is uniform along with the room height.

The barriers to the use of polypropylene heating mats in Azerbaijan are:

- the production of local equipment for heating mats has not yet been established;
- the presence of complex automation system control;
- lack of experience in designing such systems among local specialists;
- lack of devices for monitoring normalized parameters–actinometers, pyrometers;
- lack of user awareness;
- the relative high cost of the system in comparison with radiator heating.

5 Conclusions

In Azerbaijan, the problem of the energy efficiency of buildings is relevant along with the issues of creating and maintaining a healthy microclimate and the construction industry's environmental friendliness. In comparison to radiator systems, low-temperature radiant heating systems using polypropylene heating mats will lower energy expenses for heating buildings by nearly two times.

And moreover, ensuring the ideal thermal regime of some types of premises, such as those with a large height of 4–6 m, with a partially occupied area or short-term use, is conceivable by means of polypropylene mats. The author recommends the proposed method for calculating the radiant heating system of polypropylene heating mats for the design and application of this system in Azerbaijan. Further research in this direction will eliminate the existing obstacles.

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Investigation of the Moisture Condition of the Outer Wall at the Junction of the Brick Pilasters to the Wall

Yurii Avramenko, Oleg Yurin, Samira Akbarova, Alina Zyhun, and Iryna Zadorozhnikova

Abstract The analysis of the moisture state of the zone of adjacency of the brick pilaster to the wall during its insulation from the inside is performed in this research. Brick pilaster is made of slotted ceramic bricks. The influence of filling the cavities of the slotted brick with cement-sand mortar on the moisture state of the adjacency zone was considered. The moisture state at the incomplete filling of the seam between the pilaster and the wall with cement-sand mortar is considered. The conditions of the beginning of the moisture condensation on the surface of the seam that is not filled with mortar are detected. The variant of a seam filling, in the case of which the condensation zone is the greatest, is revealed. The reasons for the detachment of the pilasters from the wall were identified. The influence of internal insulation on the formation of condensation and ice in the zone of adjacency of the pilaster to the wall is revealed. Methods of improving the moisture condition and eliminating the identifying shortcomings are proposed.

Keywords Pilasters · Partial pressure · Condensation · Exfoliation · Insulation

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_2

1 Introduction

As a result of research of a condition for a house external walls in Poltava peeling of brick pilasters made of slotted ceramic brick from a wall was revealed. The reasons for the peeling could be the lack of a foundation or reinforced concrete slab, built into the walls, under the pilasters, insufficient or poor implementation of communication channels [1–6]. It has also been suggested that incomplete filling of the seam between the pilaster and the wall with cement-sand mortar may affect the wet state of the area where the pilaster adheres to the wall. In the case of condensation in the zone and its transformation into ice (the area of adjacency is in the zone of negative temperatures), it is possible to separate the pilaster from the wall [6–12]. Many works by various authors are devoted to the study of the moisture condition of external enclosing structures.

2 Materials Properties

The basic provisions of the methodology for calculation the indicators of heat resistance and a thermal-moisture mode of enclosing structures are stated in Procopchuk [1].

The authors did not consider the searching for ways to eliminate the above shortcomings, so the research of the moisture state of the zone of adjacency of the pilaster to the wall is relevant.

3 Results

As a result of research of a condition for a house external walls in Poltava peeling of brick pilasters made of slotted ceramic brick from a wall was revealed Fig. 1.

The lack of foundation or reinforced concrete slab to support the pilasters, insufficient or poor execution of the toothing of brick wall could be the reasons for exfoliation.

Exfoliation of the brick pilasters from the wall occurs at the junction of the pilasters to the wall. This is possible if water vapor moving from the indoor air of the house to the outside air condenses in this area. The area in which condensation can occurs is in the negative temperature zone, so the condensing moisture turns into ice. Expanding ice can tear the pilaster from the wall.

Analysis of the moisture state of the zone of adjacency of the pilaster to the wall is performed for the climatic conditions of Poltava in January. Estimated values of temperature and relative humidity of the outside air are taken equal to the average monthly value of January [3]. The estimated scheme of the site is shown in Fig. 2.

Fig. 1 Exfoliation of brick pilasters from the walls

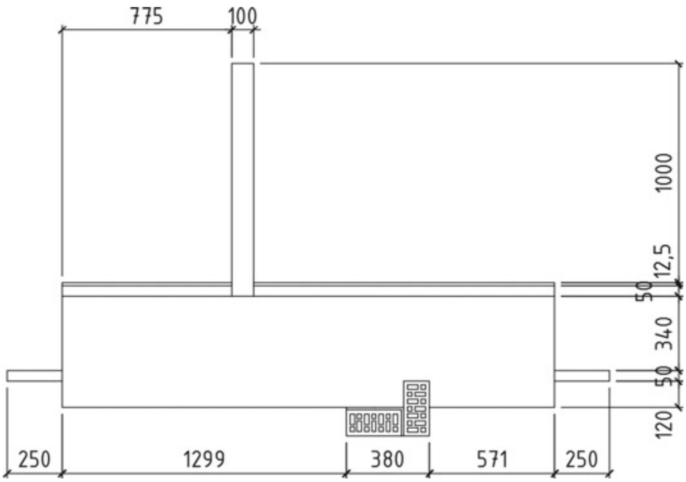

Fig. 2 Scheme of the calculated section

Thickness and thermal conductivity of the layers of the enclosing structure are taken for [2] and are given in Table 1. Numbering of layers runs from the inner surface of the fence.

Table 1 Characteristics of the layers of the enclosing structure

№	Name	Thickness, m	Thermal conductivity, $w/(m \cdot K)$
1	Gypsum plasterboard	0,0125	0,21
2	Mineral wool	0,05	0,048
3	Brick	0,51	0,81

Pilaster is made of dense facing brick.

Estimated indoor air temperature according to Table 2 [2] is $t_{in} = 20$ °C, and relative humidity $\varphi_{in} = 55\%$. The monthly average temperature of the outside air in January in Poltava according to Table 2 [3] is $t_{ex} = -5.6$ °C, and relative humidity according to Table 2 [3] $\varphi_{ex} = 85\%$.

At the beginning of the research, an analysis of the moisture condition is performed under conditions that the entire of the seam between the pilaster and the wall is filled with cement-sand mortar. Cavities in ceramic bricks are not filled with cement-sand mortar.

Table 2 The results of the determination

N	Length of the seam		Condensation area length, mm
	Filled with cement-sand mortar, mm	Not filled with cement-sand mortar, mm	
1	10	250	20
2	20	240	60
3	30	230	80
4	40	220	90
5	50	210	110
6	60	200	110
7	70	190	120
8	80	180	120
9	90	170	120
10	*100*	*160*	*130*
11	110	150	130
12	120	140	120
13	130	130	110
14	140	120	100
15	150	110	90
16	160	100	80
17	170	90	70
18	180	80	60
19	190	70	50
20	200	60	40
21	210	50	30
22	220	40	20
23	230	30	0
24	240	20	0
25	250	10	0

Figure 3 shows the temperature field, and Fig. 4 illustrates field of partial pressure of water vapor in the calculation area. The area in the pilaster on which the peeling occurs is shown in Fig. 5.

The values of the partial pressure of saturated water vapor (*E*) are obtained in the area of the pilaster on which the exfoliation takes place using the temperature field. The graph of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) are shown in Fig. 6.

As can be seen from the graphs in Fig. 6 partial pressure of saturated water vapor in the whole area is greater than the actual water vapor pressure. That is, condensation of water vapor in this area does not occur.

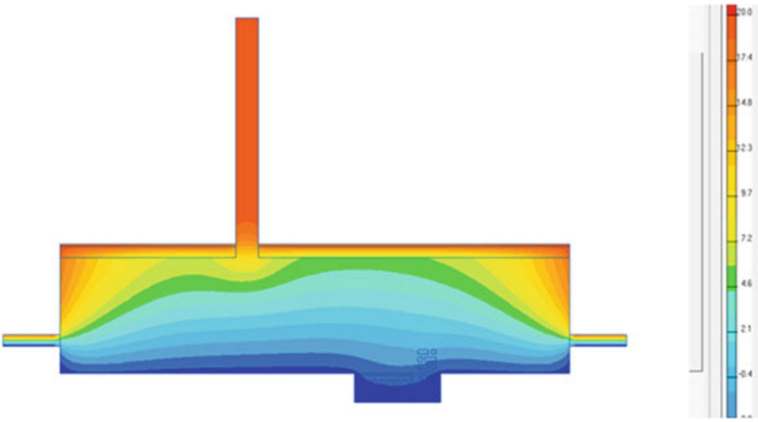

Fig. 3 Temperature field of the calculated area

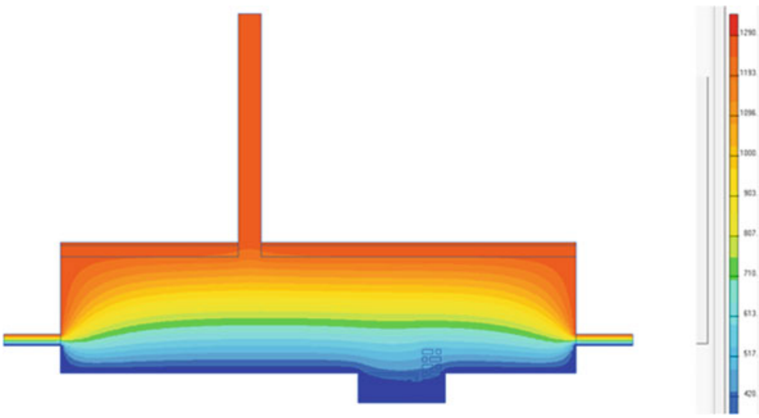

Fig. 4 The field of partial pressure of water vapor in the calculation area

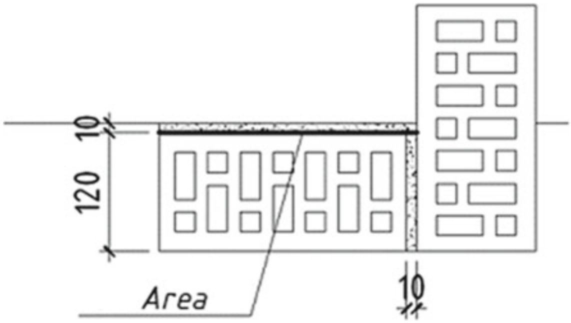

Fig. 5 Area in the pilaster on which the exfoliation takes place

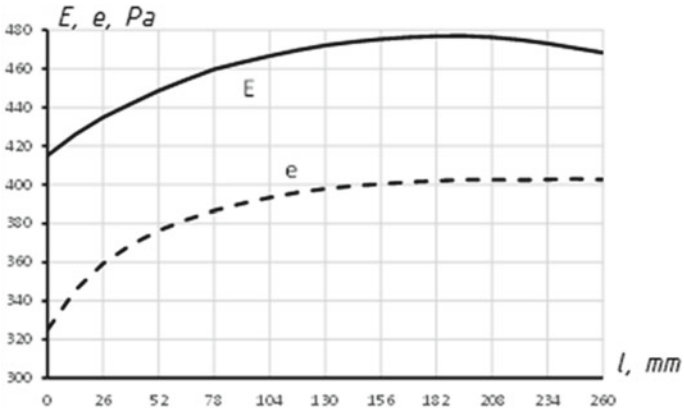

Fig. 6 Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) (cavities in the brick are filled with cement-sand mortar)

Subsequently, the analysis of the moisture state was performed when filling the seam between the pilaster and the wall with cement-sand mortar and the cavities in the ceramic brick were also filled with cement-sand mortar.

Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) are shown in Fig. 7.

As can be seen from the graphs in Fig. 6 the partial pressure of saturated water vapor in the whole area is greater than the actual water vapor pressure. That is, condensation of water vapor in this area does not occur.

Subsequently, the analysis of the moisture state was performed when filling the seam between the pilaster and the wall with cement-sand mortar and the cavities in the ceramic brick are also filled with cement-sand mortar.

Graphs of changes in the partial pressure of saturated water vapor (E) and the actual partial pressure (e) are shown in Fig. 7.

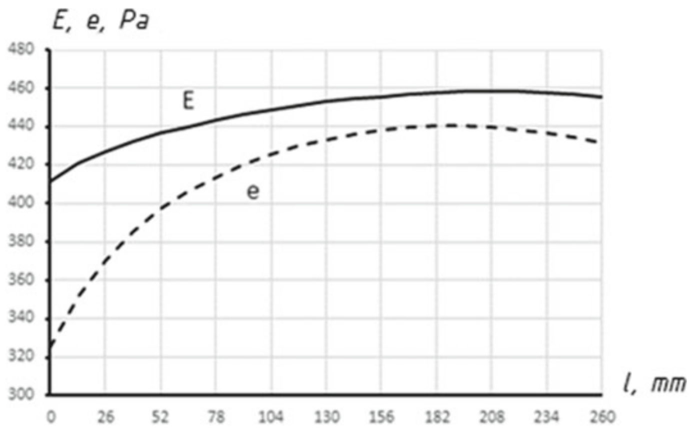

Fig. 7 Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) (cavities in bricks are not filled with cement-sand mortar)

If you compare the graphs in Figs. 6 and 7 it is seen that the distance between the graphs E and e in Fig. 7 less than in Fig. 6. That is, when filling the cavity of the slotted brick with cement-sand mortar, the humidity at the junction of the pilasters to the wall is greater. The probability of water vapor condensation and ice formation is higher. Therefore, the cavity of the slotted brick is taken filled with cement-sand mortar in further research.

After that, the moisture state of the adjacent zone with incomplete filling of the seam between the pilaster and the wall with cement-sand mortar is investigated. Options with filling the seam with cement-sand mortar with a length of 10 mm to 250 mm through 10 mm are considered.

The results of determining the possibility of condensation of water vapor on the surface of the seam unfilled with cement-sand mortar and the length of the condensation area are given in Table 2.

As can be seen from Table 1 condensation of water vapor on the surface of the seam, between the wall and the pilaster, filled with cement-sand mortar occurs at length of cement-sandy solution of 10 mm, and comes to an end at length of 230 mm (Fig. 8).

The maximum length of the condensation area on the surface of the seam not filled with cement-sand mortar is observed at the length of the seam filled with mortar 100 mm. It is 130 mm (Fig. 9).

In this scheme, the amount of ice formation in the area of the seam is not filled with cement-sand mortar, and the probability of separation of the pilasters from the wall is greatest.

The influence of internal insulation on the condensation process is also studied. An option without a layer of insulation on the inside of the wall was considered. Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) on the surface of the seam, with the length of the part filled with

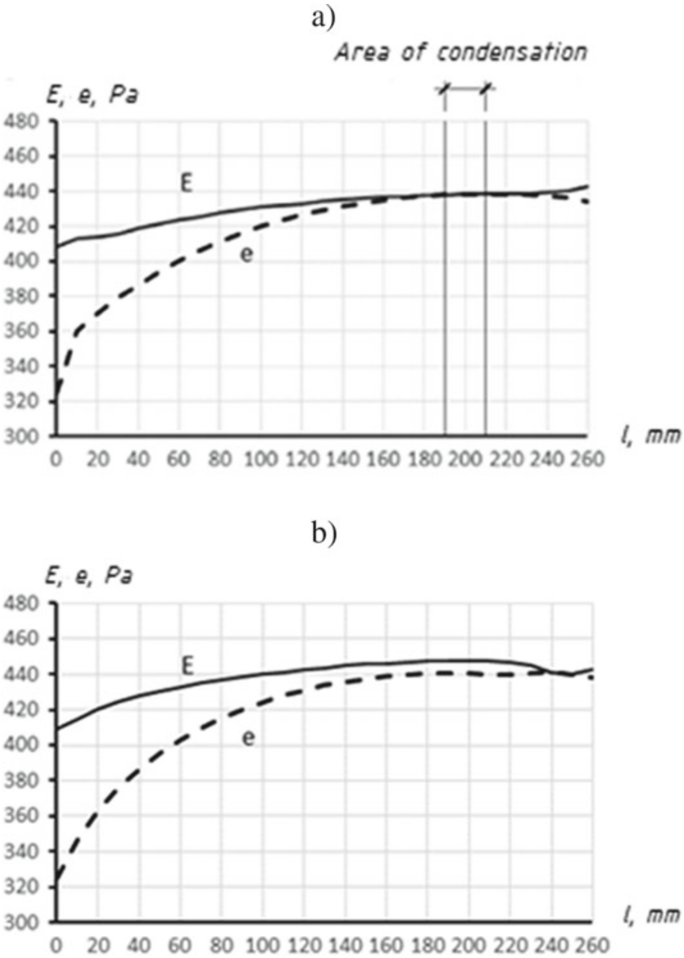

Fig. 8 Schemes at the length of the seam **a** 10 mm, **b** 230 mm

cement-sand mortar equal to 100 mm, are shown in Fig. 10. The length of the seam, which is filled with cement-sand mortar, 100 mm is accepted because it has the largest area of condensation.

The partial pressure of saturated water vapor, as can be seen from the graphs in Fig. 10, along the entire length of the seam is greater than the actual water vapor pressure. That is, condensation of water vapor, in the absence of insulation on the inside, at this length of the seam does not occur.

The influence of additional external insulation (in the presence of internal insulation) on the condensation process is studied. External insulation is made of mineral wool with a density of 125 kg/m^{3}. The thickness of the insulation is 130 mm. The heat transfer resistance was $R_{\Sigma} = 3{,}315\ \text{m}^2 \cdot K/W$ with this insulation.

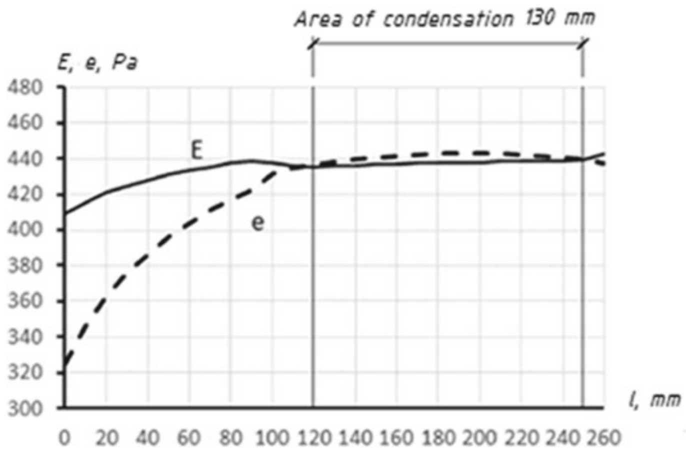

Fig. 9 Scheme in which the condensation area is the largest

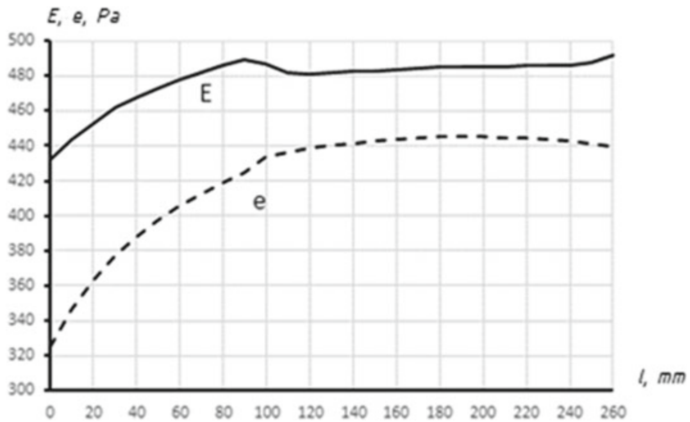

Fig. 10 Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) on the seam surface, (without internal insulation)

Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) on the surface of the seam, with the length of the part filled with cement-sand mortar equal to 100 mm, are shown in Fig. 11. The length of the seam of 100 mm is accepted because the area of condensation is the largest.

As can be seen from the graphs in Fig. 11 the partial pressure of saturated water vapor along the entire length of the seam is greater than the actual water vapor pressure. That is, condensation of water vapor does not occur. Moreover, the area of adjacency of the pilasters to the wall with external insulation is in the zone of positive temperatures. Ice is not formed.

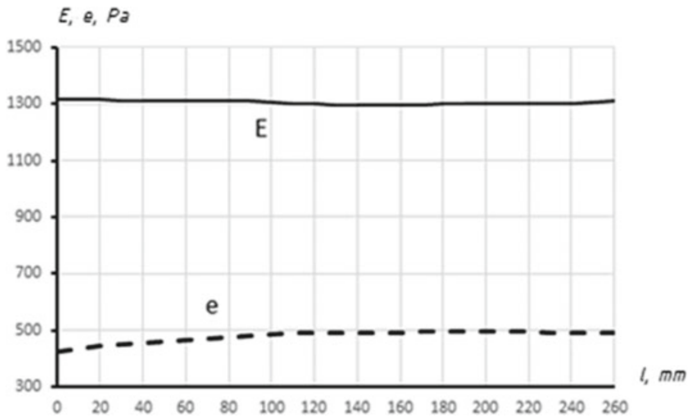

Fig. 11 Graphs of changes in the partial pressure of saturated water vapor (*E*) and the actual partial pressure (*e*) on the seam surface (with internal and external insulation)

4 Conclusions

1. If the seam between the pilaster brick and the wall is not completely filled with cement-sand mortar, condensation of water vapor is possible in the area of the seam where there is no mortar.
2. Condensation is observed when filling the seam with cement-sand mortar 10 mm long (filling the seam from the outer surface of the pilaster), and ends at a length of 230 mm.
3. The air layer is in the region of negative temperatures, so condensable moisture is converted into ice. The expanding ice tears the pilaster from the wall.
4. The reason of condensation is insulation on the inside of the wall with a layer of mineral wool 50 mm thick.
5. Condensation does not occur if the wall have the additional insulation on the outside side.

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Experimental Studies of Compressed Reinforced Concrete Elements with Tape Reinforcement

Volodymyr Byba, Nataliia Pinchuk, and Nurmammad Mammadov

Abstract The results of experimental researches of compressed elements with sheet reinforcement are given. Based on the experiment, conclusions were made about the influence on the bearing capacity of the structural solution (element height, type of reinforcement), the eccentricity of the application of force. Rational methods of frames reinforcement with external reinforcement in the form of sheets allow on the one hand to increase the bearing capacity of the concrete core, creating a volume-stress state, and on the other–more profitable to use reinforcement by changing the static scheme of individual elements or structures. The main task of finding new types of steel and concrete is to achieve the highest technical and economic performance of buildings by using the advantages of each of the components. Reinforced concrete is used in various fields of construction. It is effective in compressed structures (racks, columns), when overlapping buildings and structures (slabs, beams, crossbars).

Keywords Reinforced concrete · Compression · Tape reinforcement

1 Introduction

Reinforced concrete structures occupy an important place in modern construction, which is characterized by the search for new connections between concrete and reinforcement for their rational joint work in building structures. Nowadays, such structures are subject to high reliability requirements with low metal consumption and low labor costs in the manufacture, as well as the use of industrial methods directly on the construction site. Reinforced concrete structures fully meet these requirements.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_3

Rational methods of frames reinforcement with external reinforcement in the form of sheets allow on the one hand to increase the bearing capacity of the concrete core, creating a volume-stress state, and on the other–more profitable to use reinforcement by changing the static scheme of individual elements or structures.

The main task of finding new types of steel and concrete is to achieve the highest technical and economic performance of buildings by using the advantages of each of the components. Reinforced concrete is used in various fields of construction. It is effective in compressed structures (racks, columns), when overlapping buildings and structures (slabs, beams, crossbars).

Common to all structures with external reinforcement is the ability to use reinforcement as formwork. It is rational to use sheet reinforcement in reinforced concrete, the structure in this case receives a smooth metal surface, which performs both a protective and load-bearing function (tanks, foundations for equipment, underground structures), where reliable waterproofing is required. In addition, the sheet fittings during operation are easy to inspect. When using structural elements with sheet reinforcement, the cost of the rod reinforcement is reduced by 40–60%.

Arrangement of reinforcement on the most stressed faces of the load-bearing element allows to increase the working height of the section and get a corresponding increase in strength and rigidity, or reduce the height of the structure–to reduce its cost and complexity during manufacture. In these designs, a clamp effect is created in the core, due to which the longitudinal compressive stresses at the moment of destruction of such an element significantly exceed the prismatic strength. With the use of high-strength reinforcement, the efficiency of reinforced concrete structures is still increasing.

2 Experimental Research of Compressed Reinforced Concrete Elements with Tape Reinforcement

At present, structures with tape reinforcement are sufficiently studied [1]. Their technical and economic efficiency is proved. However, compressed reinforced concrete structures with strip reinforcement have not been studied so far, and therefore the task of studying the strength, load-bearing capacity and stress–strain state of compressed reinforced concrete elements with sheet reinforcement and the development of methods for their calculation is relevant.

Reinforced concrete structures are increasingly used in construction [2]. Our country has accumulated experience in research and use of reinforced concrete in this area. Pipe-concrete constructions, beams and crossbars with sheet reinforcement, complex constructions with internal rigid reinforcement, bar constructions, constructions with profile sheet reinforcement are deeply studied [3, 5]. There are publications on certain types of reinforced concrete structures. As shown by the results of experimental research and implementation practice, they are quite effective and meet all the requirements of economy [4, 6–11].

Given that there are still no general works on steel concrete and universal regulations for their design, the use in the construction of prefabricated and monolithic structures with external sheet reinforcement, requires detailed study of their work in different types of loading.

In order to study the work of compressed reinforced concrete elements with tape reinforcement, the task is to investigate the impact on the load-bearing capacity of the structural solution (element height, type of reinforcement), the eccentricity of the application of force.

2.1 Characteristics of Test Specimens and Test Equipment

Experimental studies were conducted to obtain data on the strength and deformability of reinforced concrete racks with sheet reinforcement. The developed method of conducting experimental research and the design of prototypes met these requirements. As a result, a sufficient amount of experimental material on the operation of centrally and eccentrically compressed reinforced concrete structural elements with sheet reinforcement under load was obtained.

Experimental studies were performed on elements (Fig. 1) with dimensions: cross section 100 × 100 mm, height 400, 800, 1000 mm. The rack consists of longitudinal sheet reinforcement, transverse reinforcement rods, end metal plates and aggregate (concrete).

Samples with a height of 400 mm were also made using additional longitudinal reinforcement Ø12 A 400C and Ø16 A400C, which was welded with a discontinuous seam along the sheet.

In the process of experimental research, longitudinal and transverse deformations were measured at different distances from the edges, as well as the movement of the average height of the cross section of the element. All this made it possible to obtain a complete picture of the work under load of reinforced concrete racks with sheet reinforcement in both central and non-center compression.

Samples with a height of 400 mm are also made using additional longitudinal reinforcement d12 and d16 A240C, which is welded to the sheet.

A 10 mm thick steel sheet is welded at the ends of the compressed elements. The production of reinforcing frames (samples of the СБ series) was carried out by manual electric welding. Production of prototypes was carried out on the basis of a construction company. For the production of prototypes, concrete of strength class B30 was used on small crushed stone (fractions 10–20) of industrial production, made in Poltava. Portland cement M400 was used as a binder.

The elements were concreted in a horizontal position and compacted on a vibrating table. The samples are stored in laboratory conditions at a temperature of +16 –22 C and a relative humidity of 70–75%.

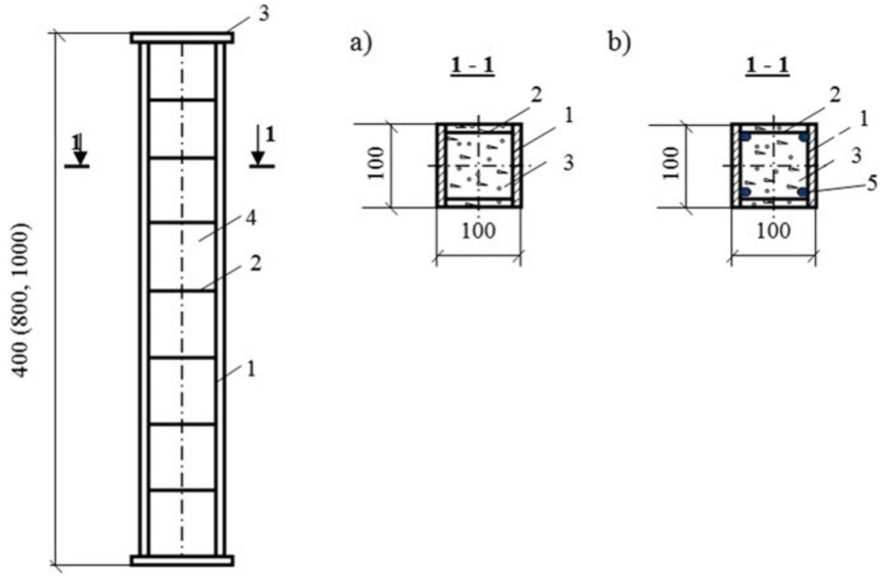

Fig. 1 Scheme of test samples **a**–without longitudinal reinforcement; **b**–with longitudinal reinforcement; 1–longitudinal sheet reinforcement; 2–transverse reinforcement; 3–end metal plates; 4–aggregate (concrete); 5–additional longitudinal reinforcement

Clock-type indicators and electric resistors installed to measure deformations. The samples tested when the design strength of concrete is reached, but not earlier than 28 days after concreting. Before the test, the metal surfaces of the samples well cleaned and varnished 2 times.

3 Results of Experimental Research

3.1 The Change in the Stress State and Its Effect on the Nature of the Destruction of the Test Specimens

The nature of the destruction of reinforced concrete elements with sheet reinforcement during axial compression is influenced by the height of the element, the type of reinforcement and other factors. At relative deformations in samples with sheet reinforcement in the middle section (for short samples), when the longitudinal deformations are equal to the yield strength of the metal ($\varepsilon = 200...300$), a grid in the form of Chernov lines was formed on the paint and varnish coating. Then there was an intensive local bulging of sheet reinforcement with the formation of corrugations perpendicular to the longitudinal axis, in the area between adjacent rows of transverse clamps. The magnitude of the load did not increase, but the destruction continued by increasing the corrugation and breaking the concrete monolith. Concrete was chipped and fell in the direction free from sheet reinforcement.

The above mechanism of destruction is inherent in short centrally compressed samples (l / b = 4). The longitudinal axis of the destroyed samples remained straight. Samples with a height of l/b = 8...10 were destroyed according to another, albeit similar scheme. Common to long specimens is that under the action of load there was a curvature of the longitudinal axis of the test specimen. This led to an uneven distribution of longitudinal deformations in the sheet reinforcement, and accordingly the corrugations were formed on the side opposite to the direction of bending. But none of the centrally compressed specimens failured from the loss of overall stability.

The nature of the destruction of short eccentric reinforced concrete elements with sheet reinforcement depends on the magnitude of the eccentricity. When the eccentricity is in 1/4 of the cross section, the fracture mechanism is close to the fracture of the centrally compressed specimens, but when the loading level of 0.3 of the destructive force is reached, the longitudinal axis begins to bend. It remains distorted until the moment of destruction.

In high eccentrically compressed reinforced concrete elements with sheet reinforcement, the curvature of the longitudinal axis was observed from the first stage of loading and increased until the moment of failure. It occurred due to the formation of corrugations in the most compressed strip of reinforcement and concrete chipping.

It should be noted that after removal of the load, the longitudinal axis in all eccentrically compressed reinforced concrete elements with sheet reinforcement remained distorted and did not return to its original rectilinear state. All the above indicates that the destruction of reinforced concrete elements with sheet reinforcement is not fragile, as in reinforced concrete elements, but on the contrary, when the load reaches a certain level, sheet reinforcement reaches the yield strength of metal, plastic failure begins without reducing the load level.

Thus, it follows from the above that as the limit state for the first group can be considered the moment of reaching the most intense fiber sheet reinforcement of the yield strength of steel, and as the load-bearing capacity to consider the force at which this limit state is reached. The values of the limiting force corresponding to the bearing capacity of the prototypes are shown in Table 1.

Based on the results presented in Table 1, we can conclude that with increasing the height of the sample in 2 times the bearing capacity decreases by 10%; with increasing eccentricity l/b = 1/4 bearing capacity decreases by 10–25%; with increasing reinforcement factor, the load-bearing capacity increases in direct proportion to it.

The nature of deformation of a reinforced concrete element with sheet reinforcement is quite specific. Thus, at the initial stage, the development of longitudinal and transverse deformations in the sheet reinforcement is moderate and proportional to the increase in load. And in concrete there is a fragmentary increase in the increase in deformation from degree to degree of loading.

Figure 2 shows the dependence of relative deformations in concrete and sheet reinforcement on the load for the sample СБ-1-10. The nature of its deformation is typical for centrally compressed specimens tested during the experiment.

Table 1 Characteristics of the studied samples

Sample series	Characteristics of samples	Height L, mm	Eccentricity e_o, mm	Load-bearing capacity, kN
СБ-1-10	Sheet reinforcement filled with concrete	400	0	414
СБ-1-20(А)	Sheet reinforcement filled with concrete	400	25	285
СБ-1-20(Б)	Sheet reinforcement filled with concrete	400	25	375
СБ-1-30(А)	Sheet reinforcement filled with concrete	400	50	275
СБ-1-30(Б)	Sheet reinforcement filled with concrete	400	50	271
СА-1-12	Sheet reinforcement with auxiliary longitudinal reinforcement of class A400C Ø12 mm, filled with concrete	400	0	582
СА-1-16	Sheet reinforcement with auxiliary longitudinal reinforcement of class A400C Ø16 mm, filled with concrete	400	0	850
СС-1-10	Sheet reinforcement, not filled with concrete	400	0	59
СС-2-10	Sheet reinforcement, not filled with concrete	800	0	33
СС-3-10	Sheet reinforcement, not filled with concrete	1000	0	32
СБ-2-10	Sheet reinforcement filled with concrete	800	0	375
СБ-2-20(А)	Sheet reinforcement filled with concrete	800	25	275
СБ-2-20(Б)	Sheet reinforcement filled with concrete	800	25	300
СБ-2-30(А)	Sheet reinforcement filled with concrete	800	50	275
СБ-2-30(Б)	Sheet reinforcement filled with concrete	800	50	250

(continued)

Table 1 (continued)

Sample series	Characteristics of samples	Height L, mm	Eccentricity e_o, mm	Load-bearing capacity, kN
СБ-3-10	Sheet reinforcement filled with concrete	1000	0	375
СБ-3-20(А)	Sheet reinforcement filled with concrete	1000	25	275
СБ-3-20(Б)	Sheet reinforcement filled with concrete	1000	25	275
СБ-2-30(А)	Sheet reinforcement filled with concrete	1000	50	240
СБ-2-30(Б)	Sheet reinforcement filled with concrete	1000	50	215

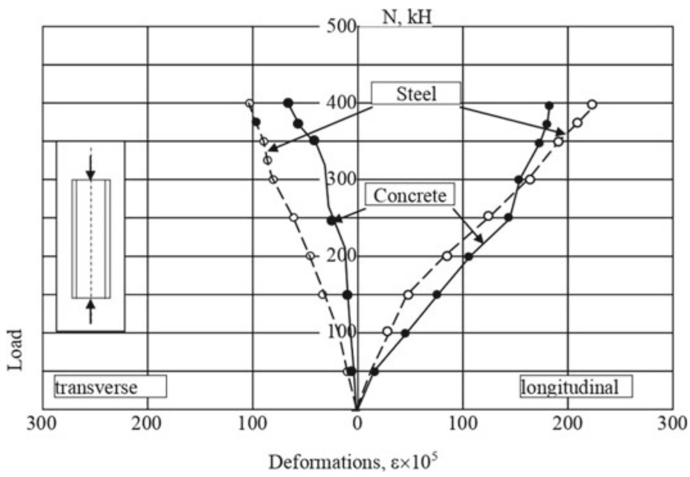

Fig. 2 Dependence of longitudinal and transverse deformations in concrete and sheet reinforcement for the СБ-1-10 sample

Longitudinal deformations of concrete at first increased quite intensively, and then their growth slowed down until the moment of destruction. Transverse deformations in concrete initially increased slowly, and after a load corresponding to 0.7 of the destructive, increased rapidly until the load-bearing capacity was exhausted.

Sheet reinforcement works in a different way. Longitudinal deformations from the beginning to failure increase in proportion to the increase in load, while transverse deformations develop unevenly.

The influence of additional rod reinforcement on the deformability of a reinforced concrete element with sheet reinforcement can be judged from the graphs in Figs. 3 and 4 (samples of the series CA-1-12, CA-1-16).

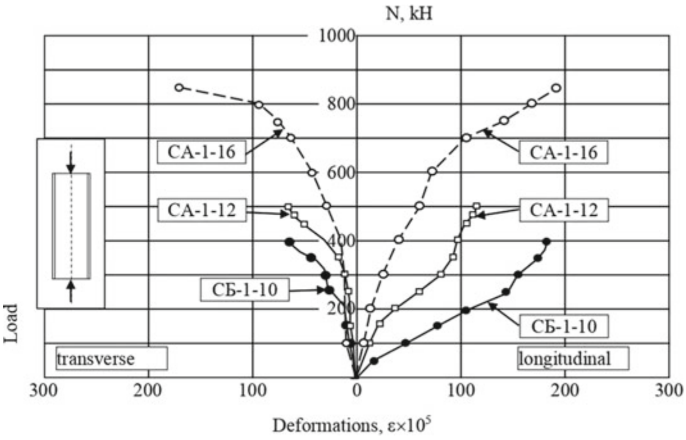

Fig. 3 Dependence of longitudinal and transverse deformations in concrete on load for samples: CБ-1-10, CA-1-12, CA-1-16

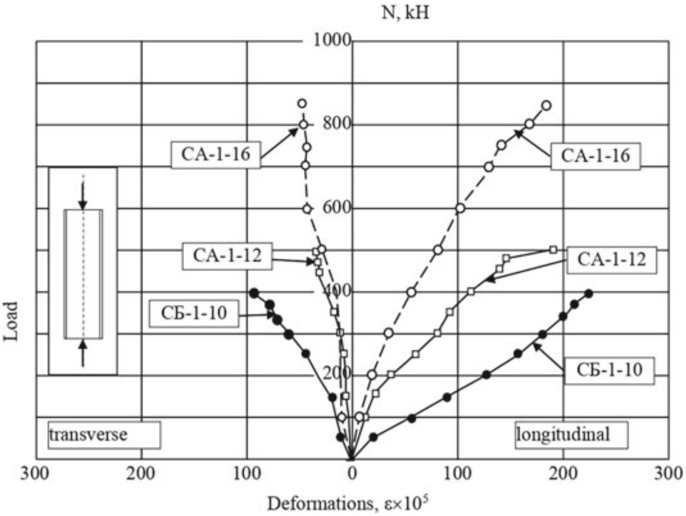

Fig. 4 Dependence of longitudinal and transverse deformations in sheet reinforcement on load for samples: CБ-1-10, CA-1-12, CA-1-16

4 Conclusions

According to the results of the experiment, it was concluded that the bearing capacity of compressed reinforced concrete elements with sheet reinforcement is significantly influenced by the height and eccentricity of the load. The destruction of the reinforced concrete element with sheet reinforcement is due to the achievement of the most intense fiber sheet reinforcement of the yield strength of steel. The introduction of additional rod reinforcement avoids the loss of local stability of sheet reinforcement and increases the load-bearing capacity of the element as a whole by 50–60%.

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Deformation Monitoring of Silos on the Basement, Reinforced with Soil–Cement Elements, Manufactured According to Boring and Mixing Technology

Serhii Bida, Oleksandr Marusych, Mykola Zotsenko, Anna Pavelieva, and Mykola Biloshytskyy

Abstract The construction of a significant number of new facilities takes place on the territories, where geological-engineering conditions are complicated by the presence of man-made soils or soils with special properties, which makes it necessary to reinforce the basement. This problem becomes particularly topical in construction of such structures as grain storage silos that transfer significant loads to the basement. One of the options for reinforcement is the installation of soil–cement elements, manufactured according to boring and mixing technology. Reinforcement of the basement in this way is quite effective due to the applicability of elements of different diameters and lengths, as well as through adequate choice of distance between them. Variation of these parameters allows to perform reinforcement almost in any geological conditions, taking into account the possibility of consolidation of the bases and foundations below the water table. However, designing and operation of the structures, standing on basements, reinforced in this way, requires intensive study of the stress–strain state of the system "foundation bed–reinforced basement", taking into account operational features of such structures. Proper allowance must be made for different degrees of silos loading and cyclic loading and unloading. Investigative research of the deformability of such systems is possible by applying various models of soils and the finite-element method as a mathematical apparatus.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_4

When choosing a model, consideration must be given to such factors as the accuracy of behavioral model of foundation soils and the simplicity of identification of parameters, required for performing calculations. Special attention should also be given to monitoring the development of subsidence of the structures, built on the reinforced basement, taking into account the time factor for comparison with the results obtained analytically.

Keywords Soil–cement elements · Man-made grounds · Loose grounds · Basement reinforcement

1 First Section

Due to the development of the agricultural sector of Ukraine, it has recently become necessary to erect facilities which can ensure longterm storage of grain crops. The solution to this problem is possible through the construction of grain storage silos, which are meant for storing tens and sometimes hundreds of thousands of tons of grain. Such structures wield major influence on the foundation soil, which requires serious land development. Another difficulty of erecting such structures is that the territories, provided for construction, can not be used as agricultural lands and have rough engineering and geological conditions (man-made soils or soils with special properties, flooded areas, etc.). Thus, the problem of a weak base had to be solved during the construction of grain storage silos with diameters of 22 m and 30 m, designed for 10 and 15 thousand tons correspondingly, at the construction facility: "Reconstruction of an integral real property portfolio with the construction of manufacturing and service buildings in the city of Nizhyn, Chernihiv region, Ukraine".

The construction site is located in the southwestern part of Nizhyn. As for geomorphologic characteristics of the territory, this construction site is coordinated with the IV floodplain terrace of the Oster River. Silos foundation is composed of aeolian-deluvial sand clays and argil sand grounds, which are underlain by alluvial clays and sand deposits. In the lot we have discovered one free aquifer, the level of which during the survey (in November of 2017) was recorded at a depth of about 3.0 m below the surface. The aquifer recharge is conducted mainly by influent seepage of atmospheric precipitation. Unloading of the aquifer (water-bearing formation) is carried out into the network of gullies (cloughs) and into the Oster River Valley. However, the larger half the territory is classified as inundated by man-made floods. With multiyear and seasonal fluctuations, the groundwater level (GW level) can rise by 0.5–1 m. Waterproof (impervious) layer up to a depth of 25 m was not detected. It ought to be noted that groundwater level fluctuations, apart from seasonal changes, are subject to years-long cyclicity. Based on long-term observations, the groundwater level (GW level) may not only rise, but also reduce over extended periods, due to natural causes. This process has recently been observed almost on the entire territory of Ukraine. Nonetheless, it remains possible that GW level will rise in future.

Geological-engineering cross-section is represented by the following engineering-geological elements (EGE):

EGE-1—loose soils (man-made grounds), which are a mixture of top soil, argil sand grounds, tree roots, with man-made soils–fragments of structures, construction and manufacturing waste. There may also occur macroporous and compressible soils;

EGE-2—yellow-gray, stratified, poor-porous, plastic sand clays with layers of silt sandy loams, which are free-flowing at full saturation with water;

EGE-3—very soft greenish-gray, light-textured, laminated, low-porous argil sand grounds;

EGE-4—greyish-green, stratified, low-porous, ferruginous, plastic sandy loams;

EGE-5—greyish-green and greenish-gray, tight, aqueous quartz sandstones of intermediate size;

ІГЕ-6—EGE-6—green, laminated, low-porous stiff loams.

Geological-engineering conditions here belong to the second category of difficulty. Geological-engineering cross-section is plotted in Fig. 1.

The basement (footing) of grain storage silos consists of bedplates (foundation slabs) with underground galleries, located in the middle. Since the basis is formed of man-made grounds to a depth of 3.5 m, and below fill-up grounds there are collapsible soils, which, when having saturated with water, fall into the category of "loose soils",

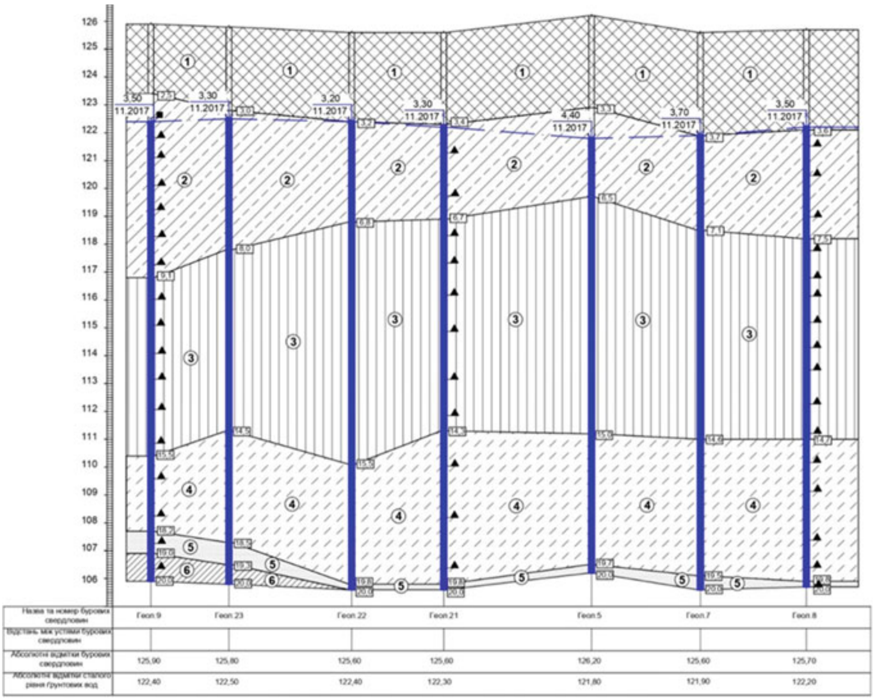

Fig. 1 Geological-engineering cross-section of the construction site

it was decided to perform land development of the site in the form of strengthening the foundation with soil–cement elements (SCE), which are manufactured according to boring and mixing technology [1, 2].

Soil–cement elements (SCE), which are seated under the construction site, have a diameter of 500 mm, a length of 8.0 m and they are located at the intervals of 1.3 × 1.3 m for silos with a diameter of 22 m and at the intervals of 1.2 × 1.2 m–for silos with a diameter of 30 m. Diameter of the elements was determined taking into account the nonuniformity of the loose soil, occurrence of construction debris in the top part of the basement and the size of bedplates (foundation slabs). The length and expansion step of SCE location was chosen from the value of the weighted-average soil deformation modulus within the compressible width (strata), at which the subsidence of silos will not exceed the standard value Su = 15 cm. In order to avoid the destruction of the upper part of soil–cement elements (SCE), it was decided to arrange a damping layer, represented by a layer of crushed stone with the fraction of 20–40 mm and with a thickness of 500 mm. Thus, thanks to soil–cement elements (SCE), it was possible to strengthen the soil column of EGE-1 man-made grounds, of EGE-2 collapsible (loose) soils and to strengthen partially EGE-3. At the maximum loading of silos, the medium pressure value under the foundation base was 200 kPa.

Thus, the foundations of silos are presented in the form of bed plates (foundation slabs) with underground galleries, which are built on the foundations consisting of soil–cement elements (SCE), reinforced with man-made grounds and collapsible (loose) soils (Fig. 2).

The SCE location was performed on the basis of calculations, carried out in order to determine subsidence, which were performed using a model in the form of a linearly deformed half-subspace with the restriction of compressed width (strata) at the level

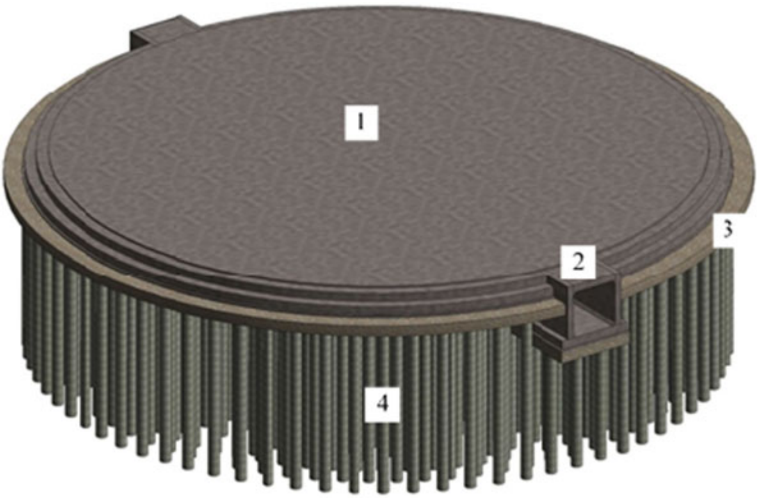

Fig. 2 Structural layout of the foundations of grain storage silos on a reinforced basis: 1–foundation slab; 2–underground gallery; 3–damping layer of crushed stone; 4–soil–cement elements

where the condition σzp = 0,5 σzg was met (where σzp is vertical intensity from external load, and σzg is vertical intensity from the soil's own weight). Enchanced soil was considered as composite material with weighted average characteristics of stiffness and deformability of soils and soil–cement elements.

To assess the change in the stress–strain state of the foundation, consisting of loose soils, which are strengthened with reinforcement by vertical soil–cement elements (SCE), observations of vertical strain (vertical deformations) of grain storage silos were performed throughout their working service. The purpose of monitoring structures is to compare their actual vertical strain (vertical deformations) with the calculated and limit values and to analyze the changes in silos depression/settlement over time depending on their workload, carried out according to the operation practice (cyclic loading–unloading).

Before monitoring, the organization–object owner, handed over to the work performers original reference network points (lubber lines), which corresponded to the II class of measurement accuracy. The location of lubber lines, the type and method of their mounting corresponded to the current regulatory documents. Generally, there were mounted 3 lubber lines.

Deformation control benchmarks for determining vertical displacements were installed on the horizontal faces of the foundations of grain storage silos. These deformation control benchmarks were located taking into account design features of the house footings, dynamic stress availability, the expected values of surface subsidence, the peculiarities of geological-engineering conditions of the object and the most favorable conditions for measuring deformation of structures. The layout chart of deformation control benchmarks is given in Fig. 3.

For reliable fastening of deformation control benchmarks on the horizontal plane they were made of a metal plate 100 × 100 × 6 mm in size, which should be attached to the basement surface with a concrete nail/an impact anchor.

After deformation control benchmarks were installed, their elevation numbers were transferred from the nearest state or local points of vertical control survey

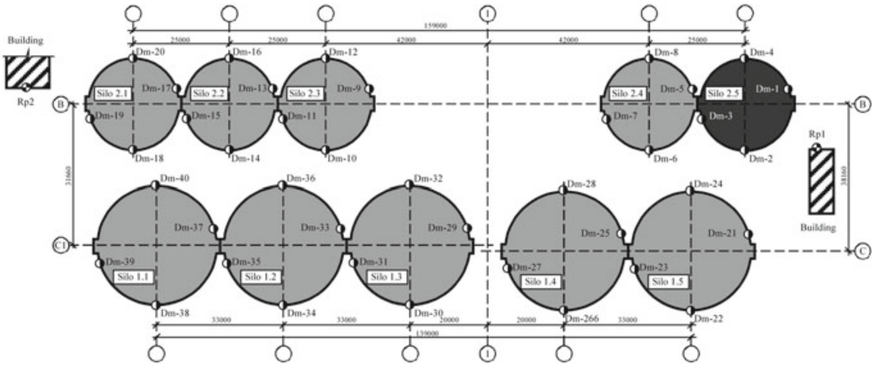

Fig. 3 The layout chart of experimental benchmarks, temporary wall marks and notation conventions

network. As a result of determining precision of measurements, it was found that the permissible error in measuring vertical strain (deformations) during othe running time of structures located on loam soils is 2 mm, with the calculated values of their subsidence up to 50 mm, according to [3–5].

The accuracy class of measuring the movements of structures to be monitored is II.

Vertical displacement of the foundations base of buildings was performed by the method of differential leveling. When carrying out the measurements, we adhered to the measurement tolerances, allowable at differential leveling of the II accuracy class:

– the length of the collimating ray should not exceed 40 m;
– the height of the collimating ray above the hindrance should be not lower than 0.8 m;
– uneven levers (length of sight) at the station should be not more than 0.4 m;
– the accumulation of uneven levers (length of sight) in a closed circuit should not exceed 2.0 m;
– the acceptable misalignment in a closed circuit is (where n is the number of stations); in the absence of the possibility of controlling the uneven levers (length of sight) under the conditions of close-packed arrangement of structures, we have used the short beam method, in which the distance from the station to the leveling boards did not exceed 25 m.

Subsequent to the results of observations, we have constructed dependency diagrams of displacements of deformation control benchmarks depending on loads, and have obtained average deformations of the foundations of grain storage silos (Fig. 4).

The initial readings of all deformation control benchmarks were taken in October 2018. Loading of grain storage silos was begun in 2018. The first cycle of loading the grain storage silo 1.4 began in late November 2018. Thereat the grain storage silo was loaded by 40%, which allowed to avoid the development of significant building tilts. The average subsidence during the first cycle was 16 mm. The maximum difference of vertical displacements of deformation control benchmarks was 20 mm with maximum and minimum displacements of 32 and 12 mm, respectively. The peak load of 100% was in October 2019, which was accompanied by the average subsidence of the silo footing of 41 mm. The estimated value of subsidence was 140 mm.

In order to forecast the value of silos subsidence, we have performed mathematic simulation of the system "foundation bed–reinforced basement" using a discrete model, which allows to obtain more explicit solutions in comparison with other models, as it takes into account the interaction of each individual reinforcement element with the soil. Individual elements of the discrete model under the action of external loading, as in common phenomenological models, are described by the equation of the known model bodies with ideal properties.

Discrete design diagrams of reinforced foundations are usually modeled by the finite element method. In this case, taking into account the work of soil–cement elements can be ensured by the introduction of variable stiffness ratios or modeling

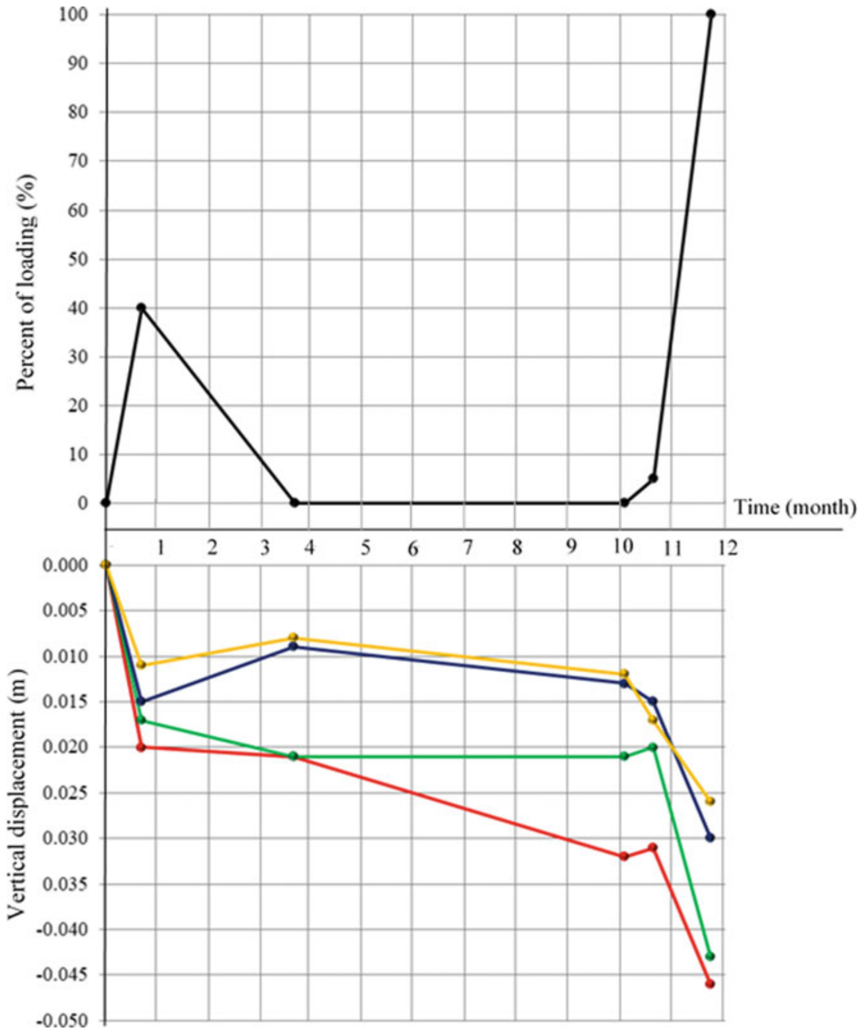

Fig. 4 Dependency diagrams of vertical strain of deformation control benchmarks on loading of a silo 1.4: green color–DCB-25 (deformation control benchmark-25); blue color–DCB-26; orange color–DCB -27; red color–DCB -28

as individual elements of the scheme using rods, plates (plane elastic problem) or solid bodies (three-dimensional problem) [6].

The use of variable bedding values (coefficients of soil reaction) for modeling the reinforced SCE foundation of a bed plate was proposed by V.H. Fedorovskyi. With such numerical calculation, the bedding values (coefficients of soil reaction) determine the stress–strain analysis of the reinforced "cell". This takes into account the nonlinear connection of deformations and stress-strains according to the bilinear

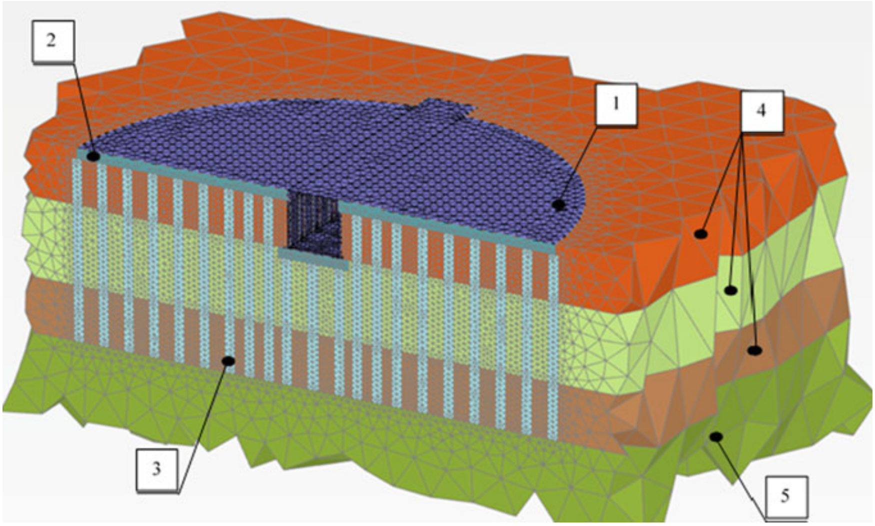

Fig. 5 Modeling of the discrete design model of the reinforced SCE grain storage foundation in the software application "PLAXIS 3D CONNECT Edition V.20": 1–foundation slab of the grain storage; 2–damping layer of crushed stone; 3–soil–cement elements; 4–loose soils to be reinforced, 5–stiff soil

model with reinforcement, displacement of the SCE relating to the soil and extension-type deformation of the surrounding soil.

The combined action of soil–cement elements (SCE) with the soil makes it possible to consider the system "soil-reinforcing elements" as a slab-pile foundation, in which the pile undertakes part of the pressure, and the rest of the pressure is undertaken by the soil. This approach to the calculation of reinforced foundations was proposed by Horikoshi and Randolph in 1999 and improved by the scientists Han in 2009 [7].

The design model of the system is presented in Fig. 5.

To this date, the models of linearly deformed half-subspace (layer-by-layer compaction or banded precipitation) prevail over mathematical method of designing the foundations, reinforced with soil–cement elements. The principle of calculation of house footings on the reinforced foundation by the method of layer-by-layer compaction of foundations provides for the usage of its weight-average mechanical parameters, which, in turn, are determined by the ratio of bank yard and reinforcement material in the total volume of the foundation. The disadvantages of these models are: overestimation of the foundations distribution properties, weak substantiation of the limitation of the bulb of pressure, and for the model of a linearly deformed layer–the necessity for a stiff layer at shallow depths.

The peculiarity of soils is their plastic (rather than elastic) deformation, that is impossibility of the foundation transition into the initial state after its unloading. This is due to the fact that when the limit of proportionality between stresses and strains is reached, the soil becomes plastic. This soil property is taken into account in linearly deformed models by means of increasing the design resistance by 20%. However, the creation of a universal model, that would take into account the simultaneous action of elastic and plastic deformations is complicated by the introduction of a significant number of parameters, because in this case it is impossible to perform analytical calculations.

The most common model, used in the calculations of foundations performed by the finite element method is Mohr–Coulomb (hereinafter MC) model, primarily due to the sufficiency of standard mechanical parameters of soils: Young's modulus E, strength parameters (angle of internal friction φ and specific cohesion c), which are determined based on the results of standard laboratory investigations of soils [8, 9]. However, this model does not take into account the strengthening/consolidation of the bases and foundations, and when it is unloaded, the recovery of deformations (the so-called elastic component of strain) significantly exceeds their actual values and etc.

The main dependence of the above mentioned model is the state-transition diagram of the ideal elastic–plastic body, introduced by Ludwig Prandtl, which is characterized by elastic work to the limit of proportionality of stress to strain, and after its achievement–by infinite increase in plastic deformation at constant stress rate. The total ground distortion is the sum of its elastic and plastic components. In this case, its elastic behavior is described according to Hooke law, while its plastic behavior–according to the associated plastic flow rule. The soil works as an elastic body until the pressure mounts the boundary surface, which should be described by the Mohr–Coulomb failure criterion, and after going beyond the boundary surface, the soil is infinitely deformed at a constant stress value.

For more realistic modeling of soil behavior, it is recommended to use progressive mathematical models. Among such models it is worth noting the models of isotropic hardening "The Hardening Soil", "The Hardening Soil Small" and "Soft Soil" [1, 10–19].

The main difference between the model of isotropic hardening and Mohr–Coulomb elastic–plastic model is strengthening of the foundation soil, which becomes apparent in the change of the boundary surface position in the space of primary stresses.

These models combine two types of hardening: soil shear and soil compaction. The first is caused mainly by the stress deviator, and the second–by compression. These models are suitable for modeling the behavior of different types of soils, including loose soils ("Soft Soil" model). When the load is beyond the soil's elastic behavior, there may develop nonrestorable plastic deformations and the deformation modulus e decreases as well as. Such advanced models use the basics of the plastic collapse theory, not the elasticity theory.

However, the use of progressive models of elastic–plastic behavior of foundations requires the introduction of additional parameters of soil characteristics, which can not always be provided in the technical reports of engineering and geological surveys. In such cases, the calculation data on these models are approximate and not accurate.

The effectiveness of strengthening the foundations of soil–cement elements, manufactured by wet process according to boring and mixing technology is confirmed by the results of field studies of deformations of the silos foundations. All actual subsidence of the foundations did not exceed 30% of the maximum allowable Su = 15 $см^2$ At the same time, building tilts that were witnessed in the silos were minimal and did not exceed the allowable value of 0.002%.

2 Conclusion

Based on the results of the research, we have arrived at the following conclusions:

1. The results of field studies of deformations of grain storage silos confirm the effectiveness of reinforcement of man-made ground and collapsible soils by their reinforcement with soil–cement elements (SCE), manufactured by wet process according to boring and mixing technology. It should be noted that the actual results of silos subsidence are much lower than expected (calculation) results. The average calculated subsidence value of silo foundations is Sp = 12 cm when using the Linear Elastic model and Sp = 14,5 cm when using the Mohr Coulomb model. The maximum actual silos subsidences were Sф = 4,5 cm
2. In order to more accurately reflect the behavior of the reinforced foundation soil of structures that accept cyclic loading, it is recommended to use advanced mathematical models of soils that take into account isotropic hardening (eg “The Hardening Soil”, “The Hardening Soil Small” and, in cases of loose soils–“Soft Soil”). However, the use of advanced models of elastic–plastic behavior of foundations requires the introduction of additional parameters of soil characteristics, which can not always be provided in the technical reports of engineering and geological surveys. In such cases, the calculation data on these models are approximate and not accurate.
3. Designing and construction of house footing on man-made ground requires more detailed engineering and geological surveys. In such a case, it is recommended to coordinate the program of additional technical studies with the design organization that will work out the project of measures for land development.
4. In the absence of data in engineering and geological surveys on the physical and mechanical characteristics of man-made grounds on the construction site, it is recommended to choose the variant of mathematical formulation of soil behavior, which requires a minimum number of initial characteristics. For example, in the analytical calculation by the method of multilayer consolidation using the model of linearly deformed half-subspace with conditional restriction of compressed width (strata), it is necessary to have information on soil density and its deformation modulus. In the case of using finite-element method, the mathematical model Linear Elastic reflects the elastic behavior of the soil and in addition to the deformation modulus of the man-made ground and its density, requires the introduction of the Poisson ratio. To take into account the most unfavorable factors,

the soil density and its deformation modulus of the man-made ground should be chosen as the minimum allowable.

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Adhesion of the Metal and Composite Fiberglass Rebar with the Heavyweight Concrete

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Abstract Since the adhesion of reinforcement to concrete is the main factor of their joint operation, and the studies of fiber-glass composite bars with concrete are obviously insufficient despite the growth in their use in road and housing construction, an analysis was conducted to compare the adhesion between metal and fiber-glass reinforcement with heavy-weight concrete by the beam method. The adhesion forces create a complex stress–strain condition in the concrete adjacent to reinforcement bars. Such condition results in distribution of stresses along the reinforcement axis, so that the longitudinal forces on the reinforcement become variable along the entire bar length. It has been experimentally proven that as the stress on the concrete beam is increasing in the areas of contact between the reinforcement and concrete, shear stresses are observed to be shifting from the starting points towards the end ones within the anchoring area; and for metal reinforcement, the shear stresses are less than for glass composite. It has been determined that the adhesion stress between glass-fiber reinforcement and concrete is significantly higher than steel reinforcement.

Keywords Metal reinforcement · Fiber-glass composite reinforcement · Heavy-weight concrete · Adhesion between reinforcement and concrete · Beam method RILEM-CEB-FIP · Shear stresses · Tension gauges

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_5

1 Introduction

Year by year, the interest to using composite reinforcement in supporting construction designs of buildings and structures is growing. It is predetermined by its improved corrosion resistance, high tensile strength, viscoelasticity nature of relative elongation over the entire range of stresses, small values of elongation at rupture (0.5–3.0%), thermal expansion coefficient close to concrete, low specific gravity, high chemical resistance, including resistance to alkalis, as well as magnetic inertness, dielectric properties, radio transparency and low heat transfer coefficient (100 times less than steel) [1, 2]. FRP strength corresponds to the class steel reinforcement Am-IV, at the same time characterized by low modulus values (3.5 times), LTEC (2.5 times) and elongation (4–5 times) [3]. In the works [4, 5] it has been proved that for the metal rebar with diameter of 16 mm the tangential stresses of the reinforcement and concrete bonding are 9.4% less than for the fiberglass reinforcement with diameter of 10 mm.

Despite the above advantages, composite reinforcement has some disadvantages: as compared to steel reinforcement, 4 times lower modulus of elasticity [6], brittleness at failure (absent fluidity limit), anisotropic properties of the material (low values of ultimate shear strength and axial compression), low fire resistance (up to 100 °C) and slight water absorption, which can lead to a loss of structures strength over time. To prevent water absorption, it is possible to treat composite rods with special substances, for example, "SILOL®" made in Ukraine, which also contributes to a significant increase in the adhesion of rods with concrete [7].

In most cases, glass-fiber and basalt composite reinforcement is used in erection (repair) of infrastructure facilities in road [8, 9], hydraulic engineering and geotechnical construction [10]: for reinforcement of slabs on distributed bases, basements of buildings and structures, as well as for reinforced concrete structures which are not subject to fire resistance requirements. To extend the scope of using composite reinforcement, it is conduct major studies and comparisons with the traditional metal reinforcement. In the researches [11, 12] it was found that the carrying capacity of beams with composite reinforcement (depending on the diameter of the rods) is 1.5 times higher and more than of beams with metal reinforcement. In almost all tests it was found that the outer shell of composite rebar works most efficiently, while the core–composite fibers–work within the limits of 10…15% by volume.

More and more scientists are currently dealing with issues of composite reinforcement functioning in flexural elements. Such research works may be divided into two groups: concrete elements reinforced exceptionally with composited fiberglass rebar FRP (AKC), and elements with combined reinforcement [13, 14]. It has been carried out the comparison of the considered methods of calculation in USA, European Union, Russia and Ukraine and it has been defined that under-estimating of calculated resistance to tension of FRP that leads to inaccurate definition of fracture character of a bending element and construction over-reinforcing up to 50% [15, 16]. The improved methods of calculation are offered [17–19], that allows to estimate

Fig. 1 Types of composite rebar

more accurately and reliably the fracture character of elements and to define breaking forces.

The adhesion between the reinforcement and concrete is an important property of reinforced concrete which determines its supporting capacity, rigidity and crack resistance, and it depends on a great number of factors, such as concrete strength, reinforcement type and diameter, the length of making bars into concrete, the nature of loads, hardening conditions, the location of bars during concreting, etc. Due to these, that at different parameters of die-rolled section [20–23] the composite reinforcement of different manufacturers (Fig. 1) will have different adhesion characteristics with concrete [24–29].

The joint operation of composite rods with concrete is ensured by the adhesion of the cement with epoxide coating rather than by mechanical interlocking of the coils in the concrete matrix, as opposed to die-rolled section metal rods. The arrangement of the die-rolled section by means of a sticking the impregnated binder bundle made of composite fibers is inexpedient, as this winding is cut from the surface of the rod at pulling, and the adhesion of concrete to the epoxy coating exceeds the cohesive strength of concrete and is sufficient to anchor the rods in it. It is more appropriate to die-roll the core itself by "crimping" it with a thin bundle in 1–2 steps of the core diameter. This increases the specific area of contact with concrete, improves the conditions of joint work of the composite with concrete under load, which will more fully realize the strength properties of the reinforcement when working in the supporting structure [30, 31].

The peculiarity of interaction between reinforcement and concrete is the presence of mutual displacements between them, resulting in a redistribution of forces. The areas in which the redistribution of forces is observed are called reinforcement anchoring zones. This issue is well known for reinforced concrete, but for composite reinforcement is almost not studied, despite its wide application in construction. It follows from the stated above that nowadays there is an urgent need for researches of composite reinforcement bonding with concrete and improvement of calculation methods and anchoring on the basis of experimental research results and comparison with metal reinforcement.

2 Methods

2.1 Structure of Test Specimens and Their Manufacturing Materials

The experimental research program provides for the testing of three BMR beams (a beam with metal reinforcement of sickle profile) and three BCR (beam with glass-composite reinforcement manufactured by LLC "Ekibazh" Technology Group) (Fig. 2). Test beams with a total length of 1230 mm made of concrete class C20/25 of rectangular cross-sectional size 120 × 220 mm and consist of two halves that are connected in a stretched area by a reinforcing bar.

The diameters of the rebars are adopted based on the equal strength replacement of the rods. The ultimate tensile strength of the composite reinforcement AKC800 is almost twice stronger than metal reinforcement (Table 1), thus it was decided to compare the adhesion with the concrete of Ø16A500C and Ø12AKC800, the adhesion area of which is twice smaller due to smaller length of anchorage 10d (160 mm–Ø16 A500C and 120 mm–Ø12AKC800).

Fig. 2 Test samples

Table 1 Comparative analysis of A500C and AKC800

Material	Steel	Fiberglass
Ultimate tensile strength, σ, MPa	495	958
Modulus of elasticity, E, MPa	199	51
Relative elongation, %	8…25	1…3
Durability, years	50 … 100 (pursuant to the construction standards)	50 … 100 (probable, theoretical)
Replacement of reinforcement (by strength)	16 A500C	12 AKC800
Weight of 1 linear meter, kg	16 A500C–1.58	12 AKC800–0.169

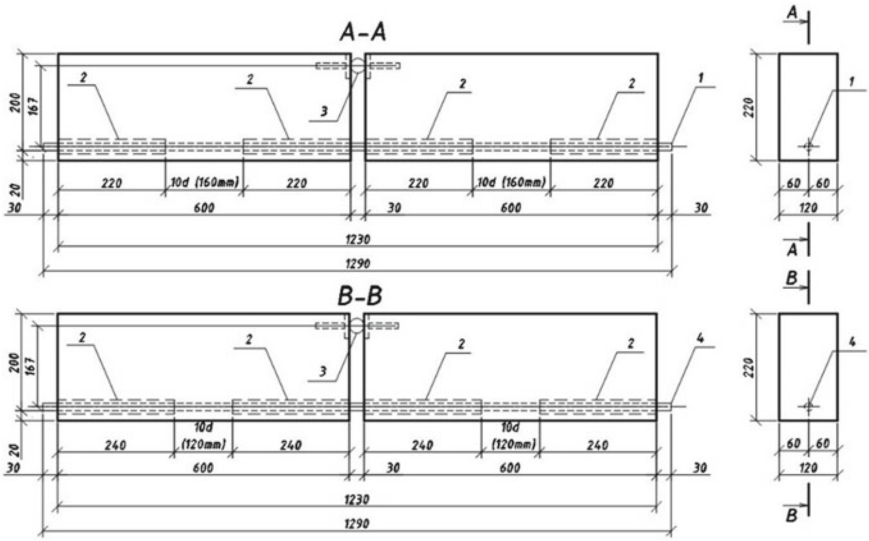

Fig. 3 Structure of test specimens–concrete beams BSR and BFR: 1–steel reinforcement Ø16 A500C; 2–plastic tube; 3–steel cylinder; 4–fiberglass composite reinforcement Ø12 AKC800

In the compression area, a swivel joint was used in the form of two embedded parts with a steel cylinder between them. In each half of the beam, the bar had adhesion to the concrete at a length of 10d (d–bar diameter), whereas other areas were free of adhesion because the reinforcement bar was placed in plastic tubes with the length l (l = 220 mm–for steel reinforcement Ø16 and l = 240 mm–for composite reinforcement Ø12) of each. In the compression area, the distance from the axis of the tested bar to the axis of the metal cylinder (lever arm) was 167 mm, the length of each half of the beam was 600 mm, the distance between the haves was 30 mm. The structure of the beams is given on Fig. 3. The reinforcement was fitted with tension gauges for studying the dynamics of tensions in the reinforcement bars.

2.2 Methods of Experimental Studies

The selection of samples and experimental studies of testing concrete beams were carried out using the RILEM/CEB/FIB beam method [32] for bending (Fig. 4a and b), since it is a generally accepted standard in most developed countries. This method consists in measuring the motions of free ends of the tested bars during the test procedure, and the measurements are recorded by means of dial indicators graduated in 0.001 mm located on the beam ends. The beams were stressed with two concentrated forces P1 (P/2), the distance between which was 400 mm.

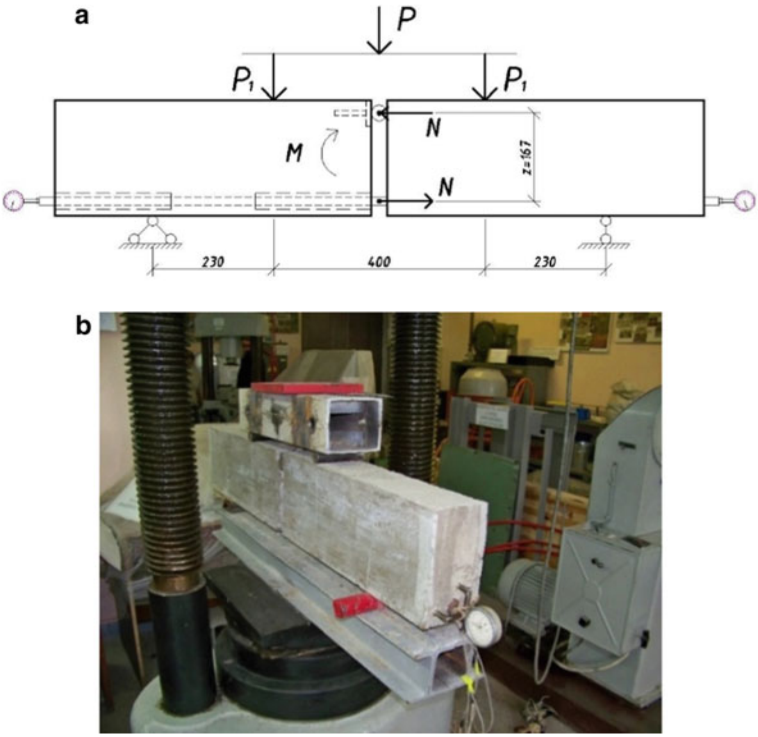

Fig. 4 **a** Design scheme for concrete beams. **b** General view for concrete beams

The longitudinal strains of the bar embedded into the concrete were measured with resistance strain gauges in the beams at each stress stage. In the reinforcement bars of the test specimens, longitudinal grooves with the depth of 2 mm were symmetrically selected, and the resistance strain gauges were located in them to measure the bar strains during the flexural test of the concrete beam (Fig. 5).

The resistance strain gauges were glued with epoxy glue BF2 and waterproofed with epoxy resin. Lead wired were set from the resistance strain gauges, and then the resistance strain gauges were connected to the tension gauge station (Fig. 6).

Fig. 5 General vies of the resistance strain gauges in the test specimen–concrete beam BSR

Fig. 6 General view of fixing the indicator and lead wires of the resistance strain gauges in the test specimen–concrete beams

3 Results and Discussion

3.1 Distribution of Strains in Adhesion Between Reinforcement and Concrete in the Test Specimens BSR (Feather-Section bar A500C with Steel Reinforcement) and BFR (AKC800 with Fiberglass Composite Reinforcement)

The destruction of all experimental twin beams occurred at fairly close loading values. Samples with BMR metal reinforcement were destroyed at 52.8; 54.0; 55.0 kN, and with glass composite reinforcement BSR at 44.0; 45.0; 46.2 kN. Further, the work shows the values of stresses at control points along the beams, which collapsed under medium loads.

When the specimen–concrete beam BSR–was tested by means of the resistance strain gauges, the strains of the reinforcement bar ε_{si} arising in the middle of the bar length, i.e. in the points i–1, 2, 3, 4, 5, 6, 7, 8, 9 (Fig. 7) were measured.

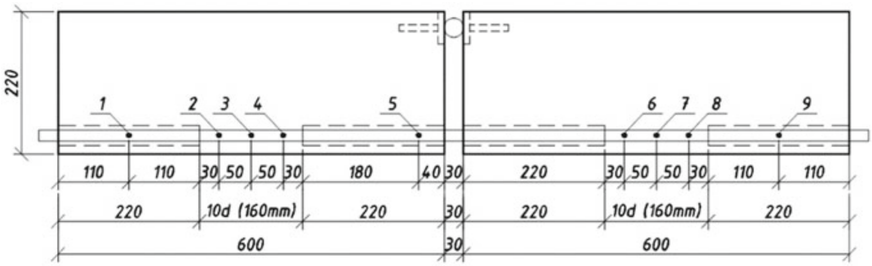

Fig. 7 Layout of the resistance strain gauges in the test specimen–concrete beam BSR

The maximum value of the strain arising in the reinforcement bar f_{ydm}= 168.16 MPa was recorded in the middle under the stress close to the destroying value of $P_u = 54$ kN.

It was more interesting to assess the distribution of tangential stresses in the reinforcement bars when in contact with concrete. For this purpose, the anchoring areas (10 d in width) containing the points i–2, 3, 4, 6, 7, 8 were examined in detail for BSR. These points divided the anchoring (concrete adhesion) areas of the bar into 9 zones. It was assumed that the force $f_{ydi}A_s$ affects each ith zone of the bar, and then it is transferred to concrete due to emerging adhesion strains, as well as to the following bar zones (which concerns only the zones located within the anchoring areas). In such case, the tangential adhesion stresses in the middle of the zones τ_{mi} may be determined by the formula:

$$\tau_{mi} = \frac{\left(f_{ydi} - f_{yd,i-1}\right) \cdot A_s}{\pi d l_i} \quad (1)$$

where f_{ydi} and $f_{yd,i-1}$ are the strains in the bar in the ith and previous zones;

A_s–the area of reinforcement;

l_i–the length of the ith zone.

The mean tangential adhesion stresses between the reinforcement and concrete may be determined by the formula:

$$\tau_m = \frac{(f) \cdot A_s}{\pi d l} \quad (2)$$

where f–is the strain in the bar;

l–is the bar length.

Based on the determined mean tangential adhesion strains in each section, the curves of their distribution have been drawn along the length of anchorage of the reinforcement bar in concrete for different level of stresses, namely P = 5, 15, 25, 35, 45, 50 kN and under such destroying stress as Pu = 54 kN (Fig. 8).

In the first adhesion zone (measured with the tension gauges 2, 3 and 4) at the first levels of stress P = 5 kN, P = 15 kN and P = 25 kN, the maximum strains emerged at the distance of x = 30 mm (4) from the starting point of the anchoring area, and they were equal $\tau = 1.14$, 1.53 and 2.31 MPa, respectively. As the stresses increased, the maximum tangential adhesion strains grew in the points 3 and, to a lower extent, in 2. But under the stress of 35 kN (64% of the destroying value), the maximum tangential adhesion strains were already recorded at the point 3 where they were much higher than at the point 4. As the stressing forces was growing, the adhesion strains were increasing in point 3 and were gradually decreasing in the points 2 and 4, which indicated gradual destruction of the contact layer in those points, as well as pulling of the reinforcement out of the concrete body. When the beam BSR (P_u = 54 kN) was destroyed, the maximum adhesion strains reached their ultimate value τ_{max}= 9.6 MPa. The beam was definitely destroyed due to an insufficient length of

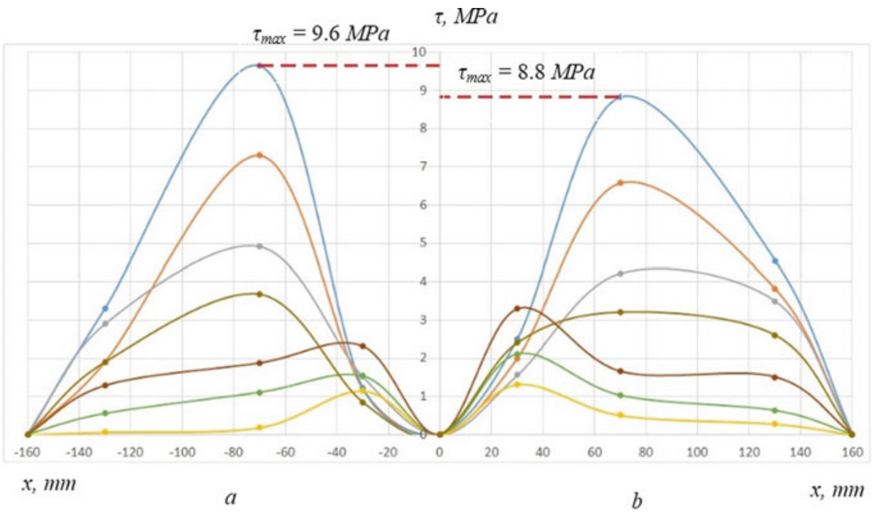

Fig. 8 Diagram of distribution of the tangential stresses in the zones of adhesion between the rod and concrete, depending on the stress P: **a**–adhesion area 1 in which the tension gauges 2, 3 and 4 are located, **b**–adhesion area 2 in which the tension gauges 6, 7 and 8 are located; –P = 5kN; –P = 15 kN; –P = 25 kN; –P = 35 kN; –P = 45 kN; –P = 50 kN; –Pu = 54 kN (destroying force), τ_{max} – represents the maximum tangential adhesion strains between the reinforcement bar and concrete determined by the formula (2)

bar anchorage, which was 10d. For the reinforcement to be broken, the necessary length of embedding should be at least 25 d.

A similar pattern was also recorded in the first adhesion zone (with the tension gauges 6, 7, 8). Under the minimum stresses P = 5 kN, P = 15 kN and P = 25 kN, the maximum strains arose at the distance of x = 30 mm (6) from the starting point of the anchoring area, and they were τ = 0.60, 2.124 and 3.29 MPa respectively. The maximum tangential adhesion strains in the point 7 under the stress of 25 kN were twice lower than in the point 6, but when the stress was increasing up to 35 kN (64% of the destructive value), the tangential adhesion strains started lowering in the point 6 and increasing in the points 7 and 8, and in all these points it was equal to a lower value: τ = 3 MPa (35% of the maximum value). As the stresses were growing, the maximum tangential adhesion strains were increasing in the points 7 and 8, while they were lowering in the starting point of the anchoring area (6). Before the beam BSR was destroyed under the ultimate stress of P_u = 54 kN, the maximum adhesion strains between the reinforcement and concrete reaches the maximum value τ_{max} = 8.8 MPa in the middle area of anchoring (8).

The analysis of each adhesion zone shows that as the stress on the beam BSR anchored with steel reinforcement Ø16 of the grade A500C is increasing, the tangential strains gradually move from the starting point of the anchoring area to its ends. Before the destruction, the maximum adhesion strains were τ_{max1} = 9.6 MPa in the left adhesion zone and τ_{max2} = 8.8 MPa in the right one.

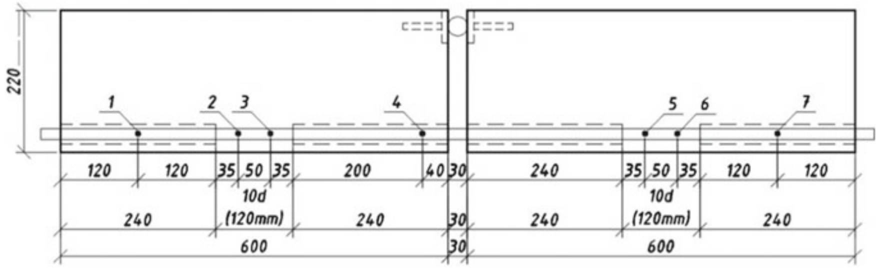

Fig. 9 Layout of resistance strain gauges in the specimen BFR

Concerning the test specimen–the concrete beam BFR reinforced with fiberglass composite Ø12AKC800, its destruction strain was P = 45 kN, which was 17% less than the ultimate stress of the beam BSR.

To compare the stress–strain behavior in the test specimens–beams BSR and BFR, it is necessary to assess the distribution of the tangential strains in the composite reinforcement bar when in contact with concrete. For this purpose, the anchoring zones with a length of 10 d containing the points i–2, 3, 5, 6 were examined in detail. These points divided the anchoring (concrete adhesion) areas of the bar into 6 zones (see Fig. 9).

Based on the determined mean tangential adhesion strains, the curves of their distribution along the length of anchorage of the reinforcement bar in concrete have been drawn in each zone for definite stress levels, namely P = 5, 15, 25, 35 kN, as well as for the destructive stress of $P_u = 45$ kN (Fig. 10).

In the first adhesion zone (with the tension gauges 2 and 3) (see Fig. 10a), under the minimum level of stress P = 5 kN, the maximum stress emerged in the proximal anchoring point at the distance of 35 mm (3) where it was equal to τ = 0.69 MPa. Under the stress of P = 15 kN, the maximum strains were τ = 1.78 MPa. As the stresses were increasing up to the level of P = 25 kN, the maximum strain was already recorded in the distant point at the distance of 85 mm from the starting point of anchorage–in the point 2 where it was equal to τ = 4.21 MPa. Before the beam BFR was destroyed under the ultimate stress $P_u = 45$ kN, the maximum adhesion strains between the reinforcement and concrete reached their maximum value: $\tau_{max}=$ 10.7 MPa in the distant area of anchorage (2).

Analyzing the location of the curves on the graph showing the distribution of the tangential strains (see Fig. 10b) shows that the adhesion zone 2 (with the tension gauges 5 and 6) symmetrically reflects the adhesion zone 1. Under the minimum level of stress P = 5 kN, the maximum strain was recorded in the area of the 5 gauge where it was equal to τ = 0.98 MPa. As the force is increased up to P = 15 kN, the strains reach their maximum value τ = 2.21 MPa in the both gauges 5 and 6. The maximum strains are τ = 4.76 MPa under the strain of P = 25 kN, and under the ultimate strain of $P_u = 45$ kN the maximum adhesion strain between the reinforcement and concrete reached the maximum value of $\tau_{max}=$ 10.1 MPa in the distant area of anchorage (6) (Table 2).

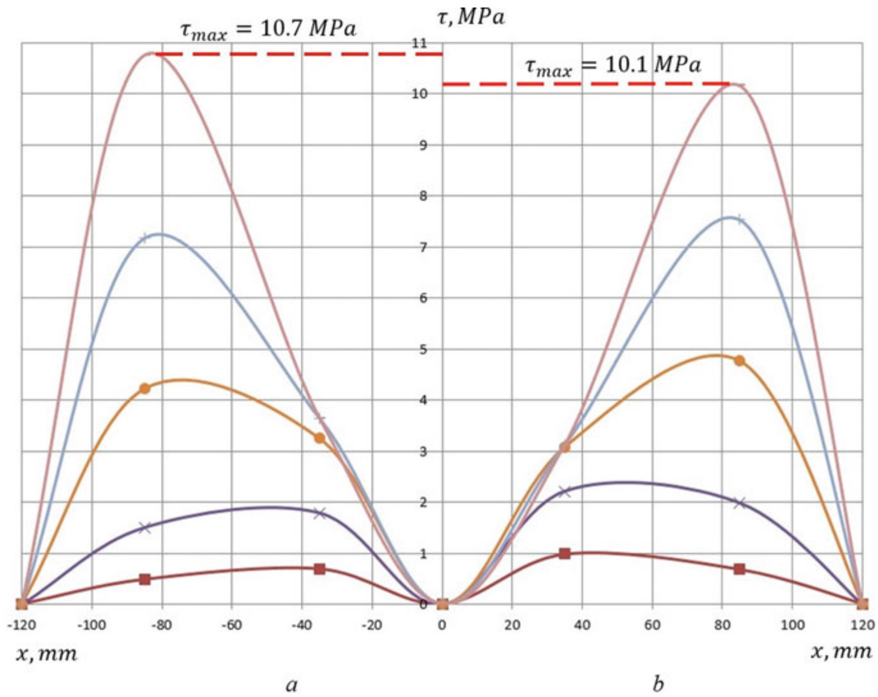

Fig. 10 Diagram of distribution of the tangential strains in the zones of adhesion between the bar and concrete, depending on the stress P: **a**–adhesion zone 1 in which the tension gauges 2 and 3 are located; **b**–adhesion Sect. 2 in which the tension gauges 5 and 6 are located; –P = 5 kN; –P = 15 kN; –P = 25 kN; –P = 35 kN; –Pu = 45 kN (destroying force), τ_{max}- maximum tangential adhesion stresses between the reinforcement bar and concrete determined by the formula (2)

Table 2 Values of tangential adhesion strains τ, MPa of metal reinforcement Ø16A500C and Ø12AKC800 with concrete

Stress level, kN	Tangential adhesion strain τ, MPa, between metal reinforcement Ø16A500C and concrete			Tangential adhesion strain τ, MPa, between composite reinforcement Ø12AKC800 and concrete		
	τ_{left}, MPa	τ_{right}, MPa	τ_{mean}, MPa	τ_{left}, MPa	τ_{right}, MPa	τ_{mean}, MPa
5	1.14	0.6	0.87	0.69	0.98	0.83
15	1.54	2.12	1.83	1.78	2.21	1.99
25	2.31	3.29	2.80	4.21	4.76	4.48
35	4.67	2.88	3.77	7.17	7.53	7.35
45	6.92	4.27	5.59	10.7	10.1	10.4
50	8.31	6.19	7.25			
55	9.60	8.80	9.20			

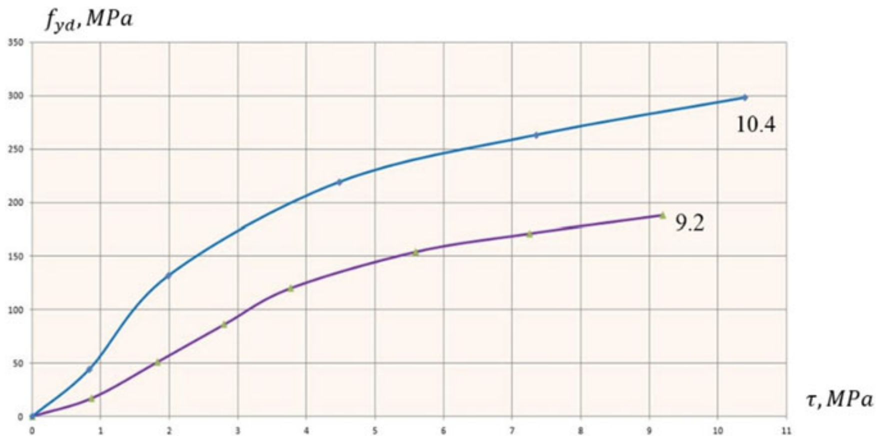

Fig. 11 Dependence of the mean value of the maximum tangential adhesion stresses between the reinforcement bars and concrete τ, MPa, of the adhesion zones of the beams BSR and BFR on the reinforcement $textf_{yd}$, MPa, —Ø16A500C; —Ø10AKC800

The graph shows the dependence of average values of the mean values of the maximum tangential adhesion strains between the reinforcement bars and concrete τ, MPa in the adhesion zones of the beams BSR and BFR on the strains in the reinforcement f_{yd}, , MPa (Fig. 11).

The curves of dependence of average values of maximum tangential tensions of rebar and concrete bonding from tensions in rebars have similar character. The maximum values are on average in metal rebar Ø16A500C–τ_c= 9.2 MPa, and in fiberglass rebar Ø10AKC800–τ_c= 10.4 MPa, which is 11.5% higher.

3.2 Discussion

After analyzing each of the adhesion sections, it shows that with an increase in the load of a concrete beam in the areas of contact between reinforcement and concrete, the maximum values are on average in metal reinforcement Ø16A500C–τ_{max}= 9.2 MPa, and in fiberglass reinforcement Ø10AKC800–τ_{max}= 10.4 MPa, which is 11.5% more.

With the anchoring length of 10d, the ultimate destroying strain in the beam BSR was equal to 54 kN, and in the beam BFR it was 45 kN. It is due to the fact that the anchoring length is 1.3 times longer, and the area of the contact layer of concrete with the metal rebar is 1.7 times larger than that of fiberglass rebar.

The graph in Fig. 11 shows that significant normal strains in composite reinforcement do not cause any increase in tangential strains. It is due to lower stress–strain properties of fiberglass composite reinforcement, although the maximum tangential adhesion strains with concrete are only 11.5% higher as compared to metal reinforcement.

4 Conclusions

1. The nature of distribution of tangential adhesion strains of both metal and fiberglass reinforcement with concrete is the same, and it is parabolic in form.
2. At maximum breaking loads in a concrete beam in the areas of reinforcement and concrete contact, the maximum stresses of metal reinforcement Ø16A500C are 11.5% less than for fiberglass rebar Ø12AKC800.
3. With a larger contact layer of concrete with metal ribbed rebar Ø16A500C in 1.7 times compared to fiberglass rebar Ø12AKC800 the maximum breaking load is only 17% higher.
4. Experimentally proved the possibility of equal replacement of metal rebar with fiberglass rebar of smaller diameter by the example of Ø16A500C and Ø12AKC800.

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Preparation and Conduct of Experimental Research of Reinforced Wooden I-Beams

Kseniia Chichulina, Anna Pavelieva, Svitlana Ivanytska, Maryna Chyzhevska, and Besik Bauchadze

Abstract The purpose of the experimental research, presented in the article is to study the work, determine the load-bearing capacity and the nature of the destruction of composite fiberglass-reinforced wooden beams with OSB wall with solid belts and their comparison. The object of the research is laminated fiberglass-reinforced wooden beams of I-beam cross-section with an OSB wall and solid belts for covering buildings and structures. To achieve this goal, we have made six composite fiberglass-reinforced wooden beams of an I-shaped cross-section with an OSB wall and solid belts. The first two beams were made with single reinforcement at the top and at the bottom, the second and the third beams were made with double reinforcement at the top and at the bottom, the fifth was made with symmetrical single reinforcement and the sixth one–with symmetrical double reinforcement, so as to make it possible to study their operation under static loads. Additionally, six beams with the same parameters but of smaller size were made to compare deflections from loading with one force. To determine physical and mechanical characteristics of pinewood, 9 specimens of a rectangular parallelepiped shape for compression tests and 3 samples of beams for bending tests were made from the same wood simultaneously with the experimental beams. To determine the characteristics of the oriented strand board, 8 samples were tested for compression along and across the fibers, 12 samples were tested for bending along and across the fibers, and the dimensions of the bending samples were increased, as well as 3 samples were tested on other test rigs. Also, tensile tests were performed according to the method of tensile tests of steel reinforcement to determine the tensile strength of fiberglass reinforcement and for this purpose, we prepared 3 samples of the same reinforcement that was used for the manufacture of beams.

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© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_6

Keywords Experimental research · Reinforced wooden I-beams · Oriented strand board (OSB) · Bending · Compression · Physical and mechanical characteristics

1 Introduction

Production and application of wooden glued structures are at the stage of dynamically sustainable development. Temporary parameters of this stage, conditions of sustainable development, trends, and priorities in ensuring the dynamics of the pace–these and other tasks require systematic analysis and software solutions.

Production of massive, large wooden glued structures for construction began in the middle of the last century. These structures are essential elements of building systems of buildings and structures, they can withstand heavy operating loads and ensure the stability and safety of construction sites. That is why the most attention is paid to these wooden glued constructions, especially in the scientific-technical and normative-methodical spheres. The purpose of the experimental studies presented in the article is to study the operation, determine the load-bearing capacity, and the nature of the destruction of composite fiberglass-reinforced wooden beams with an OSB wall with solid belts and their comparison. The object of the study is glued reinforced with glass-plastic reinforcement wooden beams of I-beam cross-section with an OSB wall and solid belts for roofing and covering buildings and structures. To achieve this goal, six folded glued glass-eraser-reinforced wooden beams of the I-beam section with an OSB wall and solid belts were made. The research is based on the experimental methods and approaches.

Let's analyze the literature on this issue. In the article [1], the authors described the proposed and patented design constructive solution of reinforced double-tee girders with a wall of the oriented standard board [2], which was made of two boards with 38 × 65 mm cross-section and 10 mm × 200 mm wall of oriented standard board (oriented standard boar–OSB), which connected with epoxy adhesive, the height of the beam is 250 mm. The experiment results analysis of suggested I-beams with fiber-glass reinforcement was carried out, the operation under the load peculiarities and fracture mode was revealed. The paper [3] proposes a new method to predict the ultimate load-bearing capacity of structural notched beams subjected to splitting. Reinforced and unreinforced cases are investigated by using an FE-model for splitting failure. The contribution of mode I and mode II in the crack extension mechanisms is implemented in the numerical model by considering a mixed-mode criterion established on the R-curves of wood. The influences of the notch and the reinforcements on the resulting quasi-brittle behavior are analyzed. The FE prediction is compared to experimental data and the current design rules of the Eurocode 5.

The paper [4] studies the behavior of a wooden portal frame with penetrated mortise-tenon (PMT) connections and column foot (CF) connections under transverse load. An analytical model for a planar loose PMT connection is proposed based on the load–displacement relationship. The mechanical behavior of these loose connections with the friction-slip-contact mechanism is studied with clear evidence of negative stiffness in the lateral resistance of the wooden frame. The different contact states of the PMT and CF connections in the load resisting process are studied. Results indicate that the lateral performances of the wooden frame are dependent on the synergistic action of the PMT and CF connections. The paper [5] is based on a hot box-cold box experiment–the impact of convective moisture transport and this for two vapor tight and one capillary active vapor open interior insulation system applied to a masonry wall with an embedded wooden beam. A comparison is made to a non-insulated wall. No wind-driven rain is included, making a pure analysis of convective moisture transport possible. For non-sealed beam junctions, a significant increase in relative humidity due to moist indoor air reaching the colder beam surface was visible. The impact of air exfiltration was most pronounced for the capillary active system and was influenced by the way of sealing the air gap between the beam end and the wall. It is recommended to avoid air exfiltration as well as air circulation near the beam end. For mineral wool, the importance of an airtight sealing was less pronounced. An overpressure was found to influence the hygrothermal conditions near the beam ends of the poorly sealed test setups. Additionally, the convective airflow near the beam ends was analyzed based on the measured temperatures. The paper [6] studies two finite element solutions are developed for the lateral-torsional buckling analysis of timber beam-deck assemblies consisting of two beams braced by decking through fasteners. In contrast to past solutions, both solutions capture the rotational flexibility provided by the connections between the deck boards and the beams. The first solution is intended for systems with partial lateral restraint provided by the deck boards allowing lateral sway while the second solution is intended for systems that are restrained from lateral movement at the deck level. An experimental program is conducted to quantify the rotational stiffness of beam-deck connections for different types of fasteners and the results are input into the finite element formulations to evaluate the corresponding buckling capacities for beam-deck systems. The results indicate that the buckling capacity of beam-deck systems can be significantly increased with commonly used fasteners while high-capacity fasteners can achieve buckling capacities nearly identical to those where rigid rotational connections are assumed. In the paper [7] a beam finite element formulation is developed for the elastic lateral-torsional buckling analysis of wood beams with rectangular cross-sections. The formulation accounts for moment gradient, load height, and pre-buckling deformation effects.

Based on the analysis, it was found that the study of the wooden structures, presented in the work, requires further study and experimental confirmation of operation.

2 Main Body

2.1 Determination of Physical and Mechanical Characteristics of Materials

2.1.1 Determination of the Compressive and Bending Strength of Wood

Compression. 9 experimental wooden specimens in the shape of a rectangular parallelepiped measuring 64 × 38 × 300 mm were tested for compressive forces, dragged along the load, and tested according to GOST 16,483.10–73.

The sample is placed into a device for compression testing (see Fig. 1a). Then the sample is loaded evenly at a constant loading speed or a constant speed of movement of the loading head of the machine. The speed should be such that the specimen collapses (1.0 ± 0.5) minutes after the start of loading. When using a machine with an electromechanical drive, it is allowed to load the sample evenly at a speed of (25,000 ± 5000) N/min.

The destruction of the samples was accompanied by the appearance of a characteristic fold (see Fig. 1b), which was formed as a result of local fracture of the fibers. The results of the study of wood samples of compression cubes are given in Table 1.

During the study, we determined the compressive strength of unconditioned samples along the fibers, the modulus of elasticity in the compression of the sample, the calculated resistance, the characteristic value of strength, respectively [8–11].

The average value of the destructive load was 79 *kN*, which created in the cross-section of the sample stress $f_{c,0,d}$ = 13.05 MPa, which was used for further calculations.

Bending. To determine the bending strength characteristics of wood, 3 samples measuring 64 × 38 × 400 mm were tested for bending forces (see Fig. 2a). The research was carried out with the help of the universal testing machine "UM-5A"

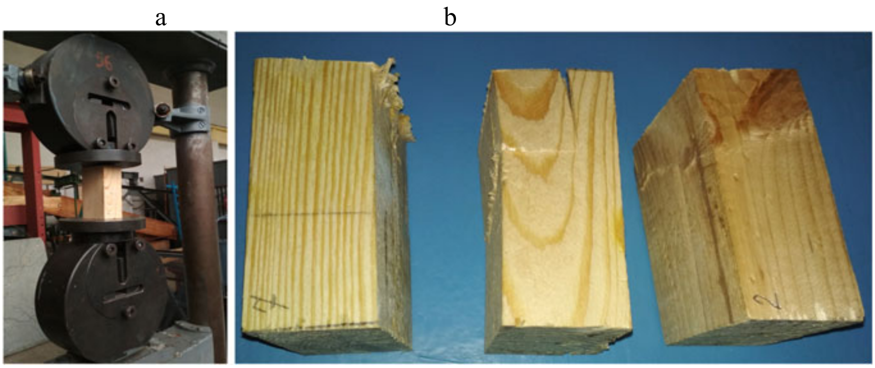

Fig. 1 **a**–Layout of the wood compression test; **b**–Layout of test specimens after destruction

Table 1 The results of compression tests of wooden blocks

№ sample	Dimensions of the cross-sectional cut of samples, *mm*		Rupture load, P_{max}		$P_{average}$, *kN*	*s, MPa*	$s_{average}$, *MPa*	Elastic modulus *E*, *MPa*	*Average design resistance*, $f_{c,0,d}$, *MPa*
	a	*b*	*kg*	*kN*					
1	2	3	4	5	6	7	8	9	10
1	64,5	38	5500	55	79	22,4	30.8	9943	13.05
2	64	37,5	6400	64		25,8		8301	
3	64	38	6800	68		27,7		10,198	
4	64	38	9500	95		40,4		7717	
5	64	37	7300	73		31,1		9314	
6	63.5	38	8200	82		35,2		7043	
7	64	38	7400	74		31,0		10,690	
8	64	37.5	10,000	100		40.6		10,112	
9	64.5	38	10,000	100		41.9		9338	

Fig. 2 **a**–overall view of the wood bending test; **b**–test specimens after destruction

according to GOST 16,483.3–84. The results of specimen studies to determine the bending strength characteristics of wood are presented (see Table 2). The results of compression tests of wooden blocks are given (see Table 2).

In the course of the following studies we will determine the compressive strength of substandard specimens along the fibers, the elastic modulus of compression of the specimen (E_i), the design resistance, the characteristic value of strength.

The average value of the rupture load was 8.09 kN, which created in the cross section of the sample stress $f_{m,d} = 14.9$ MPa, which was used for further calculations. The general graph of the dependence of deformations on stress in this case is presented (see Fig. 3).

2.1.2 Determination of Strength Characteristics of an Oriented Strand Board

6 series of samples were made for the tests, all of them were made of OSB-3 material, manufactured by "Krono-Ukraine", which was later used for beam walls.

The first series of samples are OSB-plates in the shape of a rectangular parallelepiped with dimensions of 150 × 50 × 10 mm, which have a longitudinal direction of the fibers.

The second series of samples are OSB-plates in the shape of a rectangular parallelepiped measuring 200 × 50 × 10 mm, with a crosswise direction of the fibers.

The third series of samples are OSB-plates in the shape of a rectangular parallelepiped with dimensions of 200 × 170 × 10 mm, which have a longitudinal direction of the fibers.

The fourth series of samples are OSB-plates in the shape of a rectangular parallelepiped measuring 200 × 150 × 10 mm, with a crosswise direction of the fibers.

Table 2 The results of compression tests of wooden blocks

№ sample	Dimensions of the cross-sectional cut of samples, mm			Rupture load, P_{max}		$P_{average}$, kN	*M, kN * cm*	*W, cm³*	*σ, MPa*	$\sigma_{average}$, *MPa*	*Average design resistance*, $f_{m,d}$
	b	*h*	*l*	*kg*	*kN*						
1	2	3	4	5	6	7	8	9	10	11	12
1	3.8	6.4	40	780	7.8	8.09	78	15.40	30.18	36.46	14.19
2	3.8	6.45	40	862	8.62		86.2	15.52	41.70		
3	3.7	6.4	40	785	7.85		78,5	14.60	37.5		

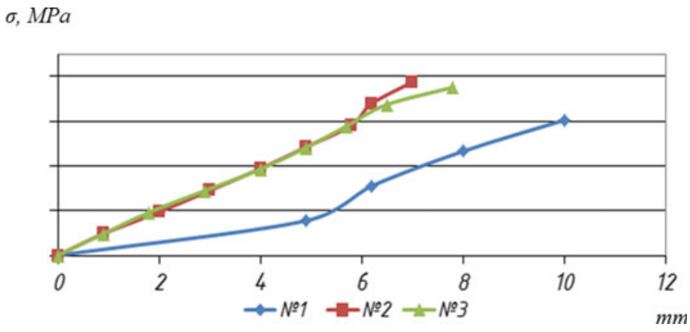

Fig. 3 The graph of dependence of deformation on stress

The fifth and sixth series of samples are square OSB boards measuring 50 × 50 × 10 mm. During the tests, the samples of these series were placed in the test machine in such a way that the destruction occurred along or across the fibers.

Preparation for tests and experimental studies of wooden flitch-beams were performed in the following sequence:

(1) Preparation of the sample for testing;
(2) Fastening of measuring devices;
(3) Installation of the sample into the test machine;
(4) Testing the connection by fixing the required parameters at all stages of loading.

The test was performed on a universal test machine "UVM-5" (control computer-5). The machine is used for static testing of samples of materials, parts, and assemblies of machines for tension, compression, and bending. The maximum force of the test machine is 5 ts (50 kN). To measure the deformation of the mutual shift of the elements of all series were used the indicators of the clock type ICH-10 with the division value of 0.01 mm.

When conducting bending tests, GOST 10,635–88 was used. These specimens were mounted on the hinge supports of the tester along the marks so that the longitudinal axis of the sample was perpendicular to the axes of the supports and the transverse axis was in the same vertical plane with the axis of the force application. At each step of the load, samples were taken from the instruments, and critical force and corresponding deformations were recorded for all samples.

When testing the first series of samples, loads were applied in 3 kg increments at the same rate until failure (see Figs. 4 and 5).

When testing the first two series of load specimens, the load was applied depending on the deformation scale of the material with step 5 separation up to fracture. And the tests of the third and fourth series of load samples were applied in steps of 20 kg at the same speed until structural failure.

The difference between the first two series of samples and the third and fourth ones is that the test was performed on another test rig.

When testing the fifth and sixth series of specimens, loads were applied in 120 kg increments until the destruction of the specimen.

Fig. 4 General view of tests of samples of the first and second series on the research installation patented at the department of technology of building constructions, products and materials

Fig. 5 General view of tests of samples of the third and fourth series

In the course of the work the physical and mechanical characteristics of oriented strand boards used as a wall were determined. Bending and compression specimens were produced and tested. When conducting an experiment according to GOST 10,635–88 "Particleboard. Methods for determining the tensile strength and modulus of flexural strength".

The destruction of the samples of the first series was fragile, the average destructive force in bending along the fibers is 45.8 kg, the tensile strength is 27 MPa, modulus of elasticity is 2300 MPa. The destruction of the samples of the second series was fragile as well, the average destructive force when bending across the fibers is 29.7 kg, the tensile strength of 13.1 MPa, the modulus of elasticity of 700 MPa (see Figs. 6 and 7).

The last two samples from the second series were subjected to a load with a holding time of 5 min to determine how the load changes over time (see Fig. 8).

The destruction of the samples of the third series was fragile, the destructive force in bending along the fibers is about 165 kg, the tensile strength is 27 MPa, the modulus of elasticity is 3500 MPa. The dependence of deformations on loads for the third series of samples is presented in Fig. 9. And for the fourth series, the destructive force when bending across the fibers is about 85 kg, the tensile strength is 17.7 MPa, the modulus of elasticity is 2600 MPa.

Fig. 6 The destruction of the samples of the first and second series

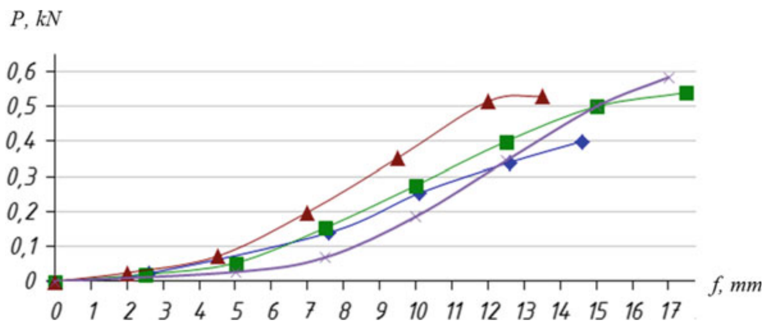

Fig. 7 Dependence of deformations on loads for the first series of samples

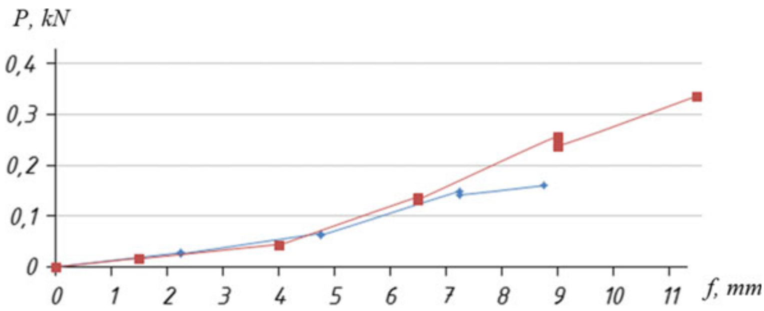

Fig. 8 Dependence of deformations on loads for the second series of samples with a time lag

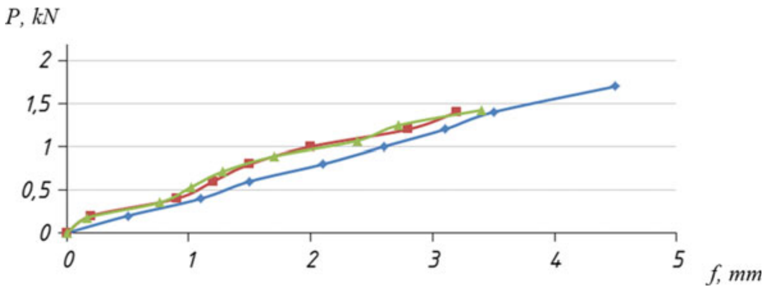

Fig. 9 Dependence of deformations on loads for the third series of samples

The tensile strength of four series of OSB samples in the bending test is presented in Fig. 10.

The destruction of the samples of the fifth and sixth series was fragile, the destructive force of compression along the fibers is about 700 kg, and 390 kg across the fibers. The tensile strengths of the fifth and sixth series of OSB specimens in the compression and fracture test are presented in Figs. 11 and 12.

2.1.3 Determination of Tensile Strength of Fiberglass Reinforcement

To study the strength and deformability of composite reinforcement, 3 samples of reinforcement Ø4 and 400 mm long were selected and prepared, all of them from fiberglass reinforcement, which is a rod obtained by combining epoxy resin and insulating glass roving (threads).

A special place among composite materials is occupied by fiberglass reinforcement. Composite reinforcement with the sand of the tradename "Hard + " was used–it is a polymer reinforcement made of fiberglass, on which an additional layer of sand or abrasive is applied during production. These materials are widely used in aircraft construction, shipbuilding, automotive, mining, and nuclear industries, laminated plastics, and much more.

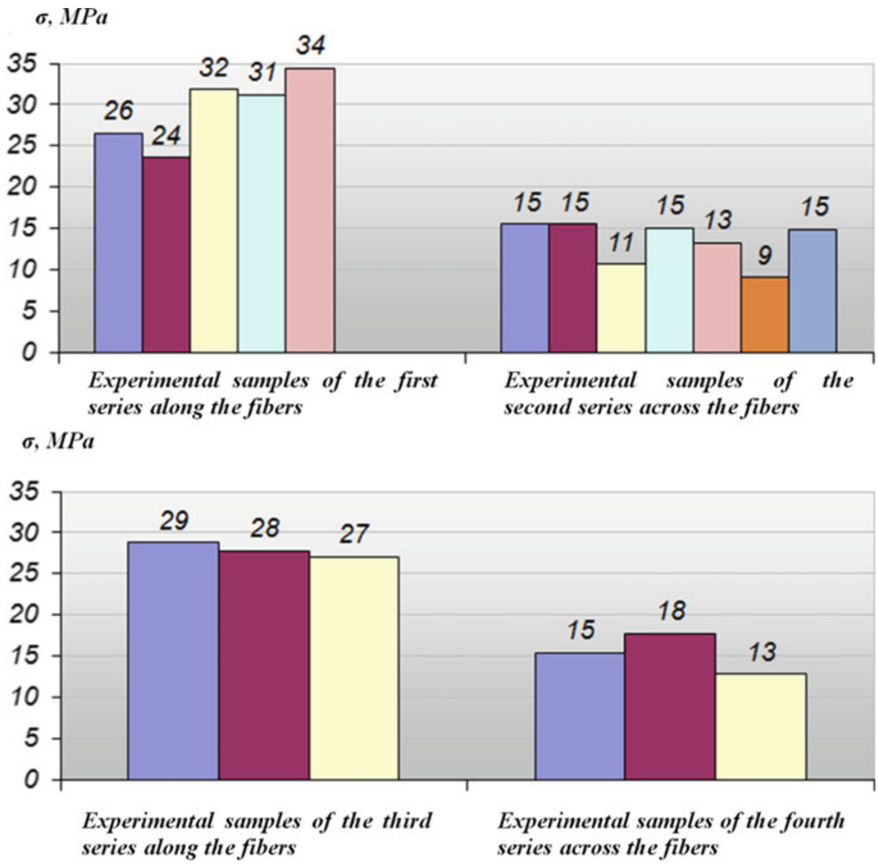

Fig. 10 The tensile strength of four series of OSB samples in the bending test

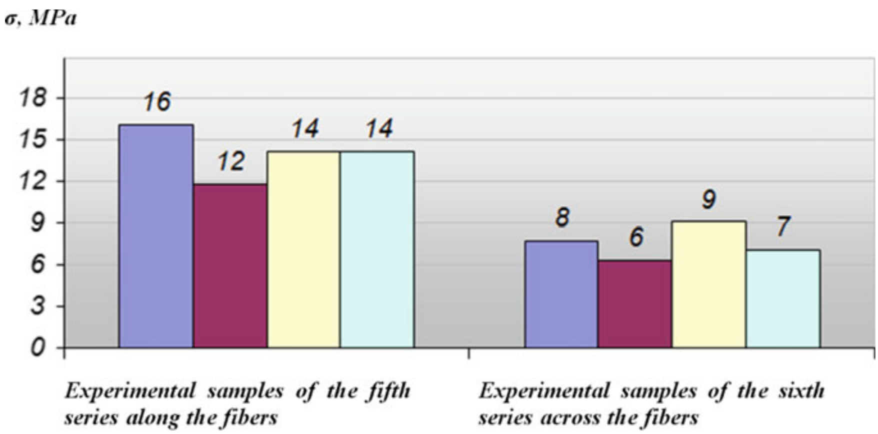

Fig. 11 The tensile strength of the fifth and sixth series of OSB samples in the compression test

Fig. 12 Destruction of the samples of the fifth and sixth series

The main advantages of fiberglass reinforcement: no corrosion and rot; minimum transportation costs; storage in damp places, without loss of quality; practicality, 200 m of reinforcement bay may be lifted by any worker; high strength, 100% stronger than steel; lightweight, 80% lighter than metal; replacement of steel reinforcement with a lower diameter without loss of strength; does not pass electricity, being a dielectric; low thermal conductivity; does not lose properties at ultra-low temperatures; service life of at least 80 years.

But as with all materials, there are disadvantages as well: when used in floors, more reinforcement is laid, as in the floors there are both longitudinal and transverse loads; flammability G1; low modulus of elasticity, so it is used mainly in tension.

The test was performed on a universal test machine "UM-5A", which is recommended for testing metal and other samples of materials for tension, compression, transverse bending at static loads with a maximum force of 50 kN. Due to the great commonality in the method of determining these characteristics, tests for different types of deformation, as a rule, are performed on universal test machines, which by replacing the working bodies are adapted to different types of tests.

When conducting tensile tests, GOST 12,004–81 was used and the samples were fixed in the jaws of the test device and connected device "AID-4" which recorded the deformation of the sample on the strain gauge. At each step of the load, samples were taken from the instruments, and critical force and corresponding deformations were recorded for all samples.

The failure of the composite reinforcement occurred in the working area of the rod (see Fig. 13). The average value of the destructive load for fiberglass reinforcement was 3.2 kN.

During the work, the strengths and deformability of fiberglass reinforcement used in beams were determined. Tensile specimens were prepared and tested (see Fig. 14). The destructive tensile strength of the reinforcement is 300 kgf for the first sample, 340 kgf for the second and 320 kgf for the third.

Fig. 13 General view of tests of samples from fiberglass reinforcement

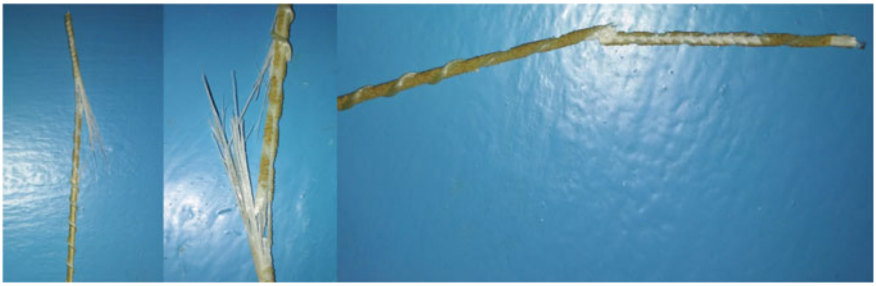

Fig. 14 Destruction of samples

The readings were taken with the help of the “AID-4” device through which the deformations in the sample were recorded on the strain gage, in the sample on the strain gage they could be removed only to a load of 0.6 kN, because there was damage in the strain gage.

2.2 Devices and Equipment for the Experiment

The test was performed on a universal test machine “UIM-50” (see Fig. 15). The machine is used for static testing of samples of materials, parts and components of machines for tension, compression and bending. The maximum force of the machine is 50 tons (500 *kN*). The largest movement of the traverse is 1630 mm. The maximum displacement of the slider is 710 mm. The greatest distance between captures is 1000 mm. The largest diameter of round samples is 50 mm. The distance between the supports when bending is 2700 mm.

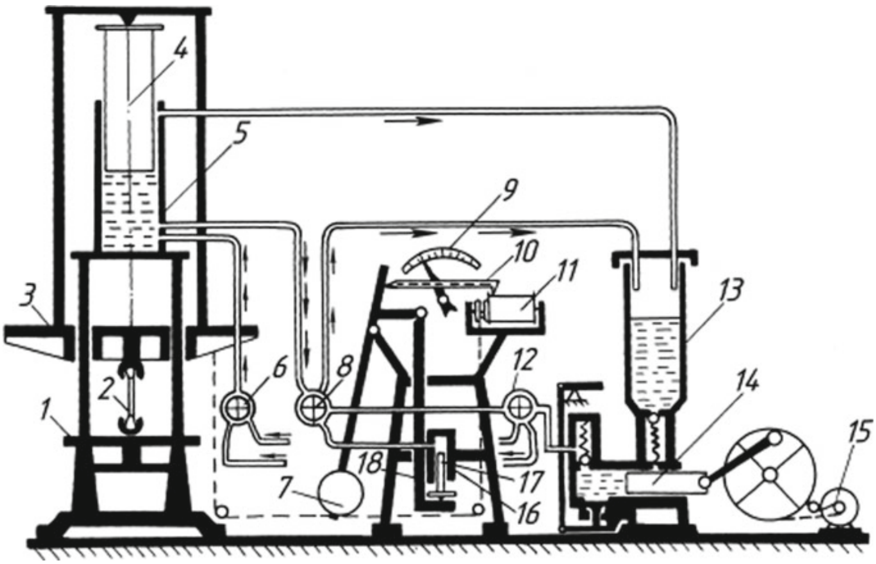

Fig. 15 Scheme of installation for testing samples: 1–fixed traverse; 2–grippers for fixing the specimen to tension; 3–movable traverse; 4–piston; 5–working cylinder; 6–the crane for the fast lifting of a traverse upwards; 7–bar with variable loads; 8–the crane for fast lowering of a traverse downwards; 9–the scale of the power meter; 10–toothed rail; 11–drum, 12–working crane; 13–oil tank; 14–plunger pump, 15–electric motor; 16–power meter cylinder; 17–the piston of the cylinder of the power meter; 18–thrust

To measure the deformation of the mutual shear of the elements of all series were used indicators of the clock type IR-10 with a division value of 0.01 mm. The indicators were attached using a bracket that was attached to one of the connecting elements with a pair of screws. Overhead devices were used for thrusting of the measuring devices–tables that were driven into the wood of the element with sharp ends.

To determine the deformations were glued strain gages, brand 2 PKB-20-200 KB, № TU 25–01-100–68. BF-2 glue was used for gluing strain gages. Before gluing, the places where the sensors were to be installed, were cleaned to a smooth state with fine sandpaper for better adhesion of the load cell to the element surface and primed with a thin layer of BF-2 glue a day before gluing sensors to absorb the required amount of glue into the wood and to give it time to dry put for better adhesion of strain gauges to wood. Then the strain gauges were glued, the surface of the element was again covered with BF-2 glue, as well as the underside of the primed strain gauge made of condenser paper and through a gasket of cellulose film GOST 7730–74 0.02 mm thick was smoothed and pumped with a rubber roller. The test was performed by step application of the load on the structure. The number of steps was taken 10 of the expected destructive load. After each degree of loading readings on indicators of clock type were taken and in parallel with it, using the device “AID-4” deformations in elements of a beam on strain gages were fixed.

2.3 Methodology of the Experiment

Preparation for tests and experimental studies of assembled wooden beams were performed in the following sequence: preparation of the sample for testing; fastening of measuring devices and connection of measuring equipment to the samples; installation of the sample in the UIM-50 test machine; testing the connection with fixing the necessary parameters at all stages of loading.

In preparation for the tests on the beams were installed two indicators of the clock type brand IR-10 in places of the greatest possible shift of the structural elements relative to each other, ie the walls relative to the belts of the beam.

Two resistance strain gauges were placed on the lower and upper belts and on the wall, each of them located on the geometric axis of the element, and were glued along the fibers. These resistance strain gauges were also glued to the reinforcement of the third and fourth series. The layout of resistance strain gauges on the tested samples is shown in Fig. 16.

2.3.1 Production and Preparation of the First Series of Samples for Testing

The first series of samples consisted of two I-beam wooden beams B1 and H1 with a wall of oriented strand board with integral belts and single reinforcement with fiberglass reinforcement.

For their production, pinewood was selected, dried to a moisture content of 12%, length 3 m, cross-section 38 × 64 mm with a hole 10 × 15 mm with a width of annual layers 1–5 mm, without destructive defects and rot. 10 mm thick OSB-3 board (manufactured by "Krono-Ukraine" in all series) was prepared and sawn into 200 mm high samples (see Fig. 17a).

After that, all surfaces to be glued were cleaned and degreased. Epoxy glue EDP TU U 24.6–2,558,309,112-006: 2006 was used for the production of beams of all series. Bonding of the samples was performed according to the instructions, then the beams were loaded for 24 h for complete curing (see Fig. 17b). A general view of the test samples B1 and H1 is presented in Figs. 18 and 19. The design scheme of the beam is a beam on two supports, loaded with two concentrated forces at a distance of 1/3 of the span from the support.

2.3.2 Production and Preparation of the Second Series of Samples for Testing

The second series of samples consisted of two I-beam wooden beams B2 (see Fig. 20) and H2 (see Fig. 21) with a wall of oriented strand board, with solid belts and double reinforcement with fiberglass reinforcement.

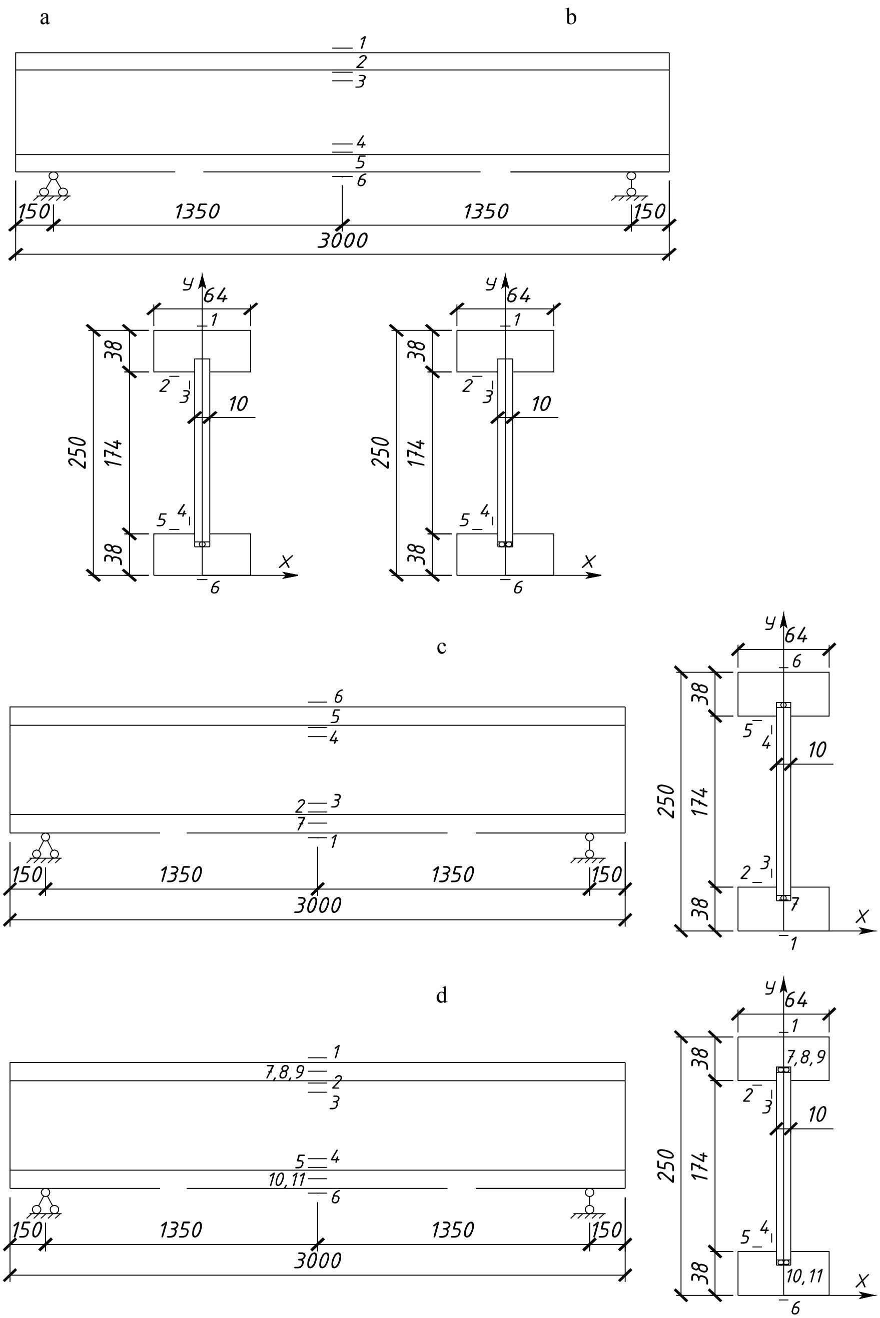

Fig. 16 Layout of resistance strain gauges: **a**–for the first group of samples, **b**–for the second group of samples, **c**–for the third group of samples, **d**–for the fourth group of samples

a b

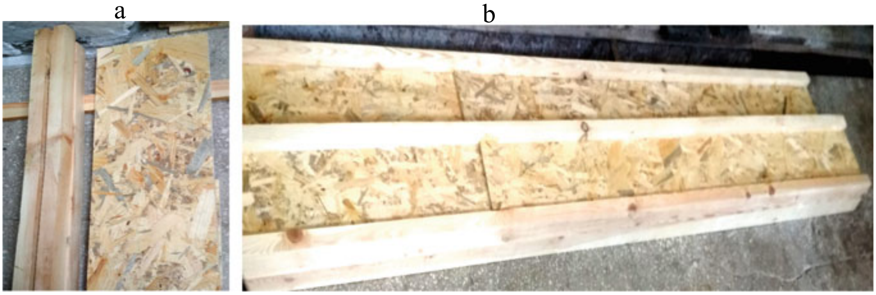

Fig. 17 **a**–Preparation for gluing beams; **b**–Glued sample of the first series

Fig. 18 General view of the test sample B1

Fig. 19 General view of the test sample H1

The design scheme of the beam is a beam on two supports, loaded with two concentrated forces at a distance of 1/3 of the span from the support.

Fig. 20 General view of the test sample B2

Fig. 21 General view of the test sample H2

2.3.3 Production and Preparation of the Third Series of Samples for Testing

The third series of samples consisted of an I-beam wooden beam HB1 with a wall of oriented strand board, with integral belts, and symmetrical single reinforcement with fiberglass reinforcement.

For their production, pinewood was selected, dried to a moisture content of 12%, length 3 m, cross-section 38 × 27 mm with a width of annual layers 1–5 mm. OSB-3 board, 10 mm thick, was prepared and sawn into 250 mm high samples.

Gluing of these samples (see Fig. 22), as well as the previous ones, was carried out according to the instructions. The design scheme of the beam is a beam on two supports, loaded with two concentrated forces at a distance of 1/3 of the span from the support (see Fig. 23).

Fig. 22 Glued sample of the third series

Fig. 23 General view of the test sample HB1

2.3.4 Production and Preparation of the Fourth Series of Samples for Testing

The fourth series of samples consisted of I-beam wooden beams B2H2 with a wall of oriented strand board and symmetrical double reinforcement with fiberglass reinforcement (see Fig. 24).

For their production, pine wood was selected, dried to a moisture content of 12%, length 3 m, cross section 38 × 27 mm with a width of annual layers 1–5 mm. OSB-3 board, 10 mm thick, was also prepared and sawn into 250 mm high samples. A general view of the test sample B2H2 is presented (see Fig. 25).

Fig. 24 Preparation for gluing and a glued sample of the fourth series

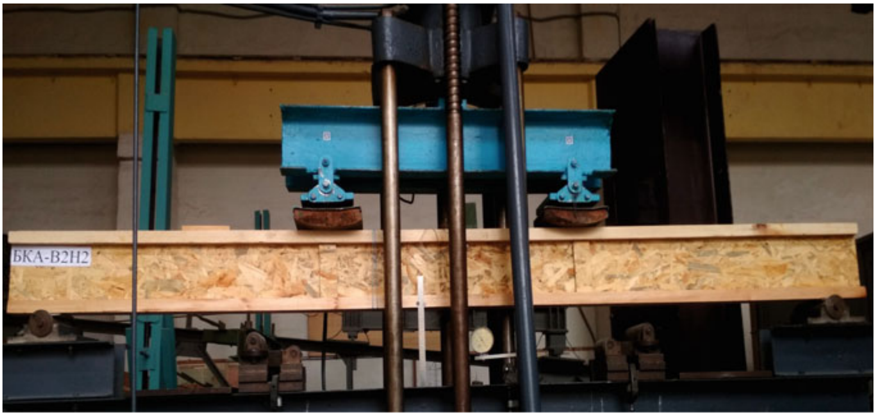

Fig. 25 General view of the test sample B2H2

Fig. 26 General view of the test of the fifth series of samples

2.3.5 Production and Preparation of the Fifth Series of Samples for Testing

The fifth series consisted of six I-beams with oriented strand board with solid belts and various fiberglass reinforcement. They differ from the previous beams in that their length has been reduced by 40 cm and loaded with a single concentrated force.

The design scheme of the beam is a beam on two supports, loaded with one concentrated force at a distance of 1/2 span from the support (see Fig. 26).

3 Conclusion

The article presents the characteristics of materials, samples, equipment and methods of experimental testing of assembled reinforced with fiberglass reinforcement wooden beams with a wall of OSB with solid belts and their comparison. The scope of research was determined and specimens were made, wood was tested to determine the tensile strength and modulus of elasticity in compression and bending. Tests of oriented strand boards for bending, compression, and tension were also carried out, their mechanical characteristics were specified and tensile reinforcement was tested. All the obtained actual characteristics were taken into account when determining the bearing capacity of the beams, testing, and analysis of the experimental results.

The design and shape of specimens make it possible to conduct experimental studies in compliance with all building codes.

Preparation of beam samples was carried out in compliance with all standards, rules, and recommendations. Technical and structural violations in the process of manufacturing beams were not detected.

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Startup: Production of New Resource-Saving Steel Beams Using European Technologies

Kseniia Chichulina, Viktor Chichulin, Svitlana Ivanytska, and Serhiy Valyvsky

Abstract The development of a solid investment project for the production of new resource-saving corrugated boxes will allow potential foreign investors to really assess the risks and prospects of such a startup project. Given this, the issue of developing a project for manufacturing structural solutions for the real construction sector is relevant, and the theoretical and practical significance of this challenge is not in doubt. The purpose of the work is to develop an innovative start-up for the production of resource-saving structural solutions in construction based on European experience; to solve an important national economic problem of improving the efficiency of construction work by creating an economically justified project of light beams with a profiled wall and determining the economic feasibility of their use. Tasks of the work are to review the market conditions of existing structural solutions for light corrugated beams, which provide a number of advantages over traditional structures; to develop a step-by-step start-up for manufacturing resource-saving structural solutions using European technology on the basis of PJSC "Kharkiv plant of metal structures". Research methods include conducting research on resource-saving structures using theoretical and analytical methods of calculation, economic justification using the AVK-5 PC.

Keywords Resource-saving · Steel beams · Profiled wall · Startup · PJSC "Kharkiv plant of metal structures" · Manufacturing · Technical and economic indicators

1 Introduction

Ensuring minimal material consumption while maintaining normal performance of building structures is the main task of modern construction. The development of a solid investment project for the production of new more efficient corrugated beams will allow potential foreign investors to really assess the risks and prospects of such a

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_7

project. Given this, the issues of developing an investment project of resource-saving design solutions for the real construction sector is relevant, and the theoretical and practical significance of this challenge is not in doubt. Economic research in this direction was initiated by the author over the past four years and has significant results. In particular, participation in International and all-Ukrainian conferences, two articles in Ukrainian professional journals, which present the development of the entire investment cycle of promotion of various types of products, performance evaluation and selection of effective pricing strategies for projects.

The purpose of the work is to develop an innovative start-up for the production of resource-saving structural solutions in construction based on European experience; to solve an important national economic problem of improving the efficiency of construction work by creating an economically justified project of light beams with a profiled wall and determining the economic feasibility of their use.

Tasks of the work are to review the market conditions of existing structural solutions for light corrugated beams, which provide a number of advantages over traditional structures; to develop a step-by-step start-up for manufacturing resource-saving structural solutions using European technology on the basis of PJSC "Kharkiv plant of metal structures".

Research methods are conducting research on resource-saving structures using theoretical and analytical methods of calculation, economic justification using the AVK-5 software package.

Let's analyze the literature on this issue. The paper [1] addresses lateral torsional buckling of coped beams with corrugated webs. It is found that the ultimate capacity of beams is remarkably reduced by 40–80% depending on the cope geometry. The reduction in the capacity depends on the cope length and cope depth compared to the capacity of un-coped corrugated web beams. The coped beams with corrugated webs still exhibit a greater capacity than do the corresponding coped beams with flat webs. Design equations are developed to depict the strength of coped beams with corrugated webs. In addition, due to low stiffness in the longitudinal direction of the corrugated beams and the absence of the flange in the coped region, the web has a tendency to elongate, and the corrugations are flattened. This phenomenon affects displacements both vertically and laterally and results in large deformations that are not acceptable in engineering practice. Strengthening solutions are introduced in the study [1] to solve this problem. The present paper [2] investigates the seismic performance of unstiffened, corrugated, and low yield point steel walls under monotonic and cyclic loadings. Currently, no design code addresses the seismic performance of low yield point corrugated steel plate shear walls. More investigations are required to develop a fundamental understanding of the performance of these seismic systems employing low yield point steel material and corrugated infill plates. An appropriate evaluation of residual stress is of great importance for the structural performance of corrugated web I-beams under monotonic and cyclic fatigue loading. An experimental programme [3] is presented to examine the residual stress distribution of corrugated web I-beam sections using hole-drilling method. It was found that, unlike flat web I-beam sections, the residual stresses on the beam flange are varied from the location with longitudinal fold to that with the inclined fold of the corrugated web. The results of validated finite element models demonstrate that the distribution of maximum residual tension stress is notably affected by its location on the flange related to corrugation. Moreover, the maximum residual stress is reduced with wider distributing range with the increase of the corrugation angle and curvature radius, especially for the flange part. The work [4] studied the microstructure of beetle forewing in an attempt to design a CSW with a columellar structure similar to that found in the core layer of the forewing. Moreover, a finite element model was used to quantitatively analyze the effects of the columellae on the deformation, shear stress distribution and buckling stability of CSW bridges, which can provide a reference for the bionic structure of a beetle forewing and for the optimization of CSW bridges. Using a curated database of test results, the paper [5] attempts to address the lack of a reliability-based design method specific to corrugated web steel beams (CWSBs). The prefabricated sinusoidal corrugated web steel beam-column joint (PSCWJ) with the earthquake-resilient design concept has been previously proposed [6]. A corrugated web beam (CWB) is a variation to the universal hot rolled or welded I section. CWBs usually comprise of wide thick plate flanges and a thin corrugated web. Due to the accordion effect shear is carried primarily by the corrugated web while bending moments are resisted by the flanges. Under shear action three different modes of shear buckling may be realized in the web—local, global or interactive. The paper [7] describes analyses performed to investigate the local shear buckling behaviour of beams with trapezoidal corrugated webs. Many mechanisms and techniques have been developed to increase the loading capacity of I-section structures, e.g., using composite materials or changing web geometry. The study [8] aims at theoretically investigating the effect of geometry on the buckling capacity of wood composite I-beams with sinusoidal corrugated web. Other studies [13–19].

2 Main Body

2.1 Basics of a Startup for the Production of Resource-Saving Beams with a Profiled Wall

The purpose of the project is to develop a sound investment project for the use of new types of boxed corrugated beams on the basis of PJSC "Kharkiv plant of metal structures" with subsequent implementation throughout Ukraine and beyond it. PJSC "Kharkiv plant of metal structures" is a specialized enterprise for the production of various types of building structures made of ferrous metals: girders, overpasses, galleries, supports, including power lines, special towers, sections and supports of bridges, structures made of sheet metal—silos structures, bunkers, shot blasting, metal cutting on a plasma cutting machine, rolling.

Investment volumes for the period from 2019 to 2021 are planned to create a production line. After the end of this period, PJSC "Kharkiv plant of metal structures" plans to review the production program and, in case of constant demand for products from 2019, its expansion, to meet the needs of potential product buyers.

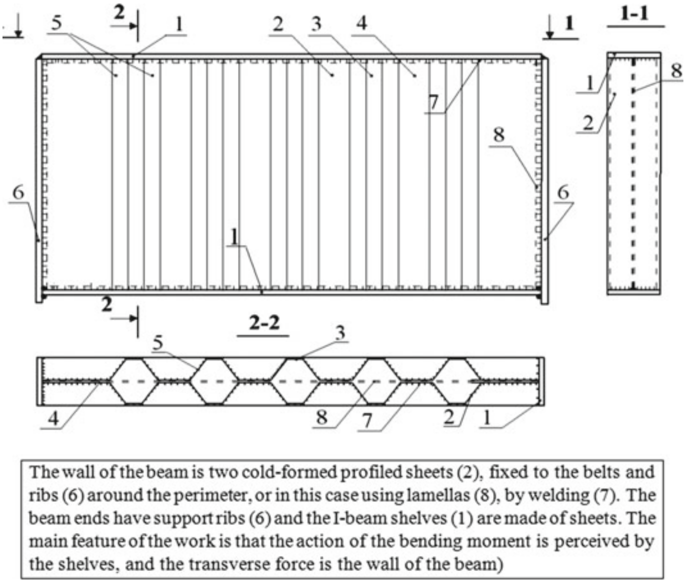


Fig. 1 Steel beam with a cross-profiled box-section wall with uneven pitch of corrugations [9]

Products and their competitiveness are welded steel beam, steel beam with cross-profiled box-section wall with uneven pitch of corrugations (see Fig. 1); steel beam with cross-profiled box-section wall with intermittent welds (see Fig. 2); steel beam with cross-profiled box-section wall with welded-brand belts (see Fig. 3) and with the t-belt from rolling (see Fig. 4).

The project provides for the acquisition of the market all over Ukraine and abroad, with plans to bring to the market products of PJSC "Kharkiv plant of metal constructions" as small and wholesale enterprises that implement metal structures on the territory of Ukraine (enterprises and organizations specializing in metal structures).

The duration of the investment cycle as a whole and by stages: total duration of the settlement period in this work is 3 years. The main stages of implementation of this business plan are its adaptation to the production base of the enterprise and its creation; the stage of business development and increase in sales; the stage of further expansion in 2019 according to the plan.

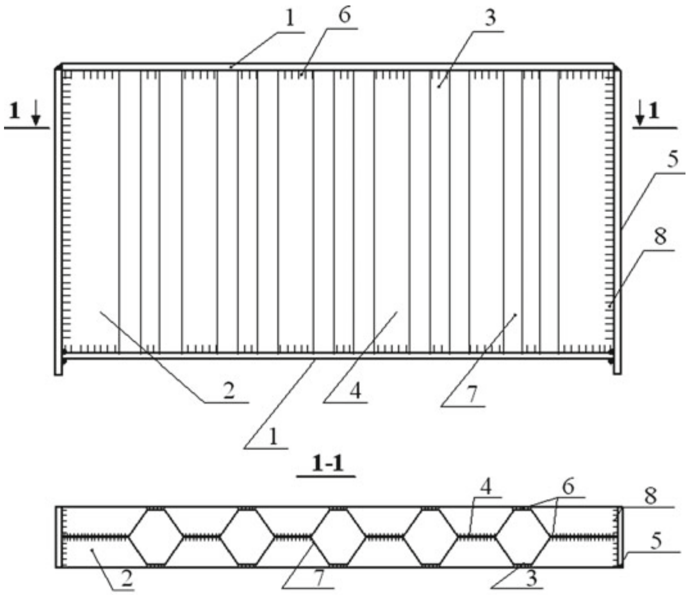
The main types of risk are technological, risk of production downtime; financial, commercial.

Total cost of the project is 1025000 UAH.

It is planned to finance the project at the expense of PJSC "Kharkiv plant of metal structures", which became possible when reserving profits in 2019.

As for the average annual income—according to the profit plan it is planned to receive 10,379,1 UAH in 2020, 20,794,2 UAH in 2021, 33,324,6 UAH in 2022.

Internal return rate is 15.83%, which is a guarantee that the project will be profitable with an increase in the impact of various risks on it.



The structure of such a beam includes a trapezoidal profiled wall (2), which is welded on both sides intermittently (6) only on horizontal sections (3, 4) parallel to the longitudinal axis of the beam. The beam wall the consists of two profiled sheets, which are attached to the edges (5) by continuous welding, and to the belts (1)

Fig. 2 Steel beam with cross-profiled box-section wall with intermittent welds [10]

Payback period is 1.39 years, that is, it is necessary for PJSC "Kharkiv plant of metal structures" to return the amount of investment capital if the factors affecting the project remain unchanged.

Now let's look at all the elements of the project.

The main advantages of these beams primarily include the reduction in the weight of building structures up to 40–60%. There are three major global manufacturers of corrugated boards. They are Dutch company GLP Corrupted plate Industry and Ranabalken, which has been operating on the Swedish market for more than 40 years, and the Austrian firm Zeman & Co. One of the most powerful manufacturers of corrugated wall beams is Zeman, which develops corrugated beams (SIN-beams) made of corrugated sheet and steel strips. So, today there is no significant competitor for the development of BGS in Ukraine. That is, the creation of a production line at PJSC "Kharkiv plant of metal structures" already has a number of significant advantages (Table 1).

Regarding the indicators for evaluating the sales markets of PJSC "Kharkiv plant of metal structures", they are grouped in Table 2. The sales market of PJSC "Kharkiv plant of metal structures" is unlimited.

The use of this type of construction was limited by the lack of appropriate welding equipment, which changed the situation at the present stage with the introduction

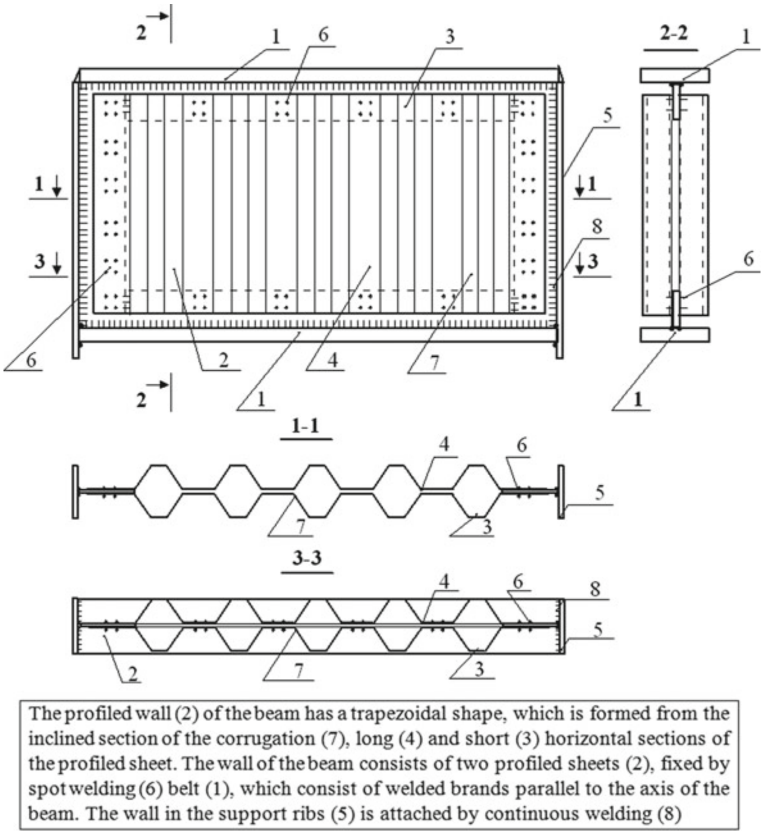


Fig. 3 A steel beam with cross-profiled box-section wall with welded-brand belts [11]

of Western European robotic welding lines, which turned the production of beams with corrugated walls into a fully automated continuous process. The essence of production is that at the first stages, rolled steel is fed from the unwinder to the rectifier to reduce the voltage, and then the steel is cut longitudinally-crosswise into strips of a predetermined width and length. At further stages of production, the billets are fed in turn to the profiling press. With the help of a hydraulic device to the corrugated wall at the welding station, one or both sides of the walls are welded to the prepared shelves. The geometry of the profiled sheet is scanned by a laser, and then two welding guns pass through the joint between the profiled sheet and the shelf. The use of this type of construction was limited by the lack of appropriate welding equipment, which changed the situation at the present stage, as the speed and angle of inclination of the welding gun are automatically controlled to ensure the best quality of one-way (two-way) welding. At the last stages of manufacturing a beam with a corrugated wall, the necessary elements are attached using manual

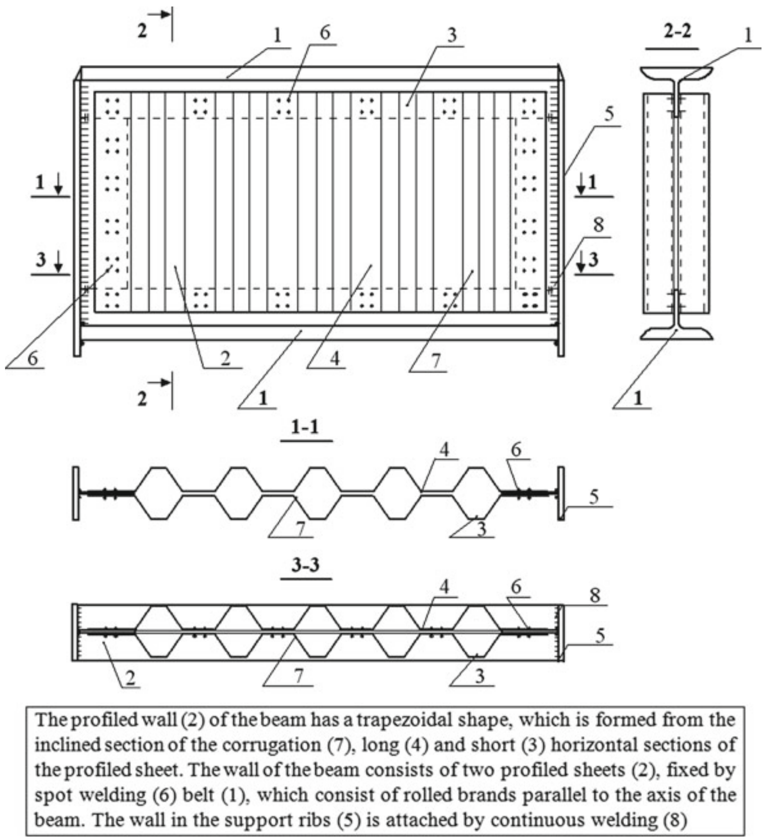


Fig. 4 A steel beam with cross-profiled box-section wall with the t-belt from rolling [12]

Table 1 Competitiveness criteria

Criteria	Beam with profiled wall
Quality	Quality performance of work
Individual approach	Creative, non-standard approach
Price level	Above-average
Location	Located in the regional center
Exclusivity of the service	New service
The reputation of the plant	Reliable reputation

welding, after which you can punch and drill holes. At the end of the beam anti-corrosion treatment is used, namely sandblasting, painting and necessarily drying. Ukrainian production now successfully presents welded beams with corrugation walls of European technology on the construction market. In General, the company's

Table 2 Assessment of sales markets

№	Indicators	Nearby city or nearby location	Localities within a 100 km radius	Markets seized within 100 km
1	Level of demand	High	High	Average
2	The degree of demand satisfaction	Low	Average	Average
3	Level of competition	Average	Average	High
4	Percentage of consumers who are ready to buy products	25%	10%	3%

production program is presented in Table 3. Having analyzed the activities of PJSC "Kharkiv plant of metal structures", we can form a number of risks and problems (Table 4).

The calculation of research structures was carried out using the software package "Automated determination of construction cost, AVK-5" in current prices as of 2019. which is intended for the automated release of estimate and resource documentation, Calculations of the total complexity of manufacturing beams with a profiled wall involved the costs of the main production, such as metal cutting, hole formation, grinding, welding, assembly, painting, as well as the costs of non-main and auxiliary production.

It should be noted that the main indicator, which in our case characterizes the economic efficiency of beam nodes with a profiled wall, is the direct cost per unit of product (raw material costs and wages of production workers). For the purpose of a comprehensive technical and economic assessment, the installation of prototype structures was taken into account, the cost of which consists of direct and overhead costs.

Thus, taking into account the manufacture and installation, possible transport costs, all materials, you can get the total estimated cost of structures. As part of the study, material costs and estimated cost per m of construction were calculated.

We have chosen design of beams with profiled double wall of standard dimensions, namely, height and thickness respectively of the double web $h_w = 45$ cm, $2t_w = 0.2$ cm, width $b_f = 34$ cm and a flange width $t_f = 2.5$ cm, area $A = 179$ cm^2 and weight $G = 142.3$ kg/m (excluding ribs).

In the proposed beam designs, a 50BC3 steel beam was selected, with a beam height of $H = 50$ cm and wall thickness of $t_w = 1.2$ cm, width of $b_f = 30$ cm and shelf thickness of $t_f = 2.5$ cm (excluding ribs).

Let's present the results of calculating the economic efficiency of the proposed beams with a profiled wall in comparison with other typical structures (composite beams) according to local estimates. Having done the comparison of designs of steel composite beams with steel beam with cross-profiled box-section wall with the t-belt from rolling, you will find out the reduction of the estimated cost to 18%, with steel beam with cross-profiled box-section wall with welded-brand belts to 72% and to 10% in comparison with steel beam with cross-profiled box-section wall with

Table 3 Production program of PJSC "Kharkiv plant of metal structures"

Product name	Price, thousand UAH per m	Production volume					
		1st year		2d year		3d year	
		% of design capacity	Quantity	% of design capacity	Quantity	% of design capacity	Quantity
1	2	3	4	5	6	7	8
Steel beam with cross-profiled box-section wall with uneven pitch of corrugations	7,137	60	600	80	1200	100	1800
Steel beam with cross-profiled box-section wall with intermittent welds	7,111	60	300	80	600	100	1200
Steel beam with cross-profiled box-section wall with the t-belt from rolling	4,661	60	600	80	1200	100	1800
Steel beam with cross-profiled box-section wall with welded-brand belts	1,975	60	600	80	1200	100	1800
Total		60	2100	80	4200	100	6600

uneven pitch of corrugations and steel beam with cross-profiled box-section wall with intermittent welds. According to the calculations, the results of which are given in Table 5 recorded a reduction in the consumption of materials in comparison with steel composite beams with steel beam with cross-profiled box-section wall with the t-belt from rolling up to 22% for steel beam with cross-profiled box-section wall with welded-brand belts from 10 and 11% with steel beam with cross-profiled box-section wall with uneven pitch of corrugations and steel beam with cross-profiled box-section wall with intermittent welds.

Table 4 Qualitative analysis of investment project risks

Type of risk	Reason	Factors	Ways to prevent
Technological	Equipment damage	Unskilled worker or untimely repair and maintenance of equipment	Timely technical inspection; employment of employees with the appropriate qualification level
Financial	Late payments of customers for services rendered	Providing services without subscription	Discussion in the contract of prepayment percentages and penalties that will accrue in case of late payments
Commercial	The company's obscurity and lack of trust in it	More famous competitors; anti-advertising competitors	Advertising our company's services; attracting the support of well-known clients and relying on their authority

The forecast of sales volumes for the next 3 years of implementation of the investment project is shown in Table 6. The composition of investment expenses is determined (see Table 7) and we have also calculated the indicators of distribution of net profit (see Table 8) in the course of the research and determination of the financial plan of the startup, the break-even point of the project was calculated (see Table 9).

The composition of investment expenses is determined (see Table 7) and the indicators of distribution of net profit (Table 8), in the course of the research and determination of the financial plan of the startup, the break-even point of the project was calculated (see Table 9). Taxation of investors and entrepreneurs is summarized in Table 10. In order to check the correctness of accounting for planned sources of funds and their distribution, a financial plan is drawn up, i.e. the balance of income and expenses (see Table 11), which horizontally reflects possible sources of funds (profit, depreciation, etc.), and vertically—the direction of funds use (payments to the budget, rent, etc.). Thus, vertical columns show the distribution of funds for each article of the revenue part of the financial plan, and the horizontal lines—the amount of funds received from various sources aimed at covering individual items of expenditure. The balance of cash flows is compiled in the context of three main types of activities: production and current (operating), investment and financing (see Table 12).

2.2 Evaluation of Economic Efficiency of the Project

To determine the effectiveness of an investment project, indicators widely used in international practice are used. These are net present value (NPV), internal rate of return (IRR), return index (IP), payback period (PP). The methodology of their calculations is based on the assessment of the current value of future cash flows of the project.

Table 5 Technical and economic comparison of rational beam nodes with profiled wall with nodes of typical beam structures

Name	Welded steel beams per m	Steel beam with cross-profiled box-section wall with uneven pitch of corrugations per m		Steel beam with cross-profiled box-section wall with intermittent welds per m		Steel beam with cross-profiled box-section wall with the t-belt from rolling per m		Steel beam with cross-profiled box-section wall with welded-brand belts per m	
		Actually	Δ, %	Actually	Δ, %	Actually	Δ, %	Actually	Δ, %
1	2	3	4	5	6	7	8	9	10
Weight of structures, kg	160,3	142,5	11	142	11	124,2	22	145	10
Estimated cost of structures, UAH	7876	7137	9	7111	10	4661	18	1975	72

Table 6 Forecast of sales volumes

Product name	Price per m with VAT, Thousand UAH	1st year		2d year		3d year	
		The volume of sales, m	Revenue from sales with VAT, thousand UAH	The volume of sales, m	Revenue from sales with VAT, thousand UAH	The volume of sales, m	Revenue from sales with VAT, thousand UAH
1	2	3	4	5	6	7	8
Steel beam with cross-profiled box-section wall with uneven pitch of corrugations	7,137	600	4282,2	1200	8564,4	1800	12846,6
Steel beam with cross-profiled box-section wall with intermittent welds	7,111	300	2133,3	600	4266,6	1200	8533,2
Steel beam with cross-profiled box-section wall with the t-belt from rolling	4,661	600	2796,6	1200	5593,2	1800	8389,8
Steel beam with cross-profiled box-section wall with welded-brand belts	1,975	600	1185	1200	2370	1800	3555
At once	–	2100	10397,1	4200	20794,2	6600	33324,6

1. Net Present Value:

$$NPV = 1025 + \frac{2923,69}{(1+0,15)^1} + \frac{2350,20}{(1+0,15)^2} + \frac{5368,36}{(1+0,15)^3} = 6824,21 UAH. \tag{1}$$

Therefore, the investment project is effective.

Table 7 Composition of investment expenses

Investment expenditure	Deposit of own funds (UAH)
Preliminary investment research and preparatory work	45,000
The land development	–
Buildings and structures	–
Infrastructure	–
Technology	–
Construction and installation works total	–
Own equipment (rent)	800 000
Means of transport	–
Adjustment works	–
Personnel training	25,000
Overhead total, including – Advertising – Insurance	50,000 20,000 30,000
Current assets	55,000
Total	**1 025 000**

Table 8 Distribution of net profit

Indicator	1st year	2d year	3d year
1	2	3	4
Revenue from product sales (gross income)	10397,1	20794,2	33324,6
Costs for materials and components	2571,9	13141,3	21504,0
The salary costs	986,1	1084,8	1355,9
Total direct expenses (4 = 2 + 3)	3558,1	14226,1	22859,9
The costs of operation and maintenance of equipment	1035,5	1242,6	1346,1
General production expenses	960,3	1152,3	1248,4
General expenses	97,8	127,1	143,4
Other production costs	64,0	64,0	64,0
Non-manufacturing costs	56,4	56,4	56,4
Depreciation	155,9	155,9	155,9
General fixed expenses (11 = 5 + 6 + 7 +8 + 9 + 10)	2369,8	2798,3	3014,2
Gross profit from project implementation (12 = 1 − (4 + 11))	4469,2	3769,8	7450,5
VAT	893,8	893,8	893,8
Land tax	200,0	200,0	200,0
Taxable income (15 = 12 – 13 − 14)	3375,3	2676,0	6356,7
Income tax	607,6	481,7	1144,2
Net profit (17 = 15 - 16)	**2767,8**	**2194,3**	**5212,5**

Table 9 Calculation of break-even point

Indicator	Unit	1st year	2d year	3d year
1	3	5	6	7
Revenue from product sales (Net income)	Thousand UAH	10,397,1	20,794,2	33,324,6
General variable costs	Thousand UAH	3558,1	14,226,1	22,859,9
Margin income	Thousand UAH	6839,0	6568,1	10,464,7
General fixed expenses	Thousand UAH	2369,8	2798,3	3014,2
Gross profit from the project	Thousand UAH	4469,2	3769,8	7450,5
Weight of the gross margin to total operating income	%	0,65,778	0,31,586	0,31,402
The break-even point	Thousand UAH	3602,8	8859,3	9598,7
The stock of financial stability	Thousand UAH	6794,3	11,934,9	23,725,9
The specific weight of the break-even volume in the maximum possible volume	%	34,65	42,60	28,80

Table 10 Taxation of business activities

Type of taxes and fees	Object taxation	Size of the taxable object	Rate	Amount of tax
1	2	3	4	5
1. Land tax	Land plot		200	200
2. Unified social contribution	Wage fund	By activity	22	182,43
3. Income tax (single tax)	Operating profit before tax			607,6
4. Excise duties	Product			–
Total				1795,8

Table 11 Sources of financing the project, thousand UAH

Possible sources of funding	Contribution	Name of the investor
1	2	3
Own funds	1025	Due to the profit of PJSC “Kharkiv plant of metal structures” in 2019
Bank loans	–	–
Raised funds in total	–	–
Investment leasing	–	–
Innovation fund	–	–
The state budget	–	–
City budget	–	–
State extra-budgetary funds	–	–
Foreign capital	–	–
Total	1025	–

Table 12 Cash flow balance of PJSC "Kharkiv plant of metal structures", thousand UAH

№	Indicator	1st year	2d year	3d year
1	2	3	4	5
1	Cash at the beginning of the period	0,00	2559,02	5470,09
2	Cash receipts			
2.1	From production (operating) activities	10,397,1	20,794,2	33,324,6
2.2	From investment activities, including proceeds from assets sale	0,00	0,00	0,00
2.3	From financial activities, including	0,00	0,00	0,00
2.3.1	Equity capital	0,00	0,00	0,00
2.3.2	External investment flows	0,00	0,00	0,00
2.4	Total cash receipts	10,397,10	20,794,20	33,324,60
3	Cash expenses by type of activity			
3.1	Production (operating) activities	6735,48	17,706,07	27,218,31
3.2	Investment activity, including	1025,00	0,00	0,00
3.2.1	The cost of acquisition of assets	45,00	0,00	0,00
3.2.2	Other expenses of the preparatory period	980,00	0,00	0,00
3.3	Financial activities, including	0,00	0,00	0,00
3.3.1	Return of funds to investors	0,00	0,00	0,00
3.3.2	Payment of interest on loans	0,00	0,00	0,00
3.4	Total cash expenses	7760,48	17,706,07	27,218,31
4	Financial reserve	77,60	177,06	272,18
5	Cash at the end of the period	2559,02	5470,09	11,304,20
6	Cash flow	2923,69	2350,20	5368,36
7	Discount cash flow	2542,34	1777,09	3529,79
8	Cumulative discounted cash flow	2542,34	4319,43	7849,21

$$NPV_2 = 1025 + \frac{2923,69}{(1+0,4)^1} + \frac{2350,20}{(1+0,4)^2} + \frac{5368,36}{(1+0,4)^3} = 63,31\,UAH. \tag{2}$$

2. Internal Rate of Return:

$$IRR = 15 + \frac{6824,21 + (40,15)}{(6824,21 + 63,31)} = 15,83\%. \tag{3}$$

3. The Profitability Index:

$$PI = \frac{1025 + \frac{2923,69}{(1+0,15)^1} + \frac{2350,20}{(1+0,15)^2} + \frac{5368,36}{(1+0,15)^3}}{1025} = 2,15. \tag{4}$$

4. Dynamic Payback Period:

$$PP = 3/2, 15 = 1, 39\, years. \quad (5)$$

3 Conclusion

We have developed the startup of resource-saving production of steel beams PJSC "Kharkiv plant of metal constructions", calculated the value of investments for the implementation of this project, determined the profit for three years and a payback period. Having conducted the comparison of designs of steel composite beams with steel beam with cross-profiled box-section wall with the t-belt from rolling, you can find out that substantial economic effect leas to the reduction of the estimated cost to 18%, with steel beam with cross-profiled box-section wall with welded-brand belts to 72 and to 10% in comparison with steel beam with cross-profiled box-section wall with uneven pitch of corrugations and steel beam with cross-profiled box-section wall with intermittent welds. According to the calculations, the results of which are given in Table 1.5, we have recorded the reduction in the consumption of materials in comparison with steel composite beams with steel beam with cross-profiled box-section wall with the t-belt from rolling up to 22% for steel beam with cross-profiled box-section wall with welded-brand belts from 10 and 11% with steel beam with cross-profiled box-section wall with uneven pitch of corrugations and steel beam with cross-profiled box-section wall with intermittent welds. It has been proven that the project is effective. The payback period was 1,39 years.

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Using a Dual-Flow-Counterflow Na-Cationite Filter in Processing Geothermal Waters

Gulnar Feyziyeva and Oleksander Matyash

Abstract Today, more than ever, the issue of environmental safety in general and, in particular, the protection of the environment from aggressive pollution arising from the operation and operation of engineering and communication systems. Therefore, there was a need to create environmentally friendly, as well as cost-effective technologies that meet modern requirements. As known, the question is also relevant at the present time use of alternative energy sources instead of traditional ones or their sharing. For application of geothermal waters in systems heat supply, heating, industrial technological processes and agricultural industry, its salt content must be brought to the required standards. To prevent the formation of solid, practically insoluble precipitation on the heat exchange surfaces of thermal equipment is mandatory the condition is the removal of hardness, alkalinity and sulfates. Since, these ions precipitate in the form of scale. It is for this reason that in heating systems to prevent the formation of scale is supplied softened network water. This article discusses a new technology softening of geothermal waters, which will be used as coolant. The article is devoted to a detailed analysis of the processing of geothermal water with a Na-cationite filter. Softening methods are also compared geothermal waters by cocurrent and countercurrent methods. Showing advantages of using a new developed technology for processing thermal water using a two-flow-counter-current cationic filter. In the article schematic diagrams of a water treatment plant with a drainless water softening based on direct-flow and counter-flow Na-cationite filter. The developed method for the treatment of geothermal waters on two-flow countercurrent filters is a new promising direction both in the preparation of water for systems heat supply and the use of alternative energy sources.

Keywords Na-cationite filter · Geothermal water · Softening · Double-flow-counter-flow filter · Direct-flow filter

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_8

1 Introduction

Tasks of the current stage of development of water treatment methods for the heating network, industrial and agricultural needs are dictated by the need creation of new environmentally friendly and cost-effective technological solutions. The issue of using alternative energy sources is also relevant. this considered case of geothermal waters. When using geothermal water you can get the following benefits:

- The use of geothermal energy does not pollute the environment
- The use of geothermal energy does not contribute to the greenhouse effect
- Geothermal power plants do not take much places
- No additional fuel consumption
- After the construction of geothermal power plants, fuel components received thermal and electrical energy can be said practically missing
- Reserves of geothermal energy in nature are huge.

2 Problem Statement

When applying a water treatment scheme using existing regeneration technologies for cation and anion filters are consumed significant amounts of reagents, the specific costs of which are several times exceed stoichiometric values and are obtained in large quantities aggressive wastewater.

The latter are acidic, alkaline and saline water, which, after neutralization with the addition of lime, is discharged. Quantity of these effluents sometimes reaches 40–50% of the chemically desalted water.

В качестве недостатков традиционной технологии регенерации ионитов можно отметить использование прямоточного, а также ступенчато-противоточного способа ее осуществления.

As disadvantages of the traditional ion exchanger regeneration technology, one can note the use of a direct-flow, as well as a step-countercurrent method of its implementation. Figure 1 shows a schematic diagram of the technology of drainless water softening based on a direct-flow Na-cationite filter [1].

The disadvantages of traditional countercurrent filter designs include the following:

- the upper drainage system in the filter is at a height where ion exchanger grains with the smallest diameters mainly prevail. This occurs when the ion exchanger is loosened and leads to the fact that the slots of the drainage system are clogged with ion exchanger grains, as a result of which the hydraulic resistance of the filter increases and the hydrodynamic mode of ion exchanger regeneration is disturbed in the case of passing the regeneration solution in the direction from bottom to top;

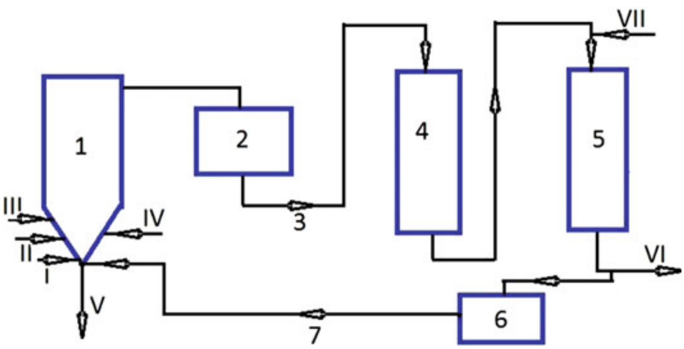

Fig. 1 Schematic diagram of a drainless water treatment plant water softening based on direct-flow Na-cationite filter

- part of the ion exchanger (15–25% of the total working volume), located above the upper drainage system, does not participate in ion exchange. For this reason, the degree of useful use of an expensive ion exchanger is reduced;
- to prevent mixing of the layers in the lower part of the load during regeneration, a "blocking" water flow is fed through the top. This increases the consumption of water for own needs and the amount of reagents used, as well as increases the volume of wastewater.

3 Main Material

To develop a new chemical water treatment scheme that meets these requirements, the latest technologies and the countercurrent principle of ionization should be introduced. The use of the latter is associated with the need to reduce the consumption of reagents. However, as already noted, the use of traditional countercurrent designs of ion-exchange filters is not possible due to their inherent disadvantages. With this in mind, a two-flow-counter-current design of ion-exchange filters was developed.

Advantages of two-flow-counterflow designs of ion-exchange filters:—In addition to the bottom filter, the middle switchgear. Part of the ion exchanger charge located below the middle switchgear operates in a countercurrent ionization mode. Part of the ion exchanger loading above the middle switchgear in both cases operates in a direct-flow mode.

The lower part of the ion exchanger always operates in a countercurrent mode, and this reduces the specific consumption of the reagent for the regeneration of the ion exchanger.

- Increases the degree of purification of treated water.
- The upper part of the ion exchanger loading is involved in ion exchange and improves the efficiency of using the entire volume of the ion exchanger.
- No need for "blocking" water flow from above.

- Middle switchgear in the dual flow filter, in comparison with counter-current filters, is installed lower, where ion exchanger grains with relatively large diameters predominate. This prevents clogging of the middle switchgear slots with ion exchanger grains and provides the necessary hydrodynamic mode of the filter.
- Dual flow filter design, if necessary, allows you to double the performance of filters.
- Reduced number of filters.
- Reduced capital investments for the installation and consumption of ion exchanger.

According to the developed technology, there is no need to process waste solutions obtained during the softening process in an additional installation. This is due to the fact that the waste solutions are processed at the main water treatment plant and reused. According to the proposed technology, spent regeneration solutions, after appropriate processing at the main plant, are used in construction [1, 2]. Figure 2 shows a schematic diagram of a drainless water softening technology based on two-flow countercurrent Na-cationization.

On the technological scheme I—source water; II—lime; III—soda; IV—coagulant; V—sludge; VI—softened water; VII—salt solution. According to the developed technology, the source water in the clarifier 1 is treated with lime, soda and coagulant. $FeSO_4$ or $FeCl_3$ compounds are accepted as a coagulant. The purpose of the coagulant is to ensure that the suspended particles contained in the water and formed as a result of the reactions stick together, increase, become heavier and, as a result, settle better. Together with the treated water, the spent solution is added to the clarifier, which, being mixed with water, is processed together with it. In this case, the following reactions take place in the clarifier:

$$MgSO4 + Ca(OH)2 = Mg(OH)_2 + CaSO_4,$$
$$Mg(HCO_3) + 2Ca(OH)_2 = Mg(OH)_2 + CaCO_3 + 2H_2O,$$
$$Ca(HCO_3) + Ca(OH)2 = 2CaCO_3 + 2H_2O,$$

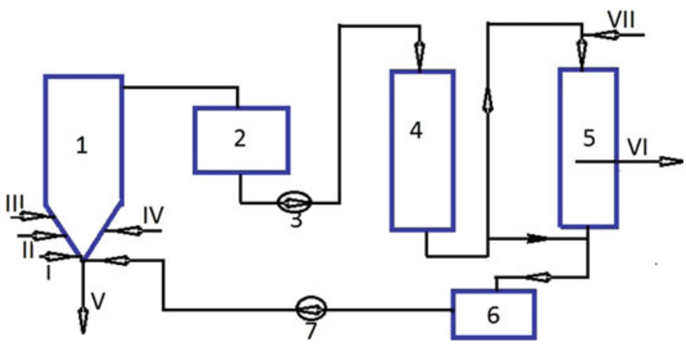

Fig. 2 Schematic diagram of a water treatment plant for drainless water softening based on a countercurrent Na-cationite filter

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4, CaCl_2 + NaCO_3 = CaCO_3 + 2NaCl,$$
$$4FeSO_4 + 4Ca(OH)_2 + O_2 + 2H_2O = 4CaSO_4 + 4Fe(OH)3.$$

The main part of the hardness ions contained both in water and in the spent solution are deposited in the clarifier with lime and soda. Clarified water with a residual hardness of approximately 1 mg-eq/l is collected in a clarified water tank 2. Then it is taken by a pump 3 and sequentially passed through a mechanical 4 and Na-cationite 5 filters. The mechanical filter retains the residual mechanical particles contained in the clarified water. After deep softening in the Na-cationite filter, water is supplied to the consumer. Na-cationite filter is regenerated with NaCl solution. The spent regeneration solution, which contains NaCl, $CaCl_2$ and $MgCl_2$ compounds, is collected in the waste solution tank 6. Then, together with the source water, it is fed into the clarifier for processing. In the clarifier, due to the decomposition of bicarbonate ions and a decrease in carbonate hardness in the treated water, the salinity of the treated water is lower than that of the original.

Salts in the composition of the waste solution to a certain extent increase the salinity of the treated water and bring its value closer to the salinity of the original. The final salinity of the treated water must always be equal to or less than the salinity of the source water. This is the main requirement for drainless water treatment technology. In the case of using a direct-flow filter in the considered technological scheme, the specific consumption of salt supplied for regeneration is taken 2–3 times higher than the theoretical one.

The specific consumption of soda for the cation exchanger KU–2–8 is assumed to be 2, and for the cation exchanger CK–1, 3 g-eq/g-eq. To reduce the amount of salt supplied to regeneration in the scheme under consideration, a counter-current filter and counter-current regeneration technology should be mainly used. But since counterflow filters have a number of disadvantages, their use is limited. Taking into account all the disadvantages of traditional counterflow filters, the considered two-flow-counterflow regeneration technology and filter design have been developed. According to the developed two-flow-counterflow technology, the regeneration solution (or treated water) enters the filter from below and from above, and is discharged through the middle drainage device installed inside the cationite. The treated water (or regeneration solution) is fed into the filter from top to bottom. The amount of salt supplied for regeneration can be reduced for the KU-2–8 cation exchanger to 1.5 g-eq/g-eq, and for the SK-1 cation exchanger to 2 g-eq/g-eq, since part of the cation exchanger in the filter, located below the middle drainage device operates in counterflow mode all the time. Since the proposed filter does not have the disadvantages inherent in traditional countercurrent filters, the range of its application increases significantly. Another significant advantage of the double-flow-counter-flow filter is its twice the capacity compared to the direct-flow and counter-flow filters due to the supply of treated water in two streams [2, 4].

4 Conclusions

As follows from the above, the disadvantages that occur on counterflow filters in double-flow-counterflow designs are eliminated.

According to our forecasts, the proposed method of processing geothermal waters with Dual flow filters will become a new direction in both water treatment and the use of alternative energy sources.

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Thermo-Technical Calculation of Combined Roof Structure with Variable Thickness Layers

Olena Filonenko

Abstract The paper aims to elaborate engineering methods of calculating heat loss through combined roof constructions. Roof heat losses can reach up to 40% of total heat losses of a building and affect its energy efficiency class. In Ukrainian construction regulations there are no methods of roof heat loss determination which would take into account structural features. Combined roofing is a multi-layer envelope with variable thickness layers (for example, to create a slope for organized drainage system). Therefore, the total thermal resistance varies in different areas of the structure. This paper analyzes calculation of heat transfer coefficient of components with variable thickness layers according to PN-EN ISO 6946:2008 and proves the necessity of including the methods above in the Ukrainian guidelines for calculating heat transfer by transmission. The article is a continuation of the author's previous scientific research. The main papers are given in the bibliography.

Keywords Heat transfer resistance · Heat loss · Combined roof · Thermal insulation · Heat transfer linear coefficient · Eave · Temperature field

1 Introduction

The change in conditions of economic environment in Ukraine, which occurred due to the pressure from a number of political and economic factors, including the change in pricing policy for services in the housing and utility services sector and in the market for construction products enhanced the need for rigid energy savings, thermal protection and thermal modernization of buildings in line with European standards. The introduction of new mechanisms to ensure the energy efficiency of construction and to increase the requirements for predicting the hydrothermal conditions of buildings and their structural elements will allow providing a higher level of energy savings.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_9

Depending on the construction solution, roof heat loss can reach up to 40% of the total house heat loss. According to the laws of convection, heated air rises, so heat losses through the roof are more noticeable. In addition, the contact of heated air from the room with a cold surface of the coating will inevitably cause condensation unless the roof is insulated. Water will gradually destroy the structure of the roof, and in the case of combined roof it will flow back into the habitable inner space. Insulation is essential in creating favorable microclimate conditions in rooms that are located directly below the combined roof in both the heating and cooling period conditions [6].

The paper [1] provides systematization of construction systems used in planar and pitched roofs for insulation. Taking into account the experience of leading companies, the peculiarities of exterior decoration systems use were considered in the paper: construction solutions, material requirements and installation recommendations for installation of these systems. Insulating the eaves of the roof is necessary to avoid cold bridges. Sketches with practical design solutions and examples were presented in the paper [2]. The calculation of heat accumulation, taking into account the thermal stability of structures shows the need to specify the engineering methods for predicting the thermal behavior in buildings.

Roofs also require attention in the summer, as they make up a large part of the building total area and significantly absorb solar radiation. In the papers [3, 4], the advantages of using ventilated roofs to reduce cooling loads in hot climates were studied. This is the first step towards ideas that transform local construction methods to make them effective in energetic, economic and functional dimensions.

The development of energy efficient solutions for the construction of combined roofs is a continuation of the author's previous scientific research [5–10]. When designing modern structures, the use of extreme principles is promising [11–16].

Combined roofing is a multi-layer envelope with variable thickness layers (for example, to create a slope for organized drainage system). Therefore, the total thermal resistance varies in different areas of the structure. There are no recommendations in the Ukrainian regulatory framework to take into account the change in heat transfer resistance when changing thickness of layers in the structure of combined roofs. Therefore, the heat transfer resistance of the structure for calculating transmission costs is greatly increased.

Ukrainian construction regulations do not specify any methods of roof heat loss determination which would take into account structural features as well as the values of linear heat transfer coefficients. For typical structural units in Annex Γ of State construction standards of Ukraine DSTU $Б$ B.2.6–189:2013, only the values of linear heat transfer coefficients for wall structures and their elements are given. Putting into practice insulation of typical energy-efficient structural units of combined roof will significantly increase thermal protection of the house. Analysis of the heat transfer coefficient calculation for components with variable thickness layers according to PN-EN ISO 6946:2008 will demonstrate the need to include the above methods in the Ukrainian guidelines for calculation of heat transfer by transmission.

The aim of the paper is to clarify calculation methods of heat loss through combined roofs taking into account layers of variable thickness.

Research methods are based on the calculation of two-dimensional temperature fields by finite element method and engineering methods for determining heat transfer coefficients.

2 A Method for Calculatin of Combined Roof Structure with Variable Thickness Layers

If there is no information (or it is insufficient) on heat-conducting inclusions in a structure, it is recommended to use a correction factor to the heat transfer coefficient to take into account the effect of heat-conducting inclusions, according to the formula (21) of the State construction standards of Ukraine DSTU Б A.2.2–12: 2015:

$$U_{op,corr} = U_{op,mn} + \Delta U_{tb}, \tag{1}$$

where $U_{op,mn}$ is heat transfer coefficient of a non-transparent part of the construction (on the main field), W/(m^2·K).

ΔU_{tb} is an additional component by default to the heat transfer coefficient of non-transparent structures, U_{op}, which includes the effect of heat-conducting inclusions, W/(m^2·K), calculated values are given in Table 4 [17] of the State construction standards of Ukraine DSTU Б A.2.2–12:2015, and for the average value of the heat transfer coefficient of non-transparent parts of construction it is $U_{op,mn}$ < 0,4 ΔU_{tb} = 0,15 W/(m^2·K).

Such a significant amount of additional component can at times reduce the actual value of combined roof thermal resistance. Therefore, to improve the accuracy of calculations, it is advisable to use the formula of the reduced thermal resistance of a thermally inhomogeneous non-transparent building envelope structure (3) in the State construction standards of Ukraine DSTU Б B.2.6–189:2013. The calculation of heat transfer linear coefficients is done on the basis of calculations of two-dimensional temperature fields and the methodology of the State construction standards of Ukraine DSTU ISO 10211–1, the State construction standards of Ukraine DSTU ISO 10211–2.

The heat transfer coefficient of components with variable thickness layers is calculated by the following method according to PN-EN ISO 6946:2008.

The construction with a variable thickness layer is shown in Figs. 1, 2, 3, 4 and 5.

The heat transfer coefficient is determined by integrating the area of the respective element. The calculations must be done separately for each part, for example, of different slope and/or shape roof parts, as shown in Fig. 1.

The heat transfer coefficient for commonly used multilayered roof forms can be calculated by formulas (2) to (5) with a slope of not more than 5%.

For rectangular surfaces (Fig. 2) the heat transfer coefficient is calculated by the formula:

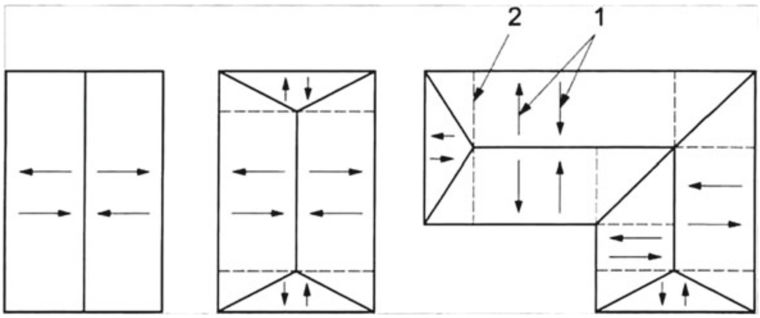


Fig. 1 Examples of dividing roofs into different parts

$$U = \frac{1}{R_2} \ln\left(1 + \frac{R_2}{R_0}\right), \tag{2}$$

where R_0 is the design thermal resistance of the part of the structure with constant thickness layers, $m^2 \cdot K/W$;

R_2 is the maximum thermal resistance of a variable thickness layer, $m^2 \cdot K/W$;

d_2 is the maximum thickness of a variable thickness layer.

1—slope direction, 2—conditional distribution, which allows to use the Eqs. (2–5).

For triangular surfaces with maximum thickness at the apex (Fig. 3), the heat transfer coefficient is determined by the following formula:

$$U = \frac{2}{R_2}\left[\left(1 + \frac{R_0}{R_2}\right)\ln\left(1 + \frac{R_2}{R_0}\right) - 1\right], \tag{3}$$

Fig. 2 Diagram of a rectangular surface

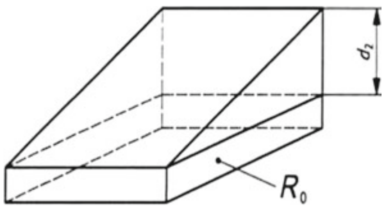
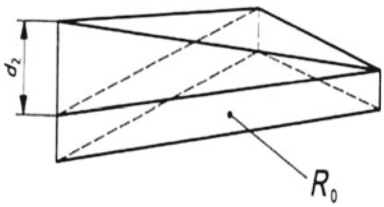


Fig. 3 Triangular surface with maximum thickness at the apex



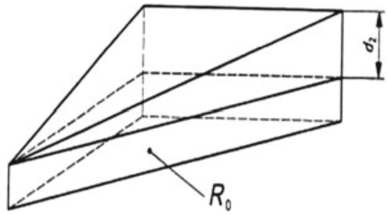


Fig. 4 Diagram of a triangular surface with a minimum thickness at the apex

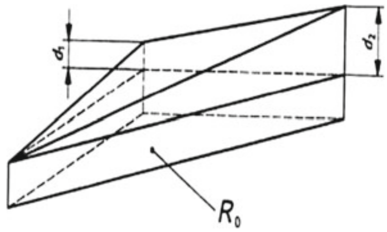


Fig. 5 Diagram of a triangular surface with different thickness at each vertex

For a triangular surface with a minimum thickness at the top (Fig. 4), the heat transfer coefficient is determined by the following formula:

$$U = \frac{2}{R_2}\left[1 - \frac{R_0}{R_2}\ln\left(1 + \frac{R_2}{R_0}\right)\right], \tag{4}$$

For a triangular surface with different thickness at each vertex (Fig. 6), the heat transfer coefficient is determined by the following formula:

$$U = 2\left[\frac{R_0 R_1 \ln\left(1 + \frac{R_2}{R_0}\right) - R_0 R_2 \ln\left(1 + \frac{R_1}{R_0}\right) + R_1 R_2 \ln\left(\frac{R_0 + R_2}{R_0 + R_1}\right)}{R_1 R_2 (R_2 - R_1)}\right], \tag{5}$$

where R_1 is the thermal resistance of a structure part with layers of variable thickness, $m^2 \cdot K/W$;

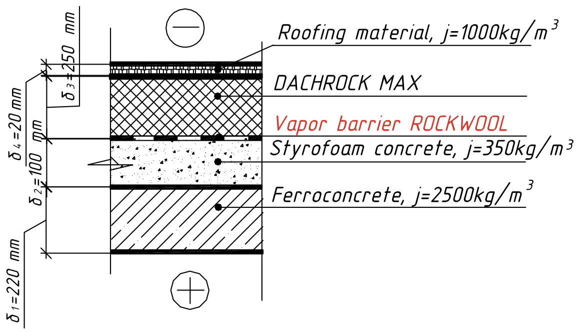


Fig. 6 Design diagram of insulated roofing

d_1 is the intermediate variable thickness layer;
d_2 is the maximum thickness of the variable thickness layer.
The heat transfer coefficient of the roof is determined as follows:

(a) calculate R_0 as the total thermal resistance of the component, excluding the variable thickness layer;
(b) if necessary, divide the area with layers of different thickness into different sections (see Fig. 1);
(c) calculate R_1 and R_2 for each variable thickness layer by the formulas

$$R_1 = \frac{d_1}{\lambda_1}, \quad (6)$$

$$R_2 = \frac{d_2}{\lambda_2}, \quad (7)$$

where d_1 is the intermediate layer with variable thickness, m;
d_2 is the maximum thickness of the variable thickness layer, m;
λ_i is the heat transmission coefficient of the material of the layer, W/(m·K).
The value of R_1 is only used for the diagram shown in Fig. 5.
(d) calculate the heat transfer coefficient of each separate part, Uj, according to the corresponding formulas (2)–(5).
(e) calculate the total heat transfer coefficient of the whole area using the following formula:

$$U = \frac{\sum U_i A_i}{\sum A_i}, \quad (8)$$

The total thermal resistance of a combined roof is calculated by the formula:

$$R = \frac{1}{U}. \quad (9)$$

3 Comparison of Methods the Methods of Ukrainian and Polish Guidelines for Determining Heat Losses by Combined Insulated Roofing

To compare the methods of Ukrainian and Polish guidelines for determining heat losses by combined insulated roofing, the calculations were done under uniform initial conditions.

For thermo-technical characteristics of the combined roof to achieve the normative value, insulation with DACHROCK MAX double-density stone wool insulation (210 kg/m^3 for the upper layer, 130 kg/m^3 for the lower) according to the

Table 1 Comparison of calculation methods of heat losses through combined roofing

Calculation course by the methods	
PN-EN ISO 6946:2008	DSTU Б А.2.2–12:2015
– thermal resistance of a part of the envelope without taking into account the variable thickness layer: $R_0 = 6.47$ m^2·K/W – the maximum thermal resistance of the variable thickness layer is: $R_2 = 3$ m^2·K/W – heat transfer coefficient according to the formula (2): $U = 0.127$ W/m^2·K – heat transfer resistance taking into account cold bridges according to the formula (3) of the State construction standards of Ukraine DSTU *Б* B.2.6–189: 2013 is: $R_{\Sigma np} = 6{,}689$ m^2·K/W	– heat transfer resistance of the combined roof, taking into account the slope-forming layer average thickness $R_{\Sigma} = 6.634$ m^2·K/W – heat transfer coefficient: $U = 0.127$ W/m^2·K – heat transfer coefficient correction according to Table 4 of the State construction standards of Ukraine DSTU *Б* A.2.2–12: 2015: $\Delta U_{tb} = 0.15$ W/(m^2·K)
The result of the calculation is the reduced heat transfer coefficient of the building roof	
$U_i = 1/6{,}689 = 0{,}149$ Вт/(м^2·К)	aorm. (21) DSTU Б А.2.2–12:2015: $U = 0.301$ Вт/м^2 К

diagram (Fig. 6) 250 mm thick is recommended. The slope-forming layer is made of polystyrene concrete.

A roof slope of 5% is provided to ensure atmospheric water runoff. In the case of a double-pitch roof and the gable facade width of 12 m, the maximum thickness of the slope-forming layer is 300 mm (Table 1).

4 Conclusions

The use of a correction factor to the heat transfer coefficient for considering the effect of heat-conducting inclusions according to the formula (21) [17] of the State construction standards of Ukraine DSTU *Б* A.2.2–12:2015 leads to a decrease of thermal resistance actual value of the multilayered combined roof construction by two times. Obtaining a certain class of energy efficiency of the building, as a whole, does not lead to economically impractical waste of thermal insulation material in the roof, the energy efficiency of which is significantly reduced. Refining calculation methods of heat losses through combined roofing will significantly increase the thermal protection of the house.

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An Analytical Model of Calculating the Flexural Strength of Encased SRC Composite T-beams with Full Interaction of Components

Tatiana Galinska, Dmytro Ovsii, Mukhlis Hajiyev, and Oleksandra Ovsii

Abstract The analytical model of calculation of flexural strength of composite steel-reinforced concrete (SRC) enclosed T-beams is proposed in the work. This model makes it possible to calculate the strength of the calculated sections of enclosed SRC T-beams taking into account their stress–strain state at the time of maximum bearing capacity. Comparison of experimental test data of enclosed steel-reinforced concrete T-beams and elements, which were performed by scientists of the world, with theoretical calculations of the proposed model confirmed the possibility of its use in the practice of their design. The following analytical dependencies can be used to solve two practical problems: checking the flexural strength and designing the optimal cross sections of span steel-reinforced concrete (SRC) elements in concrete casing in the form of a T-section.

Keywords Steel-reinforced concrete · Composite · T-beams · Flexural strength

1 Introduction

Composite elements of concrete and steel reinforcement can be divided into three types: a combination of reinforced concrete slabs and steel profiles; composite elements made of steel profile in concrete encasement, also known as reinforced concrete elements with rigid reinforcement; prefabricated monolithic composite elements made of external precast steel or reinforced concrete formwork filled with concrete. Composite steel reinforced concrete element allows to effectively taking advantage of the characteristics of structural steel and reinforced concrete and provides a design solution for elements that require high strength and ductility.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_10

Calculation of flexural strength of steel-reinforced concrete elements used in the design standards AISC 360–10 [1], Eurocode 4 [2], KBC 2014 [3], JGJ 138–2016 [4], JSCE 2009 [5] and DBN B.2.6 -160: 2010 [6], is based on four basic analytical models with different prerequisites that allow them to be designed by civil engineers.

According to Chen in [7], in the building codes of AISC [1] consistently from simple to complex set out for the convenience of engineers at designing, four analytical methods for determining the strength of steel-reinforced concrete elements in bending. Simple analytical methods are based on conservative calculations, using which in some cases such a design can lead to excessive reserves of strength and overconsumption of components of steel-reinforced concrete elements. Conversely, complex methods that require a lot of effort in calculations are expected to be more accurate than simple methods, which will lead to more cost-effective design. Therefore, information on the accuracy of each method is crucial for engineers to choose between conservatism and austerity.

As noted Chen in his work [7], AISC 360–10 [1] proposes the following analytical methods for determining the bending strength of reinforced concrete elements in a shell:

- the superposition of elastic stress;
- the plastic stress distribution on the steel section alone;
- the plastic stress distribution on the composite section (PSD on the composite section);
- strain compatibility method.

As Chen in [7], of the four analytical methods, the last two methods are allowed, according to the AISC specification [1], only if the structure provides anchor elements to prevent displacement, ensuring the joint interaction of the components in enclosed SRC T-beams at the operational and boundary stages.

Today, scientists continue to improve analytical models for calculating the bending strength of reinforced concrete and steel-reinforced concrete elements, which are based on the model of balanced failure (ideal failure), when the calculated cross section is simultaneously crushing compressed concrete and rupture of reinforsment bars, when stresses in cross section of the steel profile reaches stresses exceeding the yield strength.

The aim of the study is development a general algorithm and analytical dependences for calculating the flexural strength of encased steel-reinforced concrete (SRC) composite T-beams depending on the stress–strain state of their design cross section at the time of failure.

2 Analytical Model of Calculation of the Flexural Strength of Composite Enclosed SRC T-beams with Full Interaction of Components

The analytical model for the calculation of the flexural strength of enclosed steel-reinforced concrete (SRC) composite T-beams is the continuation of the authors' scientific research results aimed to improve their calculation procedure. The main theoretical methodological prerequisites for the calculation of the enclosed SRC composite T-beams have been previously developed by the authors in the following academic papers [8, 9]. In order to work out the analytical model for the calculation of the flexural strength of encased steel-reinforced concrete (SRC) composite.

T-beams with full interaction of components have defined the following prerequisites:

- strain distribution in cross-sections of an SRC T-beams at plastic (Composite-PSD) or elastic–plastic (Composite-SC) stages is carried out jointly by linear dependencies. Anchor elements are expected to be used to prevent shear and ensure the co-operation of components of steel-reinforced concrete elements in operational and boundary stages. The criterion for the limit state at the breaking moment of the design section of the SRC composite T-beams is the extremum criterion for achieving deformations of the compressive zone of the concrete with the limit value ε_{cu}, at which the flexural strength M_{Rb} of elements will be maximum:

  case a: $M_{plRb}(\varepsilon_{cu}, \varepsilon_a > \varepsilon_{au}) = max-$ is the plastic stage of destruction of encased SRC T-beams (Composite-PSD);

  case b: $M_{Rb}(\varepsilon_{cu}, \varepsilon_a = \varepsilon_{au}) = max-$ boundary stage of destruction of encased SRC T-beams—the border set between plastic stage (Composite-PSD) and elastic–plastic stage of destruction (Composite-SC);

  case c: $M_{Rb}(\varepsilon_{cu}, \varepsilon_a < \varepsilon_{au}) = max-$ elastic–plastic stage of destruction of encased SRC T-beams.

  The extremum criterion for the destruction of $M_{Rb}(\varepsilon_{cu}, \varepsilon_a = \varepsilon_{au}) = max$ was formulated similarly to the criterion $N(\varepsilon_{cu}, \varepsilon_s = \varepsilon_{su}) = max$, which was recommended by Mitrofanov in article [10] in order to calculate optimal compression RC elements.

- the effort N_c in the compression area of the encased SRC T-beam's cross-section is determined by mathematical relations, proposed by the scientists James K. Wight and James G. Macgregor and is now the basis for calculating the flexural strength of RC beams in Eurocode 2 and SRC beams in Eurocode 4 [2];
- the analysis of cross sections of encased SRC T-beams revealed that most part of cross-sections can be corrected to generalized characteristic design sections, which will be reduced to their vertical axis. The steel profile in the cross section of the encased SRC T-beams can be in the form of an I-beam or a U-shaped profile (Fig. 1);

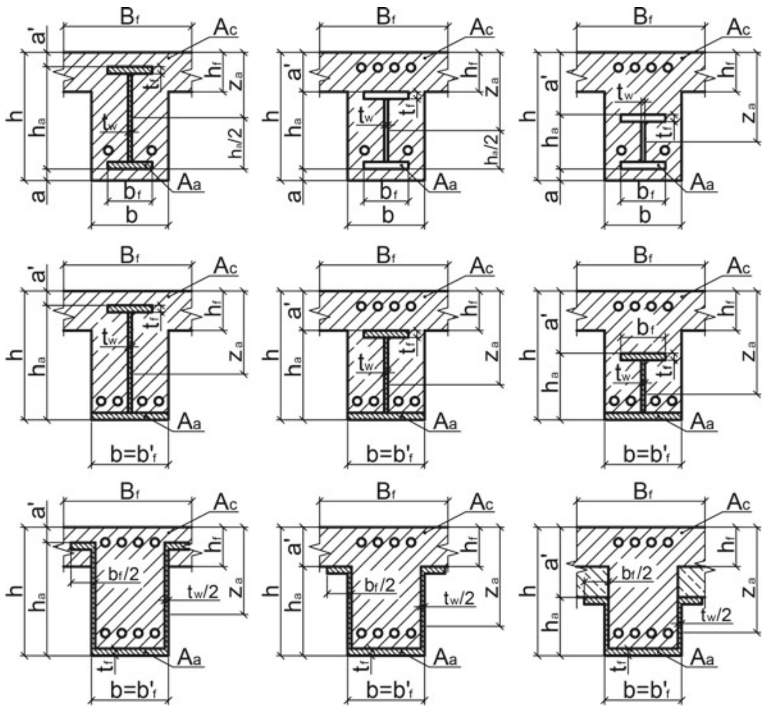

Fig. 1 Typological series of characteristic design sections of composite SRC T-beams in concrete casing in the form of a T-section

- to solve a multifactorial problem of determining the bending strength in sections of closed T-beams, it was necessary to bring one of them to the design transformed section, taking into account the type and magnitude of its reinforcement. To approximate the steel-reinforced concrete cross-section of the SRC T-beam to the steel–concrete section, it was proposed to use the value of the calculated compressive strength of reinforced concrete f_{zM} instead of the calculated compressive strength of concrete f_c, which the authors to determine in [11, 12, 17–21] depending on the type and coefficient of reinforcement ϖ:

$$f_{zM} = f_c \cdot k_z$$

$$f_c = f_{zM}/k_z$$

where k_z—parameter which depends on the mechanical reinforcement coefficient ϖ and options for reinforcing the section; presented in Tables 1, 2 and 3.

Table 1 Dependence of $\varpi - k_z$ by the flat bend for a rectangular section with single reinforcement [12]

ϖ	0	0,1	0,15	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,6	0,7	1	2	3
kz	0	0,568	0,828	1,071	1,299	1,511	1,706	1,885	2,028	2,07	2,14	2,95	2,31	2,476	2,542

Table 2 Dependence of $\varpi - k_z$ by the flat bend for a rectangular section with symmetrical reinforcement [12]

ϖ	0	0,1	0,15	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,6	0,7	1	2	3
kz	0	0,368	0,523	0,673	0,821	0,967	1,110	1,253	1,394	1,53	1,81	2,072	2,78	5,06	7,32

Table 3 Parameter values k_z for non-central compressed elements of rectangular cross-section with symmetrical reinforcement $\lambda \leq 4$ ($\lambda \leq 0$) [12]

ϖ	Relative initial eccentricity of longitudinal force application e_0/d									
	0,01	0,15	0,30	0,65	1,0	1,5	2,0	3,0	4,0	5,0
0,10	1,159	0,817	0,575	0,206	0,090	0,047	0,032	0,019	0,014	0,011
0,15	1,209	0,875	0,640	0,272	0,131	0,070	0,047	0,029	0,020	0,016
0,20	1,259	0,918	0,682	0,326	0,169	0,092	0,062	0,038	0,027	0,021
0,25	1,309	0,959	0,721	0,375	0,204	0,114	0,077	0,047	0,034	0,026
0,30	1,359	0,999	0,758	0,420	0,238	0,136	0,092	0,056	0,040	0,031
0,35	1,409	1,040	0,794	0,461	0,270	0,157	0,107	0,065	0,047	0,037
0,40	1,458	1,077	0,829	0,499	0,301	0,177	0,123	0,075	0,054	0,042
0,45	1,509	1,113	0,864	0,535	0,330	0,197	0,137	0,084	0,060	0,047
0,50	1,558	1,148	0,897	0,568	0,359	0,217	0,152	0,093	0,067	0,052
0,60	1,658	1,216	0,964	0,619	0,413	0,256	0,180	0,111	0,080	0,062
0,70	1,758	1,284	1,029	0,667	0,464	0,293	0,209	0,130	0,093	0,073
1,0	2,058	1,544	1,221	0,804	0,597	0,400	0,290	0,183	0,133	0,104
2,0	3,058	2,297	1,340	1,222	0,916	0,676	0,535	0,354	0,261	0,205
3,0	4,057	3,068	1,462	1,665	1,256	0,930	0,738	0,515	0,384	0,305

- a typological analysis of the cross-sections of an enclosed SRC T-beams showed that all their sections can be converted to one calculated transformable section in order to generalize their calculation method for bending. The converted design transformable cross-section of the enclosed SRC T-beams consists of a steel I-beam (steel profile) in concrete casing in the form of a T-section (Fig. 2);
- as a result of the generalization, we have selected six isolated cases of strain–stress state of the design section of the encased SRC T-beams at determining the flexural strength (Fig. 3). Differentiation of cases for encased SRC T-beams limit state depending on the position of the neutral axis in their section allows us to work out a stepwise algorithm of the analytical calculation model of their flexural strength and to obtain the basic calculated correspondences.

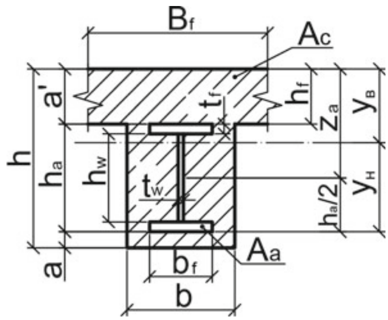

Fig. 2 The transformable calculated cross-section of the enclosed SRC T-beams

2.1 *The Algorithm of Calculation of Flexural Strength Encased SRC T-beams*

The purpose of the analytical method of design flexural strength of the encased SRC T-beam is determineting the limit value of the bending moment M_{Rb}, which perceives its design section, and to compare it with the external moment M from the load action: $M_{Rb} \geq M$ or $M_{plRb} \geq M$.

The succession of determining the encased SRC composite T-beam's flexural strength according to the proposed analytical method of design (mathematical method of calculation) is shown in the block diagram (Figs. 4 and 5).

At the first stage of calculation the flexural strength of the encased SRC T-beam at present parameters, dimensions of the design section and strength of the composites (ε_{cu}, ε_{au}, E_C, E_a, f_{cd}, f_y. A_C, A_a and h_w are calculated using Eqs. (1), (2) and (3)), we will find the following:

$$A_C = B_f \cdot T_f \tag{1}$$

$$A_a = 2 \cdot t_f \cdot b_f + h_w \cdot t_w \tag{2}$$

$$h_w = h_a - 2 \cdot t_f \tag{3}$$

– the result of the product $\alpha_a \cdot \mu$ Eq. (4) will be calculated as:

$$\alpha_a \cdot \mu = E_a \cdot A_a / (E_C \cdot A_C) \tag{4}$$

– let us check the constraint:

$$\alpha_a \cdot \mu \geq \alpha_a \cdot \mu_{onm},$$

– where $\alpha_a \cdot \mu_{onm}$ is the optimal value of the product, at which the maximum flexural strength will be equal to the mathematical relation: $M_{Rb}(\varepsilon_{cu}, \varepsilon_a = \varepsilon_{au}) = max$,

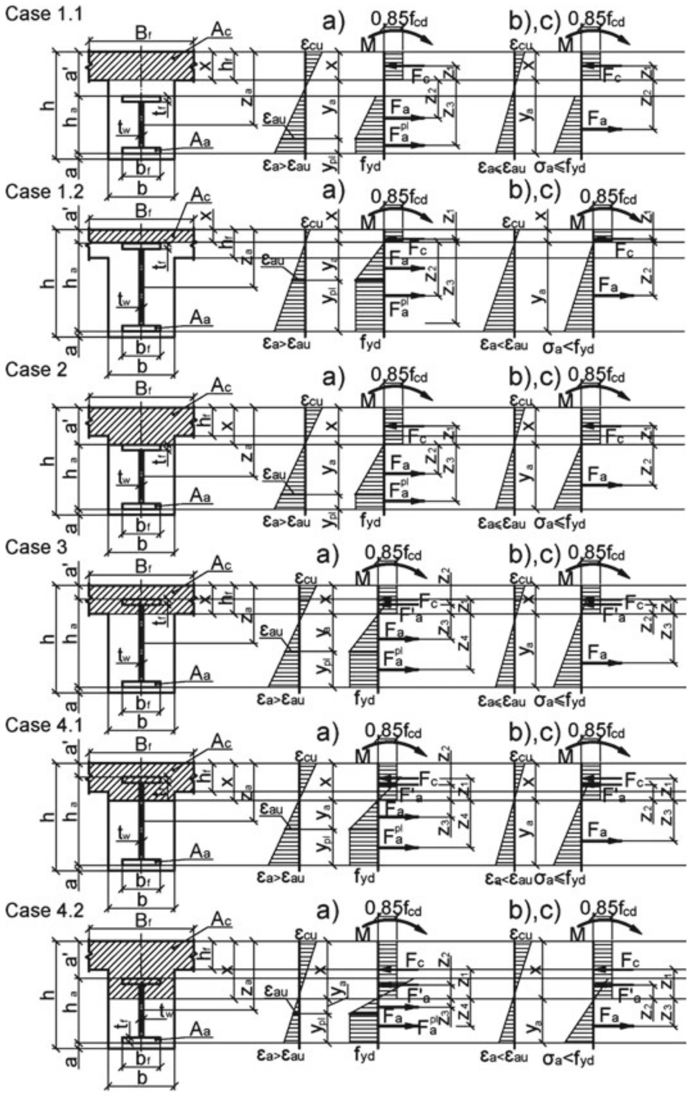

Fig. 3 Cases of the limit stress–strain state for calculated transformed cross-section of the enclosed SRC T-beams design at determining their flexural strength

when the deformations in the extreme fiber of the compressive zone of the concrete reach the value $\varepsilon_C = \varepsilon_{cu}$, and in the steel segment they reach the value $\varepsilon_a = \varepsilon_{au}$. The values of the product quantities $a_a \cdot \mu_{onm}$ can be determined from the data in the tables given in the authors' research work [9], or using the mathematical relations given in Eqs. (5), (6), (7), (8) and (9):

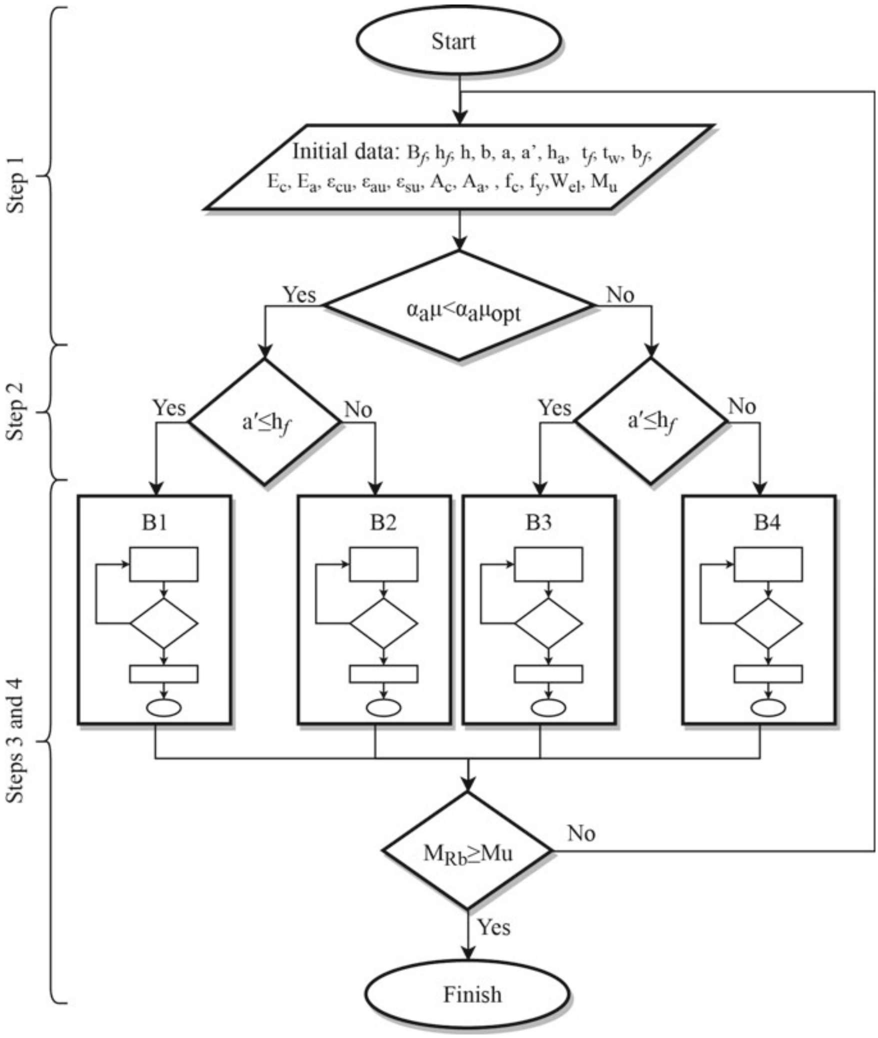

Fig. 4 The block diagram of the succession of determining flexural strength the encased SRC T-beam

$$\alpha_a = E_a/E_C \tag{5}$$

$$\mu_{onm} = (1 - \Delta_\varepsilon)/\{\alpha_a \cdot [2 - (\Delta_c + \Delta_h) \cdot (1 + \Delta_\varepsilon)]\} \tag{6}$$

$$\Delta_C = a/h \tag{7}$$

$$\Delta_\varepsilon = \varepsilon_{cu}/\varepsilon_{au} \tag{8}$$

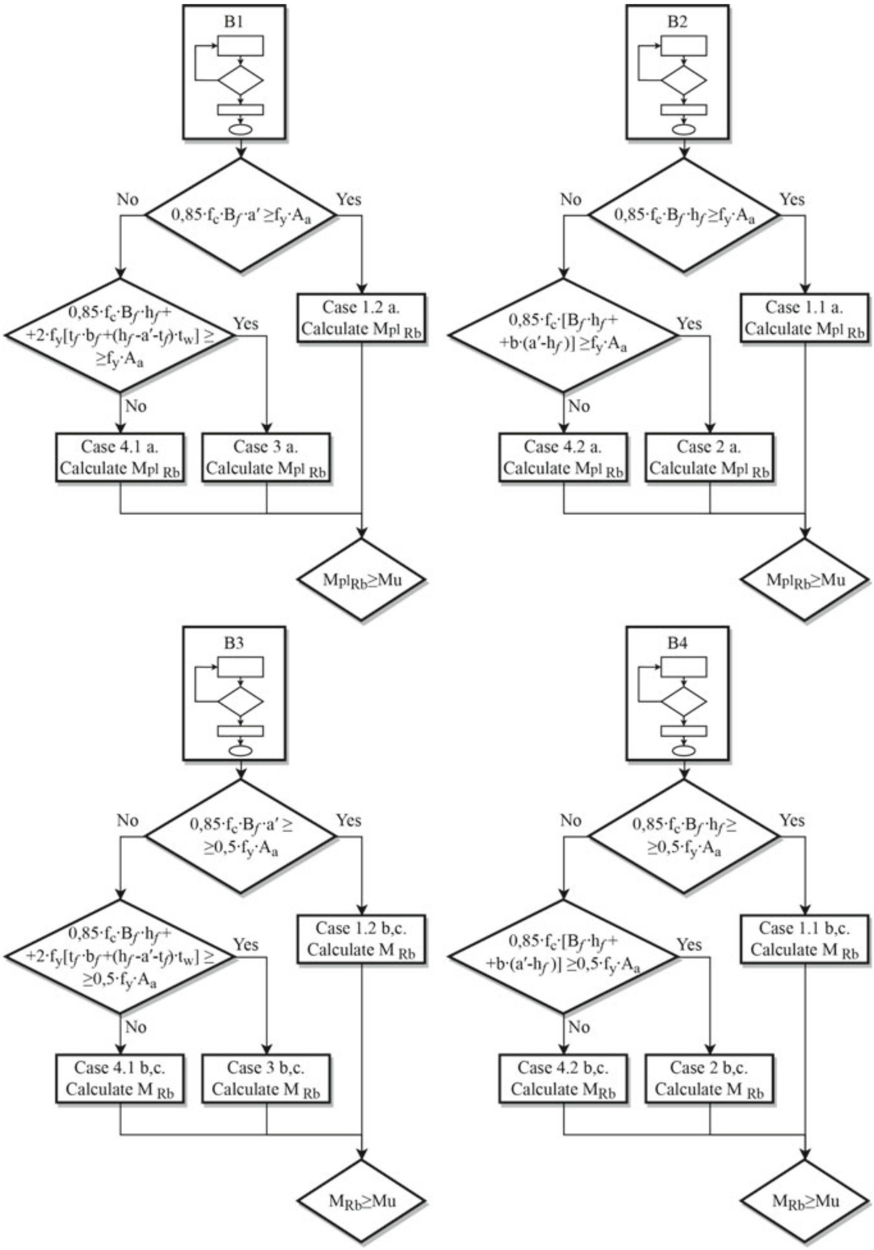

Fig. 5 Elements B1, B2, B3, B4 of the block diagram of succession for determining flexural strength of encased SRC T-beam

$$\Delta_h = h_a/h \tag{9}$$

At the second stage of calculation is determined the position of the steel I-beam profile in height relative to the shelf and the wall of the T-section of the beam, provided:

$$a' \le h_a$$

At the third stage of calculation, depending on the variant of the stress–strain state of the T-beam section, is determined the possibility of the neutral horizontal axis of the section within the height (a') of the T-section shelves under the action of external moment (M) under the conditions:

$$0,85 \cdot f_c \cdot B_f \cdot h_f \ge f_y \cdot A_a;$$

$$0,85 \cdot f_c \cdot B_f \cdot a' \ge 0,5 \cdot f_y \cdot A_a.$$

If the conditions $0,85 \cdot f_c \cdot B_f \cdot h_f \ge f_y \cdot A_a$ and $0,85 \cdot f_c \cdot B_f \cdot a' \ge 0,5 \cdot f_y \cdot A_a$ are met, the neutral horizontal axis of the section of the element passes within the height of the shelf (a') and outside the steel I-beam profile. Next, determine the height of the compressed zone of concrete (x_C) and the value of the bending moment (M_{Rd}) for the calculated cross section of encased SRC T-beam in the stress–strain state in cases 1.1a 1.1b, c, or 1.2a, 1.2b, c (Fig. 5) according to the dependencies below in Table 4.

The value of flexural strength (M_{Rd}) in the calculated cross section of the encased SRC T-beam is compared with the value of the moment from external forces (M). The cross-sectional strength of the encased SRC T-beam will be provided provided that:

$$M_{Rd} \ge M.$$

If the bending strength condition of the encased SRC composite T-beam is not satisfied, it is necessary to increase the size of their calculated cross-section in the direction of increase and accept the materials of their components with higher values of strength characteristics, and then repeat the calculation.

Table 4 Analytical dependences of the calculation of flexural strength of the encased SRC T-beams depending on the case of strain–stress state of their design section

№ ca-se	Analytical dependences of the calculation of flexural strength of the encased SRC T-beams in the determinate case of the boundary strain–stress state of its design section at the breaking moment
Case 1.1a	When the conditions $\alpha_a\mu < \alpha\mu$; $a' \leq h_f$; $0,85 \cdot f_c \cdot B_f \cdot a' \geq f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (A_a \cdot f_y)/(0,85 \cdot f_c \cdot B_f)$ Flexural strength will be: $M_{plRb} = A_a \cdot f_y \cdot (z_a - x/2)$; $z_a = a' + h_a/2$
Case 1.2a	When the conditions $\alpha_a\mu < \alpha\mu$; $a' \geq h_f$; $0,85 \cdot f_c \cdot B_f \cdot h_f \geq f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (A_a \cdot f_y)/(0,85 \cdot f_c \cdot B_f)$ Flexural strength will be: $M_{plRb} = A_a \cdot f_y \cdot (z_a - x/2)$; $z_a = a' + h_a/2$
Case 2a	When the conditions $\alpha_a\mu < \alpha\mu$; $a' \geq h_f$; $0,85 \cdot f_c \cdot \left[B_f \cdot h_f + b \cdot \left(a' - h_f\right)\right] \geq f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (A_a \cdot f_y - 0,85 \cdot f_c \cdot B_f \cdot h_f)/(0,85 \cdot f_c \cdot b) + h_f$ Flexural strength will be: $M_{plRb} = A_a \cdot f_y \cdot (z_a - y_c)$ $z_a = a' + h_a/2$ $y_c = \frac{(B_f - b)\cdot(h_f^2/2) + b \cdot x^2/2}{(B_f - b)\cdot h_f + b \cdot x}$
Case 3a	When the conditions $\alpha_a\mu < \alpha\mu$; $a' \leq h_f$; $0,85 \cdot f_c \cdot B_f \cdot h_f + 2 \cdot f_y[t_f \cdot b_f + (h_f - a' - t_f) \cdot t_w] \geq f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (A_a \cdot f_y - 2 \cdot f_y[t_f \cdot b_f + (h_f - a' - t_f) \cdot t_w])/(0,85 \cdot f_c \cdot B_f)$ Flexural strength will be: $M_{plRb} = 0,85 \cdot f_c \cdot B_f \cdot \frac{x^2}{2} + f_y \cdot \left[W_{pl} + (z_a - x)^2\right]$; $z_a = a' + h_a/2$
Case 4.1a	When the conditions $\alpha_a\mu < \alpha\mu$; $a' \leq h_f$; $0,85 \cdot f_c \cdot B_f \cdot h_f + 2 \cdot f_y[t_f \cdot b_f + (h_f - a' - t_f) \cdot t_w] < f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (A_a \cdot f_y + 2 \cdot f_y[t_w \cdot a' + t_f \cdot (t_w - b_f) \cdot t_w])/(0,85 \cdot f_c \cdot b + 2 \cdot f_y \cdot t_w)$ Flexural strength will be: $M_{plRb} = \left[\left(B_f - b\right) \cdot h_f \cdot \left(x - \frac{h_f}{2}\right) + b \cdot \frac{x^2}{2}\right] \cdot 0,85 \cdot f_c + f_y \times [W_{pl} + (z_a - x)^2]$; $z_a = a' + h_a/2$

(continued)

Table 4 (continued)

№ ca-se	Analytical dependences of the calculation of flexural strength of the encased SRC T-beams in the determinate case of the boundary strain–stress state of its design section at the breaking moment
Case 4.2a	When the conditions $\alpha_a\mu < \alpha\mu;\ \ a' > h_f;$ $0,85 \cdot f_c \cdot \left[B_f \cdot h_f + b \cdot \left(a' - h_f\right)\right] < f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (A_a \cdot f_y + 2 \cdot f_y[t_w \cdot a' + t_f \cdot (t_w - b_f) \cdot t_w])/(0,85 \cdot f_c \cdot b + 2 \cdot f_y \cdot t_w)$ Flexural strength will be: $M_{plRb} = \left[\left(B_f - b\right) \cdot h_f \cdot \left(x - \frac{h_f}{2}\right) + b \cdot \frac{x^2}{2}\right] \cdot 0,85 \cdot f_c + f_y \times [W_{pl} + (z_a - x)^2];$ $z_a = a' + h_a/2$
Case 1.1b, c	When the conditions $\alpha_a\mu > \alpha\mu;\ \ a' \le h_f;\ \ 0,85 \cdot f_c \cdot B_f \cdot a' \ge 0,5 \cdot f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (0,5 \cdot A_a \cdot f_y)/(0,85 \cdot f_c \cdot B_f)$ Flexural strength will be: $M_{Rb} = 0,5 \cdot A_a \cdot \sigma_a \cdot (z_a - x/2);$ $z_a = a' + h_a/2$ $\varepsilon_a = (\varepsilon_{cu} \cdot (h_a + a' - x))/x; \qquad \sigma_a = \varepsilon_a \cdot E_a$
Case 1.2b, c	When the conditions $\alpha_a\mu > \alpha\mu;\ \ a' \ge h_f;\ \ 0,85 \cdot f_c \cdot B_f \cdot h_f \ge 0,5 \cdot f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (0,5 \cdot A_a \cdot f_y)/(0,85 \cdot f_c \cdot B_f)$ Flexural strength will be: $M_{Rb} = 0,5 \cdot A_a \cdot \sigma_a \cdot (z_a - x/2);$ $z_a = a' + h_a/2$ $\varepsilon_a = (\varepsilon_{cu} \cdot (h_a + a' - x))/x; \qquad \sigma_a = \varepsilon_a \cdot E_a$
Case 2 b, c	When the conditions $\alpha_a\mu > \alpha\mu;\ \ a' \ge h_f;$ $0,85 \cdot f_c \cdot \left[B_f \cdot h_f + b \cdot \left(a' - h_f\right)\right] \ge 0,5 \cdot f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (0,5 \cdot A_a \cdot f_y - 0,85 \cdot f_c \cdot B_f \cdot h_f)/(0,85 \cdot f_c \cdot b) + h_f$ Flexural strength will be: $M_{Rb} = 0,5 \cdot A_a \cdot \sigma_a \cdot (z_a - y_c);\ z_a = a' + h_a/2$ $y_c = \frac{(B_f - b) \cdot (h_f^2/2) + b \cdot x^2/2}{(B_f - b) \cdot h_f + b \cdot x};$ $z_a = a' + h_a/2 \qquad \varepsilon_a = (\varepsilon_{cu} \cdot (h_a + a' - x))/x; \qquad \sigma_a = \varepsilon_a \cdot E_a$

(continued)

Table 4 (continued)

№ ca-se	Analytical dependences of the calculation of flexural strength of the encased SRC T-beams in the determinate case of the boundary strain–stress state of its design section at the breaking moment
Case 3 b, c	When the conditions $\alpha_a\mu > \alpha\mu;\quad a' \le h_f;$ $0,85 \cdot f_c \cdot B_f \cdot h_f + 2 \cdot f_y[t_f \cdot b_f + (h_f - a' - t_f) \cdot t_w] \ge 0,5 \cdot f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (0,5 \cdot A_a \cdot f_y - 2 \cdot f_y[t_f \cdot b_f + (h_f - a' - t_f) \cdot t_w])/(0,85 \cdot f_c \cdot B_f)$ Flexural strength will be: $M_{Rb} = 0,85 \cdot f_c \cdot B_f \cdot \frac{x^2}{2} + 0,5 \cdot \sigma_a \cdot \left[W_{pl} + (z_a - x)^2\right];$ $z_a = a' + h_a/2 \qquad \varepsilon_a = (\varepsilon_{cu} \cdot (h_a + a' - x))/x; \qquad \sigma_a = \varepsilon_a \cdot E_a$
Case 4.1 b, c	When the conditions $\alpha_a\mu > \alpha\mu;\quad a' \le h_f;$ $0,85 \cdot f_c \cdot B_f \cdot h_f + 2 \cdot f_y[t_f \cdot b_f + (h_f - a' - t_f) \cdot t_w] < 0,5 \cdot f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (0,5 \cdot A_a \cdot f_y + 2 \cdot f_y[t_w \cdot a' + t_f \cdot (t_w - b_f) \cdot t_w])/(0,85 \cdot f_c \cdot b + 2 \cdot f_y \cdot t_w)$ Flexural strength will be: $M_{Rb} =$ $\left[\left(B_f - b\right) \cdot h_f \cdot \left(x - \frac{h_f}{2}\right) + b \cdot \frac{x^2}{2}\right] \cdot 0,85 \cdot f_c + 0,5 \cdot \sigma_a \times [W_{pl} + (z_a - x)^2];$ $z_a = a' + h_a/2 \qquad \varepsilon_a = (\varepsilon_{cu} \cdot (h_a + a' - x))/x; \qquad \sigma_a = \varepsilon_a \cdot E_a$
Case 4.2 b, c	When the conditions $\alpha_a\mu > \alpha\mu;\quad a' > h_f;$ $0,85 \cdot f_c \cdot \left[B_f \cdot h_f + b \cdot \left(a' - h_f\right)\right] < 0,5 \cdot f_y \cdot A_a$ are met The height of the compressive zone of the concrete will be: $x = (0,5 \cdot A_a \cdot f_y + 2 \cdot f_y[t_w \cdot a' + t_f \cdot (t_w - b_f) \cdot t_w])/(0,85 \cdot f_c \cdot b + 2 \cdot f_y \cdot t_w)$ Flexural strength will be: $M_{Rb} =$ $\left[\left(B_f - b\right) \cdot h_f \cdot \left(x - \frac{h_f}{2}\right) + b \cdot \frac{x^2}{2}\right] \cdot 0,85 \cdot f_c + 0,5 \cdot \sigma_a \times [W_{pl} + (z_a - x)^2];$ $z_a = a' + h_a/2 \qquad \varepsilon_a = (\varepsilon_{cu} \cdot (h_a + a' - x))/x; \qquad \sigma_a = \varepsilon_a \cdot E_a$

2.2 Analytical Dependences of Encased SRC T-beams Flexural Strength Depending on the Case of Strain–Stress State of the Design Section at the Breaking Moment

Analytical dependences of calculation flexural strength of encased steel-reinforced concrete (SRC) T-beams, depending on the case of strain–stress state of their design section at the breaking are shown in Table 4.

3 Comparisons Between Experimental and Analytical Results of Bending Strength Calculation Encased SRC Composite T-beams

In order to compare the proposed analytical model of calculation of flexural strength of encased SRC composite T-beams, we have used the results of experimental studies of scientists, such as: A.P. Vasiliev (specimens of beams 4, 5a, 5b, 6a, 6b, 7, 9a, 9b, 10a, 10b, 11a, 11b, 13a, 13b) [13]; B.A. Kalaturov (specimens of beams BG-1… BG-4, BG-6…BG-9) [14]; Myong-Keun Kwak (specimens of beams SB200, SB250-B, SB300-A, SB300-C, SB300-E) [15]; Cl. Goralski (specimens of beams S1… S4) [16].

When comparing the results, we have determined arithmetic mean ($\overline{X}$), root-mean-square deviation (σ_{n-1}) and coefficient of variation (ν).

The comparisons of experimental results (M^{test}) and analytical findings of the calculation of flexural strength of encased SRC T-beams (M^{calc}) are given in Table 5.

Comparison of experimental and theoretical strength values of 31 specimens of encased SRC composite T-beams beams, which components are bond, leads to the following statistical indicators:

– for partial factors for concrete $\gamma_C = 1,0$ and for material property, also accounting for model uncertainties and dimensional variations $\gamma_M = 1,0$ – $\overline{X} = 1,195;\ \sigma_{n-1} = 0,025;\ \nu = 2,1\%$;
– for partial factors for concrete $\gamma_C > 1,0$ and for material property, also accounting for model uncertainties and dimensional variations $\gamma_M > 1,0$ – $\overline{X} = 1,242;\ \sigma_{n-1} = 0,019;\ \nu = 1,5\%$.

4 Conclusions

The algorithm and analytical dependences of the method for calculating the flexural strength of encased steel-reinforced concrete (SRC) composite T-beams are presented in the academic paper. Comparative analysis of the experimental findings with theoretical calculations of flexural strength of encased SRC composite T-beams has showed their adequate convergence, which allows to apply the proposed analytical dependencies in the design practice.

The model of balanced failure (ideal failure) allows for optimal (rational) design of reinforced concrete elements working on the bend, with minimal costs, taking into account design constraints, such as: design of structures taking into account the type of loads acting on them, and formation (typing) case of their ultimate stress–strain state depending on the defined ultimate criteria for the destruction of their components.

Table 5 Comparison of experimental bending moments with theoretical

№	Author	Specimen	M^{test} kNm	$M^{cala}_{\gamma=1,0}$kNm	$\frac{M^{test}}{M^{cala}_{\gamma=1,0}}$	$M^{cala}_{\gamma=1,0}$ kNm	$\frac{M^{test}}{M^{cala}_{\gamma=1,0}}$
1	Vasiliev [13]	4	97,5	96,5	1,01	84,9	1,15
2		5 a	105,0	89,0	1,18	75,9	1,38
3		5 b	95,0	89,0	1,07	75,9	1,25
4		6 a	97,5	94,2	1,04	81,1	1,20
5		6 b	97,5	94,2	1,04	81,1	1,20
6		7	85,0	77,7	1,09	70,1	1,21
7		9 a	132,5	99,7	1,33	98,9	1,34
8		9 b	132,5	99,7	1,33	98,9	1,34
9		10 a	150,0	106,8	1,40	105,9	1,42
10		10 b	155,5	106,8	1,46	105,9	1,47
11		11 a	183,0	129,4	1,41	117,3	1,56
12		11 b	172,5	120,8	1,43	109,5	1,58
13		13 a	167,0	146,0	1,14	132,2	1,26
14		13 b	187,0	146,5	1,28	132,7	1,41
15	Kalaturov [14]	BG-1	1071,0	808,2	1,33	740,4	1,45
16		BG -2	1092,0	794,6	1,37	716,6	1,52
17		BG -3	1060,0	738,3	1,44	665,9	1,59
18		BG -4	1013,0	707,6	1,43	638,7	1,59
19		BG -6	918,0	794,2	1,16	725,4	1,27
20		BG -7	906,0	745,4	1,22	683,0	1,33
21		BG -8	904,0	738,0	1,22	672,8	1,34
22		BG -9	988,0	754,0	1,31	683,0	1,45
23	Myong-Keun Kwak [15]	SB200	411,0	393,2	1,05	377,7	1,09
24		SB250-B	819,3	764,2	1,07	706,4	1,16
25		SB300-A	923,5	598,5	1,54	559,1	1,65
26		SB300-C	1046,0	657,2	1,59	607,1	1,72
27		SB300-E	1157,4	816,6	1,42	743,5	1,56
28	Goralski [16]	S1	3001,0	2506,8	1,20	2292,8	1,31
29		S2	2981,0	2490,1	1,20	2270,1	1,31
30		S3	1728,0	1619,2	1,07	1461,5	1,18
31		S4	1703,0	1617,3	1,05	1459,0	1,17

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The New Approach and Requests in Designing the Composite Steel and Concrete Grid Structures

Grygorii Gasii, Olena Hasii, Myron Hohol, and Jihane Obbad

Abstract The study of the composite steel and concrete grid structures is considered and updated. The structures are made of separate spatial units. The units have the shape of a pyramid, where a reinforced concrete slab is at the base, and the role of the pyramid's ribs is played by steel rods made of hollow tubes of a circular cross-section. The connection of a reinforced concrete slab and steel rods to each other is carried out during concreting the slab by putting the rods into the slab solid. Such structures were fairly well studied by the authors in early works, but still, the structures are not devoid of drawbacks. First of all, the disadvantage of the structures is the way of connecting the units into a roof structure. The units connecting are provided via bolted flange connections. As the practice of introducing such structures into the real sector of construction has shown, flange bolted joints in such structures are not the best solution. Since they are difficult to manufacture, they complicate the structure, make the structure vulnerable, and quite significantly increase the weight of the structure. In this regard, the current investigation is devoted to the study of such structures in the context of the search for a way that helps to avoid flange connections and indirectly increase the reliability of structures and reduce their weight.

Keywords Slab · Rod · Join · Flange · Unit

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_11

1 Introduction

In recent years, the authors have studied the space composite steel and concrete grid structures of high bearing capacity and rather universal use [1–6]. The space composite steel and concrete grid structures have found application in both civil and industrial construction. Investigation of such structures included both theoretical studies and experimental studies [7]. In general, the research results are satisfactory, which indicates the effectiveness of space composite steel and concrete grid structures, as well as their high bearing capacity.

The space composite steel and concrete grid structures are prefabricated structures that consist of separate volumetric units. It is proposed to make such units in the form of a pyramid, where a reinforced concrete slab is the basis. As an exception, the slab can have dispersed reinforcement, that is, it can be reinforced with woven mesh from steel wire. By the way, structures with dispersed reinforcement are very popular not only among architects in the middle of the last century but among shipbuilders too. Moreover, such designs have not lost their popularity in our time [8–12], which, in other ways, can serve as a new impetus for the improvement of composite steel and concrete grid structures, in particular in the context of weight reduction.

Nevertheless, now the actual issue is a departure from flange connections in the composite steel and concrete grid structures.

2 Method

The basic method for solving this problem is the study of previous investigations in the context of new achievements of science and technology. These are theoretical studies, as well as the search for modern ways to eliminate the shortcomings of the space composite steel and concrete grid structures.

3 Results and Discussions

The current research is based on the results of theoretical and experimental studies of the composite steel and concrete grid structures obtained earlier [7, 13]. It should be noted that the concepts of “space structures” and “grid structures” are synonymous in the current and reviewed research.

The basic investigation is [7], where the author has developed and widely investigated the composite steel and concrete grid structures. The author has developed roof structures for heavy loads, including for industrial buildings and structures, and later adapted to the conditions of the mining industry [2, 6]. The peculiarity of such structures is that they can be prefabricated or monolithic, depending on the span L (Fig. 1).

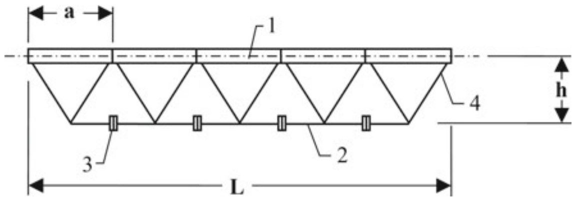

Fig. 1 General view of the composite steel and concrete grid structures with flange bolted joints: 1—top (outer) layer; 2—bottom (inner) layer; 3—flange bolted joints; 4—diagonal of the grid; h—the depth of the composite steel and concrete grid structures; L—the length of the composite steel and concrete grid structures; a—size of the unit

The composite steel and concrete grid structures are two-layer systems. The layers are spaced apart using diagonals of the grid by the distance h. In this case, the search for the optimal ratio of the geometric parameters h and L is a complex issue and requires an integrated approach. If we consider the effect of h/L on the stress–strain state of the structure, then the methods can be applied [14–16].

The top (outer) layer is made of solid reinforced concrete slabs. As a rule, the slabs have bar reinforcement. The second layer (bottom or inner) is made in the form of a grid, which is formed by crossbars, as is the case in conventional steel space grid structures [17].

The advantage of such structures is the joint way of the slab and the rods. Monolithic and prefabricated composite steel and concrete grid structures also have disadvantages. The disadvantages of monolithic structures are the limited area of use, and prefabricated ones are the complexity and laboriousness of nodal connections. This is especially true for the bottom layer, where flange bolted connections are used to connect the rods.

Analysis of recent studies of flanged bolted joints indicates that it is not entirely rational and effective to use them as tensile members [18–33] since the flange connections are time-consuming, as well as it is expensive and increases the weight of the structure. All this, combined with the complexity of taking into account the stress–strain state of the members of such joints while designing the structure, requires an improvement of the design of the composite steel and concrete grid structures.

It is obvious that even a small reduction in the mass of the structure will increase the masses of the payload, reduce the cost of the structure, and labor costs for manufacturing and installation. It is possible to reduce the number of flange connections if large-scale units are used but at the same time, the depth h of the structure increases too, which is not always acceptable.

For example, consider a prefabricated composite steel and concrete grid structure with dimensions of 3 × 9 m, that is an area of 27 m^2. For such an area, based on the design features of the units, the units of the following dimensions can be used (a × a × h): 3.0 × 3.0 × 1.5 m, 1.5 × 1.5 × 0.75 m, 1.0 × 1.0 × 0.5 m, 0.75 × 0.75 × 0.375 m and 0.6 × 0.6 × 0.3 m. Figure 2 shows how the number of flanges bolted connections increases depending on the size of the space module, as well as the number of modules depending on its size.

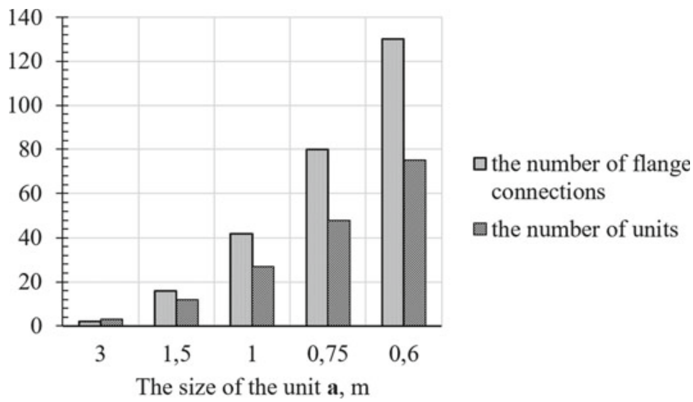

Fig. 2 Dependence of the number of flange connections on the size of the unit

Analysis of the diagram (Fig. 2) indicates the need to move away from flange connections. It is also necessary to pay attention to the fact that, in addition to flange connections; there are welded connections in the composite steel and concrete grid structure that connect the diagonals of the space grid with the members of the bottom layer, which are connected at the flanges.

So, there is a prefabricated structure, where the number of flange connections is very large. It is obvious that the need to move away from flanges as they are current is natural, caused by modern requirements. First of all, this is efficiency, quick and ease of installation, reduction of steel consumption, etc.

By the way, attempts have already been made to improve the composite steel and concrete grid structure in the context of the bottom chord and to reduce the mass of the structure, and quite good results have been obtained [34]. In solving this problem, the experience of designing nodal systems of classical space grid structures will also be useful [17] (Fig. 3).

On the other hand, early work [2, 7] reveals that the bolted flange connections in the truss structure are subject to tensile and stresses of bending. The bearing capacity and stiffness of the bottom belt of the truss are increased by the depth of the flange and diameter of the rods. Some shortcomings of the bolted flange connection under bending were found in [22]. In addition, in [20], where a steel member is connected

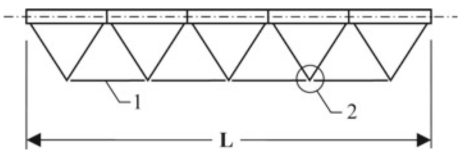

Fig. 3 The possible way to improve the composite steel and concrete grid structure by removing the flange bolted connection: 1—the element of the bottom layer; 2—the proposed way of bottom layer members joints arrangement

with a bolted flange is studied. In the investigation were take the connection is under tension and bending stresses, as well as shear force caused by vertical and horizontal loads. The studies are reliable because the tests study of the behavior of full-scale sample bolted flange connections, as well as finite element analysis series of 10 connections, were carried out. As a result, it has been found that the diameter of the hole for the bolt does not influence the bearing capacity of the connection. This is an interesting fact, but it is not decisive. At the same time, it was found that increasing the thickness of the flange caused increasing the stiffness of bending and the bearing capacity of the connection, and the destructive behavior of sample changes from flange flow to bolt flow. Also in this work, using experimentally verified finite element models, the influence of the axial tension coefficient on the bolt tension was investigated. It should be clarified that the coefficient of axial tension was taken as a value that divides the axial force of the column by the cross-sectional area and the design strength of the material. So, studies have shown that increasing the axial tension coefficient can increase the tension of the bolts, which, for obvious reasons, adversely affects the bolts from the side of the tensioned flange.

So, all these results of the author's research and research of other scientists lead to the decision to move away from flange bolted connections in the structures under study because of some shortcomings as well as the development of new ways of connecting modular elements of the structures under study.

4 Conclusions

Thus, the problem of the composite steel and concrete grid structure has been studied, as well as the task of further research of the composite steel and concrete grid structure is stated in the article.

The essence of further research is to find a way to replace flanged bolted connections with others. It can be the bolted joints, but their location in the structure should be different from the current location. It is a possible way of placing the joints of the members of the bottom layer in the spot where the diagonals of the space grid. Moreover, the placement of the joints of the members of the bottom layer can be in the plane of the node of the diagonals of the space grid or it can be in different planes, as, for example, it is done in [34].

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Reconstruction Methods of Continuous Working Groundwater Canals

Akif Gasimov and Anatolii Kryvorot

Abstract The article describes the methods of reconstruction of groundwater irrigation canals, which work continuously or intermittently during the year. In Azerbaijan 50% of main canals with a total length of 2370.45 km, 82% of first-class distribution canals with a total length of 8867.2 km and 75% of second and third distribution canals with a total length of 41,985.3 km are operated in the ground canal. An average of 30–35% of the irrigation water transported through these canals is exposed to leakage losses, and therefore there is a shortage of water during the irrigation season. At the same time, as a result of global climate change in recent years, freshwater resources in the world, including Azerbaijan, are gradually declining. In the first method, to carry out reconstruction work the canal is divided into separate parts, a temporary transmission canal is laid in parallel and the main canal is covered. At the same time, the hydraulic structures on the canal are being repaired or reconstructed. In the second method, the main canal is divided into two parts by longitudinal partition boards, and the dried part of the canal is reconstructed. After the completion of this work, the second part will be reconstructed. In the third method, without compromising the operation of the canal, the bottom and slopes of the canal are covered with prefabricated reinforced concrete or asphalt concrete, as well as with the mats made of bentizol materials. In the fourth method, underwater concreting is carried out with the help of caisson chambers, it means the bottom and slopes of the canal are provided with a waterproof coating. There is also information about the advantages and disadvantages of the methods described in the article.

Keywords Irrigation canal · Lining · Facelift · Continuous operation · Reconstruction · Method

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_12

1 Introduction

Azerbaijan has a total length of 2370.45 km of highways, 8867.2 km of first-class distribution (inter-farm) and 41,985.3 km of second and third class canals [1]. About half of the main canals, 82% of the primary canals and 75% of the secondary and tertiary canals were built in the ground.

According to experts, 30–35% of the water taken from the springs is used for leakage losses, because irrigation canals are built in the ground. Therefore, on average, 2.1–3.0 billion m^3 of water used for irrigation is lost every year and does not participate in the production of agricultural products. At the same time, freshwater resources in Azerbaijan are very limited. During the extreme drought years, the country's underground and surface fresh water reserves amounted to 11.1 billion m^3, and in rainy years −46.3 billion m^3 [2].

Due to recent climate changes in the world, the average annual temperature has increased by 0.74–1.3 °C compared to the average multi-year norm, and the average annual precipitation has decreased by 20% [3–6]. According to forecasts, if climate change continues at this pace, then by 2050 the country's water resources may decrease by more than 40% [3, 7]. Therefore, the protection, efficient use and prevention of water losses are the most important issues of the day. One of the most important conditions for preventing water losses is the reconstruction of canals operating in the ground, especially permanent and main distribution canals, by providing them with anti-leakage coatings. Reconstruction of permanent canals should be carried out in such a way that the operation of the canal does not stop during the reconstruction and does not cause serious damage to agriculture, including the country's economy. Many works are devoted to equipment for the production and transportation of construction mortars, where their cost-effectiveness and more are also given [8–14].

2 Main Part

2.1 Purpose of the Article

One of the most pressing issues of the day is the more efficient and economical use of available water resources to meet the water needs of agriculture, industry and the population. The article proposes ways of reconstruction to prevent the loss of water and to increase the efficiency of irrigation canals, i.e., four reconstruction methods have been proposed to cover them with waterproof coatings.

2.2 Research Methodology

Different research works on reconstruction technologies of hydro-ameliorative systems, organization and mechanization of canal construction works were collected, studied and involved in scientific analysis. Based on the acquired knowledge, methods for the reconstruction of continuous canals have been developed.

2.3 Results

Sufficient information is provided in the list of references on the technology of construction of irrigation canals covered with soil and anti-leakage coatings (concrete, reinforced concrete, asphalt concrete, insulation materials, etc.) [15, 16].

At the same time, there are instructions, recommendations and guidelines for the current and overhaul of canals. However, information, technology and techniques on the reconstruction of ground canals, especially year-round irrigation canals, are almost non-existent in the list of references. Only typical projects describe the reconstruction technologies of permanent canals, the main essence of which is that the water entering the main pumping station of the reconstructed canal is cut off and the construction and installation work is carried out in the onshore part of the canal. In this case, it is impossible to plant and get crops in the area served by the canal. Depending on the structure and type of agricultural crops included in the crop rotation, the farmer and ultimately, the state suffer losses a lot. During the reconstruction, the canal is closed. Experience shows that reconstruction work takes 2–3, even 5 years or more. According to rough estimates, a farmer or landowner loses more than 3,000 manats per hectare of irrigated land per year due to the loss of clover fodder productivity alone. The amount of damage caused by the loss of productivity of cotton and other agricultural crops is more than 6–8 thousand manats per hectare. On the other hand, part of the rural population in the regions uses canal water for both domestic and livestock irrigation. In such a situation, it is necessary to pay attention to the reconstruction of canals.

Azerbaijan Upper Golitsyn (Sabir) main canal, put into operation in 1908, consumption 21.3 m^3/s, length 84 km, Upper Golitsyn (Sabir) canal, put into operation in 1913, consumption 30.9 m^3/s, length 66.2 km Mugan, put into operation in 1916, consumption 36.8 m^3/s, length 70.3 km Lower Mugan, commissioned in 1917, consumption 41.9 m^3/s, length 76.7 km Middle Mugan, The South Mugan main canals, commissioned in 1918 with a consumption of 35 m^3/s and a length of 92.6 km, are currently operating in the ground.

The Maralyan canal, which supplied irrigation water to Jabrayil and Fizuli districts and put into operation in 1931 with a consumption of 12 m^3/s and a length of 24 km, put into operation in 1958 with a consumption of 113 m^3/s and a length of 172.4 km. Karabakh and Upper Shirvan main canals with a consumption of 78 m^3/s and a length of 123.5 km were also built on the ground canal.

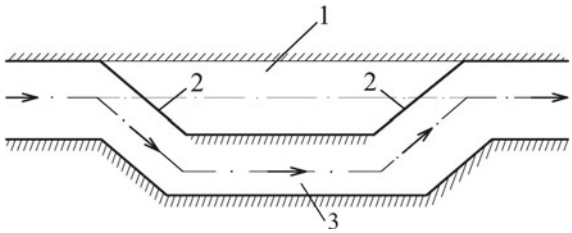

Fig. 1 Scheme of water discharge outside the canal: 1—main canal; 2—partition; 3—temporary transmission canal

Currently, 50% of the main canals operating in Azerbaijan, 82% of first-class distribution canals, and 75% of second- and third-class canals are in the ground. There is a serious need to rebuild these canals. Thus, one of the most urgent and important issues of the day is the reconstruction of groundwater canals, covering them with waterproof coatings in the conditions of modern climate change and extreme drought. Taking into account the importance of the issue, several reconstruction methods have been developed.

In the first method, i.e., the method of out-of-canal discharge of water, the length of the reconstructed canal is divided into separate parts. In the first part, separated from the last part, the front of the canal is completely cut off and a temporary transmission canal is dug parallel to the initial canal (Fig. 1). The water of the main canal is directed to the temporary transmission canal, and in this part the bed and slopes of the primary part of the canal are shaped in the project. Then the canal is covered with concrete or reinforced concrete. The coating technology is implemented as in ordinary canals.

It should be noted that in the paved part of the reconstructed canal, the front of the canal is cut in a sloping direction to allow water to flow freely. To block the canal, cast clay soil or boards are used, which are tightly connected to each other and provided with a waterproof intermediate layer at the joints. The end of the lined part of the canal, on the contrary, closes the slope. Upon completion of the paving works in this section, the ground canal, which is laid parallel to the main canal, is filled, strengthened and leveled by pouring back the excavated soil. The work is being carried out in the same sequence in other parts of the reconstructed canal. The application of this method in relatively small canals built in full casting, such as inter-farm, on-farm and field canals, is subjected to certain challenges. Thus, on the left and right sides of the canal, built in full drilling, the ground level is below the bottom level of the canal. It is not possible to direct the temporary transmission canal along the main canal. A second method of reconstruction has been developed, taking into account both this issue and the specifics of local conditions.

In the second method, i.e., in the method of partition or flow compression (by narrowing the canal), as in the first method, the length of the canal is divided into separate parts, and the work is carried out in the following technological sequence. In any separated part of the canal, it is divided into two parts by plates (for example, steel plates) made of steel or other solid materials, tightly connected to each other, the joints are provided with a waterproof intermediate layer (Fig. 2). The entrances and

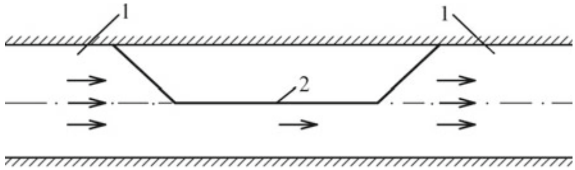

Fig. 2 Flow compression: 1—canal; 2—partition boards

exits of the cladding part are closed in the same way with the help of steel plates. Half or a certain part of the water consumption is released into the free flow of the canal. In general, the water consumption of the canal is determined taking into account the structure and demand for water of agricultural crops grown in the fields it serves.

The separated dry part and slope of the reconstructed canal bed will be shaped and covered in the project. Upon completion of the work on the paved side of the canal, connecting plates are removed from its entrance and exit and installed on the unpaved side of the canal and the water is cut off. The water is directed to the facing side. In the same way, the unpaved part and slope of the canal are shaped and covered. After the completion of the works in this part, the partition boards will be dismantled and installed in the second part of the canal to be covered. Here, after the completion of the work, the work is carried out in the same sequence in other parts of the canal.

Narrow cracks in the bed and slope of the canal created by the partition boards being knocked to the ground are filled with underwater-hardening isomaterial. For this purpose, isomaterial is injected into these cracks (joints) under pressure.

In order to carry out reconstruction works quickly and in a short period of time, paving works can be carried out simultaneously in several parts of the canal along its length. In this way, it is possible to cover all small and large canals with waterproof coatings. There is no need for additional drilling, re-casting, leveling and hardening. According to rough estimates, construction costs are reduced by 2 times, the speed of work is increased by 5–10 times, and there is no need to use heavy earth-moving machines and mechanisms.

The above mentioned methods are based on drying the canal in the paved parts of the reconstructed canal and carrying out works on dry beds and slopes. The application of these methods allows for quality work, long-lasting, durable and reliable canals. At the same time, it is possible to ensure their accuracy by making mechanization easier.

Studies have shown that it is possible to cover existing canals under water. For this purpose, you can use the third method—the floor method.

In the third method—asphalt, asphalt-concrete, concrete, reinforced concrete, bentoizol and other prefabricated elements are used to cover the reconstructed canal in the flooring method. One of the prefabricated elements is reinforced concrete mattresses or reinforced concrete slabs (slabs). Reinforced concrete mattresses or reinforced concrete slabs (slabs) with a thickness of 10–15 cm are made in the factory under special constructions that is the edges of the slabs are laid on top of each other and their joints are insulated with isomaterials (Fig. 3).

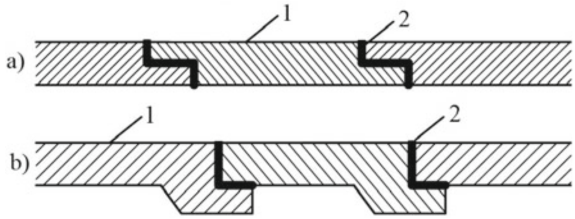

Fig. 3 Slab contraction joints should intersect at the openings for columns: **a** smooth combination; **b** protruding joint; 1—plate (plate); 2—insulated place of connection

The gaps between the plates are covered with rubber intermediate layers or filled with insulating materials. For example, layers of rubber are placed on the ends of the tiles and they are connected to each other.

When lining the canals with prefabricated reinforced concrete slabs, the slopes and bottom (bed) of the canals should be smooth. Slopes of canals are usually the most deformed (collapsed, covered with vegetation, rough, etc.). Therefore, the slopes of the reconstructed canals must be perfectly leveled. The leveling of the submerged part of the slope can be carried out with multi-stage levelers used for leveling ordinary slopes and excavators equipped with dragline.

Prefabricated asphalt-concrete slabs and asphalt-concrete mats can be used to cover the slopes and bed of the canal with waterproof asphalt or asphalt-concrete pavement. Prefabricated asphalt-concrete slabs in the size of 3000 × 4000 × 10 mm are made in the factory in metal forms and they are discharged to the installation site, i.e., to the canal. The finished slabs are laid directly on the leveled slopes and bed with the help of a crane or a floating crane. The procedure for laying asphalt or asphalt-concrete slabs is the same as for laying precast concrete or reinforced concrete slabs. However, as asphalt-concrete slabs have a high elasticity, there is no need to use a preparatory layer when applying them.

In addition to prefabricated asphalt or asphalt-concrete pavements (slabs), elastic asphalt-concrete mats (floors) can be used to cover the reconstructed canals. Asphalt-concrete mats are made in the factory in the specified sizes and are rolled on separate drums. The finished drums are assembled and spread on the smoothed slopes and bottom of the canal with the help of a crane or floating crane (Fig. 4) [17].

One side of asphalt-concrete mats is covered with 20–30 cm on top of the other. The edges of the mat are placed on top of each other in the direction of water flow

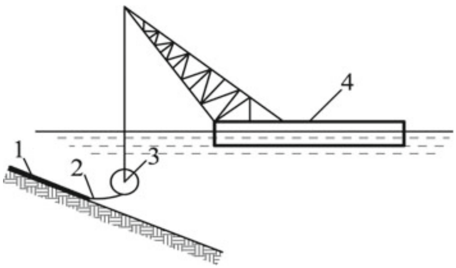

Fig. 4 Laying of asphalt-concrete mats: 1, 2—asphalt-concrete mat (mattress); 3—drum; 4—floating crane

in the canal. The thickness of the edges of asphalt-concrete mats on both sides is up to half of its average thickness. This prevents swelling at the junction of the asphalt-concrete mats and eliminates roughness at the bottom and slopes of the canal. The formation of a solid and smooth surface in the canal eliminates the risk of siltation and increases the flow rate.

In the fourth method, the bottom and slopes of the canal can be covered by underwater concreting. For this purpose, special devices can be used in the paved part of the canal, such as caisson chambers, piles and lowered wells and other devices [8, 11, 18–22]. As the slopes of the canals are sloping, they have a strong impact on the quality, timing and cost of concreting. In general, underwater concreting works along the canals are very complicated. Special underwater facilities, equipment and machinery are required. Tests show that a small mistake made during underwater work cannot only degrade the quality of work, but also lead to great damage.

It is more expedient to carry out underwater concreting works using new techniques and technologies developed in recent years.

When the underwater bottom and slopes of the canal are covered with waterproof concrete, reinforced concrete and asphalt-concrete materials by the method of "underwater concreting", the properties and characteristics of these materials, especially the full hardening time of concrete or asphalt-concrete, washing and temperature resistance to changes, static and dynamic (vibration) effects must be taken into account.

3 Conclusions

1. 50% of the main canals built for irrigation purposes in Azerbaijan, 75–82% of the distribution canals of different grades were built in the landfill and they are still operating in the landfill. Therefore, 30–35% of the water transported through these canals is exposed to leakage losses. Every year 2.1–3.0 billion m^3 of irrigated water is lost.
2. Global climate change in recent years has led to a gradual decline in Azerbaijan's freshwater resources. According to forecasts, by 2050 the country's freshwater reserves will decrease by more than 40%. Therefore, prevention of water losses, efficient and economical use of available resources is one of the most important issues of the day.
3. One of the necessary measures to prevent water losses is the reconstruction of existing irrigation canals, i.e., covering of canals operating in the ground canal with waterproof materials and improvement, overhaul or replacement of hydraulic structures located on the canals.
4. Rehabilitation and reconstruction of permanent canals operating during the irrigation season can cause serious damage to agriculture. Therefore, these canals should not be shut down during rehabilitation or reconstruction. To achieve this goal, rehabilitation and reconstruction work should be carried out using special methods during the operation of the canals.

5. Various reconstruction methods have been proposed to ensure that the canals are not damaged and that agricultural crops are regularly supplied with irrigation water during the irrigation season. When selecting these methods, a feasibility study should be conducted and the most cost-effective reconstruction method should be selected.

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Mathematical Modeling of Pumping Stations Reliability

Aleksandr Guzynin

Abstract The pumping stations of water supply systems, which belong to the restored objects, are considered. Reliability indices for restored objects can be calculated by compiling and solving a system of differential or linear algebraic Kolmogorov equations. Such solutions are obtained by numerical methods on a computer. A method for calculating the reliability of such stations, based on the analysis of the state graph in the form of a tree, is proposed. This allows to obtain an analytical solution to the main indicators of pumping stations reliability. Thus, there is no need to compose and solve the Kolmogorov equations by numerical methods.

Keywords Reliability · Pumping stations · Water supply · State graph

1 Introduction

To assess the reliability of technical systems, various methods of describing technical systems are used, for example, structural diagrams, functions of logic algebra, graphs of system states, systems of differential, algebraic and integral equations [1–3]. There are also heuristic approaches to calculating reliability [2].

The calculation of reliability of water supply systems constantly attracts the attention of researchers. One of the first issues of reliability of such systems was considered by Abramov [4, 5], Ilyin [6, 7], Naimanov and Gosteva [8] and others [9–19].

Naimanov and Gosteva [8] propose to carry out an approximate calculation of pumping stations reliability of water supply systems. All pumps are assumed to be the same. Redundancy is carried out by replacing failed pumping units. The pumping station availability factor is calculated using the Bernoulli total probability formula.

Ilyin [7] provides ready-made formulas for calculating reliability indicators for certain configurations of pumping stations.

The heuristic method for calculating reliability, developed by I.A. Ushakov, is given in [9].

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_13

However, despite many existing methods, the problem of calculating of pumping stations reliability constantly attracts attention.

2 Presentation of the Main Material

Pumping stations of water supply systems are complex systems with an unloaded reserve that must be restored. The reliability of such systems is influenced by:

reliability of the elements that make up the pumping station;
reliability category of pumping stations;
pumping station topology;
configuration of included items;
the number of service teams;
service discipline.

Further, the technological scheme of the pumping station and the state graph will be considered. Using the theory of graphs, namely, the minimum or shortest paths and a certain structure of the determinants of the Kolmogorov system of equations, it is possible to obtain analytical dependences for calculating the main indicators of the reliability of the restored pumping stations of water supply and wastewater disposal systems.

Let is consider a certain restored pumping station, which has k working pumping and m reserve pumps. Standby pumps are in cold standby and can be turned on as the working pumps are turned off.

The pumping station can be in n discrete states $x_1,\ x_2, ..., x_n$. Under the influence of some streams of events, a pumping station can move from one state to another. We will consider such streams of events to be the simplest Poisson streams. Due to the alternation of failures and restorations, pumping station can move from one state to another.

The duration of operation and the quality of repair and maintenance work, the quality indicators of the equipment will determine the number of states in which the pumping station may find itself repeatedly and the time spent in these states.

The transition of a system from one state to another can be represented as a state graph. The nodes of the graph correspond to the states of the pumping station, and the arcs correspond to possible transitions from state to state. The arrows on the arcs indicate the directions of possible transitions. The intensity of the transitions is indicated near the arrows, placing the parameters λ and μ. If there are n nodes in the state graph, of which k will correspond to the operational states of the station, then the remaining n-k nodes will be failure states. The set of states when i elements have failed in the pumping station is called the i-th level of the graph. At i = 0 (zero level), all the elements of the pumping station are in good order. For i = 1 (first level), any one element has failed, and the rest are operational, for i = 2 (second level), any two elements have failed, and the rest are operational, etc.

The state graph is used to compile a system of Kolmogorov differential equations [1–3], describing the change in time of the reliability indicators of any technical systems, including pumping stations. The solution of such systems of equations is obtained, as a rule, by numerical methods on a computer [1].

To obtain the final values of the reliability indicators, in the steady-state operating mode, at $t \rightarrow \infty$ Kolmogorov's system of differential equations transforms into a system of linear algebraic equations. The solution is also obtained by numerical methods using a computer.

However, for a state graph in the form of a tree, an analytical solution can be obtained without compiling and solving systems of differential or algebraic Kolmogorov equations. Such a method for assessing reliability by a state graph is based on a certain structure of determinants of linear algebraic equations system [1]. The structure of determinants allows to write a rule for finding expressions for reliability indicators directly from the state graph. This rule for the stationary probability of the pumping station being in the j-th state is formulated as follows: in the directed graph of states, the shortest paths are calculated from all end nodes of the graph to each state (node of the graph) in the direction of the arrows. The shortest path along an oriented edge can only pass once [10]. All transition intensities are multiplied.

The final probability of finding a pumping station in the j-th state is determined by the expression

$$P_j = \frac{\Delta_j}{\sum_{i=0}^{n} \Delta_i} \tag{1}$$

where Δ_j—is the product of transition intensities from all end states to state j when moving along the shortest paths in the direction of the arrows;

Δ_i—the same—to state i;

$n + 1$—the number of all considered states of the pumping station.

End nodes of an oriented state graph are called nodes that do not have outgoing arrows for a non-recoverable system, and at most one outgoing arrows for a recoverable system.

Using Eq. (1), an equation can be obtained to calculate the availability factor of a pumping station.

The availability factor can be calculated as the sum of the final probabilities of the pumping station being in operational states

$$K_g = \sum_{j=0}^{k} P_j \tag{2}$$

where k—is the number of operational states of the pumping station.

Let us denote by E the set of all states of the pumping station. Then

$$E = E^{+} + E^{-} \tag{3}$$

where E^{+}—is the set of all operable states;

E^{-}—is the set of all unworkable states.

MTBF is calculated using the following formula

$$T = \frac{\sum_{j \in E^{+}} P_j}{\sum_{\substack{j \in E^{-} \\ j \in E^{+}}} \left(P_i \cdot \mu_{i,j}\right)} \tag{4}$$

where $\mu_{i,j}$—the rate of transition of the pumping station from the inoperative state i to the operable state j.

Equation (4) is the most general [1], since allows calculating MTBF for any number of failure conditions and any service discipline.

Mean time to recovery is related to availability and MTBF by the expression

$$T = \frac{K_g}{1 - K_g} \cdot T_B \tag{5}$$

Average recovery time of a pumping station

$$T_B = \frac{1 - K_g}{K_g} \cdot T \tag{6}$$

Thus, based on the state graph, it is possible to calculate the main indicators of the restored pumping station reliability without solving the Kolmogorov system of algebraic equations.

Example 1 Consider a pumping station (PS) of the second reliability category [20], in which there is 1 working and 1 standby pump.

The λ and μ parameters are constant. Uptime follows an exponential distribution. Service discipline is the reverse priority. The technological scheme of the pumping station is shown in Fig. 1.

Determine the following reliability indicators: pumping station availability, MTBF, mean recovery time. We will enlarge the elements of the pumping station. Let's combine the valve on the suction pipeline, the pump, and the check valve into one element. There will be two such elements in the station with numbers 1 and 2. The valves on the pressure pipelines will be presented as separate elements with numbers 3 and 4. The valve on the pressure manifold is element 5.

The indicators of the reliability of the pumping station elements [6, 9] are presented in Table 1.

For enlarged elements 1 and 2 the failure rate is determined by the equation

$$\lambda_1 = \lambda_{gs} + \lambda_p + \lambda_{cv} = (1.25 + 3.33333 + 1.42857) \cdot 10^{-4} = 6.01190 \cdot 10^{-4} \text{ 1/hour.}$$

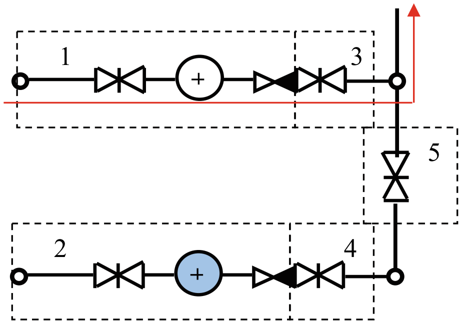

Fig. 1 Scheme of the pumping station. Dotted lines show enlarged elements of the station. 1, 2—enlarged circuit elements (valve on the suction line, pump, check valve); elements 3,4—valves on pressure pipelines; 5—gate valve on the discharge manifold

Table 1 Pumping station reliability indicators [6, 9]

Elements of the pumping station	Running time to refuse, hour	Failure rate, $\lambda \cdot 10^{-4}$, 1/hour	Failure rate, λ, 1/year	Average recovery time, hour	Recovery rate, $\mu \cdot 10^{-2}$, 1/hour	Recovery flow rate, μ, 1/year
Gate valves:—on suction lines	8000	1.25000	1.095	20	5.00000	438
on pressure lines	2500	4.00000	3.504	10	10.0000	876
on pressure manifolds	8000	1.25000	1.095	20	5.00000	438
Pumping units	3000	3.33333	2.920	60	1.66667	146
Check valves	7000	1.42857	1.251	10	10.0000	876

$$T = \frac{1}{\lambda_1} = \frac{1}{6.01190 \cdot 10^{-4}} = 1663.368\,\text{hour}.$$

Average recovery time

$$T_B = \frac{1}{\lambda_1} \cdot \left(\frac{\lambda_{gs}}{\mu_{gs}} + \frac{\lambda_p}{\mu_p} + \frac{\lambda_{cv}}{\mu_{cv}} \right) = \frac{1}{6.01190 \cdot 10^{-4}} \left(\frac{1.25 \cdot 10^{-4}}{5 \cdot 10^{-2}} + \frac{3.33333 \cdot 10^{-4}}{1,66667 \cdot 10^{-2}} + \frac{1.42857 \cdot 10^{-4}}{1,251 \cdot 10^{-2}} \right) = 39.8\,\text{hour}.$$

Option 1. Pumping unit 1 is operating, and pumping unit 2 is in a cold standby and turns on after a failure of pumping unit 1. For unit 1 to work, enlarged elements 1, 2, 5 must be in good working order. If elements 3 or 5 fail, the pumping station goes into failure condition. Let's make a graph of states of the pumping station (Fig. 2 and Table 2).

Nodes 2, 3, 4, 5, 6, 7 are terminal, of which only one arrow goes out with designations μ_j, where $j = 2, 3, 4, 5$. Let us compose the product of the intensities of transitions from all terminal states to state 0 and to states 1, 2, 3, 4, 5, 6, 7.

$$\begin{aligned}\Delta_0 &= \mu_1 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5^2 \\ &= 220.085955 \cdot 220.08955 \cdot 876^2 \cdot 876 \cdot 438^2 \\ &= 6.24683E + 18;\end{aligned}$$

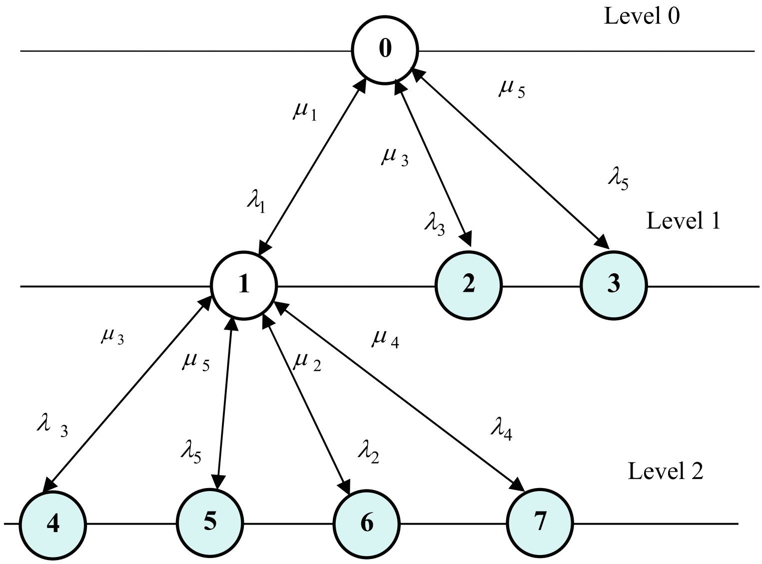

Fig. 2 Graph of states of the pumping station, the diagram of which is shown in Fig. 1. Pump No 1 is running. Working states are indicated by numbers 0, 1. Failure states—in numbers 2, 3, 4, 5, 6, 7

Table 2 Reliability indicators of enlarged elements

Enlarged elements	Running time to refuse, hour	Failure rate, $\lambda \cdot 10^{-4}$, 1/hour	Failure rate, λ, 1/year	Average recovery time, hour	Recovery flow rate, μ, 1/year
1	1663.36673	6.011903	5.26643	39.80198	220.08955
2	1663.36673	6.011903	5.26643	39.80198	220.08955
3	2500	4.00000	3.504	10	876
4	2500	4.00000	3.504	10	876
5	8000	1.25000	1.095	20	438

$$\Delta_1 = \lambda_1 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5^2 = 1.49478\text{E} + 17;$$

$$\Delta_2 = \lambda_3 \cdot \mu_1 \cdot \mu_2 \cdot \mu_3 \cdot \mu_4 \cdot \mu_5^2 = 2.49873\text{E} + 16;$$

$$\Delta_3 = \lambda_5 \cdot \mu_1 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5 = 1.56171\text{E} + 16;$$

$$\Delta_4 = \lambda_1 \cdot \lambda_3 \cdot \mu_2 \cdot \mu_3 \cdot \mu_4 \cdot \mu_5^2 = 5.97911\text{E} + 14;$$

$$\Delta_5 = \lambda_1 \cdot \lambda_5 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5 = 3.73694\text{E} + 14;$$

$$\Delta_6 = \lambda_1 \cdot \lambda_2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5^2 = 3.57679\text{E} + 15;$$

$$\Delta_7 = \lambda_1 \cdot \lambda_4 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_5^2 = 5.97911\text{E} + 14;$$

Let's calculate the sum

$$\sum_{i=0}^{7} \Delta_i = 6.44205\text{E} + 18$$

The final probabilities of finding the pumping station in eight states is determined by the formula (1)

$$P_0 = \frac{6.24683 + 18}{6.44205 + 18} = 0.969694708;\ P_1 = \frac{1.49478 + 17}{6.44205 + 18} = 0.023203416;$$

$$P_2 = \frac{2.49873\text{E} + 16}{6.44205 + 18} = 0.003878779;\ P_3 = \frac{1.56171\text{E} + 16}{6.44205 + 18} = 0.002424237;$$

$$P_4 = \frac{5.7911\text{E} + 14}{6.44205 + 18} = 9.28137\text{E - }05;\ P_5 = \frac{3.73694\text{E} + 14}{6.44205 + 18} = 5.80085\text{E - }05;$$

$$P_6 = \frac{3.57679\text{E} + 15}{6.44205 + 18} = 0.000555225; P_7 = \frac{5.97911\text{E} + 14}{6.44205 + 18} = 9.28137\text{E - }05.$$

The availability factor is calculated by the expression (2)

$$K_g = P_0 + P_1 = 0.969694708 + 0.023203416 = 0.992898124 \approx 0.9928981;$$

The MTBF is determined by the formula (4).

$$T = \frac{P_0 + P_1}{P_2 \cdot \mu_3 + P_3 \cdot \mu_5 + P_4 \cdot \mu_3 + P_5 \cdot \mu_5 + P_6 \cdot \mu_2 + P_7 \cdot \mu_4}$$
$$= 0.20816162 \text{ years or } 1823.5 \text{ hours.}$$

We find an average recovery time from the expression (6)

$$T_B = \frac{1 - K_g}{K_g} \cdot T = \frac{1 - 0.992898124}{0.992898124} \cdot 0.20816162 = 0.001488912 \text{ years or } 13.04 \text{ hours.}$$

Option 2. Pump No 2 is running. Pump No 1 is in cold standby. Reverse service priority. The digraph of the pumping station states is shown in Fig. 3. This graph differs from Fig. 2 in the number of states at levels 1 and 2. The total number of states has increased to 11.

Let's make the product of the intensities of the transitions from the end nodes of the digraph (Fig. 3) to the nodes 0,1,2,3,4,5,6,7,8,9,10.

$$\begin{aligned}\Delta_0 &= \mu_1^2 \cdot \mu_2 \cdot \mu_3^3 \cdot \mu_4 \cdot \mu_5^3 \\ &= 220.085955^2 \cdot 220.08955 \cdot 876^3 \cdot 876 \cdot 438^3 \\ &= 5.27518E + 26\end{aligned}$$

$$\Delta_1 = \lambda_2 \cdot \mu_1^2 \cdot \mu_3^3 \cdot \mu_4 \cdot \mu_5^3 = 1.26227 + 25;$$

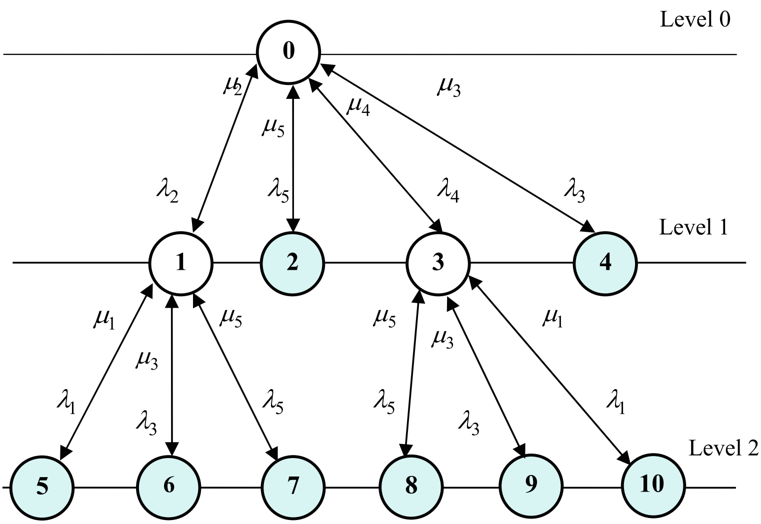

Fig. 3 Graph of pumping station states, the diagram of which is shown in Fig. 1. Pump No 2 is running. Working states are indicated by the numbers 0, 1, 3. Failure states—by the numbers 2, 4, 5, 6, 7, 8, 9, 10

$$\Delta_2 = \lambda_5 \cdot \mu_1^2 \cdot \mu_2 \cdot \mu_3^3 \cdot \mu_4 \cdot \mu_5^2 = 1.31879\text{E} + 24;$$

$$\Delta_3 = \lambda_4 \cdot \mu_1^2 \cdot \mu_2 \cdot \mu_3^3 \cdot \mu_5^3 = 2.11007\text{E} + 24;$$

$$\Delta_4 = \lambda_3 \cdot \mu_1^2 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5^3 = 2.11007\text{E} + 24;$$

$$\Delta_5 = \lambda_1 \cdot \lambda_2 \cdot \mu_1 \cdot \mu_3^3 \cdot \mu_4 \cdot \mu_5^3 = 3.02044\text{E} + 23;$$

$$\Delta_6 = \lambda_2 \cdot \lambda_3 \cdot \mu_1^2 \cdot \mu_3^2 \cdot \mu_4 \cdot \mu_5^3 = 5.0491\text{E} + 22;$$

$$\Delta_7 = \lambda_2 \cdot \lambda_5 \cdot \mu_1^2 \cdot \mu_3^3 \cdot \mu_4 \cdot \mu_5^2 = 3.15569\text{E} + 22;$$

$$\Delta_8 = \lambda_4 \cdot \lambda_5 \cdot \mu_1^2 \cdot \mu_2 \cdot \mu_3^3 \cdot \mu_5^2 = 5.27518\text{E} + 21;$$

$$\Delta_9 = \lambda_4 \cdot \lambda_3 \cdot \mu_1^2 \cdot \mu_2 \cdot \mu_3^2 \cdot \mu_5^3 = 8.44028\text{E} + 21;$$

$$\Delta_{10} = \lambda_1 \cdot \lambda_4 \cdot \mu_1 \cdot \mu_2 \cdot \mu_3^3 \cdot \mu_5^3 = 5.0491\text{E} + 22;$$

$$\sum_{i=0}^{10} \Delta\_i = 5.46128\text{E} + 26.$$

The final probabilities of finding a pumping station in each of the 11 states are

$$P_0 = \frac{\Delta\_0}{\sum_{i=0}^{10} \Delta\_i} = \frac{5.27518 + 26}{5.46128 + 26} = 0.965923751;$$

$$P_1 = \frac{\Delta_1}{\sum_{i=0}^{10} \Delta_i} = \frac{1.26227 + 25}{5.46128 + 26} = 0.023113182;$$

$$P_2 = \frac{1.31879 + 24}{5.46128 + 26} = 0.002414809; \; P_3 = \frac{2.11007 + 24}{5.46128 + 26} = 0.003863695;$$

$$P_4 = \frac{2.11007 + 24}{5.46128 + 26} = 0.003863695; \; P_5 = \frac{3.02044 + 23}{5.46128 + 26} = 0.000553066;$$

$$P_6 = \frac{5.0491 + 22}{5.46128 + 26} = 9.24527 - 05\,; \; P_7 = \frac{3.15569 + 22}{5.46128 + 26} = 5.7783 - 05;$$

$$P_8 = \frac{5.27518 + 21}{5.46128 + 26} = 9.65924 - 06; \; P_9 = \frac{8.44028 + 21}{5.46128 + 26} = 1.54548 - 05;$$

$$P_{10} = \frac{5.0491 + 22}{5.46128 + 26} = 9.24527 - 05.$$

Availability ratio

$$K_g = P_0 + P_1 + P_3 = 0.965923751 + 0.023113182 + 0.002414809 = 0.99290.$$

MTBF

$$T = \frac{P_0 + P_1 + P_3}{P_2 \cdot \mu_5 + P_4 \cdot \mu_3 + P_5 \cdot \mu_1 + P_6 \cdot \mu_3 + P_7 \cdot \mu_5 + P_8 \cdot \mu_5 + P_9 \cdot \mu_3 + P_{10} \cdot \mu_1}$$
$$= 0.210877586 \text{ years or } 1847.3 \text{ hours.}$$

Average recovery time

$$T_B = \frac{1 - K_g}{K_g} \cdot T = \frac{1 - 0.992900628}{0.992900628} \cdot 0.210877586$$
$$= 0.001507803 \text{ years or } 13.21 \text{ hours.}$$

In the case when pump No 2 is running, and pump No 1 is in cold standby, and with the reverse priority in service, the availability factor increased slightly from to 0.99290. MTBF increased from 1823.5 h to 1847.3 h, and mean recovery time increased from 13.04 h to 13.21 h. Therefore, with an asymmetric pumping station scheme, the number of the pump in operation matters.

Example 2 Let's change the scheme of the pumping station. Let's add one more pressure water conduit (Fig. 4). Let the pumping station operate in normal mode if at least one of the two water lines is working.

Reverse service priority. Pump No 1 is working, pump No 2 is in cold reserve. The NN state graph is shown in Fig. 5.

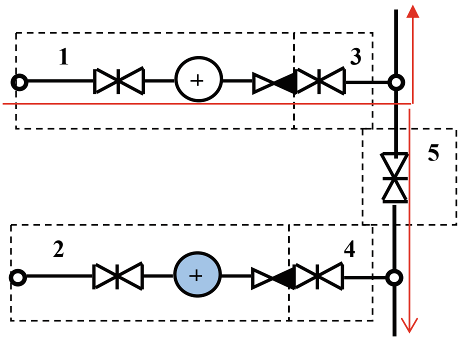

Fig. 4 Scheme of a pumping station with a valve and two pressure conduits:, 2, 3, 4, 5—numbers of elements of the scheme, 1, 2—enlarged elements of the scheme

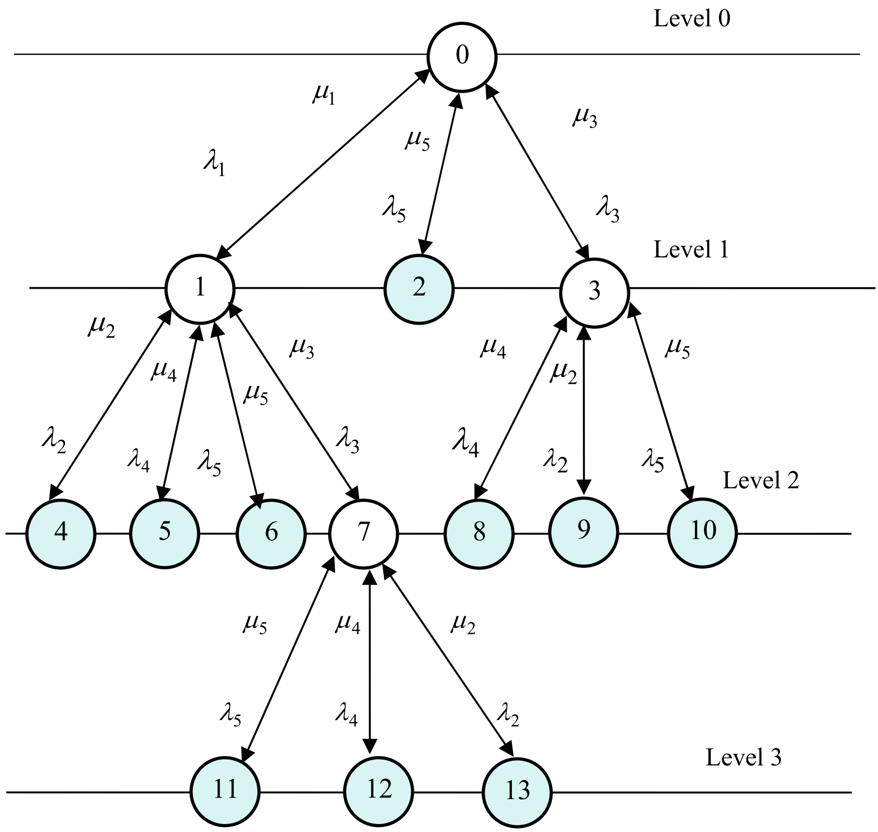

Fig. 5 The state graph of the pumping station, the diagram of which is shown in Fig. 4. Pump No 1 is running. Working states are indicated by the numbers 0, 1, 3, 7. Failure states—by the numbers 2, 4, 5, 6, 8, 9, 10, 11, 12, 13

The number of states of the pumping station increased to 13. Let us calculate the intensities of transitions from the end nodes of the digraph to the nodes 0,1,2,3,4,5,6,7,8,9,10,11,12,13.

$$\Delta_0 = \mu_1 \cdot \mu_2^3 \cdot \mu_3^2 \cdot \mu_4^3 \cdot \mu_5^4 = 4.45466E + 34;$$

$$\Delta_1 = \lambda_1 \cdot \mu_2^3 \cdot \mu_3^2 \cdot \mu_4^3 \cdot \mu_5^4 = 1.06594E + 33;$$

$$\Delta_2 = \lambda_5 \cdot \mu_1 \cdot \mu_2^3 \cdot \mu_3^2 \cdot \mu_4^3 \cdot \mu_5^3 = 1.11367E + 32;$$

$$\Delta_3 = \lambda_3 \cdot \mu_1 \cdot \mu_2^3 \cdot \mu_3 \cdot \mu_4^3 \cdot \mu_5^4 = 1.78186E + 32;$$

$$\Delta_4 = \lambda_1 \cdot \lambda_2 \cdot \mu_2^2 \cdot \mu_3^2 \cdot \mu_4^3 \cdot \mu_5^4 = 2.55064E + 31;$$

$$\Delta_5 = \lambda_1 \cdot \lambda_4 \cdot \mu_2^3 \cdot \mu_3^2 \cdot \mu_4^2 \cdot \mu_5^4 = 4.26375E + 30;$$

$$\Delta_6 = \lambda_1 \cdot \lambda_5 \cdot \mu_2^3 \cdot \mu_3^2 \cdot \mu_4^3 \cdot \mu_5^3 = 2.66484E + 30;$$

$$\Delta_7 = \lambda_1 \cdot \lambda_3 \cdot \mu_2^3 \cdot \mu_3 \cdot \mu_4^3 \cdot \mu_5^4 = 4.26375E + 30;$$

$$\Delta_8 = \lambda_3 \cdot \lambda_4 \cdot \mu_1 \cdot \mu_2^3 \cdot \mu_3 \cdot \mu_4^2 \cdot \mu_5^4 = 7.12746E + 29;$$

$$\Delta_9 = \lambda_2 \cdot \lambda_3 \cdot \mu_1 \cdot \mu_2^2 \cdot \mu_3 \cdot \mu_4^3 \cdot \mu_5^4 = 4.26375E + 30;$$

$$\Delta_{10} = \lambda_2 \cdot \lambda_3 \cdot \mu_1 \cdot \mu_2^3 \cdot \mu_3 \cdot \mu_4^3 \cdot \mu_5^3 = 4.45466E + 29;$$

$$\Delta_{11} = \lambda_1 \cdot \lambda_3 \cdot \lambda_5 \cdot \mu_2^3 \cdot \mu_3 \cdot \mu_4^3 \cdot \mu_5^3 = 1.06594E + 28;$$

$$\Delta_{12} = \lambda_1 \cdot \lambda_3 \cdot \lambda_4 \cdot \mu_2^3 \cdot \mu_3 \cdot \mu_4^2 \cdot \mu_5^4 = 1.7055E + 28;$$

$$\Delta_{13} = \lambda_1 \cdot \lambda_3 \cdot \lambda_2 \cdot \mu_2^2 \cdot \mu_3 \cdot \mu_4^3 \cdot \mu_5^4 = 1.02025E + 29.$$

Final probabilities of finding a pumping station at each of the 14 states

$$P_0 = 0.96958;\ P_1 = 0.02320;\ P_2 = 0.00242;\ P_3 = 0.003878;$$

$$P_4 = 0.55516E - 03;\ P_5 = 9.28024E - 05;\ P_6 = 5.80015E - 05;$$

$$P_7 = 9.28024E - 05;\ P_8 = 1.55132E - 05;\ P_9 = 9.28024E - 05;$$

$$P_{10} = 9.69578E - 06;\ P_{11} = 2.32006E - 07;\ P_{12} = 3.7121E - 07;$$

$$P_{13} = 2.22063E - 06.$$

Availability ratio

$$K_g = P_0 + P_1 + P_3 + P_7 = 0.996749$$

The MTBF was 0.749577 or 6566 h. Average recovery time is 0.00244 years or 21.42 h. The second pressure line increased the availability factor to 0.996749.

Table 3 Influence of levels on solution accuracy

Number of levels	The number of states	Kg	T, hours	T_B, hours	Deviation, % Kg	T	T_B
4	14	0,996,749	6566	21,4	0	0	0
3	11	0,997,304	7235	19,6	0,0557	10,18	8,69
2	4	0,997,574	8223	20,0	0,08,273	25,24	6,61

MTBF has increased to 6566 h. The average time to recover the station also increased from 13.2 h to 21.42.

3 Conclusion

The proposed method for calculating the of pumping stations reliability using the state graph is simple and clear. For the graph of pumping station states in the form of a tree, it allows to get a solution without making up a system of algebraic or differential equations. You can take into account the discipline of service. Consider the tasks of the sequence of switching on of pumps, take into account the different types of equipment of pumping stations. Solving large-scale problems will require scaling the reliability indicators of the enlarged elements of pumping stations.

For large-scale problems, it is possible to limit the number of levels in the state graph of the pumping station. We get a truncated state graph and a problem of lower dimension.

For example, for Fig. 5 we will restrict ourselves to 3 levels: 0, 1, 2. This corresponds to the failure of two elements of the pumping station. Such a state graph will be truncated. The number of states is 11. The availability factor will increase to Kg = 0.9973. MTBF will be T = 7235 h. Average recovery time will decrease T_B = 19.6 h.

If we restrict ourselves to 2 levels: 0, 1. The number of states of the station will be 4. The availability factor will increase and will amount to Kg = 0.99675. This will lead to an increase in MTBF T = 8223 h. Average recovery time T_B = 20 h (Table 3).

The depth of failure of the station will be determined by the specific task and configuration of the technological part. Checking the accuracy of the truncated task can be obtained by increasing the number of levels of station states.

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Calculation of the Normal Force and Bending Moment from Compression Stresses in Concrete

Mukhlis Hajiyev, Fovzi Guliyev, and Dmytro Ovsii

Abstract Calculating reinforced concrete structures based on a nonlinear deformation model, it is important to calculate the normal force and bending moment from the compression stress that occurs in concrete in cross section. An essential role in the development of a nonlinear model for calculating reinforced concrete structures at an arbitrary load level is played by the presence of an expression of the bending vector and the bending moment formed from compression stresses arising during detonation. It is accepted that the hypothesis of flat sections for a reinforced concrete section up to the moment of complete collapse is correct. Using this hypothesis and the fractional rational expression of concrete proposed by Eurocode during compression, analytical expressions were obtained for the normal force and bending moment depending on the level of deformation on the compressible section face and the height of the compressible section zone for an arbitrary load level.

Keywords Deformation · Stretching · Diagram · Stiffness · Normal force · Bending moment

1 Introduction

During the development modern nonlinear calculation methods for inflexible working reinforced concrete structures, an essential role in the development of calculation methods of this type is played by the presence of normal expressions of concrete forces and moments formed from normal stresses in concrete in the compression zone in the cross section of the bent reinforced concrete element using its complete scheme,

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_14

which also takes into account the descending lever during concrete compression [1, 4, 8–14]. The article presents axiomatic expressions for calculating the normal force and bending moment from the compression stress in concrete on a rectangular cross-sectional element using a fractional-rational expression of the complete concrete compression scheme proposed in Eurocode. From the expressions obtained for an arbitrary load level, the corresponding formulas used in the calculation of reinforced concrete elements for strength over normal cross-sections are obtained, as a last resort, as a special case, which makes it possible to calculate reinforced concrete elements by the traditional method using a diagram of real deformations during concrete compression.

2 Main Part

2.1 Purpose of the Article

The main purpose of the article is to obtain appropriate analytical expressions for the normal force and bending moment created by compression stresses in concrete, used in the calculations of working rectangular broadband reinforced concrete elements without bending at arbitrary load levels. Here, also, as a special case, the specification of analytical expressions for normal force and bending moment used in the calculation of reinforced concrete elements for strength according to the first group of limiting cases of normal cross-sections is given.

2.2 Research Methodology

For a reinforced concrete element of rectangular cross-section working for bending, using the hypothesis of flat sections, in the general case, the calculation of the bending vector and bending moment is given using the fractional-rational dependence of compression stresses arising in concrete in the compressible section zone proposed in the Eurocode.

2.3 Results

Let us assume that the dimensions and clearance of the cross-section of the element are the same as shown in Fig. 1. Let us suppose that the diagram of concrete deformation under compression is determined by the law of the fractional-rational function proposed in the Eurocode, as follows [2–5, 7]:

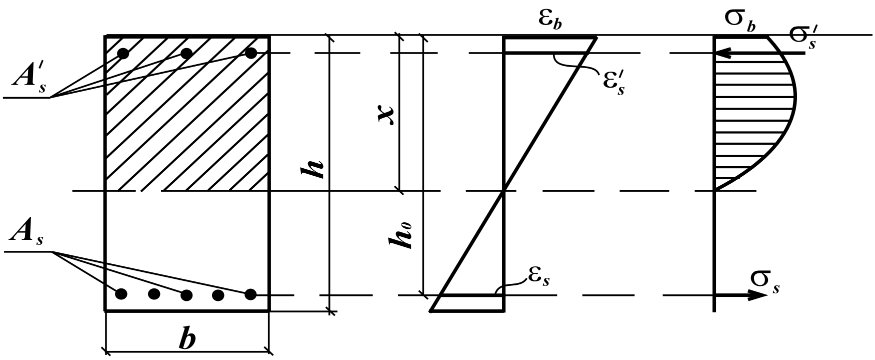

Fig. 1 Design scheme of a rectangular cross-section element

$$\sigma_b = R_b \cdot \frac{k \cdot \beta - \beta^2}{1 + (k-2) \cdot \beta} \tag{1}$$

In Eq. (1), the parameter $\beta = \varepsilon_b/\varepsilon_R$ which define levels of compression deformation in concrete, and ε_{b}—the value of the deformation that occurs in concrete when the fiber of the edge of the cross section is compressed, $k = \frac{E_b \cdot \varepsilon_R}{R_b}$.

Based on the deformation model, the hypothesis of flat sections for the cross section is considered correct [2–7]. On the basis of this hypothesis for the distribution of the deformation on the cross section, we can write by adopting the coordinate beginning at the center of gravity of the stretched armature

$$\beta_z = \frac{\beta}{x} \cdot (z + x - h_0) \tag{2}$$

Then, for the distribution of normal stresses in concrete along the height in the compression zone of the section, we obtain

$$\sigma_b(z) = R_b \cdot \frac{k \cdot \beta_z - \beta_z^2}{1 + (k-2) \cdot \beta_z} \tag{3}$$

Then, from the compressive stresses in concrete, we obtain according to the well–known formula of the resistance of materials to the normal force and bending moment

$$N_b = \int\limits_{A_b} \sigma_b(z) dA_b = b \cdot \int\limits_{h_0 - x}^{h_0} R_b \cdot \frac{k \cdot \frac{\beta}{x} \cdot (z + x - h_0) - \frac{\beta^2}{x^2} \cdot (z + x - h_0)^2}{1 + (k-2) \cdot \frac{\beta}{x} \cdot (z + x - h_0)} dz. \tag{4}$$

$$M_b = \int_{A_b} \sigma_b(z) \cdot z \cdot dA_b$$
$$= b \cdot R_b \cdot \int_{h_0 - x}^{h_0} \frac{k \cdot \frac{\beta}{x} \cdot (z + x - h_0) - \frac{\beta^2}{x^2} \cdot (z + x - h_0)^2}{1 + (k-2) \cdot \frac{\beta}{x} \cdot (z + x - h_0)} \cdot z \cdot dz \quad (5)$$

After calculating these integrals, we obtain the following expressions

$$N_b = R_b \cdot b \cdot x \cdot \omega_b(\beta, k) \quad (6)$$

$$\omega_b(\beta, k) = \left(\frac{k-1}{k-2}\right)^2 - \frac{\beta}{2(k-2)} - \frac{(k-1)^2}{(k-2)^3 \cdot \beta} \cdot \ln[1 + (k-2) \cdot \beta] \quad (7)$$

$$M_b = R_b \cdot b \cdot \left[(h_0 - x) \cdot x \cdot \omega_b(\beta, k) + x^2 \cdot \lambda_b(\beta, k)\right] \quad (8)$$

$$\lambda_b(\beta, k) = -\frac{1}{3} \cdot \frac{\beta}{k-2} + \frac{1}{2} \cdot \frac{(k-1)^2}{(k-2)^2} - \frac{(k-1)^2}{(k-2)^3 \cdot \beta} + $$
$$+ \frac{(k-1)^2}{(k-2)^4 \cdot \beta^2} \cdot \ln(1 + (k-2) \cdot \beta) \quad (9)$$

From the above integrals, we show, for example, the calculation of the integral (5). For this let's insert a replacement $u = 1 + (k-2) \cdot \frac{\beta}{x} \cdot (z + x - h_0)$, then, since $\frac{\beta}{x} \cdot (z + x - h_0) = \frac{u-1}{k-2}$, $z = \frac{x}{\beta} \cdot \frac{u-1}{k-2} + h_0 - x$ və $dz = \frac{x}{\beta} \cdot \frac{du}{k-2}$ this Integral is concretized as follows

$$M_b = b \cdot R_b \cdot \frac{x}{(k-2) \cdot \beta} \cdot \int_1^{1+(k-2)\cdot\beta} \frac{1}{u} \cdot \left[k \cdot \frac{u-1}{k-2} - \left(\frac{u-1}{k-2}\right)^2\right]$$
$$\times \left(\frac{x}{\beta} \cdot \frac{u-1}{k-2} + h_0 - x\right) du = b \cdot R_b \cdot x \cdot (h_0 - x)$$
$$\cdot \omega_b(\beta, k) + b \cdot R_b \cdot x^2 \cdot \lambda_b(\beta, k)$$

Here

$$\lambda_b = \frac{1}{(k-2)^2 \cdot \beta^2} \cdot \int_1^{1+(k-2)\cdot\beta} \left(1 - \frac{1}{u}\right) \cdot \left[k \cdot \frac{u-1}{k-2} - \left(\frac{u-1}{k-2}\right)^2\right] du$$

This integral can be easily calculated

$$\lambda_b(\beta,\ k) = \frac{1}{(k-2)^4\cdot\beta^2}\cdot\int\limits_1^{1+(k-2)\cdot\beta}\left(1-\frac{1}{u}\right)\cdot\left[\left(k^2-2k\right)\cdot(u-1)-(u-1)^2\right]du$$

$$= \frac{1}{(k-2)^4\cdot\beta^2}\cdot\int\limits_1^{1+(k-2)\cdot\beta}\left(-u^2+\left(k^2-2k+3\right)\cdot u-2k^2+4k-3+\frac{(k-1)^2}{u}\right)du$$

$$= \frac{1}{(k-2)^4\cdot\beta^2}\cdot\left[-\frac{1}{3}\cdot(k-2)^3\cdot\beta^3-(k-2)^2\cdot\beta^2-(k-2)\cdot\beta\right.$$

$$+\frac{1}{2}\cdot\left(k^2-2k+3\right)\cdot(k-2)^2\cdot\beta^2+\left(k^2-2k+3\right)\cdot(k-2)\cdot\beta$$

$$\left.-\left(2k^2-4k+3\right)\cdot(k-2)\cdot\beta+(k-1)^2\cdot\ln(1+(k-2)\cdot\beta)\right]$$

$$= -\frac{1}{3}\cdot\frac{\beta}{k-2}+\frac{1}{2}\cdot\frac{(k-1)^2}{(k-2)^2}-\frac{(k-1)^2}{(k-2)^3\cdot\beta}+\frac{(k-1)^2}{(k-2)^4\cdot\beta^2}$$

$$\cdot\ln(1+(k-2)\cdot\beta)$$

Graphs of the dependence of their newly introduced coefficients $\omega_b(\beta, k)$ and $\lambda_b(\beta, k)$ on the level of deformation depending on the concrete class are shown in the figures below.

As can be seen from the Fig. 2, the nature of the dependence of these two parameters on the level of deformation is similar, and the influence of the concrete class on the change of these parameters is quite strong. The obtained analytical expressions can be used in the calculation of reinforced concrete elements of rectangular cross-section for strength over normal cross-sections in extreme cases (Fig. 3).

For example, when $\beta = \beta_u$ the entered parameters are converted to constant coefficients. At the same time, the formulas for calculating reinforced concrete elements of rectangular cross-section, working for bending, for strength in normal sections are written as Eq. 10.

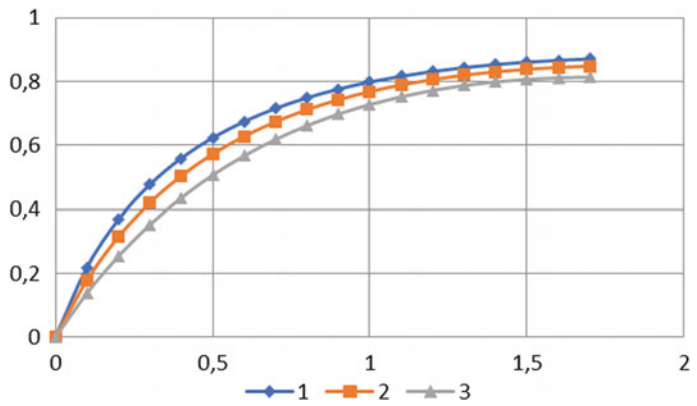

Fig. 2 Graphs of the dependence of the parameter $\omega_b(\beta, k)$ on the level of deformation β: 1—B 15 ($C$12/15), 2—B 25 ($C$20/25), 3—B 45 ($C$35/45)

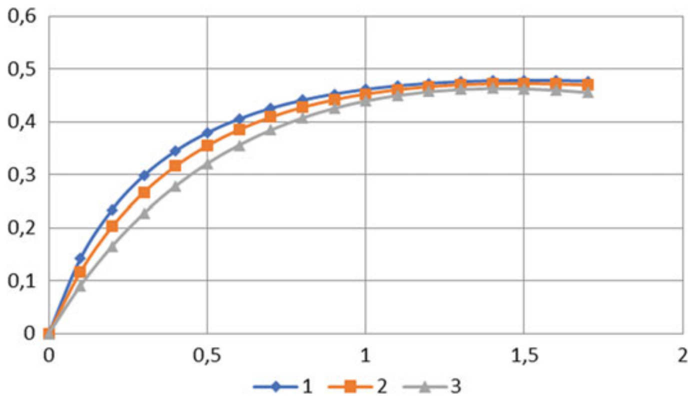

Fig. 3 Graphs of the dependence of the parameter $\lambda_b(\beta, k)$ on the level of deformation β: 1—B 15 ($C$12/15), 2—B 25 ($C$20/25), 3—B 45 ($C$35/45)

$$\begin{cases} R_b \cdot b \cdot h_0 \cdot \omega_b \cdot \xi + R_{sc} \cdot A'_s - R_s \cdot A_s = 0 \\ M = \alpha_m^* \cdot R_b \cdot b \cdot h_0^2 + R_{sc} \cdot A'_s \cdot \left(h_0 - a'_s\right) \\ \alpha_m^* = \xi \cdot (1 - \xi) \cdot \omega_b + \lambda_b \cdot \xi^2 \\ \xi = \dfrac{1 - \sqrt{\omega_b^2 - 4 \cdot \alpha_m^* \cdot (\lambda_b - \omega_b)}}{2 \cdot (\lambda_b - \omega_b)} \end{cases} \tag{10}$$

The table below shows the values for limit cases and coefficients depending on the concrete class Table 1.

Table 1 Values of coefficients ω_b and λ_b

Class of concrete	k	ω_b	λ_b
B 15 (C 12/15)	5.41176	0.87,034	0.47965
B 20 (C 16/20)	4.69565	0.85,891	0.47332
B 25 (C 20/25)	4.13793	0.84,772	0.46944
B 30 (C 25/30)	3.82353	0.84,013	0.46662
B 35 (C 28/35)	3.53846	0.83,217	0.46349
B 40 (C 32/40)	3.27273	0.82,351	0.45986
B 45 (C 35/45)	3.00000	0.81,294	0.45514
B 50 (C 40/50)	2.83636	0.80549	0.45159
B 55 (C 45/55)	2.63333	0.79466	0.44613
B 60 (C 50/60)	2.42424	0.78091	0.43866

2.4 Scientific Novelty

Using the proposed fractional-rational Eurocode scheme for concrete compression, analytical expressions were obtained for calculating the normal force and bending moment arising from the compression of rectangular reinforced concrete elements of cross section at an arbitrary load level, and on the basis of these expressions, formulas for calculating bent reinforced concrete elements for strength over normal sections were improved.

2.5 Practical Importance

The analytical expressions obtained for calculating the normal force and bending moment can be used in the calculations of reinforced concrete structures based on nonlinear deformation models, as well as in calculations for limiting cases.

3 Conclusions

Analytical expressions are obtained for calculating the internal normal force and bending moment created by compressive stresses in the compression zone of working reinforced concrete elements that are not subject to bending by introducing two new parameters.

The formulas for calculating the strength of normal cross-sections based on a nonlinear model of deformation of reinforced concrete elements of rectangular cross-section working without bending are given.

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Research of Bearing Capacity and Refrigeration Efficiency of Structural Elements of a Multi-storey Industrial Refrigerator in Kharkiv

Liudmila Haponova, Viacheslav Popovych, and Konul Aghayeva

Abstract On the basis of the existing building of the industrial refrigerator, owned by LLC "KHLADOPROM" in Kharkiv, a study of the causes of destruction of wall enclosing structures for a 60-year period of operation was conducted. It is established that due to the physical aging of mineral wool insulation, as well as due to its shedding, there was a violation of the heat and moisture regime of the wall enclosing structures. This led to the accumulation of moisture in the wall panels and subsequent corrosion of the working reinforcement of the panels. At opening of separate parts of panels it is established that due to corrosion the section of working armature makes 1.5–3 mm, and in separate places is destroyed completely. In combination with the passive action of the wind, this led to the removal of the thin-walled part of the panels.

Keywords Enclosing constructions · Heat and moisture regime

1 Analysis of Existing Approaches to the Research Topic

These days the energy efficiency of the buildings is subject to multiple demands. This is conditioned by the climate changes, limited amounts of minerals and their cost. These factors condition the application of efficient insulation for the rational use of energy, during the construction and exploitation of the buildings and facilities. Noteworthy that currently Ukraine still applies the multiple-deck industrial warehouses-refrigerators which in contrast to the modern refrigerators have the form of the monolithic reinforced concrete refrigerators.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_15

The objective of the work is to study the bearing capacity and cooling efficiency of the existing enclosing structures of the multi-deck industrial refrigerator and elaboration of recommendations in improvement of the energy efficiency of the cooling structures.

Task and research:

– determination of the construction arrangement of the research object;
– identification of the crucial components of the cooling structures;
– inspection of the building structures;
– determination of the strength of basic bearing structures of the building and enclosing structures through the destructive and non-destructive method;
– calculation of cooling efficiency (heat losses) through the walls of the refrigerator with the variation of the insulation material;
– elaboration of recommendations in the improvement of the bearing capacity of existing cooling constructions and renewal of the cooling efficiency of enclosing structures.

Object of the research. Multi-deck industrial refrigerator of KHLADOPROM LLC located to the address: 1 Khabarova str., Kharkiv.

Subject of the research. Enclosing structures of the refrigerator walls and insulation system.

Research methods. The work applies numerical methods of the construction mechanics, numerical method of calculating the heat losses of the enclosing structures. To determine the strength of the concrete of the building frame and assembly curtain wall panels, the Schmidt hammer (determination of the strength of concrete through non-destructive method) was applied. The laboratory method with the characteristics identification through the destruction of samples (hammer ПСУ-250 for testing the construction materials and structures according to GOST 7855-61) was applied.

Practical importance of the obtained results is as follows: implementation of recommendations concerning the improvement of the bearing capacity of enclosing structures; implementation of the efficient synthetic-based insulation system in the industrial multi-deck refrigerator of KHLADOPROM LLC in 1 Khabarova str., in Kharkiv.

The assembly self-supporting wall panels are used as the enclosing structures and the basalt mineral wool slabs are used as the efficient insulation. Such insulation has the perfect heat-saving properties, however, in contrast to the modern synthetic materials can accumulate the moisture which can degrade its performance. Taking into account that the insulation is applied under the conditions of quite high moisture, the period of its efficient exploitation is drastically reduced and the expenses for maintenance of the microclimatic conditions inside the refrigerator increasingly grow. Within the inspection of the studied building the technical conditions of the basic bearing structures were assessed with the assignment of the related category according to ДСТУ-Н Б В.1.2-18-2016 "Instruction on Inspection of Buildings and Facilities to Determine and Assess their Technical Condition" [1–4].

In the process of inspection of brick walls the local sections of the destruction of their surface and finishing plaster layer were detected. This is the result of impact of the precipitations and periodic temperature changes in the refrigerator compartments. The reasons for the destruction (protuberance) of the wall panels was the passive pressure of wind and corrosion of the principal reinforcement of the thin-wall part of panel. General view of the building from facade is shown in the photos (Fig. 1). Surface destruction of the external layer of walls and plaster is not of the physical nature and does not affect the bearing capacity in general. The brickwork of the internal walls is characterized by the local brick destruction sections up to 35–50 mm deep which is also connected with the periodical temperature changes of the refrigerator compartments (Fig. 2).

Fig. 1 Main facade

Fig. 2 Local destruction of the internal walls and plaster within the technical areas

The enclosing structure is composed of the following elements: the assembly reinforced concrete wall panel t = 60 mm; vapor barrier–dorulin; insulation–mineral wool slabs t = 300 mm in the thin-wall part of the panel and t = 180 mm in the vertical joints of panels; wooden frame for insertion of insulation slabs; finishing layer of the sand-cement plaster t = 20 mm.

2 Analysis of the Reasons for Destruction of the Wall Enclosing Structures

The inspection found that the external wall panels have essential defects of the outwards protuberance of the slab (thin) part of panels between the ribbed stiffener—up to 15–20 cm in the middle part.

The panel walls are 50–60 mm thick.

According to the design specifications, the slab part is 50–60 mm thick and is reinforced with the mesh panels Ø6mm AI(A240C) with the cell 150 × 150 mm. The mesh panels are located inside the section of the slabs part.

The designed resistance of reinforcement is $f_{yd} = 225$ MPa = 22.5 kN/cm^2.

The effective depth of section of the panel wall is: d = 25 mm.

In case of the wall protuberance between the longitudinal ribs of the panel the protective concrete layer is destroyed and the moisture (atmospheric and condensed) penetrates through the gaps, which causes the corrosion of the reinforcement and further destruction of the concrete which is in progress.

The opening of separate sections of the protuberant panels found that due to the corrosion the impairment occurred in the principal reinforcement section with the diameter of 1.5.. 2.5 mm, and in some sections the reinforcement was totally destroyed and poured out as the corrosion product.

The protuberance of the thin-wall part of the wall panels is caused by the passive pressure of wind (negative wind pressure).

According to ДБН B.1.2–2: 2006 “Loading and Impact. Design Standards” [5] the calculated wind load on the walls of the building is as follows:

$$q_w = \gamma_{fm} \cdot w_o c_{aer} c_d c_h \tag{1}$$

where for the building located in the industrial area of Kharkiv at T > 0.25 s.

$$\gamma_{fm} = 1.14;\ w_o = 0.43\ \text{kH/m}^2;\ c_{aer} = 0.6;\ c_d = 1.2;\ c_h = 1.55;$$
$$q_w = 1.14 \cdot 0.43 \cdot 0.6 \cdot 1.2 \cdot 1.55 = 0.547\ \text{kH/m}^2.$$

With the correlations between the height and width of the slab *h*/*lb* = 4.8/1.8 = 2.67 potential linear bending moment in the slab in case of plastic hinges in junction between the slab walls and the ribs is as follows:

$$M = q_w l_b^2/8, \tag{2}$$

$M = 0.547 \cdot 1.82/8 = 0.222$ kHm/m.

$$\alpha_m = M/\mathrm{f}_{cd} b d^2, \tag{3}$$

where within the analysis of the instrumental non-destructive testing of slab concrete the strength of concrete was determined, make 250 (according to the current category classification C16/20) with the designed strength $\mathrm{f}_{cd} = 11.5$ MPa $= 1.15$ kH/cm^2). $\alpha_m = 22.2/1.15 \cdot 100 \cdot 2.52 = 0.0308$; $\zeta = 0.984$.

The calculated area of the reinforcement section of the linear width of the slab is as follows:

- at the finishing diameter of reinforcement 1.5 mm $A_{s1} = 0.124$ cm^2;
- at the finishing diameter of reinforcement 2 mm $A_{s2} = 0.22$ cm^2;
- at the finishing diameter of reinforcement 2.5 mm $A_{s3} = 0.343$ cm^2

The bearing capacity of slab with the wind pressure at different level of reinforcement corrosion is correspondingly as follows:

$$M_{u1} = \zeta A_s \mathrm{f}_{yd} d, \tag{4}$$

$M_{u1} = 0.984 \cdot 0.124 \cdot 22.5 \cdot 2.5 = 6.86$ kHcm $= 0.0686$ kHm $<$ M $= 0.222$ kHm;
$M_{u2} = 0.984 \cdot 0.22 \cdot 22.5 \cdot 2.5 = 12.18$ kHcm $<$ M $= 0.222$ kHm;
$M_{u3} = 0.984 \cdot 0.343 \cdot 22.5 \cdot 2.5 = 19.0$ kHcm M $= 0.222$ kHm.

Thus, in case of the corrosion reducing the diameter of the working section of bars to 2.8… 3.0 mm the bearing capacity of the slab can decline which can cause the slab destruction.

In case of any excess wind impact (force-majeure) the thin-wall part of panels can protuberate and destroy.

The bar fixing the wall panels and roofing perceives the tensile force of the wind load from the area of 4.8 × 2.0 m which is as follows:

$$\mathrm{N} = 0.597 \times 4.8 \times 2 = 5.73 \text{ kN}.$$

Permissible section of the panels fixing bar As = 5.73/22.5 = 0.255 cm^2.

The permissible minimum bar diameter $\mathrm{d}_{\min} = 6$ mm.

3 The Impact of the Hygrothermal Conditions on the Bearing Capacity of the Enclosing Structures and the Reasons for Their Destruction

As it was mentioned above, the reason for the destruction (protuberance) of the wall panels was the passive pressure of wind and corrosion of the principal reinforcement of the thin-wall part of panel.

The corrosion of reinforcement is conditioned by the abnormality of the hygrothermal conditions of the enclosing structure exploitation.

The abnormality of the hygrothermal conditions is connected with the following:

– defects of the then-existing constructive solutions of certain units of thermal insulation of the enclosing structures;
– irregularities in the production technology, mainly, the violation of the vapor barrier integrity as of the moment of its installation;
– thickening of the heat-insulating material. As of the moment of inspection the separate parts of the heat-insulating material were opened and the peeling of the mineral wool slabs and violation of the vapor barrier layer were detected;
– expiration of period of the heat insulation material exploitation. The object of the research was built in the early 60 s of the nineteenth century and the capital repair has not been carried out as of the moment of inspection.

The enclosing structure is composed of the following elements:

– double T-beam t = 60 mm;
– vapor barrier—dorulin;
– insulation—mineral wool slabs t = 300 mm in the thin-wall part of the panel and t = 180 mm in the vertical joints of panels;
– wooden frame for insertion of insulation slabs;
– finishing layer of the sand-cement plaster t = 20 mm.

In the place of fastening the wall panels to the roofing (horizontal joints) almost the whole insulation is gone which conditions the substantial loss of cold and causes the abnormality of the hygrothermal conditions.

The hygrothermal conditions of the enclosing structures are calculated using ДСТУ-Н Б В.2.6-192:2013 “Instructions for the calculation of the hygrothermal conditions of the enclosing structure” [6].

In this case the hygrothermal conditions of the enclosing structures (wall panels) are calculated considering the abovementioned defects and the peeling of the mineral wool insulation, physical ageing [7–12].

The calculations will be carried out for the warmest month without regard to the insulation layer since its efficiency is minimal and in some places it is gone at all. Table 1 provides the indexes of the average monthly temperature and moisture in Kharkiv according to ДСТУ-Н Б В.1.1-27:2010.

Table 1 Indexes of the average monthly temperature and moisture in Kharkiv

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average monthly air temperature $t_з$, °C	−5.9	−5.1	0.0	9.0	15.5	18.9	20.7	19.7	14.1	7.5	1.0	−3.7
Average monthly air humidity $\varphi_з$,%	84	83	79	67	60	64	66	64	70	77	86	87

Table 2 Estimated performance of material under the exploitation conditions

No	Title	Thickness δ, м	Thermal conductivity λ_p, W/(m^2 · K)	Vapor permeability coefficient μ, mg (m · h · Pa)
1	Dorulin	0.003	0.17	0.001
2	Reinforced concrete wall panel	0.06	2.04	0.03
3	Texture layer, plaster base on the cement and sand composition	0.02	0.17	0.09

Indexes of temperature and humidity in the refrigerator compartments: air temperature $t_в$ = –18 °C, relative humidity $\varphi_в$ = 90%. Estimated performance under the exploitation conditions, thickness of the separate layers is shown in Table 2.

Vapor permeability resistance of each layer R_{ex} and structure in general $R_{E\sum}$ shall be calculated as follows:

$$R_{ex} = \sum_{j=1}^{n} \frac{\delta_i}{\mu_i}; \quad (5)$$

$$R_{ex} = \sum_{j=1}^{n} \frac{\delta_i}{\mu_i}, \quad (6)$$

where n is a total number of the structure layers; δ_i is the thickness of I structure layer; μ_i—is the vapor permeability coefficient of I layer of the structure.

The results of calculation of vapor permeability resistance of separate layers and structure in general are shown in Table 3.

The temperature distribution $t(x)$, °C, is calculated according to the structure thickness.

$$t(x) = t_B - \frac{t_B - t_3}{R_{\sum}} \cdot \left(\frac{1}{\alpha_B} + R_x\right), \quad (7)$$

where $R_{\sum}$ is the enclosing structure transfer resistance, (m^2 * K)/W; $\alpha_в$ is the coefficient of heat transmission of the internal surface of the enclosing structure,

Table 3 Indexes of the construction layers vapor permeability

Layer	Index of the vapor permeability resistance R_{ex}, $(m^2 \cdot h \cdot Pa)/mg$
Dorulin	3
Reinforced concrete wall panel	2
Texture layer of sand and cement mixture	0.22
	Total resistance $R_{\sum}$
	5.22

W/(m^2 * K), according to Annex Б ДСТУ Б В.2.6-189 [4] for walls is 8.7; R_x is a thermal resistance of the part of enclosing structure located between the internal surface and area of calculation, (m^2 * K)/W.

$$R_{\sum} = \frac{1}{\alpha_B} + \left(\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3}\right) + \frac{1}{\alpha_3}, \tag{8}$$

$$R_{\sum} = \frac{1}{8.7} + \left(\frac{0.003}{0.17} + \frac{0.06}{2.04} + \frac{0.02}{0.17}\right) + \frac{1}{23} = 0.33, \ (m^2 \cdot K)/W.$$

The temperature distribution calculation results $t(x)$ are shown in Fig. 3 and Table 4.

The partial water vapour pressure e, Pa on the internal e_B and external e_3 structure surface are calculated according to the formulas:

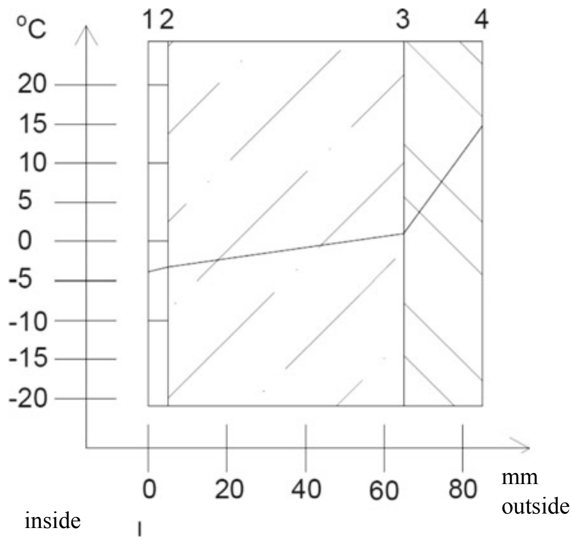

Fig. 3 Pattern of temperature distribution along the structure thickness

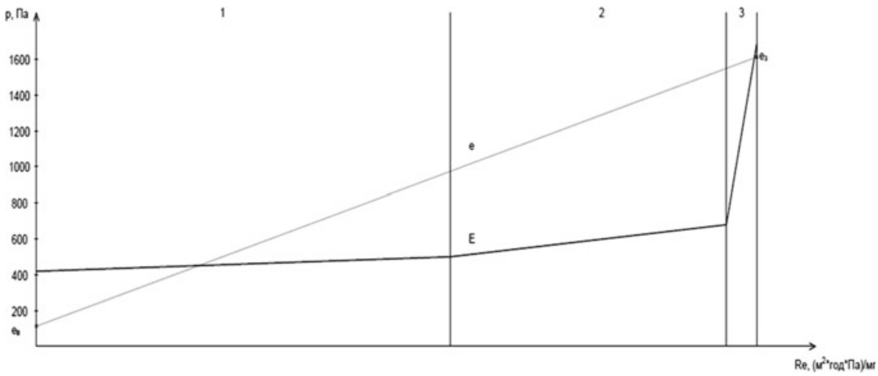

Fig. 4 Diagram of the partial water vapour pressure distribution along the structure thickness

Table 4 Temperature indexes on the margins of layers

Calculation point	T1	T2	T3	T4
Temperature, °C	−4.52	−2.45	0.99	14.79

$$e_B = 0.01 \cdot \varphi_B E_B, \tag{9}$$

$$e_3 = 0.01 \cdot \varphi_3 E_3 \tag{10}$$

where E_B and $E_з$ are the indexes of pressure of the saturated steam with the internal and external temperature correspondingly, calculated according to the Table Б.1 ДСТУ-Н Б В.2.6–192:2013.

$$e_B = 0.01 \cdot 90 \cdot 125 = 112.5,\ \text{Pa},$$
$$e_B = 0.01 \cdot 66 \cdot 2443 = 1512,\ \text{Pa}.$$

The partial water vapour pressure distributed along E_x structure thickness is determined according to the distribution $t(x)$ and Table Б.1 ДСТУ-Н Б В.2.6-192:2013.

In the place of joining the wall panels and the roofing (horizontal joints) almost the whole insulation is gone which conditions the substantial loss of cold and causes the abnormality of the hygrothermal conditions. The partial water vapour pressure distributed along E_x structure thickness is determined according to the distribution $t(x)$ and Table Б.1 ДСТУ-Н Б В.2.6-192:2013.

As it shown on the diagram, the lines E and e intersect. It means that in the structure where the mineral wool insulation peeled (is gone) and in the place of the fire-protection monolithic concrete strip joining the wall panels the condensation area is formed.

The hygrothermal conditions of the enclosing structures were calculated using ДСТУ-Н Б В.2.6-192:2013 "Instructions for the calculation of the hygrothermal conditions of the enclosing structure". In this case the hygrothermal conditions of the enclosing structures (wall panels) are calculated considering the abovementioned defects and the peeling of the mineral wool insulation, physical ageing. The calculations were carried out for the warmest month without regard to the insulation layer since its efficiency is minimal and in some places it is gone as at all. Through the application of Formulas (7)–(10), it was determined that the moisture accumulation period is 12 months. To calculate the amount of the accumulated moisture in the structure, the Formulas (11)–(13) shall be applied

$$i_3 = \frac{e_3 - p_3}{R_{e3}} \tag{11}$$

$$i_B = \frac{p_B - e_B}{R_{eB}} \tag{12}$$

$$W = \tau R_{eB} \cdot (i_3 - i_3) \cdot 10^{-6} \tag{13}$$

where i_3 is the amount of the water vapor, mg/(m^2 * h), penetrating the condensation area from outside;

where i_B is the amount of the water vapor, mg/(m^2 * h), released from the condensation area into the premise;

R_{e3} is the vapor permeability resistance of the part of structure located between the external surface of the enclosing structure and the condensation area, (m$^2 \cdot$ h $\cdot$ Pa)/mg;

R_{eB} is the vapor permeability resistance of the part of structure located between the internal surface of the enclosing structure and the condensation area, (m$^2 \cdot$ h $\cdot$ Pa)/mg;

τ is the amount of hours in the calculation month of the moisture accumulation period, h;

W is the amount of moisture condensed in the structure for the calculation month, kg/m^2.

Since under the given conditions there was no evaporation period further calculations have not been carried out. The calculation results under the Formulas (11)–(13) are shown in Table 5.

Table 5 Collective results of calculating the amount of moisture in the enclosing structure for the calculation period

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XIII
i_3	438	483	925	1632	2373	3556	4240	3795	2818	1883	1316	694
i_B	28.5	29.8	50.8	74.5	102	118.5	129	123	95	68	46	33.5
W	0.3	0.3	0.65	1.12	1.68	2.47	3.05	2.73	1.96	1.35	0.91	0.49

To conclude, the defects of the heat insulation of the enclosing structures (wall panels) caused the moisture accumulation in the wall panels thickness and corrosion of the principal reinforcement which, as combined with the passive pressure of wind (negative wind pressure) resulted in the protuberance of separate wall panels.

4 Conclusions

On the basis of the analysis of the reasons for destructions the recommendations were elaborated on the renovation of the operational integrity of existing enclosing structures and renewal of their cooling efficiency through the application of the modern heat insulation material i.e. foamed polyurethane. Based on the offered solution on renewal of the cooling efficiency the comparative calculation was carried out of the heat losses of the existing constructive solution of the heat insulation under the ideal conditions and the suggested solutions.

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Structural Synthesis of Rational Constructive Forms of Combined Steel Trusses

Myron Hohol, Dmytro Sydorak, Svitlana Sivitska, and Liudmyla Cherednyk

Abstract The rational topology of combined steel trusses with spans of 12–30 m is offered in the work, which meets the criterion of minimum mass. It is shown that the rational calculation scheme for combined steel trusses is a scheme with inseparable upper and lower chords, and the connection of the lattice elements to them is hinged. Decreased for 30 m of combined truss, moments in the upper chord up to 28.4% compared to the truss when connected at all hinges. New methods of stress-deformed state (SDS) control in combined steel trusses are proposed. According to the results of numerical studies found that hat when adjusting the stress-deformed strain state in the combined steel truss with a span of 30 m, it is possible to reduce the moments in the extreme panels of the beam stiffness up to 13.8%. It is shown that to increase the efficiency of the estimated regulation of SDS it is rational to apply the optimal design. The practical implementation of the proposed methods of SDS regulation during construction confirmed its effectiveness.

Keywords Combined truss · Rational truss · Stress deformation state · Regulation · Stiffness beam

1 Introduction

The use of lightweight coatings has recently become a general trend in modern construction: in this regard, the opportunities and prospects are very great and not yet fully disclosed. Today, steel rafter trusses are widely used in the construction

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_16

Fig. 1 Combined steel trusses with I-beam stiffness beam [4]

and reconstruction of buildings. Combined steel trusses, as one of the types of such systems, have the following advantages over traditional truss, the main of which are: rather big rigidity of the top chord that allows to work on a local bend, due to which the placement of runs is not connected with the nodes of the truss; relatively small number of truss elements; ease of nodal connections.

According to the main technical and economic indicators, combined trusses are more efficient in comparison with typical trusses with parallel chords [1, 2]. The technical and economic analysis proved the feasibility of using combined trusses with I-beam stiffness (Fig. 1). It was found that in all cases it is more rational and profitable for the formation of the upper chord of combined trusses is the use of beam I-beams than wide-shelf [3].

Since the most widely used in industrial and civil construction are buildings with spans of 12, 18, 24 and 30 m, then finding effective ways to save resources for such trusses of these spans and reduce their steel consumption is extremely important.

2 Analysis of Basic Research and Publications

Historically, the development of steel structures is associated with the problem of reducing the weight of structures and, consequently, in reducing the cost of steel. One of the determinants of the effectiveness of these structures is the consumption of material spent on the creation of elements and joints. Central to solving this problem are studies to improve the constructive forms and methods of their calculation [5–9].

When designing load-bearing combined steel trusses must take into account both parametric and structural properties of the structure, such as geometric shapes, relative positions of elements, their dimensions and type of cross-sections. This allows you to effectively place the material, and therefore reduce the weight of the structure as a whole [10–18]. Despite the fact that combined systems have been known for a long time and some experience has been gained in their practical application, but from the analysis of existing research it can be concluded that these studies on combined systems can not be called complete. Thus, theoretical and experimental studies, mostly performed to identify the bearing capacity of these structures and focused mainly on traditional trusses [19–23].

A characteristic feature of the current stage in the design of buildings—development of a systematic approach and reduction of time between the development of a constructive idea and its broad practical implementation. Under these conditions, the methods of rational design of structures are becoming increasingly important. Thus under rational design of structures it is accepted to understand a choice of the design of a structures, that satisfies all the limitations of the problem and close, in a sense, to the optimal solution with sufficient accuracy.

That is, the term "rational design" means the organization of such a design process, in which, along with achieving the basic requirement—the minimum weight of the structure—it is also envisaged to take into account such requirements as manufacturability, minimum cost, various limitations in resources, materials, terms of creation, etc. (Fig. 2).

It is possible to reduce the consumption of material by finding a rational form of structures, and abandoning the idea of maximum unification of the elements, as well as by designing nodes according to their real stress state. The practice of designing hinged metal structures shows that structural changes and changes in shape can give a much greater economic effect than the optimization of parameters in a given shape [2, 8]. This method does not require additional material costs when creating regulatory efforts and is the least time consuming. The effect is achieved by controlling the main characteristics of the system, such as mass distribution, stiffness, cross-sectional area.

Building constructions, especially rafter combined steel trusses, belong to complex multiparameter systems and for them it is quite difficult, even for an experienced designer, to immediately choose the optimal parameters.

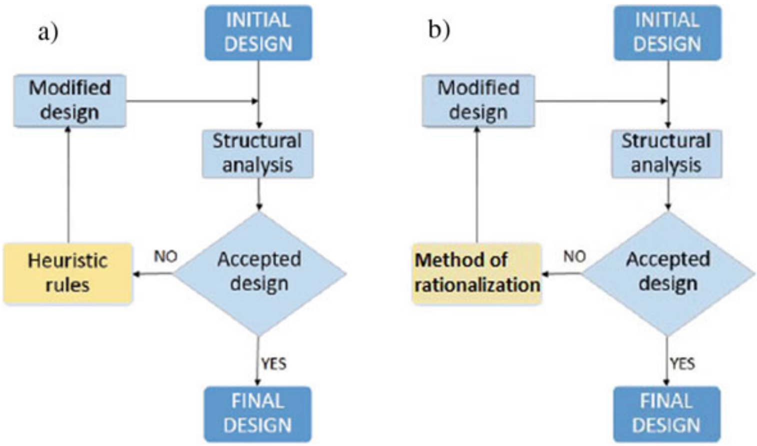

Fig. 2 Block diagrams of design processes. (Adapted from Hernández [24]): **a** traditional, **b** rational

Insufficient attention is also paid to the development and study of rational structural forms of combined steel trusses, and the topological form of the structural system of the truss has a great influence on its final design weight and hence at its cost. Despite its relevance, most of the work on material saving in trusses is devoted only to the issues of parametric synthesis, and much less attention is paid to structural synthesis.

The need for research of combined steel trusses is also due to insufficient justification for their implementation in construction practice and the lack of recommendations for their design. Based on the above, it can be argued that the structural synthesis of structural forms of combined steel trusses, which combines not only the rational size, shape and topology of flat trusses, but also the rational stress-deformed state (SDS) is an urgent task in the implementation of parametric design. This will allow to obtain arational structure of the combined truss as a whole.

3 Presentation of the Main Research Material

The aim of the work is to find rational physical (distribution of material between the elements of the truss) and geometric (outline of the truss) parameters of the combined steel truss.

The most rational in terms of minimizing the cost of steel, as well as the cost of manufacture and installation, are the following structural forms of trusses: Xoy (V—truss, Fig. 3a) and Pratt (N—truss, Fig. 3b) [25].

At Xoy truss, diagonal lattice members are introduced to prevent each section from approaching each other. The result is that long, diagonal elements work in compression, and this is not rational in terms of steel costs. At the same time, at asymmetric loading some elements of a lattice are excluded from work.

Pratt's truss solves the need for triangulation by a combination of diagonal stretched elements and vertical compression elements. The advantage of the Pratt truss for use in rafter structures is the efficiency of using flexible elements made of high-strength steel as diagonal stretched elements. The vertical short, compressed lattice elements of the Pratt truss tend to have a smaller cross section than those used on the Xoy truss. It is likely that the configuration similar to the Pratt truss is best suited for use as structures with parallel chords, and this type of lattice in combined steel trusses.

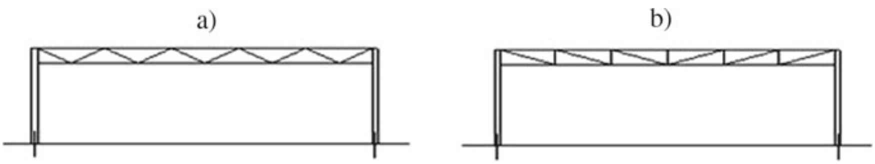

Fig. 3 Truss schemes; **a** Xoy (V—truss); **b** Pratta (N-truss)

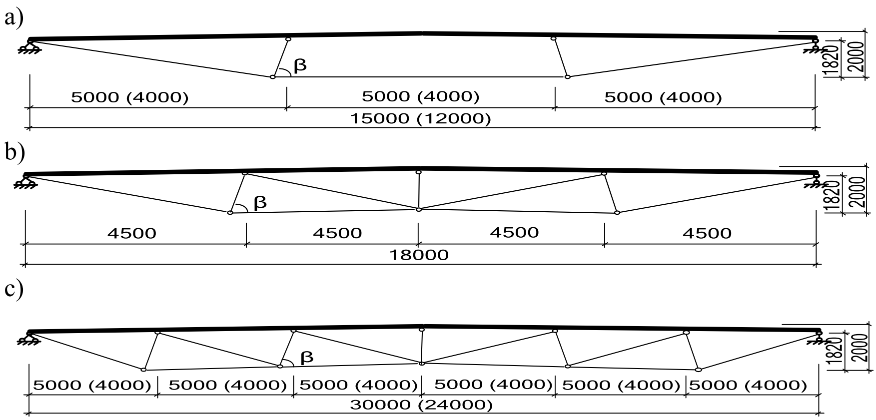

Fig. 4 Structural forms of rational steel combined trusses for spans: **a** −12 and 15 m; **b** −18 m; in −24 and 30 m

On the basis of the conducted researches on development of rational constructive forms (on geometrical parameters) of steel combined trusses [26] spans of 12, 15, 18, 24 and 30 m the following are offered (Fig. 4).

3.1 Features of Calculation of Combined Steel Trusses

Currently, in the field of design and calculation of building structures using personal computers, it is possible to accept such calculation schemes, which correspond much more to the actual work of structures. Now there is no need to simplify the calculation schemes. A number of the most complex structures, the calculation of which was previously impossible, became available with the use of a computer, including in the rationalization and optimization of new opportunities.

The calculation of statically defined trusses, determination of internal forces in their elements, according to DBN [1, 21, 27] is carried out by an approximate method, that is, in the calculation scheme it is assumed that all elements in each node are hinged (Fig. 5a). This allows only normal forces to be taken into account (no moments). The main advantage of this method is its simplicity.

We offer for combined trusses [2], more accurate method, but more difficult to calculate and analyze the results, which leads to more real stresses, which in the calculation scheme assumes the indivisibility (continuity) of the upper and lower chords, and the and braces and struts are hinged to the chords. Thus, in risers and braces normal forces are defined, and in the flanges—additional moments (Fig. 5b, c). This method is more consistent with the actual operation of trusses, which will increase their reliability.

For combined trusses it is most rational to use the calculation schemes shown in Fig. 5a, b: in Fig. 5, a shows the inseparable upper chord and all hinge assemblies;

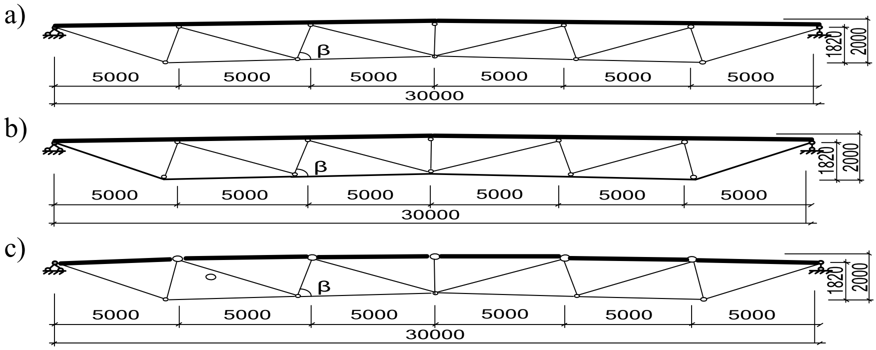

Fig. 5 Calculation schemes of rational combined trusses with a span of 30 m: **a**, **b** statically indeterminate; **c** statically defined

in Fig. 5b—inseparable upper and lower chords, and the connection of the lattice to them is hinged. The scheme (Fig. 5c) is typical for statically defined farms, ie traditional, typical: the connection at all nodes is hinged, even in the upper chord.

In order to evaluate the effectiveness of the above calculation schemes (Fig. 5), a numerical experiment was conducted for a combined steel truss with a span of 30 m. Such, rational combined steel trusses with a span of 30 m (Fig. 5), with the same geometric parameters and cross sections of the elements, ie the same mass of trusses, but with different calculation schemes was calculated for PC with the program "LIRA-CAD 2016 R5" from a uniformly distributed load q = 12.75 kN/m, at an angle of compressed rods β = 80°. Based on these results, plots of moments (Fig. 6) and normal forces (Fig. 7) were obtained.

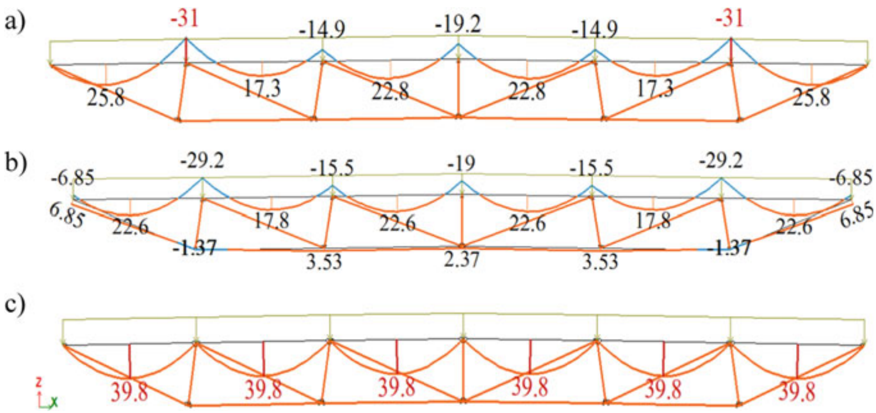

Fig. 6 Plots of moments (kNm) in the beam of rigidity of rational combined trusses with a span of 30 m: **a**, **b** statically indeterminate; **c** statically determined

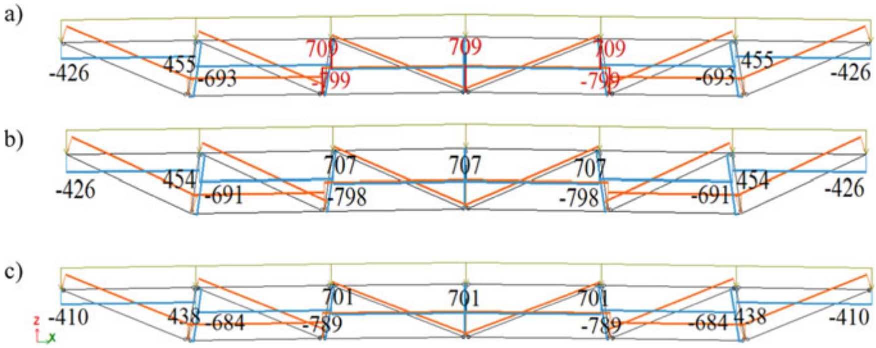

Fig. 7 Plots of normal forces (kN) in rational combined trusses with a span of 30 m: **a**, **b** statically indeterminate; **c** statically determined

According to the results of calculations, the largest values of bending moments in the stiffening beam for a truss with a hinged connection in all nodes (Fig. 6c) and they are 39.8 kNm, and in a truss with an inseparable upper chord and hinged connection in all nodes (Fig. 6a) −31.0 kNm, which is 28.4% more.

In a truss with inseparable upper and lower chords, and the connection of the lattice to them is hinged (Fig. 6b), they are even smaller and equal to 29.2 kNm, which in turn, compared to the truss (Fig. 6a) is lower by 5.8%. Normal forces (Fig. 7) for all three combined trusses are almost the same.

Therefore, according to the results of a numerical experiment for combined steel trusses with a span of 30 m, their most effective calculation scheme is a scheme with inseparable upper and lower chords and hinged connection of the lattice, which reduces bending moments to 34.2% and significantly increases the efficiency of the truss.

This confirms that in statically indeterminate combined farms there is less internal effort, which determines their cost-effectiveness compared to statically determined. Related to this are additional opportunities to regulate SDS on such trusses.

Therefore, it is more rational to use the calculation schemes of statically indeterminate combined trusses with inseparable upper and lower chords.

3.2 Regulation of SDS in Rational Combined Steel Trusses

The paper proposes rational new constructive forms of combined steel trusses according to geometrical parameters according to the criterion of minimum mass for spans of 12–30 m (Fig. 4). At the same time, only by rationalization geometric parameters, we have not achieved the rationality of trusses on the criterion of equality of stresses in all calculated sections of the stiffening beam while meeting the requirements of both limit states [26].

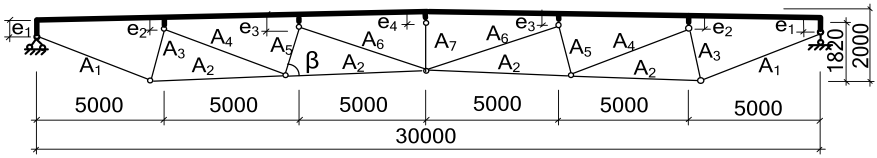

Fig. 8 General scheme of SDS regulation in the combined truss

Therefore, to achieve equality of stresses in the calculated cross-sections of the stiffening beam and reduce them, the calculated method of adjusting the SDS of the stiffening beam with the use of optimal design is recommended.

One of the most rational and technological methods of estimated regulation of SDS in the beam of rigidity of the combined truss is the creation of reference moments on the extreme supports—eccentricity e_1, which are the opposite actions from the external load (Fig. 8).

The second method is to change the cross sections of the struts, struts and the lower chord (rational ratio of the mass of the stiffening beam to the total mass of the truss −50%). The third method is the creation of eccentricities e_2–e_4 in the nodes of the suspension system to the stiffening beam (Fig. 8).

In order to assess the effectiveness of SDS regulation methods in combined trusses, numerical studies of combined steel trusses with a span of 30 m on a PC with the program "LIRA-CAD 2016 R5" were conducted. To do this, we calculated the truss at $e_1 = e_2 = e_3 = e_4 = 0$ and non-variable cross-sections of elements A_i under the uniformly distributed load q = 12.75 kN/m, which was the standard (Fig. 8). According to the results of the calculation, the following plots of moments (kNm) in the stiffening beam were obtained (Fig. 9).

For the reference truss, a plot of moments was obtained in a stiffening beam with a maximum value of 29.7 kNm (Fig. 9a). When adjusting the SDS reference moments equal to $e_1 = 3.4\ h_{sb}$ (where h_{sb}—the height of the stiffening beam) obtained—Fig. 9b with a maximum bending moment value of 25.6 kNm, which is 13,8% less than the reference value. To regulate SDS by nodal eccentricities equal to $e_2 = 0.2\ h_{sb}$, a plot was obtained—Fig. 9c, and at $e_1 = 2.0\ h_{sb}$ and $e_2 = 0.2\ h_{sb}$—Fig. 9, г.

Adjustments were made by setting such eccentricities symmetrically along the length of the truss. The results of a numerical experiment to regulate SDS by changing e_1 and e_2 in a 30 m combined truss showed, that this makes it possible to reduce the cross section of the stiffness beam.

For example, moment reduction from $e_1 = 3.4\ h_{sb}$ by 13.8% reduces the cross section in the end panels of the stiffening beam by about 5%. To assess the impact and calculate the maximum effect of all control variables, it is necessary to develop an algorithm for optimal control.

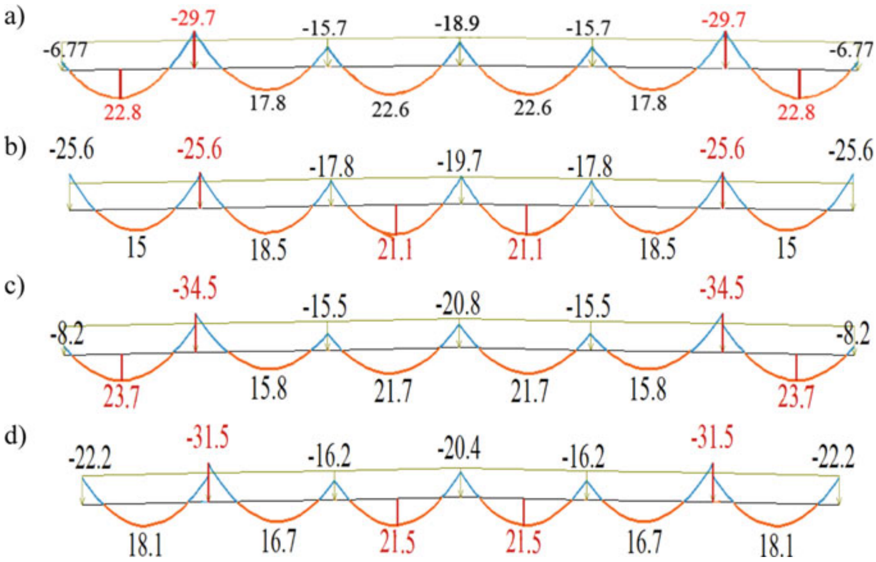

Fig. 9 Plots of moments in the stiffness beam of a 30-m combined truss: **a** without SDS adjustment; **b** with adjustment of reference moments, $e_1 = 3{,}4\ h_{sb}$; **c** with regulation of nodal eccentricity $e_2 = 0{,}2\ h_{sb}$; **d** with adjustment at $e_1 = 2.0\ h_{sb}$ and $e_2 = 0.2\ h_{sb}$

Research results implemented: during the construction of the concrete products shop as a combined rafter truss with a span of 12 m with SDS regulation at the Lviv plant of experimental mechanical tests (Fig. 10a); combined systems with an inseparable upper chord with a span of 18 m in the shop of concrete products LLC "Magic", p. Milyatychi, Lviv region (Fig. 10b), reduced height and cost compared to standard designs.

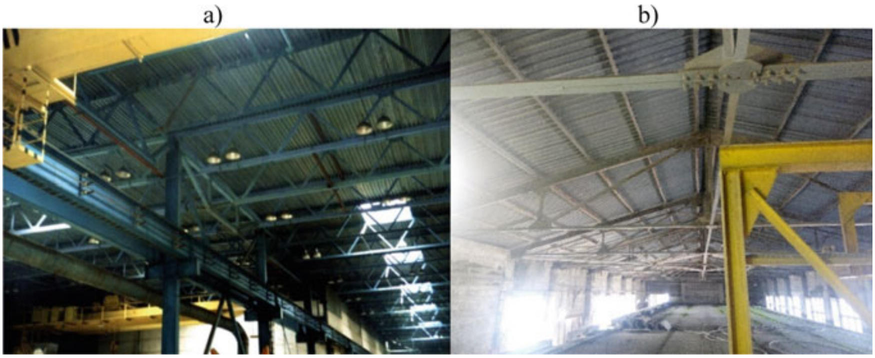

Fig. 10 **a** sub-rafter beam truss L = 12 m, plant of experimental mechanical tests in Lviv; **b** combined steel trusses with span L = 18 m. Concrete products shop LLC "Magic", p. Milyatychi, Lviv region

4 Conclusions and Prospects

A rational topology of combined steel trusses with spans of 12–30 m was selected, which meets the criterion of minimum mass. It is shown that the rational calculation scheme for combined steel trusses is a scheme with inseparable upper and lower chords, and the connection of the lattice elements to them is hinged. This scheme reduces the bending moment in the upper chord for 30 m of the combined truss to 28.4% compared to the truss when all joints are hinged. According to the results of numerical studies, it is established that the regulation of SDS in such a truss can reduce the moments in the extreme panels of the stiffness beam to 13.8%. To reduce the absolute values of normal stresses in the calculated cross sections of the stiffening beam and its cross sections, it is rational to use the optimal design. The use of rational structural forms of combined steel trusses and optimal design will systematically increase their efficiency and economy.

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Theoretical and Experimental Investigations of the Pumping Medium Interaction Processes with Compensating Volume of Air in the Single-Piston Mortar Pump Compensator

Korobko Bogdan, Shapoval Mykola, Roman Kaczynski, Kryvorot Anatolii, and Virchenko Viktor

Abstract The article considers the theoretical and experimental investigations of the pumping medium interaction processes with compensating volume of air in the single-piston mortar pump compensator as well as factors that affect the air removal kinetics from the compensator of single-piston mortar pumps. The problem of air removal from the cylindrical chamber analysis of the combined mortar pump compensator is carried out. Indicators characterizing the rate of compressed air removal from the compensator during the operation of the mortar pump are set. It is established and proved that air is removed from the cylindrical chamber depending on: pressure, productivity of mortar pump, solution temperature and intensity of exchange between pumped solution and compressed air. The allowable compressed air contact area of the compensator's cylindrical chamber is established by installing a float at the air-solution interface.

Keywords Mortar pump with increased volume combined compensator · Cylindrical chamber · Degree of pressure pulsations · Volumetric efficiency · Solution mobility

1 Introduction

Analysis of modern mortar pumps indicates the search for ways to simplify and improve the schematic diagram of single-piston mortar pumps while minimizing ripples in the pipeline during the transportation of mortars.

In order to reduce the ripple in modern single-piston mortar pumps, pressure ripple compensators are used mainly in the form of air caps of different volumes.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_17

But the caps, along with the advantages of simplicity of design, have significant disadvantages: the compressed air in contact with the pumped solution is quickly removed from the cap during operation of the mortar pump. Especially the removal of air is observed with increasing supply pressure to 1,2…1,5 MP. At the same time pressure pulsations increase, and efficiency of work of the compensator essentially decreases. But in the compensator, the process of kinetic interaction of air with the solution is currently insufficiently studied.

Therefore, there is a need to develop new designs of compensators and improve single-piston mortar pumps of increased reliability, which will provide moderate levels of pulsations of the solution, ease of operation and maintenance, increased technical parameters and efficiency.

2 The Analysis of the Latest Sources of Research

An important negative phenomenon in the pumping of mortars is the removal of compressed air from the compensators, which negatively affects the level of the degree of pulsation and the quality of finishing work.

Studies on the relationship between the state of contact of the liquid with air in the compensators are diverse. But the processes of both interaction and removal of air from the compensator are not sufficiently confirmed by experimental studies.

From the literature [1] we can note the statement, which considers that at a volume of the compensator in 350 l and supply of the pump of 50 l/s, at high pressures, the air which is placed in the compensator, dissolves in liquid, owing to continuous passing of the last through the compensator and gradually decreases. It is also stated that after 13.3 min the air is completely removed from the compensator. Conclusions based on experiments to determine the solubility of air in petroleum products. But these conclusions cannot be compared with the operation of compensators in mortar pumps, as there is a significant difference in the solubility of air in petroleum products and in mortars.

Known experimental data [1], which were carried out when pumping water and clay solutions with specific gravity 1,22; 1,28; i 1,6 г/см^3, with a duration of pumping, which ranged from 1 h 45 min to 4 h 45 min at a pump supply of 260 l /min and a pressure of 5 MPa. When pumping the clay solution, it was found that the volume of compressed air in the compensator, reduced to atmospheric pressure, has not changed.

Highlight parts of a common problem that have not been solved before. To solve the problem of removing air from the cap, it is necessary to analyze how the air dissolves in the mortar at the interface “solution—air” when the pressure increases, as well as how the solution is compressed. It is known that the compression of a fluid depends on its properties, temperature and pressure.

With increasing pressure, the air in the solution in the free state, partially becomes soluble in the interaction with water, and the rest of the insoluble solution is compressed according to the Boyle-Marriott law.

According to research [2], the value of absolute compression is the difference between the volume of free air at atmospheric pressure V_0^{noB} and the volume of air in the free state $V_{B.c}^{noB}$, remaining after partial dissolution at the appropriate pressure p_1

$$\Delta V_p = V_0^{noB} - V_{B.c}^{noB} = V_0^{noB} - \left(V_0^{noB} - k \cdot V_p \cdot \left(\frac{p_1}{p_0} - 1 \right) \right) \cdot \frac{p_1}{p_0} \tag{1}$$

The equation shows that all the free air that is in solution in the form of bubbles at some pressure $p_{p.n}$ will go into a soluble state and further compression of the solution will stop, ie the change in the volume of the solution will be carried out only by compressing its liquid and solid phases. But according to the data [3, 4], water at room temperature at a pressure of 70 MPa is compressed only by 2,9%. It can be assumed that water is practically not compressed to the pressure of the solution (not higher than 4 MPa).

The magnitude of the pressure $p_{p.n}$, in which there is a complete dissolution of the air mixed in the solution, assuming that $\Delta V_p^{\max} = V_0^{noB}$, is equal to [2]

$$p_p \cdot n = p0 \cdot \left(\frac{V_0^{noB}}{k \cdot V_p} + 1 \right) \tag{2}$$

This dependence indicates that as the volume of free air that is in the solution in the form of bubbles under normal conditions increases, the pressure of the maximum volumetric compression of the solution increases.

An important value that characterizes the air content in the solution is the relative volumetric compression of the mortar

$$\varepsilon_p \left[\frac{V_0^{noB}}{V_{\mathrm{p}}} - \frac{p_0}{p_1 \cdot V_p} \cdot \left(V_0^{noB} - k \cdot V_{\mathrm{p}} \cdot \left(\frac{p_0}{p_1} - 1 \right) \right) \right] \cdot 100\% \tag{3}$$

Formula analysis makes it possible to state that for sedentary solutions that have less water and more air, the maximum compression of the solution is carried out at a higher pressure than for solutions with greater mobility. Theoretical analysis of the compression of the solution is confirmed by experimental data [2], shown in Fig. 1.

The considered theoretical and experimental researches do not fully reveal processes of dissolution and removal of air in air compensators.

As notes in [5] the capacity of the compensator of the mortar pump should be not less than 50 l that at its diameter of 150 mm will have height about 2800 mm. Such overall dimensions of a cap are very big and inadmissible from the operational point of view. There is a statement of Charny [1], that the compensator of the big sizes, almost in complete absence of air in it, nevertheless is capable to reduce to some extent pressure pulsations due to elasticity of the pumped liquid, walls of the compensator and discharge pipes.

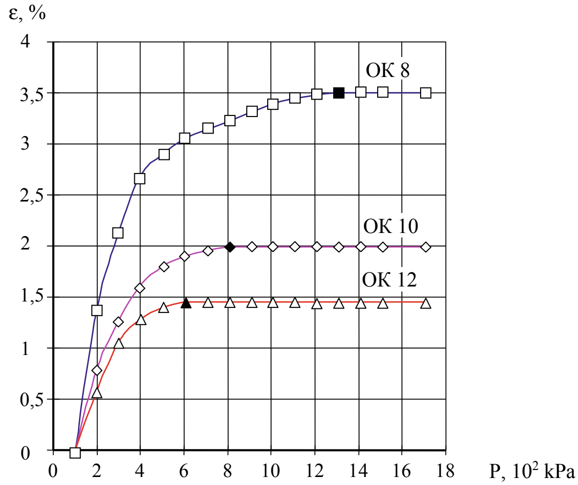


Fig. 1 Graph of the dependence of volumetric compression of solutions of different mobility on pressure

Experimental data [5] indicate that the level of pressure fluctuations of the pumped solution does not exceed 25–30%, if the compensator has a volume of 4–5 L, and the supply pressure is not more than 1.5 MPa. The same level of pressure pulsation in compensators with a volume of 10–15 l gives the chance to raise pressure to 2,5–3,0 MPa [5–14].

Increasing the working pressure of the solution above the level of 2.5 MPa makes the air compensator inefficient. It is also necessary to take into account that, as industrial practice shows, after operation of the mortar pump at a pressure of 4–5 MPa in the compensator at all there is no air presence [5].

Sometimes, to increase the efficiency of the air compensator, compressed air is pumped into it through the non-return valve during pump operation. Of course, such pumping will have a positive effect on the level of pressure ripples. But it is technically difficult to pump air when the pump is running at high pressure, because reciprocating compressors usually allow air compression of up to 0.7 MPa.

Setting a task. To solve this problem, experiments were performed with a solution pump C-263 by pumping various solutions with compensators with a capacity of 2.2; 4.4; 6,6 and 8,8 l both without introduction, and with introduction in the compensator of compressed air [5]. Experiments have shown that when operating without compressed air, the volume of the compensator increases, as expected, and the pressure ripple decreases. At a pressure of up to 0.6–0.8 MPa and the introduction of compressed air sufficient uniformity of the solution in the main was observed already at the compensator with a capacity of 6.6 l. It is proved that to ensure a sufficiently uniform pulsation of the pressure of the solution it is necessary to install compensators with a capacity of 8–10 l.

The analysis of operation of operating compensators has shown that for stabilization of pulsations of pressure actual use of the combined compensators of the closed type is actual.

The purpose and objectives of the study. The purpose of the presented work is to increase the efficiency of a single-piston mortar pump by reducing the ripple of the supply through the pipeline and increase its volumetric efficiency through the use of a combined compensator of increased volume in rational modes of technological processes.

It is necessary to perform the following tasks: to establish the mechanism of dissolution intensity and removal of the proportion of the compensating volume of air in the cylindrical chamber of the combined compensator depending on the factors influencing this process; theoretically investigate on the basis of the laws of hydraulics and thermodynamics the process of dissolving and removing air from the cylindrical chamber of the compensator and experimentally confirm the results.

Research methods. The object of the study is a single-piston mortar pump with combined compensators of pressure pulsation and increased volume.

The subject of research is the working processes of transporting mortars through the pipeline when they are fed by a single-piston mortar pump with combined compensators of pressure pulsation and increased volume.

Research methods—thermodynamic analysis of processes in the cylindrical chamber of combined compensators of the mortar pump on the basis of methods and provisions of thermodynamics, hydraulics, mathematical physics, physical and mathematical modeling by methods of applied mechanics, processing of experimental data. The basis of mathematical modeling is the equation of classical machine-building hydraulics and thermodynamics.

The studies were performed using a full-scale sample of the mortar pump, as well as test benches.

The main material. Combined pressure compensators of the investigated mortar pumps (Fig. 3a) have two chambers, one of which is filled with atmospheric air before the start of the mortar pump. When the pump begins to pump mortar, the air in the cylindrical chamber is compressed at the top of the chamber, in constant contact with the pumped mortar.

Since the air pressure in the compensator chamber during operation of the mortar pump is higher than atmospheric, part of the compressed air, according to Henry's law, is additionally dissolved in the aqueous component of the solution and removed from the cylindrical compensator chamber together with the pumped solution. At the same time the total reduced volume of air in the combined compensator of pressure considerably decreases that causes deterioration of efficiency of work of the compensator therefore, pulsations of pressure of solution increase.

A similar phenomenon is observed during the operation of all mortar pumps equipped with pressure compensators in the form of an air cap filled with free air. But the consequences of air removal in this case will be more negative—because together with the pumped solution can be removed most of the available air compensator and it will cease to perform a compensatory function. Therefore, the study of factors that contribute to the accelerated removal of air from the caps by the pumped solution is of practical importance.

It is necessary to mathematically analyze the influence on the intensity of air removal from the cylindrical chamber of the compensator, such factors as solution supply pressure, air solubility coefficient in the solution of this mobility, solution temperature, solution pump supply and the degree of solution renewal in the upper part of the chamber.

The structural component of mortars is water, in which air dissolves with increasing pressure. Therefore, the current concentration of dissolved air in the solution can be represented by the ratio of the volume of air dissolved in its aqueous component to the volume of the aqueous component in the solution.

$$C = \frac{V_{noB \cdot p}}{V_{Bo\partial}}$$

The solubility of gases in liquids, according to Henry's law, is directly proportional to the external pressure [2, 15]

$$V_{noB.p} = k \cdot V_{Bo\partial} \frac{p}{p_0} \tag{4}$$

where $V_{no\text{в}.\,p}$—the volume of air that is removed from the cylindrical chamber by dissolving the air in the aqueous component of the mortar under the action of pressure; $V_{\text{в}o\partial}$—the volume of the aqueous component in the solution; k—the coefficient of solubility of air in the aqueous component of the solution at a given temperature; p_0—pressure at the beginning of the solution supply; p—pressure at the end of the solution supply.

According to Henry's law, you can determine the current concentration of air saturation in the soluble component

$$c_{Hac} = k \cdot \frac{p_{cp}}{p_0} \tag{5}$$

where k—the coefficient of solubility of air in the aqueous component of the solution at a given temperature; p_0—the initial supply pressure of the solution; p_{cp}—the final supply pressure of the solution.

Coefficient k solubility of air in the aqueous component of the mortar at base temperature $t = 20$ °C, by data [2], can be determined by dependence

$$k = \frac{V_{0noB}}{V_{Bo\partial} \cdot \left(\frac{p_{zp}}{p_{amM}} - 1\right)} \tag{6}$$

where $V_{0\,no\text{в}}$—the content of air in a solution of a certain mobility at atmospheric pressure; $V_{\text{в}o\partial}$—the volume of the aqueous component in the solution; $p_{\text{г}p}$—the ultimate pressure at which all the free air in the solution in the form of small bubbles dissolves in the aqueous component of the solution; $p_{am\text{м}}$—atmospheric pressure.

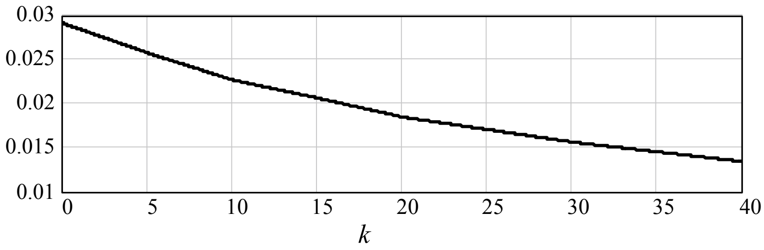


Fig. 2 Dependence of the coefficient k solubility of gases in the aqueous component depending on the temperature

Quantitative values of the coefficient k for mobility solutions П 8, 10 i 12 cm given in the work [2].

The coefficient of solubility of air in the aqueous component, respectively, and in solution, according to [15], largely depends on the water temperature (Fig. 2) (Table 1).

Taking into account the temperature of the solution, which varies depending on the ambient temperature and affects the dissolution of the air in the cylindrical chamber, as well as taking into account the pressure change, the solubility coefficient of air in the mortar, taking into account the dependences, [16–19]. will look like

$$0 \le \varphi \le \pi \quad k = \frac{p_{amM} \cdot V_{0noB}}{VBo\partial \cdot \left(\frac{V_{koMn}}{V_0 - F_n \cdot \left\{ R\cdot(1-\cos\varphi) - \left[l - \sqrt{l^2 - (R\cdot\sin\varphi - e)^2} \right] - \frac{h_n}{2\pi}\cdot\varphi \right\}} \cdot \frac{T_0}{T} - p_0 \right)}$$

$$0 \le \varphi \le 2\pi \quad k = \frac{p_{amM} \cdot V_{0noB}}{VBo\partial \cdot \left(\frac{V_{koMn}}{V_0 - F_n \cdot \left[\left(x_\pi - \frac{h_n}{2} \right) - \frac{h_n}{2\pi}\cdot(\varphi - \pi) \right]} \cdot \frac{T_0}{T} - 1 \right)} \tag{7}$$

Therefore, taking into account the known dependence of the dissolution of air in the aqueous component depending on the temperature, which are shown in Fig. 2 and the value of the dissolution coefficients in the gases listed in Table 2, determine the dissolution coefficient of air k in the aqueous component of the cylindrical chamber of the expansion pump compensator.

The processes occurring in the cylindrical chamber of the compensator can be described by the Mendeleev-Clapeyron law, which are true when $p \le 1$ MPa and at $T \ge 20$ °C.

$$p \cdot V = \nu \cdot R \cdot T \tag{8}$$

For real gas with increasing temperature, as well as high pressure, the van der Waals equation holds

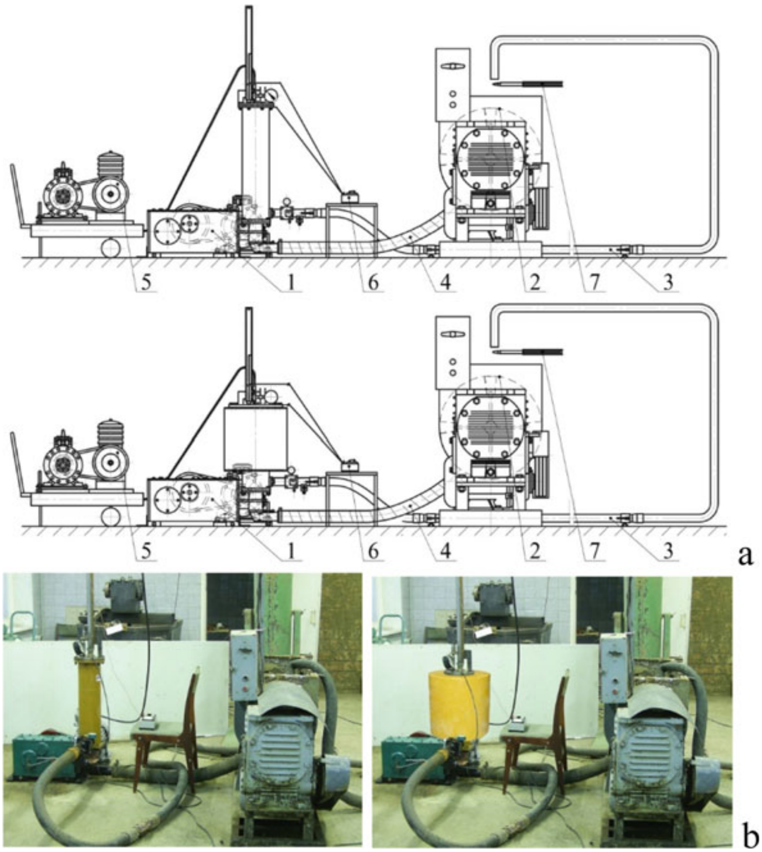


Fig. 3 Experimental stand for determining the intensity of air removal from the cylindrical chamber of the mortar pump when pumping solutions by mobility П 8, 10, 12 cm and at medium supply pressures $p = 0,9$ MPa, $p = 1,2$ MPa, $p = 1,7$ MPa: a—schematic image; b—photo of experimental stands. 1—single-piston mortar pump with combined pressure ripple compensator; 2—mortar mixer; 3—pressure line; 5—suction pipe; 6—mobile compressor; 7—milliammeter; 8—alcohol thermometer

$$\left(p - \frac{\nu^2 a}{V^2}\right) \cdot (V - b \cdot \nu) = \nu \cdot R \cdot T \tag{9}$$

where p—pressure in the cap; V—volume of gas (air); a i b—gas constants (air (80% N_2, 20% O_2) $a = 135,8$ KPa·dm6/moll2, $b = 0,0364$ dm^3/moll); R—gas constant; ν—amount of gas.

As the temperature of the solution increases, the density of the solution changes, and the process of expanding the solution by increasing the volume of air bubbles in the solution. In this case, the gas bubble will pop up if its lifting force is sufficient to overcome the shear forces of the layers in the solution. The limiting diameter of a bubble that does not pop up can be determined by the equation [7]

Table 1 Coefficients of solubility of gases in the aqueous component (volume of gas that is reduced to normal conditions in the volume of water)

	Temperature									
Degrees Celsius	0	5	10	15	20	30	40	50	60	80
Degrees of Kelvin	273	278	283	288	293	303	313	323	333	353
Gases	Water solubility coefficients in water									
N_2	0,0236	0,0209	0,0185	0,0168	0,0151	0,0130	0,0111	0,0095	0,0084	0,0053
O_2	0,0486	0,0429	0,0376	0,0342	0,0304	0,0251	0,0216	0,0186	0,0158	0,0097
$78\%N_2 + 22\%O_2$	0,0291	0,0257	0,0227	0,0206	0,0185	0,0156	0,0134	0,0115	0,0100	0,0062

$$d_0 = \frac{6 \cdot \tau_0}{\lambda \cdot g \cdot \left(\rho_p - \rho_n\right)} \tag{10}$$

where τ_0—dynamic shear stress of the solution; ρ_p—the density of the solution; ρ_n—air density; g—free fall acceleration; λ—experimental coefficient ($\lambda = 1 \ldots 1, 25$).

If you use the speed of the ball to fall into the viscous-plastic liquid u, then it is possible to take advantage of the dependency

$$u = \frac{d \cdot \tau_0}{2 \cdot \mu} \cdot \left[\sqrt{\frac{g \cdot d \cdot (\rho_p - \rho_n)}{6 \cdot \lambda \cdot \tau_0}} - 1\right] \tag{11}$$

where d—the diameter of the air bubble; μ—structural viscosity.

When flowing, the bubble increases in volume, then according to the Boyle-Marriott law we have the expression.

$$Z \cdot \frac{\pi \cdot d_H^3}{6} \cdot \rho_{noy} = Z_H \cdot \frac{\pi \cdot d^3}{6} \cdot \rho \tag{12}$$

where, $d_н$, d—diameters of bubbles at $\rho_{поч}$, ρ; $Z_{поч}$, Z—compression ratios at the initial and current density of the solution $\rho_{поч}$, ρ.

Solving this equation with respect to and substituting in the equation, we will receive

$$u = \frac{d_H \cdot \tau_0}{2 \cdot \mu} \cdot \sqrt[3]{Z_{om} \cdot \frac{\rho_{noy}}{\rho}} \cdot \left[\sqrt{\left(\frac{d_H \cdot g \cdot (\rho_p - \rho_n)}{6 \cdot \lambda \cdot \tau_0} \cdot \sqrt{Z_{om} \cdot \frac{\rho_{noy}}{\rho}}\right)} - 1\right] \tag{13}$$

Under such conditions, the dissolution of air decreases, and, accordingly, the dissolution of air in the aqueous component of the solution decreases. Bubbles with a diameter of about 0.12 cm begin to float in a straight line, larger—in a spiral [6].

Coalescence and dispersion of air bubbles are also observed during the movement of a viscous medium. In the flow of solution, air bubbles are more dispersed. Under certain conditions, shear stresses and dispersion levels, the motion of bubbles in the solution stops.

The rate of dissolution of air in the aqueous component depends on the lack of gas to equilibrium, and the frequency of collisions of gas molecules with the interface.

Then we can assume that one of the important factors in removing air from the compensator at the distribution of soluble and air phases is the rate of dissolution

$$W = \alpha \cdot \left(\frac{c_{Hac} - c}{c}\right)^{A} \cdot \left(\frac{p_{cp}}{p_0}\right)^{B} \tag{14}$$

where c—the current concentration of dissolved air in the aqueous component of the solution; $c_{нас}$—equilibrium concentration of dissolved air, which changes over time; p_{cp}—the average pressure at which all the free air that is in the solution in the form of small bubbles, dissolves in the aqueous component of the solution; p_0—atmospheric pressure; A, B—indicators of degree (are experimentally depending on temperature); α—the intensity factor of saturation-dissolution of air in the aqueous component of the solution.

Expression $\frac{c_{Hac}-c}{c}$—characterizes the lack of gas (air) to equilibrium, and expression $\frac{p_{cp}}{p_0}$—characterizes the frequency of collisions of gas molecules with the interface; c, $c_{нас}$, p_{cp}—functions from time, which are determined as a result of processing for each of the experiments.

The intensity of dissolution, removal of air from the cylindrical chamber at the separation of the solution and the air phases per unit time will be

$$W = -\frac{dV_{noB}}{d\tau} \quad \text{or} \quad -dV_{noB} = Wd\tau. \tag{15}$$

From where the amount of dissolved air in the aqueous component of the solution over time will look like

$$-dV_{noB} = \int_0^{\tau} Wd\tau = \int_0^{\tau} \alpha \cdot \left(\frac{c_H - c}{c}\right)^{A} \cdot \left(\frac{p_{cp}}{p_0}\right)^{B} d\tau \tag{16}$$

In expression (3) unknown value is the coefficient of intensity of dissolution-saturation of air—the aqueous component of the solution, which after solution can be determined by

$$\alpha = \frac{\Delta V_{noB}}{\int_0^{\tau} \left(\frac{c_H - c}{c}\right)^{A} \cdot \left(\frac{p_{cp}}{p_{amM}}\right)^{B}} = \frac{\Delta V_{noB} \cdot \left[\frac{T_1(\tau)+K}{293}\right]^{-1}}{\int_0^{\tau} \sqrt{\left(\frac{k \cdot V_{Bo\partial \cdot p03}}{V_{p \cdot noB}}\right) \cdot \left(\frac{p_{cp}}{p_{amM}}\right)} d\tau} \tag{17}$$

where $\Delta V_{noв}$—the amount of dissolved saturated air over time.

Depending on (4) the amount of air removed by the pumped solution from the compensator, namely from the cylindrical chamber during the operation of the mortar pump, is directly proportional to the magnitude of the solution pressure increase from atmospheric level and the exchange rate between the pumped solution and compressed air in the chamber α, and the solubility coefficient of air in the aqueous component of the solution k at a given temperature T_1.

However, the solution is heated during pumping, and the rate of air removal should decrease, because the solubility coefficient of air in the aqueous component, with increasing temperature, decreases by the inversely exponential law. That is, the process of dissolving gases in the aqueous component of the solution is accompanied by the release of heat according to the exothermic law [6, 7]. It follows that in summer, when the pumped solution has a higher temperature, the rate of removal of compressed air from the cylindrical chamber will be much lower than in the cold season. The effect of increasing the temperature of the solution on the rate of air removal due to its pumping in production conditions will be insignificant, because the mortar passes through the hydraulic part of the mortar pump and pipelines once.

From the analysis of all factors influencing the rate of air removal from the cylindrical chamber, it is necessary to reduce the area of contact of the volume of compressed air with the pumped solution. This reduction can be achieved by using in the middle of the cylindrical chamber a float made of a material whose density is much less than the solution (Fig. 4), and which insulates most of the surface of the solution from contact with compressed air. But the best design solution will be complete isolation of the surface of the solution from compressed air, although this solution requires special diaphragms or containers made of flexible elastic materials.

Confirm the results of theoretical research on the intensity of air removal from the cylindrical chamber of the combined compensator single-piston mortar pump when pumping mortars of different mobility, created a test bench (Fig. 3), which is designed in accordance with the requirements for technological kits in different conditions playgrounds. The studies were performed on a single-piston mortar pump with two structurally different compensators.

The stand consists of a single-piston mortar pump 1, mortar mixer 2, pressure line made of steel pipelines 3, pressure rubber hoses 4, suction pipe 5 made of reinforced rubber fabric sleeve, compressor 6, milliammeter 7 and alcohol thermometer 8.

As part of a single-piston mortar pump installed a measuring device, which was used to measure the parameters of the intensity of air removal from the cylindrical chamber of the compensator. The measuring device consists of a solution pump of single action [3, 19] (Fig. 4), which is equipped with a cylindrical chamber 1, in the cover 2 of which there are three holes. Through the first hole hermetically passed rod 3, designed to determine the volume of air in the cylindrical chamber, which passes through the hole in the nut 4 and the rubber gasket 5, which prevents the etching of air from the cylindrical chamber.

The dependences of the reduced volume of compressed air in the cylindrical chamber of the mortar pump and the degree of pulsations of the solution supply on the time of pumping the solution are established.

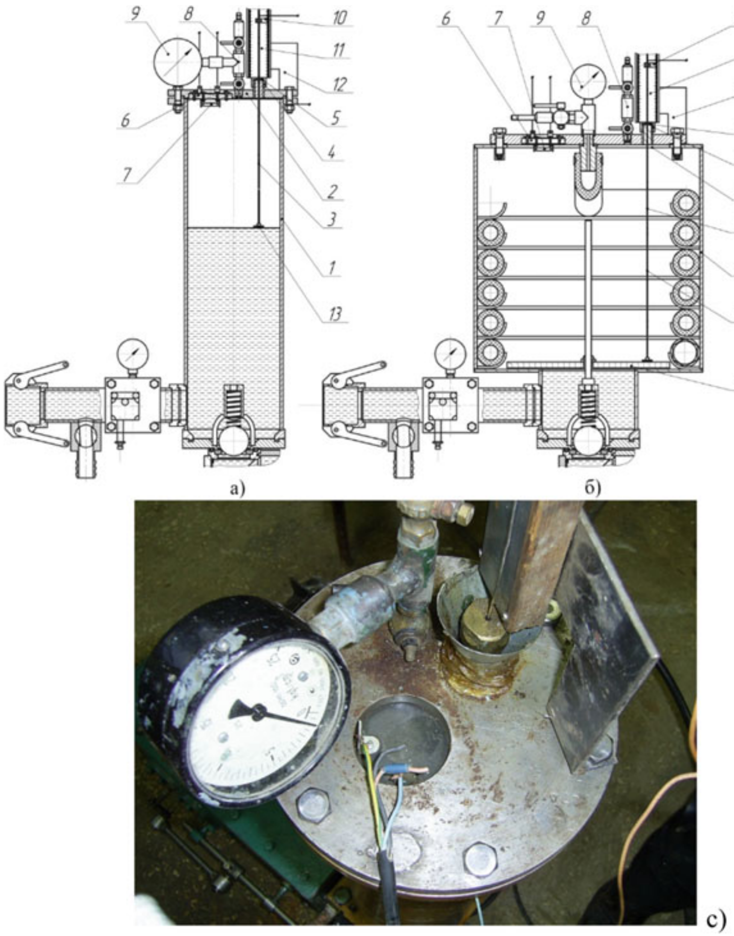


Fig. 4 Measuring device as part of a single-piston mortar pump to determine the intensity of air removal from the cap when pumping solutions by mobility П 8, 10, 12 cm and at supply pressures $p = 0,9$ MPa, $p = 1,2$ MPa, $p = 1,7$ MPa: **a** the scheme of the cylindrical chamber of the combined pressure ripple compensator; **b** scheme of the combined compensator of the increased volume with a float; **c** image of the measuring device. 1—cylindrical air cap; 2—cover; 3—rod; 4—nut; 5—rubber gasket; 6—organic glass; 7—light bulb; 8—air valve; 9—manometer; 10—check box; 11—metal ruler; 12—tripod; 13—rubber gasket; 14—float

The reduced air volume in the cylindrical chamber of the combined pressure pulsation compensator is presented as a function of the main parameters of the working process (19), over time, depending on the current temperature of the solution was determined by the formula (18).

In the second hole is fixed organic glass 6 and an electric light bulb of the cap 7. This hole is needed to control the contact surface of the solution in the cylindrical chamber with the lower end of the rod 3. Also, to check the contact moment of the solution meniscus with the end of the rod Ц 4354-М1 ТУ 25–04-3303–95.

For more precise contact of the rod with the solution, the contact meniscus is separated by a rubber gasket 13. The air valve 8 with the manometer 9 is screwed into the third hole, through which air is pumped from the compressor. Fixing the height of the air column in the cylindrical chamber is carried out using a flag 10, which is fixed on the rod 3 and equipped with a ruler 11 (0–1000 DSTU GOST 427–2001), which is mounted on a tripod 12.

To confirm the theoretical research, a number of experimental studies were conducted on the stand discussed above in Figs. 3 and 4 to determine the intensity (speed) of air removal from the compensators of different design solutions for single-piston mortar pump when pumping lime-sand solutions of different mobility.

The given volume is determined by the formula

$$V_{koMn} = \pi \cdot \frac{D^2_{y.k.}}{4} \cdot H_{noB} \cdot \frac{p_{cp}}{p_{amM}} \cdot \frac{T_0}{T} \tag{18}$$

where $D_{ц.к.}$—the diameter of the cylindrical chamber; $H_{noв}$—the height of the air column in the cylindrical chamber of the compensator, dm; T—the current temperature of the solution, К.

Dependencies in Fig. 3 are presented as a function

$$V_{koMn} = f\left(\tau, T, p, V_{p03}, \rho\right) \tag{19}$$

where τ—the time of pumping the solution pump, dm; T—the current temperature of the pumped solution, К; p—solution supply pressure, MPa; $V_{poз}$—volume of solution in a cylindrical chamber; ρ—the density of the solution, kg/dm^3.

The results of measurements and calculations are presented in Table 2 and in Fig. 5. The test results (Fig. 5) indicate that during the operation of the mortar pump compressed air is relatively quickly removed from the cylindrical chamber of the compensator by the pumped solution. In this case, the rate of air removal is significantly affected by the supply pressure. The higher the supply pressure, the higher the rate of compressed air removal. If at a pressure of 0.9 MPa for 180 min of pumping solutions with a mobility of P 8, 10 and 12 cm (Fig. 5) on the differences of the current fixed volumes were removed, respectively, 2.57; 2.45 and 2.04 dm^3 of the reduced volume of air, and already at a pressure of 1.7 MPa—already 6.56; 5.31 and 4.18 dm^3.

This result is partly explained by Henry's law, which is based on the dissolution of air in solution. Observations of the process in the cylindrical chamber through the glass window showed that the removal of compressed air is affected by the pulsation of the solution, or rather the amplitude of oscillations of the solution, due to which more intensive mixing of the solution with the contact air. In addition, with pressure drops from p_{max} till p_{min} there is a condensation of vapors which were saturated with air and at increase of pressure settle down on a solution surface.

Table 2 Parameters of intensity of removal of air from the cylindrical chamber of the combined compensator of pulsation of pressure of the single-piston mortar pump

Mobility of the solution, cm	The height of the air column $H_{noв}$, dm	Time of change of an air column τ, s	p_{max}/p_{min}, MPa	Average supply pressure p_{cp}, MPa	Changing the degree of pulsation	The temperature of the solution T, °C	Time of change of temperature of solution τ, c
П8	2,4329 2,3848 2,3366 2,2884 2,2872	0 35 80 173 180	0,98/0,82 0,99/0,81 1,00/0,80 1,01/0,79 1,01/0,79	0,9	17,8 20,0 22,2 24,4 24,4	22 22 24 26 27,5 28,5 29,2	0 30 60 90 120 150 180
	1,8247 1,7647 1,7107 1,6703 1,6610	0 40 106 159 180	1,35/1,05 1,37/1,03 1,38/1,02 1,39/1,01 1,39/1,01	1,2	25,0 28,3 30,0 31,7 31,7	22 23,2 25,5 27 28,5 29 30	0 30 6 90 120 150 180
	1,2880 1,2571 1,1919 1,1439 1,0959 1,0911	0 12 62 107 176 180	1,94/1,46 1,96/1,44 1,98/1,42 1,99/1,41 2,00/1,40 2,00/1,40	1,7	28,2 30,6 32,9 34,1 35,3 35,3	22 22,5 26 28 29,5 31 32	0 30 60 90 120 150 180
П10	2,4329 2,3841 2,3444 2,2985 2,2940	0 35 80 160 180	0,96/0,84 0,97/0,83 0,98/0,82 0,99/0,81 0,99/0,81	0,9	13,3 15,6 17,8 20,0 20,0	22 22 24 25,9 27,5 28,3 29	0 30 60 90 120 150 180
	1,8247 1,7677 1,7180 1,6822 1,6759	0 40 94 148 180	1,31/1,09 1,32/1,08 1,33/1,07 1,34/1,06 1,34/1,06	1,2	18,3 20,0 21,7 23,3 23,3	22 23 25,2 26,8 28,4 28,9 29,9	0 30 60 90 120 150 180

(continued)

Table 2 (continued)

Mobility of the solution, cm	The height of the air column $H_{пов}$, dm	Time of change of an air column τ, s	p_{max}/p_{min}, MPa	Average supply pressure p_{cp}, MPa	Changing the degree of pulsation	The temperature of the solution T, °C	Time of change of temperature of solution τ, c
	1,2880 1,2610 1,2460 1,1994 1,1292 1,1286	0 18 58 107 172 180	1,87/1,53 1,89/1,51 1,90/1,50 1,91/1,49 1,92/1,48 1,92/1,48	1,7	20,0 22,4 23,5 24,7 25,9 25,9	22 22,5 25,8 28 29,4 30,9 31,7	0 30 60 90 120 150 180
П12	2,4329 2,3848 2,3365 2,3172	0 35 104 180	0,95/0,85 0,96/0,84 0,97/0, 83 0,975/0,825	0,9	11,1 13,3 15,6 16,7	22 22,5 24,2 26 27,3 28,5 29	0 30 60 90 120 150 180
	1,8247 1,7767 1,7286 1,7095	0 33 105 180	1,29/1,11 1,30/1,10 1,31/1,09 1,315/1,085	1,2	15,0 16,7 18,3 20,0	22 23,3 25 28 29 30 30,5	0 30 60 90 120 150 180
	1,2880 1,2400 1,1919 1,1632 1,1652	0 38 109 177 180	1,84/1,56 1,85/1,55 1,87/1,53 1,88/1,52 1,88/1,52	1,7	16,5 17,6 20,0 21,2 21,2	22 23 26 29 30 31 31,5	0 30 60 90 120 150 180

In addition to the pressure, the intensity of compressed air removal is affected by the mobility of the pumped solutions. The results of research show (Fig. 5) that the lower the mobility of the solution, the higher the intensity of air removal. Thus, with a decrease in mobility from P 12 to 10 and 8 cm at a pressure of 1.7 MPa, the reduced volume of removed air increases to 4.18; 5.31 and 6.56 dm^3.

The rate of air removal slows down over time, as evidenced by the decrease in the angles of inclination of the dependencies (Fig. 5) $V = f(\tau)$. There are two reasons for this (Table 3).

First, over time, the volume of compressed air in the cylindrical chamber decreases, and the height of the volume of the solution in it, on the contrary, increases. Therefore, there is a decrease in the plane of interaction of compressed air with the

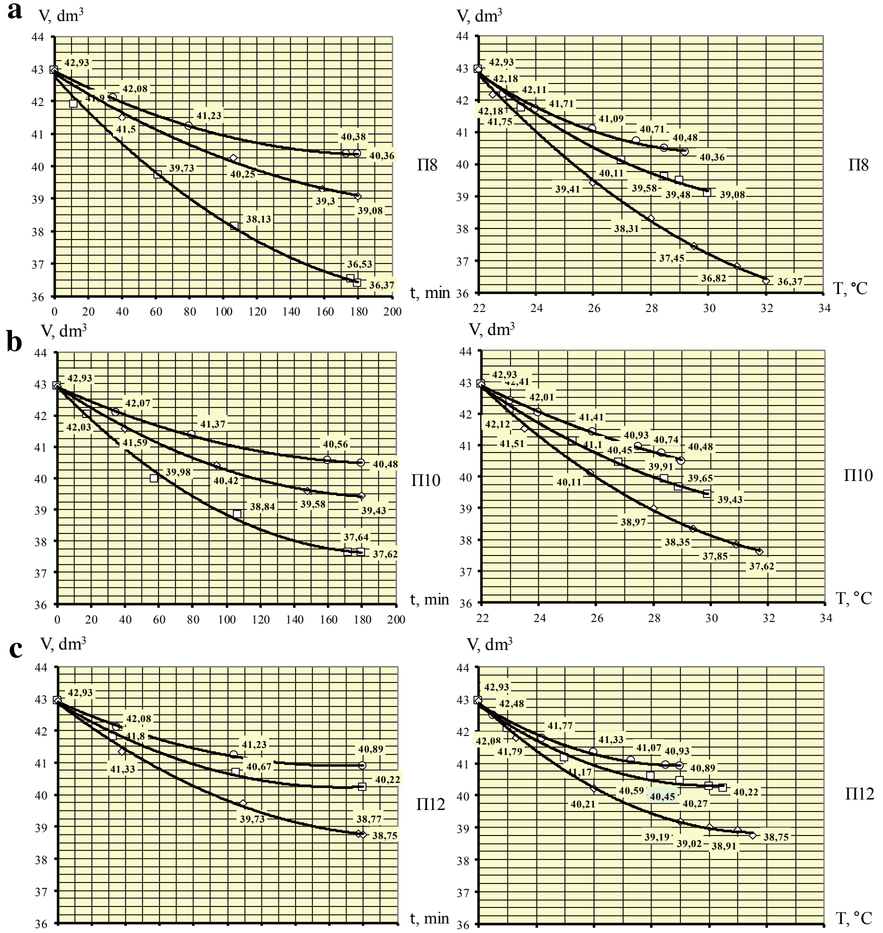


Fig. 5 Dependences of the reduced volume of compressed air in the cylindrical chamber of the combined compensator of pulsation of pressure of solution pump and temperature of solutions on time of pumping of solutions by mobility П 8 cm (**a**), П 10 cm (**b**) i П 12 cm (**c**) at medium pressure $p_{cp} = 0, 9$ (O); 1,2 (Δ); 1,7 (□) MPa

solution and the intensity of mixing of the solution. Secondly, the results of research (Fig. 5) indicate that the gradual decrease in the intensity of air removal from the cylindrical chamber is due to an increase in the temperature of the pumped solution. In addition, increasing the temperature of the solution in the summer to 40 °C and above leads not only to the suspension of air removal from the cylindrical chamber, but also an increase in air volume in the cylindrical chamber, which is accompanied by the emergence of air bubbles from the solution.

The results of research (Fig. 5) show that the intensity of air removal from the cylindrical chamber of the compensator is affected by the volume of solution in the

Table 3 Parameters of intensity of removal of air from the cylindrical chamber of the combined compensator of the increased volume of the single-piston mortar pump with the float established in it

Mobility of the solution, cm	The height of the air column $H_{пов}$, dm	Time of change of an air column τ, c	p_{max}/p_{min}, MPa	Average supply pressure p_{cp}, MPa	Changing the degree of pulsation, %	The temperature of the solution T, ^oC	Time of change of temperature of solution τ, s
П8	2,4329	0	0,98/0,82	0,9	17,8	22	0
	2,4273	43	0,99/0,81		20,0	23	30
	2,4221	104	1,00/0,80		22,2	25,5	60
	2,4165	180	1,00/0,80		22,2	27,0	90
						29,0	120
						29,5	150
						31,5	180
	1,8247	0	1,35/1,05	1,2	25.0	22	0
	1,8111	34	1,36/1,04		26,7	22,5	30
	1,8055	113	1,365/1,035		27,5	25,0	60
	1,8038	180	1,365/1,035		27,5	26,5	90
						28,7	120
						29,5	150
						30,0	180
	1,2880	0	1,94/1,46	1,7	28,2	22	0
	1,2703	37	2,01/1,39		29,4	22,5	30
	1,2610	109	2,02/1,38		30,6	26	60
	1,2595	180	2,02/1,38		30,6	28	90
						29,5	120
						31	150
						32	180
П10	2,4329	0	0,96/0,84	0,9	13,3	22	0
	2,4272	47	0,97/0,83		15,6	22,6	30
	2,4244	102	0,975/0,825		16,7	23,2	60
	2,4233	180	0,975/0,825		16,7	24,0	90
						25,5	120
						27,5	150
						28,3	180
	1,8247	0	1,31/1,09	1,2	18,3	22	0
	1,8145	33	1,32/1,08		20,0	23,5	30
	1,8073	116	1,33/1,07		21,7	24,5	60
	1,8064	180	1,33/1,07		21,7	25,4	90
						27,6	120
						28,5	150
						29,0	180

(continued)

Table 3 (continued)

Mobility of the solution, cm	The height of the air column $H_{пов}$, dm	Time of change of an air column τ, c	p_{max}/p_{min}, MPa	Average supply pressure p_{cp}, MPa	Changing the degree of pulsation, %	The temperature of the solution T, ^{o}C	Time of change of temperature of solution τ, s
	1,2880 1,2742 1,2670 1,2655	0 36 111 180	1,87/1,53 1,88/1,52 1,89/1,51 1,895/1,505	1,7	20,0 21,2 22,4 22,9	22 23,6 24,8 26,5 28,4 29,5 30,5	0 30 60 90 120 150 180
П12	2,4329 2,4289 2,4272 2,4250	0 51 100 180	0,95/0,85 0,95/0,85 0,955/0,845 0,955/0,845	0,9	11,1 11,1 12,2 12,2	22 22,3 23,0 24,0 25,7 27,4 28,2	0 30 60 90 120 150 180
	1,8247 1,8153 1,8094 1,8081	0 38 120 180	1,29/1,11 1,29/1,11 1,30/1,10 1,33/1,07	1,2	15,0 15,0 16,7 16,7	22 22,7 23,8 25,5 27,3 28,4 29,0	0 30 60 90 120 150 180
	1,2880 1,2754 1,2685 1,2670	0 32 114 180	1,87/1,53 1,89/1,51 1,89/1,51 1,90/1,50	1,7	16,5 16,5 17,6 17,6	22 23,3 24,6 26,4 28,1 29,2 30,2	0 30 60 90 120 150 180

cylindrical chamber, and the larger this volume, the lower the intensity of air removal from the compensator.

This is due to the decrease in the rate of mixing of the solution on the surface of contact with air.

To reduce the intensity of air removal from the cylindrical chamber of the combined compensator of increased volume in its middle is installed a float with a diameter of 14 Ø 270 mm and height 8 mm (Fig. 4, б). Due to the float, the contact area of the solution with air in the cylindrical chamber decreased from 1.96 dm ^{2} till 0,15 dm^{2} (for the experimental-industrial sample of the solution pump).

Research results (Fig. 6) show that due to the introduction into the cylindrical chamber of the combined compensator of the increased volume of the float, the intensity of air removal from the cylindrical chamber is significantly reduced.

So, with reduced mobility П 12 till 10 and 8 cm at pressure 1,7 MPa the reduced volume of air in the cylindrical chamber of the combined pressure ripple compensator

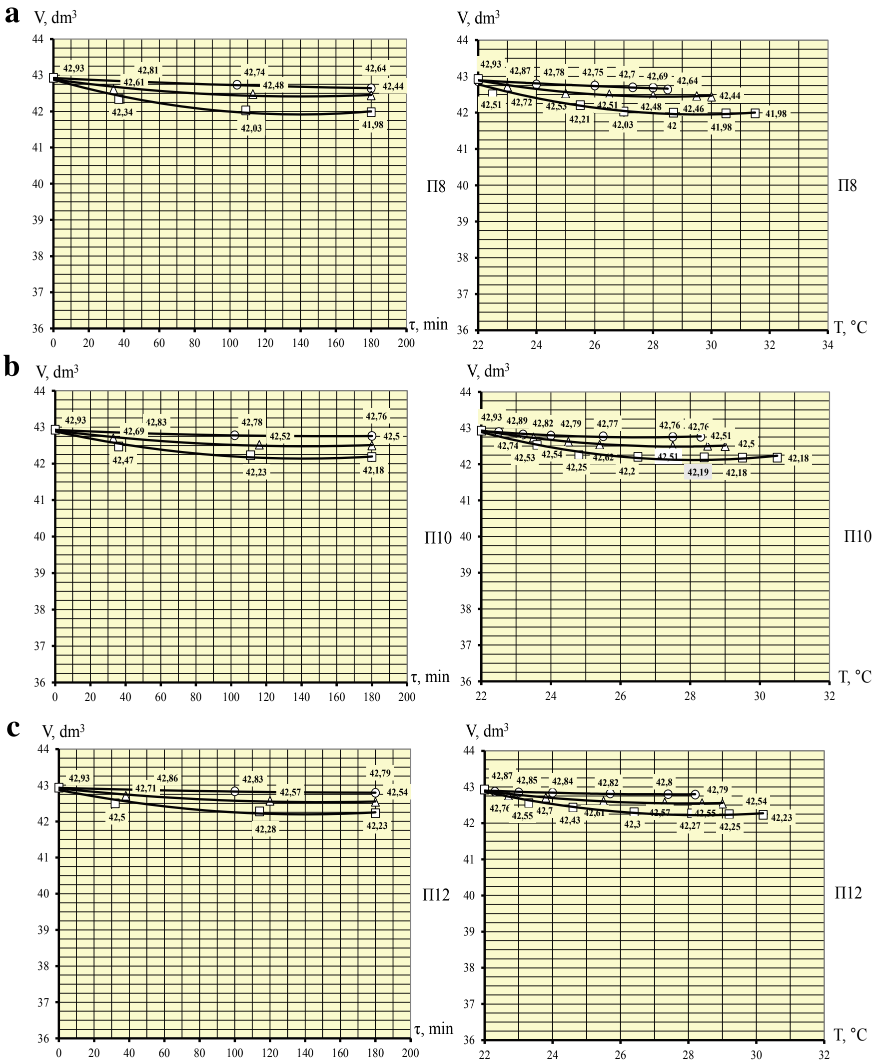


Fig. 6 Dependences of the reduced volume of compressed air in the cylindrical chamber of the combined compensator of the increased volume of the solution pump with a float and temperature of solutions on time of pumping of solutions by mobility П 8 cm (**a**), П 10 cm (**b**) i П 12 cm (**c**) at medium pressure $p_{cp} = 0,9$ (O); 1,2 (Δ); 1,7 (□) MPa

in relation to the volume of the cylindrical chamber of the combined compensator of the increased volume with a float has changed from 4,18 to 0,7 dm^3; from 5,31 to 0,75 dm^3 and from 6,56 to 0,95 dm^3 accordingly.

Dependencies (Fig. 7) indicate that during the pumping of the solution over time there is an increase in the degree of pressure pulsations. This is due to two factors: a decrease in the volume of air in the cylindrical chambers of the combined volume compensators and the combined pressure ripple compensator, and an increase in the average supply pressure of the solution. There is also a proportional increase in the degree of pressure pulsations in relation to the decrease in the compensation volume in the cylindrical chambers of the compensators, as well as with increasing supply pressure.

Therefore, the expediency of installing a float in the middle of the cylindrical chamber of the compensator of increased volume at the separation of the air and liquid phases is justified in relation to reducing the degree of pulsation of the supply pressure.

Experimental studies of air removal from a cylindrical chamber with different mobility of solutions are consistent with the previously considered hypotheses and are a practical confirmation of the results of theoretical studies of changes in the volume of compressed air in a cylindrical chamber by changing the current air concentration per minute with increasing pressure by 0.1 MPa.

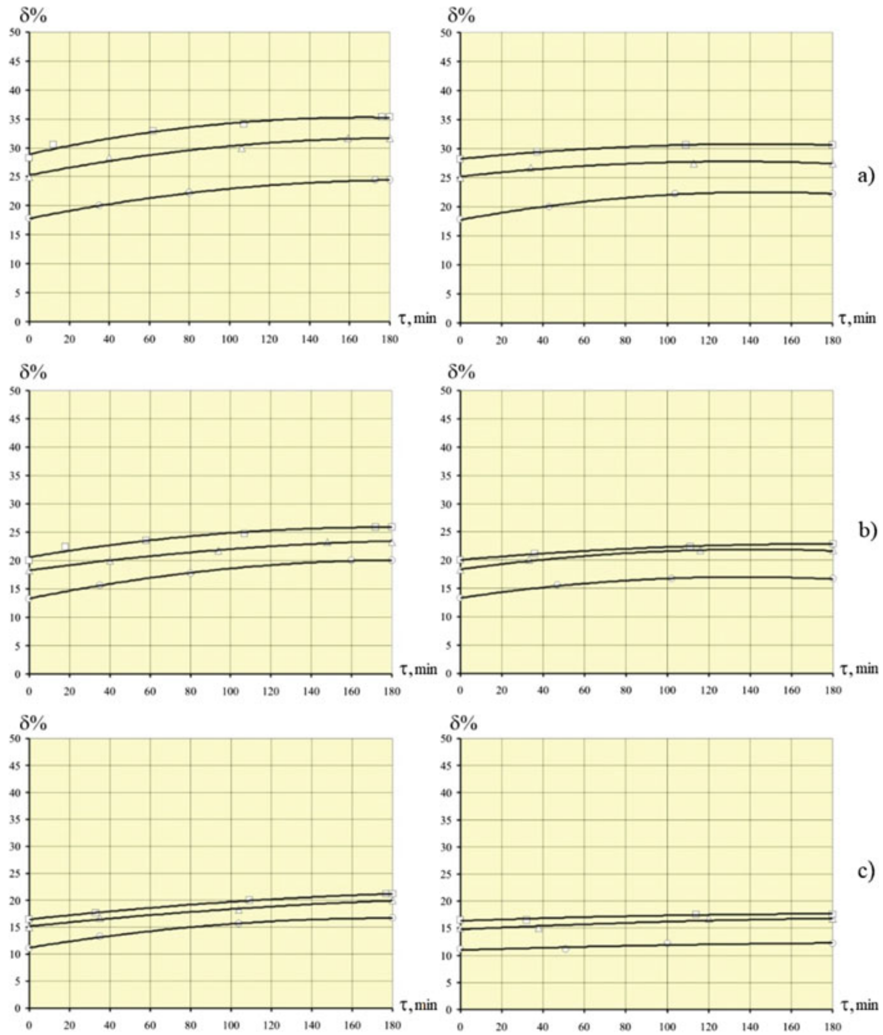
The coefficient of intensity of air removal from the cylindrical chamber, which is determined on the basis of dependence (4) and are given in Tables 4 and 5.

Dependencies (Fig. 8) indicate that the concentration of air in the solution decreases with decreasing air volume in the cylindrical chamber during the pumping of the solution of reduced mobility. Also, the introduction into the cylindrical chamber of the combined compensator of the increased volume of the float provides a decrease in the coefficient of intensity of air removal from the cylindrical chamber in proportion to the area of contact of the solution with air. The research results confirm the need to isolate the air volume in the cylindrical chamber of the combined compensators by means of a float with chipboard 10 mm thick with a guide rod, which will reduce air removal and increase the degree of pulsations of the solution.

According to research, it can be argued that in sedentary solutions, which have a lower water content and, accordingly, more air, the maximum compression of the solution occurs with increasing pressure than for solutions with greater mobility. Also, when the pressure rises to the limit, depending on the mobility, there is a complete dissolution of air in the water of the solution.

According to Henry's law, Mendeleev-Clapeyron's law, the van der Waals equation, processes occur, both dissolution and the emergence of air bubbles on the separation of air and liquid phases depending on pressure and temperature.

Coalescence and dispersion of air bubbles are also observed during the movement of viscous media. In the flow of the solution, due to the viscosity of the medium, air bubbles are more dispersed. Under certain conditions of shear stresses during the supply or stop of the solution and the level of dispersion, the movement of bubbles in the solution stops.



cylindrical chamber of the compensator pressure ripple

cylindrical chamber of the compensator increased volume

Fig. 7 Dependences of the degree of solution pressure pulsations in cylindrical chambers of combined pressure pulsation compensators at free contact of air with the solution and the increased volume with the float on the time of pumping solutions by mobility П 8 cm (**a**), П 10 cm (**b**) i П 12 cm (**c**) at medium pressure $p_{cp} = 0,9$ (O); 1,2 (Δ); 1,7 (□) MPa

Table 4 The coefficient of intensity of air removal from the cylindrical chamber of the combined compensator of pulsation of pressure of a solution pump at the parameters characterizing this process

Parameters			8 cm	10 cm	12 cm
№ experiment	The height of the air column H, dm	Medium pressure filing p_{cp}, MPa	The coefficient of intensity of air removal from the cylindrical chamber,α		
1	2,4329	0,9	0,00,383	0,00,379	0,00,373
2	1,8247	1,2	0,00,368	0,0035	0,00,314
3	1,2880	1,7	0,00,343	0,0029	0,00,241

Table 5 The coefficient of intensity of air removal from the cylindrical chamber of the combined compensator of the increased volume of the mortar pump at the parameters characterizing this process

Movability		8 cm		10 cm		12 cm	
№ експерименту	Average supply pressure P_{cp}, MPa	The height of the air column H, dm	The coefficient of intensity of air removal from the cylindrical chamber,α	The height of the air column H, dm	The coefficient of intensity of removal of air from a cylindrical chamber, α	The height of the air column H, dm	The coefficient of intensity of removal of air from a cylindrical chamber, α
1	0,9	2,47	0,00,089	2,46	0,00,085	2,445	0,00,071
2	1,2	1,82	0,00,081	1,78	0,00,072	1,735	0,00,065
3	1,7	1,26	0,00,069	1,25	0,00,063	1,29	0,00,062

The rate of dissolution of air in the aqueous component depends on the lack of gas to equilibrium, and the frequency of collisions of gas molecules with the interface.

On the basis of theoretical and experimental researches quantitative indicators of coefficient of intensity of removal of air from a cylindrical chamber are established α, which characterizes quantitatively the current concentration of air removed by dissolving in the solution, as well as due to the saturation of the solution with air (in the process of changing the surface of the solution in the area of contact with air during pumping). It is experimentally proved that the air from the cylindrical chambers of the combined compensators of the solution pump is removed under the influence of such factors as: solution supply pressure, mobility of pumped solutions, temperature of solution or air and saturation of solution with air.

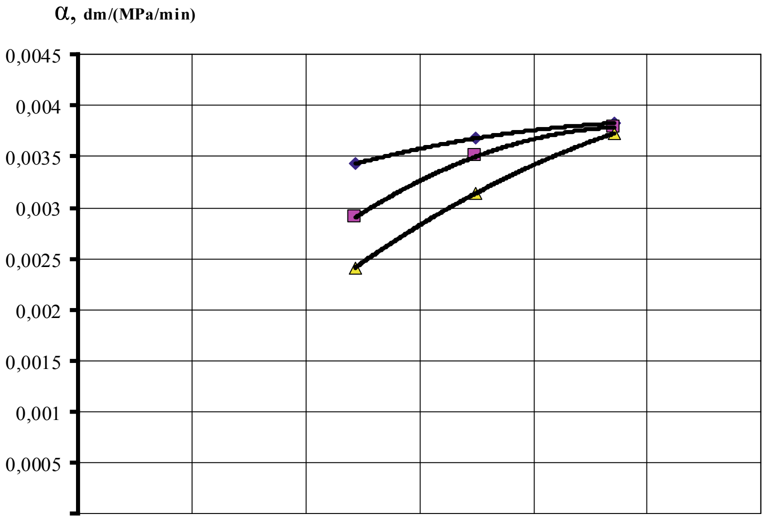


Fig. 8 Dependences of the coefficient of intensity of air removal from the cylindrical chambers of the mortar pump on the height of the column of compressed air *H* when pumping solutions at medium pressure: 0,9; 1,2; 1,7 MPa: ◆—П8; ■—П10; ▲—П12—for a cylindrical chamber of the combined pressure pulsation compensator; × – П8; □—П10; ●—П12—for the cylindrical chamber of the combined compensator of the increased volume

3 Conclusions

1. The relative amount of air that can dissolve in the soluble mixture to its saturation is directly proportional to the pressure at the phase distribution surface.
2. Compressed air is saturated on the distribution surface when changing the surface layer of the solution is partially joined and together with the flow of solution is removed.

   The rate of air removal slows down over time, as evidenced by the angles of inclination of the tangents to the horizontal. This is established for two reasons. First, during pumping, the volume of compressed air in the cylindrical chamber decreases intensively over time, and the height of the column of the volume of the solution in it, on the contrary, increases. As a result, there is a decrease in the plane of interaction of compressed air with the solution and the intensity of mixing of the solution. Secondly, as the temperature of the pumped solution increases, the intensity of air removal from the cylindrical chamber gradually decreases. The rate of removal of air from the cylindrical chamber of the compensator is also affected by the volume of solution in the cylindrical chamber, and the larger this volume, the lower the intensity of removal of air from the compensator. This is explained by the fact that at a relatively minimum height of the solution column in the cylindrical chamber there is a faster change of the solution layer at the interface due to the flow of solution from the valve space, which in turn is much faster saturation-mixing of air into the solution.

3. The research results show that the quantitative indicator is the coefficient of intensity of air removal from the cylindrical chamber during pumping by the compensator of the increased volume in relation to pumping by the compensator pressure pulsations decreased by 5 times due to installation of a float in the cylindrical chamber. This significantly reduced the pressure ripple of the solution 10%.

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Optimization of Trapezoidal Corrugated Profile for Rectangular Hopper

Anton Makhinko, Nataliia Makhinko, and Oleg Vorontsov

Abstract The article presents solutions for the problems of determining the rational geometric parameters of corrugated sheets at which their minimum mass is achieved. The study concerns the sheets of the body steel rectangular silo for the storage of bulk materials. Various options for jointing the sheets with each other were considered. The dimensions of the sheet cross section are determined by four independent parameters—the corrugation height, the width of the corrugation shelves, the distance between the corrugations and the angle of tip of the walls. The thickness and length of the sheet are constant values. According to the optimality criterion set, formulas are obtained convenient for engineering use to determine the height of the corrugation and the width of its shelves, for different types of sheet mounting. The domains of applicability of these expressions for each considered case are substantiated.

Keywords Corrugation profile · Geometric characteristics · Minimum mass · Optimal parameters · Rectangular hopper · Square silo

1 Introduction

The calculation of the geometric parameters of thin-walled elements is a very important study, since the field of use of these structures is very wide [1–3]. This is especially true for the design of steel rectangular hoppers for storing bulk products, since they almost completely consist of corrugated thin-walled elements [4–7]. In this case, when calculating the strength or stability of a structure or an individual element, the

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_18

engineer always operates with the specified sheet sizes and corrugation characteristics. The manufacturer determines these dimensions in the process of bending the flat steel sheet, by adjusting the equipment. The result of the calculation is usually the determination (or verification) of the required sheet thickness at a certain altitude level for a given load [8–22]. In this case, thickness parameter will determine final steel hopper weight. However, what happens if you change the geometry of the profiled sheet itself? Different ratios of the angle of tip of the wall, the height of the profile, the width of the corrugation shelves will affect the final mass of the sheet.

2 Research Results

Thus, the search for the optimal parameters of the corrugated sheet geometric characteristics is an important optimization problem, which will provide a more economic solution.

It should also be noted that technical limitations when taking profile sizes would play an important role. For example, methods of jointing sheets to each other, technological constraints to the maximum height of the corrugation and so on. Therefore, in this study, attention was focused on the three most common jointing options for rectangular hopper sheets (see Fig. 1).

These include the option of a corrugated sheet with a limited number of joints along the length (see Fig. 2a), a sheet of small height and a joint device with complete overlapping in each corrugation (see Fig. 2b) and a sheet with partial overlapping of the joint (see Fig. 2c).

2.1 General Solution to the Problem (on the Example of a Corrugated Sheet with Equal Widths of Both Corrugations)

The procedure for determining the optimal parameters of the corrugated sheet of minimum mass, which schematizes the wall of the storage hopper and which is pressurized p_0, was presented by the authors earlier [11].

At the same time, a sheet with a limited number of mounting joints was considered, which had little effect on its bending characteristics. Based on the obtained dependences for the area A_p, the length of the horizontal projection ℓ_p, the second moment of area J_p and the section modulus W_p from the strength condition, we obtain the expression

$$M_p = h_p \frac{p_0 L_0^2}{\alpha_0} \left(2\alpha_p + \frac{1}{tg\beta_p} \right), \quad (1)$$

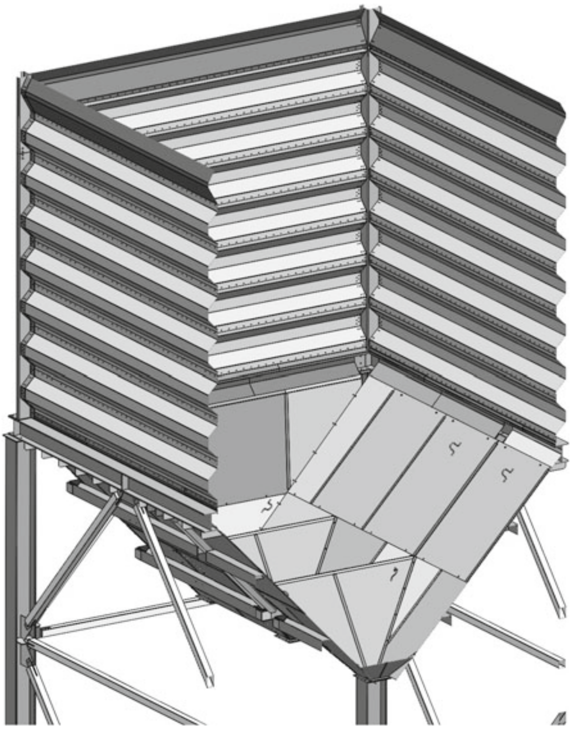

Fig. 1 Sectional view of a rectangular grain storage hopper

where α_0 is the coefficient of the bending moment function. For example, with a hinged bearing $\alpha_0 = 8$, and with a fixed bearing $\alpha_0 = 12$; $\alpha_p = a_p/h_p$ is the ratio of the shelf width a_p and the corrugation height h_p; β_p is the angle of tip of the corrugation walls; L_0 is the length of the corrugated sheet.

Hence, the expression for the cross-section area of the corrugation is obtained

$$A_p = \frac{3p_0L_0^2(1 - cos\beta_p) - \alpha_0 R_y h_p t}{3\sin\beta_p\left(p_0L_0^2/\left(h_p t_p\right) - 0.5\alpha_0 R_y\right)}, \tag{2}$$

where R_y is the yield strength; t_p is the thickness of the sheet.

Based on the minimization of this expression under h_p, we obtained formulas for determining the optimum height of the corrugation and the width of its shelves that satisfy the criterion of optimality

$$h_{opt} = \left[p_0L_0^2/\alpha_0 R_y t_p\right]\left(2 + \sqrt{2}\cdot\sqrt{3\cos\beta_p - 1}\right). \tag{3}$$

$$a_{opt} = \frac{p_0L_0^2}{3\alpha_0 R_y t_p}\left(\frac{3\cos\beta_p + 0,5\sqrt{2}\cdot\sqrt{3\cos\beta_p - 1} - 2}{\sin\beta_p}\right). \tag{4}$$

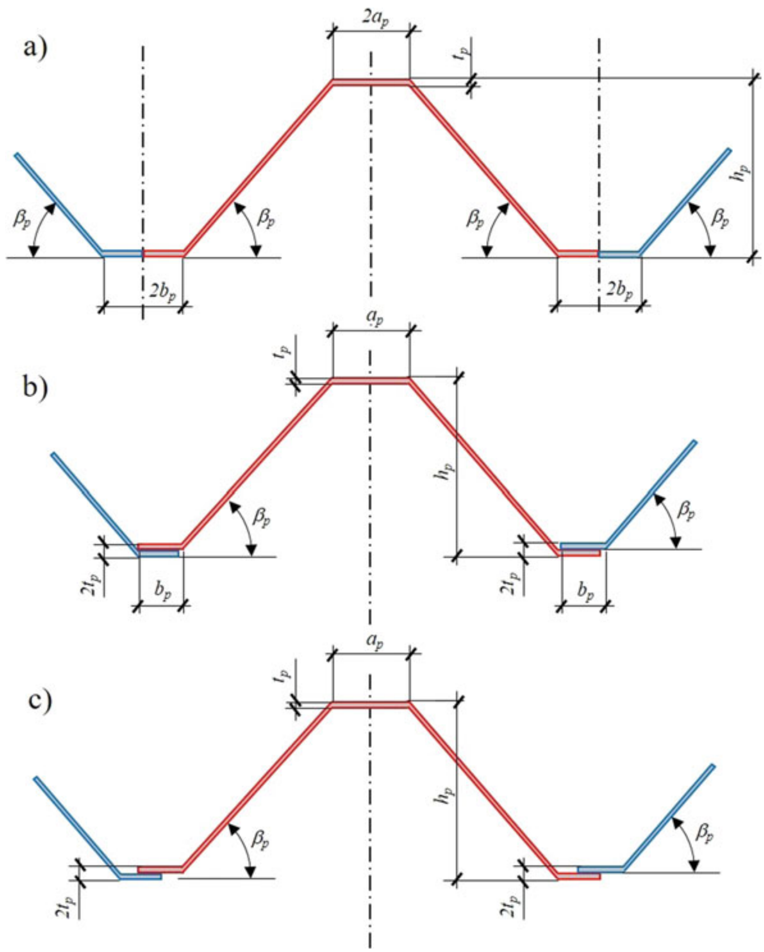

Fig. 2 Jointing options for corrugated sheets: **a** jointing without overlapping; **b** with a complete overlapping of the corrugation; **c** with partial overlapping of the corrugation

A limitation on the use of Eqs. (3) and (4) is the limit value of the angle $\beta_p = \pi/3$. It is due to the fact that the width a_p cannot be a negative value.

2.2 Solution for Corrugated Sheet with Complete Overlapping of the Lower Corrugation

In practice, it is very common that the sheets are made of small height and are joined with overlapping in each corrugation (Fig. 2b). From this perspective, the width of the upper corrugation a_p will be twice as long as the lower one b_p and the thickness of the lower corrugation will be twice as large as the main thickness of the sheet t_p. Solving the formulated problem in the same sequence as the previous one, we obtain the following results.

Optimum corrugation height

$$h_{opt} = 0.75\left[p_0 L_0^2/\left(\alpha_0 R_y t_p\right)\right]\left(2 + \sqrt{2}\cdot\sqrt{4\cos\beta_p - 1}\right). \tag{5}$$

Corrugation shelf width a_{opt}, that meets the criterion of optimality

$$a_{opt} = \frac{p_0 L_0^2}{2\alpha_0 R_y t_p}\left(\frac{2\cos\beta_p + 0.25\sqrt{2}\cdot\sqrt{4\cos\beta_p - 1} - 1}{\sin\beta_p}\right). \tag{6}$$

We define the domains of applicability of these expressions, as equating (6) to zero and solve a simple trigonometric equation with respect to β_p. . Omitting the intermediate calculations, we present only the result for the limiting angle of tip of the corrugation wall, to which the Eqs. (5) and (6) can be applied

$$\beta_p = \arccos(3/8) = 67.976^\circ \approx 68^\circ. \tag{7}$$

We perform a numerical example similar to the calculation performed earlier in the study [11]. For a corrugated sheet with a length $L_0 = 5000$ mm, which is made of steel with a yield strength $R_y = 240$ MPa it is necessary to determine the optimal dimensions of the corrugated sheet for two thicknesses $t_p = 4.0$ mm and $t_p = 3.0$ mm, five load levels p_0 and four angles of tip β_p The ends of the sheet are rigidly restrained at the edges. The result is summarized in Table 1.

Comparing the results of similar calculations for a corrugated sheet with equal widths of both corrugations and the data of Table 1, it was noted that the optimum corrugation height is less in the second version, and the width of the corrugation shelves is slightly larger. Moreover, this trend persists for all levels of external load and the entire range of angles of tip of the corrugation wall.

Table 1 Optimal corrugated sheet dimensions with complete overlapping of the corrugation

p_0, kPa	$\beta_p = 20^\circ$		$\beta_p = 50^\circ$		t_p, mm
	h_{opt}, mm	a_p, mm	h_{opt}, mm	a_p, mm	
30	212.4	139.6	184.2	31.0	4
25	177.0	116.3	153.3	25.8	4
20	141.6	93.1	122.8	20.6	4
15	106.2	69.8	92.1	15.5	4
10	70.8	46.5	61.4	10.3	4
30	283.1	186.1	245.6	41.3	3
10	94.4	62.0	81.9	13.8	3

Table 2 Optimal corrugated sheet dimensions with partial overlapping of the corrugation

p_0, kPa	$\beta_p = 20°$		$\beta_p = 50°$		t_p, mm
	h_{opt}, mm	a_p, mm	h_{opt}, mm	a_p, mm	
30	234.0	126.4	202.3	24.3	4
25	195.0	105.3	168.6	20.2	4
20	156.0	84.2	134.9	16.2	4
15	117.0	63.2	101.2	12.1	4
10	78.0	42.1	67.4	8.1	4
30	312.0	168.5	269.8	32.4	3
10	104.0	56.2	89.9	10.8	3

2.3 Solution for Corrugated Sheet with Partial Overlapping of the Lower Corrugation

Let us consider another case with a partial overlapping of the sheet in the lower corrugation. We assume that the overlapping width is equal to the width of two free sections and occupies a length $0.5a_p$, i.e. along the length of the lower corrugation there are three sections of the same length $0.5a_p$, two of which have a thickness t_p, and another one $2t_p$. Under this condition, the areas of the upper and lower corrugations will be equal, which will ensure equal stresses in both shelves. Because of the solution, we obtain the following.

$$h_{opt} = \frac{1}{8}\frac{p_0 L_0^2}{\alpha_0 R_y t_p}\left(14 + \sqrt{14}\cdot\sqrt{24\cos\beta_p - 7}\right). \tag{8}$$

$$a_{opt} = \frac{p_0 L_0^2}{12\alpha_0 R_y t_p}\left(\frac{12\cos\beta_p + {}^{\sqrt{14}}\!\big/_{4}\sqrt{24\cos\beta_p - 7} - 7}{\sin\beta_p}\right). \tag{9}$$

The domains of applicability of the obtained expressions

$$\beta_p = \arccos(7/16) = 64.056° \approx 64°. \tag{10}$$

An example of the use expressions is shown in Table 2.

2.4 Comparison of Results of the Three Options Considered

A logical question arises: which of the three options considered will be more economical. To answer it, we find the dependence of the cross-section areas of the corrugated sheets with the optimal parameters h_{opt} and a_{opt}. For the three areas designated as

$A_{p,1}$, $A_{p,2}$ and $A_{p,3}$, we obtain

$$\eta_{12} = \frac{A_{p,1}}{A_{p,2}} = \frac{12cos\beta_p + 8\sqrt{6\cos\beta_p - 2} + 4}{12cos\beta_p + 6\sqrt{8\cos\beta_p - 2} + 3}. \quad (11)$$

$$\eta_{32} = \frac{A_{p,3}}{A_{p,2}} = \frac{24cos\beta_p + 2\sqrt{336\cos\beta_p - 98} + 7}{24cos\beta_p + 12\sqrt{8\cos\beta_p - 2} + 6}. \quad (12)$$

A graphical interpretation of Eqs. (11) and (12) is shown in Fig. 3.

We can see that the second option leads to a more economical solution, although not a big one. In the range of practically important angles of tip of the corrugation wall, the difference is 6–7%, i.e. sheets with overlapping the shelves in each lower corrugation are more economical than solid ones, although this savings is leveled on the connection bolts. To summarize the problems considered, we will give simple and convenient recommendations for quickly determining the optimal geometric dimensions of corrugated sheets. To do this, we select the separate value, which we call the sheet loading parameter

$$\eta_p = p_0 L_0^2 / \left[\alpha_0 R_y t_p\right]. \quad (13)$$

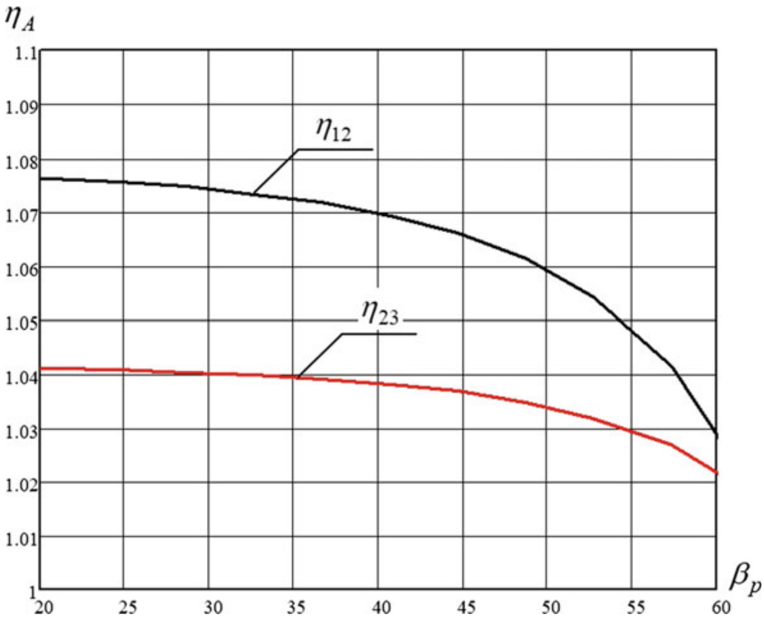

Fig. 3 Dependence of the coefficient η_A on the angle of tip of the wall

This value, which has length units, plays the role of the proportionality coefficient in the formulas for determining the optimal parameters h_{opt} and a_{opt} by which it is necessary to multiply the remainder of the expressions, which depends only on the angle of tip β_p of the corrugation wall. It is convenient to present this part graphically both for the optimum sheet height h_{opt} (see Fig. 4) and the corresponding corrugation shelf width a_{opt}.

Formulas for determination h_{opt} and a_{opt} take the form

$$h_{opt} = \eta_p \Delta h_p, \tag{14}$$

$$a_{opt} = \eta_p \Delta a_p, \tag{15}$$

where Δh_p and Δa_p are are the dimensionless factors, which are determined from the Eqs. (3) and (4), (5) and (6), (8) and (9).

Thus, in order to find the optimal cross-sectional dimensions of the corrugated sheet, it is necessary to determine the loading parameter by the Eq. (13), the factors Δh_p and Δa_p for the accepted angle of tip of the corrugation wall β_p and use Eqs. (14) and (15). It bears repeating that it is also necessary to determine in advance the type of joining between the sheets.

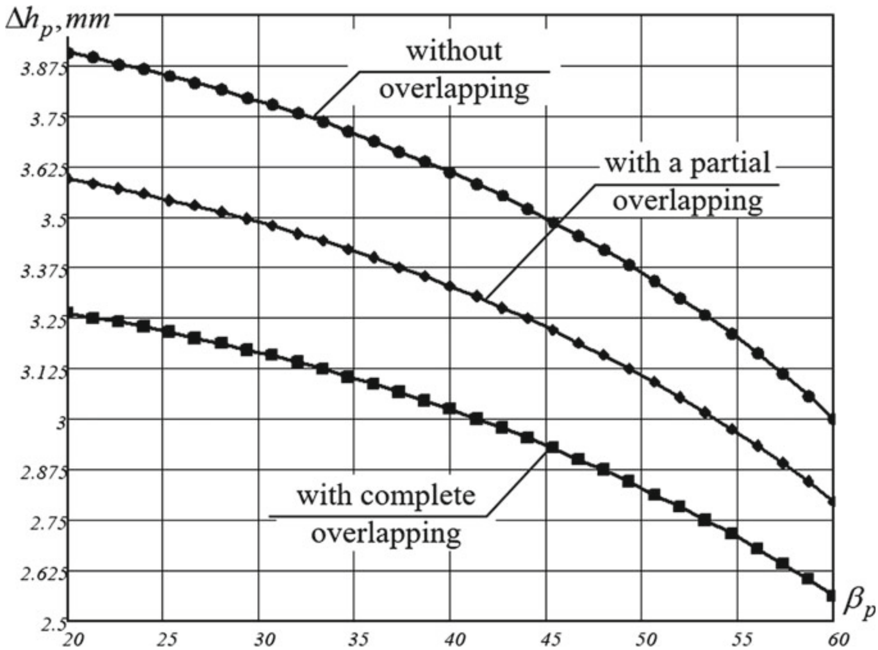

Fig. 4 Dimensionless factors Δh_p for different type of joining between the sheets

3 Conclusion

1. The article summarizes the procedure for determining the geometric characteristics of corrugated steel sheets from the condition of their minimum mass. Typical sheets that are used to design bodies of rectangular storage hoppers and three options for their joining are considered.
2. Laconic and engineering-friendly dependencies are proposed for determining the optimal characteristics of the corrugation height and the width of its shelf for three options of jointing corrugated sheets.
3. A number of numerical calculation examples and a comparison of their results were performed to determine a more economical type of jointing.
4. General recommendations are formulated to the optimal parameters of the corrugation in the form of a simple numerical and graphic algorithm.

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The Current State of Energy Efficiency and Light Quality of Led Products

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Abstract The results of researches of light and colorimetric parameters LED lamps and fixtures for general lighting entering the market of Ukraine are given. Conclusions are made about high energy efficiency of products and satisfactory level of light quality.

Keywords LEDs · Lamps · Luminaire · Energy efficiency · Light quality

1 Introduction

The International Energy Agency (IEA) claims that 19% of world electricity production is spent on lighting, so the problem of reducing electricity consumption by lighting installations is extremely important. The European legislation in the field of energy efficiency has adopted a number of regulations aimed at improving the energy efficiency of lighting [1–3] on the basis of which Ukraine has implemented the relevant technical regulations. The problem of light quality is no less important, although less attention has been paid to it so far. One of the main tasks of quality lighting is to ensure comfortable visual work and adequate perception of the environment. The parameters of light quality include: colour (correlated colour temperature CCT), colour quality, the level of flicker (pulsation) of light flux, photobiological safety. Recent medical and biological studies have shown that light, in addition to visual functions, causes non-visual biological and psychological effects on the

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_19

human body. Short-wave light suppresses melatonin secretion, increases the feeling of vitality, heart rate, body temperature and other. Good lighting has a positive effect on health, vitality, productivity and even sleep quality [4–6].

Lighting systems designed on the principles that take into account the biological and emotional effects of light on human beings should provide light values and spectral composition of radiation close to natural, high-quality colour reproduction, no flicker of light, so the lighting systems should "copy" natural sunlight.

Today, lamps and luminaires using LEDs have become the main lighting technology in almost all areas. They have a number of advantages over incandescent and discharge lamps. In addition to high energy efficiency, it is necessary to mention high reliability and long service life, environmental friendliness, resistance to mechanical impacts, electrical, fire and explosion safety.

Due to the compact size of LEDs, new opportunities are created for the use of effective optics of various design solutions, as well as additional conveniences in the operation of lighting installations due to lighting control systems, the use of digital controllers, etc.

Despite significant advances in energy efficiency, modern LED lighting systems have not yet met many of the requirements of biologically and emotionally efficient lighting, but they have great potential to improve parameters and have been constantly improving. This applies to colorimetric parameters, in particular deviations from the normative values and the quality of colour rendering of their angular non-uniformity.

Flickering of light flux is also an actual problem of light quality. At least flicker can cause discomfort, but it can also be a health hazard—causing fatigue, reduced visual performance, provoking headaches, migraines, creating neurological problems such as epileptic seizures, increasing autistic behaviour in children and others [7, 8].

The aim of this work is to study the level of energy efficiency and light quality of commercial samples of LED lamps and luminaires for general lighting entering the lighting market, including light output, energy efficiency class, colour and colour quality, light flux modulation and photobiological safety.

We investigated LED lamps for direct replacement of incandescent lamps (IL) with E27 bases and linear LED lamps for replacement of fluorescent lamps (FL) with G13 bases, as well as LED lamps for general lighting. Electrical, light and colour parameters were measured according to [9], depth and frequency of light brightness modulation according to [10], visibility of stroboscopic SVM effect according to [11], short-term P_{st}^{LM} flicker according to [12]. Energy efficiency classes of lamps and luminaires were calculated according to [1].

A ball photometer with a diameter of 3 mm, a goniophotometer GO 2000 and a spectroradiometer MK 350S were used to measure photometric and spectral parameters. The flicker parameters and visibility of the stroboscopic effect of SVM were measured using an MK 350S Premium spectroradiometer. Based on the spectral data using the MK 350S software, the chromaticity coordinates, correlated colour temperatures (CCT), and colour rendering indices were calculated. The angular uniformity of colour parameters was determined according to [9].

2 The Main Results of Research

1. The light output of LED lamps with threaded bases with a power of 5–15 W with CCT 2700–5000 K is in the range of 80–115 lm/W, the total colour rendering index R_a—in the range of 71–86 units. The average value of light output is approximately 94 lm/W, and R_a is 77 units. The energy efficiency of lamps mainly corresponds to classes A and A^+. The luminous efficiency of linear LED lamps (to replace fluorescent lamps) with a power of 9–27 W is in the range of values of 80–160 lm/W, and R_a—in the range of 74–84. The energy efficiency of these lamps corresponds to classes A, A^+ and A^{++}.
2. The luminous efficiency of luminaires for indoor lighting (non-directional and directional light) with a power of 9–70 W with CCT 3000–5100 K is in the range of 85–150 lm/W, and R_a—81–86 units. The energy efficiency of directional luminaires corresponds mainly to classes A and A^+, and directional luminaires to classes A, A^+ and A^{++}.
3. The luminous efficiency of luminaires for outdoor lighting with CCT 3800–6400 K is in the range of 92–163 lm/W, and R_a—in the range of 71–82. The average value of light output is approximately 130 lm/W, and $R_a - 75$.
4. LED lamps and luminaires without diffuse diffusers have a significant angular unevenness of chromaticity, which may exceed 7 standard deviations of the colour of comparison (SDCM). For lamps and luminaires with diffuse diffusers SDCM does not exceed 2 SDCM.
5. The level of scatter of colour parameters of commercial samples of LED lamps and fixtures at this stage does not meet modern requirements for ensuring the values of chromaticity coordinates within the three-degree McAdam ellipses (3 SDCM) and colour rendering quality with $R_a \geq 80$.
6. LED products entering the Ukrainian market have, in general, a safe level of light modulation and visibility index of the stroboscopic effect of SVM. The depth of light modulation at a frequency of 100 Hz in most cases does not exceed 8%, and SVM is much less than one, which does not cause the appearance of a stroboscopic effect.

One of the main requirements for the quality of light is the deviation of the chromaticity coordinates (x, y) from their nominal values for a given CCT within the 3-step McAdam ellipses. The degree by McAdam is the distance on the chromatic diagram within which the average human eye does not distinguish colour differences. The size of the McAdam ellipse is determined by the number of units of standard deviations of the comparison colour (SDCM) between the center of the ellipse (coordinates of the nominal CCT) and its boundary. Standardized nominal values and tolerances of colour coordinates x and y for LED lamps and fixtures are set in [13–15]. Tolerances are determined by McAdam ellipses in one of 4 categories, which are built around the nominal values of the chromaticity coordinates.

Evaluation of the level of angular uniformity of colorimetric parameters of LED lamps was performed on commercial samples of lamps for indoor and outdoor lighting. Also LED lamps for general lighting with a base E 27 were measured.

Table 1 The results of measuring the angular uniformity of the colorimetric parameters of commercial samples of LED lamps and fixtures

Name and features of the research object		CCT, K		$\Delta_{u',v'}$, rel.un	R_a, rel. un	
		0°	80°		0°	80°
1	LED lamp with diffuse-transmitting bulb	3083	3089	0,0014	83,5 83,5	83,5
2	LED lamp with diffuse-transmitting bulb	2992	3035	0,0017	71,3	71,3
3	LED lamp for interior lighting with clear glass	6472	6257	0,0070	73,6	73,3
4	LED luminaire for interior lighting with diffuse-transmitting glass	5413	5453	0,0019	72,9	73,0
5	LED lamp for interior lighting with prismatic glass	6510	6976	0,0096	71,6	75,9

The degree of change in the angular uniformity of colour parameters due to light scattering was investigated on lamps in which light diffusers were changed. Matte opal glass diffusers and polycarbonate prismatic diffusers were used.

The results of the study of the angular homogeneity of the colorimetric parameters of some LED lamps and fixtures are given in Table 1.

All investigated LED lamps and luminaires with diffuse diffusers have good uniformity of colour parameters. The angular non-uniformity $\Delta u'$, v' does not exceed 0.0031, which is less than the 3-degree McAdam ellipses (one degree corresponds to the value of 0.0013). Luminaires with clear protective glass, prismatic diffusers and lens optics have an unevenness that exceeds the 3-step Mc-Adam ellipses. The angular non-uniformity of these experimental luminaires $\Delta u'$, v' was in the range of values 0.0048–0.0096.

Analyzing the obtained data, we can conclude that the angular non-uniformity of LED lamps for general illumination, which almost all have a diffuse light scattering bulb, is within the 3-step McAdam ellipse ($\Delta u'$, $v' \leq 0{,}0039$), which meets the requirements to quality lighting. LED luminaires with transmitted diffuse light diffusers also have an angular non-uniformity of chromaticity not exceeding 3-step McAdam ellipses ($\Delta u'$, $v' \leq 0{,}0039$). For such lamps, in our opinion, it is enough to declare the average values of colorimetric parameters and the category of their deviation from the nominal values.

The results of measuring the angular dependence of CCT and SDCM for LED luminaires of different standard designs are shown in Figs. 1 and 2.

Currently, modulation depth (modulationdept, MD) and flicker index (flickerindex, FI) are often used to quantify flicker [14], but a number of publications have shown that both of these indicators are not fully able to objectively assess the level of flicker in terms of how they are actually perceived by man [15].

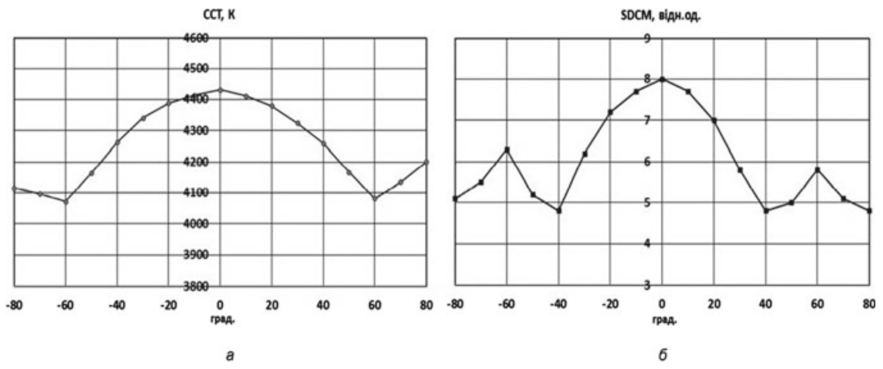

Fig. 1 Angular dependence of CCT (**a**) and SDCM (**b**) LED lamp with transparent protective glass

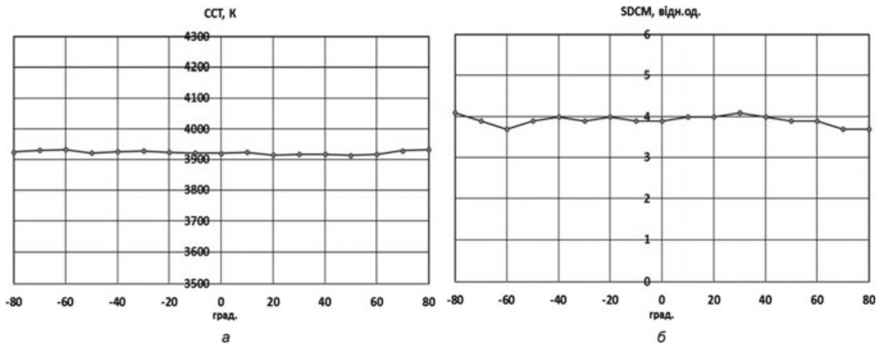

Fig. 2 Angular dependence of CCT (**a**) and SDCM (**b**) LED lamp with diffuse light diffuser

Flicker is of the greatest importance in the general lighting of residential premises, children's, school and medical institutions, industrial premises with mobile equipment and workplaces with intense visual work, etc. Criteria for low risk of light flicker and methods for their evaluation are recommended in the following regulations [16–30].

In [14] the data of many independent studies was summarized and the following safety criteria for light modulation were formulated:

(1) modulation depth Mod $\% = (L_{max} - L_{min})/(L_{max} - L_{min}) \times 100$ (where L_{max}, L_{min}—respectively maximum and minimum brightness), which corresponds to a low level of risk at frequencies below 90 Hz should not exceed the numerical values (in percent) determined from the expression

$$\text{Mod}\ \% \leq 0{,}025\text{f}, \tag{1}$$

(f—modulation frequency);

(2) at f > 90 Hz, the allowable modulation depth is determined from the expression

$$\text{Mod}\ \% \leq 0{,}08\text{f}, \quad (2)$$

The level of modulation at which no biological effects on the human body exist should be 2.5 times less than defined by expressions (1) and (2). P_{st}^{LM} of all studied lamps and fixtures also does not exceed 1—this means that the level of flicker detected by the observer with a probability of 50% lower than that of incandescent lamps with a power of 50 W.

Recently, scientific models have been developed that take into account the peculiarities of the human visual system in relation to the flicker of light. Such models are the indicator of short-term light modulation P_{st}^{LM}, and for the stroboscopic effect—the visibility index of the stroboscopic effect SVM.

The results of SVM can be interpreted as follows:

– at SVM = 1—the stroboscopic effect created by modulation of light is on the threshold of visibility. This means that the average observer can detect a stroboscopic effect with a probability of 50%;
– if the value of SVM < 1, the probability of detection is less than 50%, and if SVM > 1—the compliance will be higher than 50%.

Based on the obtained results, conclusions and recommendations for improving the light quality requirements of LED lamps and fixtures were made.

Today, short-term modulation dose has become a common standard and is proposed by CIE TN 006 to assess the perception of flicker to frequencies up to 80 Hz.

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Evaluation Criteria the Corrosion Protection of Structures by Actual Condition

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Abstract This work includes the results of studies about the state of the secondary protection against corrosion to ensure the building metal structures' durability. The task of preserving the qualitative and quantitative indicators under the influence of the aggressive atmosphere in industrial enterprises is being solved. **Methodology**. The technique of improving the efficiency of the means technology and methods of metal structures secondary protection from corrosion during the technical condition monitoring is stated. **Results**. The developed diagnostic procedures include statistical accounting and the corrosion state monitoring of metal structures, identifying the causes of the occurred defects and damage. The basis of prediction for service life and reaching the limit states are determined by the level of vulnerability and threats, taking into account the actual state. **Scientific novelty**. A procedure for servicing structures based on the actual state has been developed. The procedure for drawing up specifications of corrosion protection measures according to the criterion of corrosion hazard has been determined. It makes possible to meet the requirements for the reliability of building metal structures, to prescribe technological safety management measures during the established service life of construction objects. **Practical significance**. The proposed generalized indicators of the actual structures' corrosion state determine the structure's operability as a whole. The functional dependencies between the operability of the main and auxiliary structures are established. The relationship between the values of corrosion resistance indicators and metal structures durability are determined. Actual technical condition control consists of checking that the values of these indicators are within acceptable limits. Taking into account the degree of operating environment aggressiveness is one of the determining factors in order to ensure the secondary protection effectiveness against corrosion. This procedure is the basis for the rational specifications appointment for anti-corrosion protection systems with subsequent display in the design and technological documentation.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_20

Keywords Steel structures · Monitoring · Corrosion hazard · Damage · Actual condition

1 Introduction

Structural metal structures are designed on the basis of the same standards, may differ from each other in the likelihood of occurrence and emergency situations development in the failure event of any structural element [1].

Such cases are possible due to errors occurring during the creation or operation of structures, which leads to emergencies [2, 3]. An important indicator of mechanical strength, stability and environmental safety is the level of corrosion hazard of a construction site. This determines the readiness factor critical intervals of metal structures anti-corrosion protection in the corrosion effects design mode [4]. At present, the assessment of the steel structures corrosion state is carried out in accordance with the standards requirements [5, 6]. However, the limited composition of the defining parameters does not allow technical diagnostics to sign corrosion hazard when assessing the structures operational state. The problem is to ensure the metal structures safety in corrosive environments that has a complex multifaceted and multifactorial nature [7].

A special aspect of the corrosion-mechanical destruction problem is the service life management of structures and their protective coatings based on the technical diagnostics methods of buildings and structures resource.

2 Purpose

Research is aimed to ensure the quality and reliability of metal structures secondary protection measures while substantiating the technical and corrosion protection technological risks of industrial facilities structures [8]. The request is to develop a design solution that prevent the development of local, crevice, contact, intergranular corrosion and corrosion cracking. At the same time, increase in the thickness of rolled metal provides for the primary protection durability assessment in the calculated compliance confirmation with the required standards. Also, a design requirement was established not to take into account changes in bearing capacity as a result of an increase in the thickness of structural elements when using primary protection measures.

Thus, the absence of criteria for corrosion protection creates difficulties for monitoring and diagnosing the performance of structures subject to corrosive wear. The identification of the corrosion hazard level is understood as the process of detecting and establishing quantitative, temporal, and spatial characteristics. These characteristics are necessary and sufficient for monitoring the defects and damages interval values, which are permissible during the normal functioning of construction objects.

In the process of identifying the technical state of anti-corrosion structures protection systems, hazards list, the likelihood of their manifestation, spatial localization, possible damage and other parameters necessary to formalize the structures diagnostics tasks are identified. Compliance with the reliability conditions and constructive safety is achieved by ensuring technological safety based on the total quality management [9]. A significant level of wear and extended periods of stay in unfavorable conditions are threats to decrease in the structures quality, which entails increased requirements for improving the structures operational properties that are losing quality [10].

3 Methodology

The methodological approach of the work substantiates the composition and structure of the parameters of structures corrosion resistance for managing technological safety by reducing risks. This reduces the corrosive destruction likelihood and limits the potential damage if it occurs. The influence of external factors (aggressive environment) and internal parameters (structural form) on the building metal structures reliability indicators is considered for the zones of location of homogeneous structural elements groups (consignments). The corrosion effects' type and intensity are taken into account in the expert diagnostics process of the structures corrosion state. The significant factors that influence the degradation processes development in the structures material are determined. The procedure makes it possible to assess the nature of their impact on the facility operation quality, determines the need to create a unified audit methodology and quality management of the metal structures operation [11]. When developing a procedure for auditing a technical condition, a methodological basis of international standards ISO 9001 and IEC 300-1 was adopted, which regulates the quality management procedure at all stages of the structure life cycle [12].

To determine the significance of the corrosion destruction factors that affect the decrease in the operational structures bearing capacity, an assessment of the quality loss based on the Pareto method is used. In accordance with the procedure, the corrosion state control is carried out accordingly to the reduced characteristic of the quality loss $\overline{\mathrm{F}}\mathrm{e}$ in corrosive media, established by the method of Taguchi [13]. The quality index $\overline{\mathrm{F}}\mathrm{e}$ is a relative measure of the effectiveness of primary and secondary protection measures. Risk levels for technological safety (Ri) are determined, taking into account the actual influence of the factors of corrosive aggressiveness of the operating mode [14]. The quality indicator $\overline{\mathrm{F}}\mathrm{e}$ is a function of the values of the monitored indicator $\gamma_{zk}(\gamma_{zn})$:

$$\overline{F_e} = \left[\frac{2}{\gamma_{zk(n)}^{max} - \gamma_{zk(n)}^{min}} \left(\gamma_{zf} - \frac{\gamma_{zk(n)}^{max} + \gamma_{zk(n)}^{min}}{2} \right) \right]^2 \quad (1)$$

where: Γ is the ratio of the reliability reserve; γ_{zk}—coefficient of reliability of anticorrosion protection, is established when substantiating methods of primary protection; γ_{zf}—coefficient of reliability of anticorrosive protection, according to the data of monitoring the corrosion state during operation.

4 Main Material

Steel structures corrosion destruction is determined by external influences of the operating mode and depends primarily on the environment aggressiveness degree. Taking into account the electrochemical nature of corrosion damage under the strength change is based on physical models. They characterize changes in the geometric parameters and properties of the material over time under environment's aggressive influences [15]. The procedure includes the implementation of the measures to identify the causes of critical corrosion damage to structural elements that are in the construction objects operation. The characteristics of the metal structures operating conditions are studied also technical condition of the main elements, assemblies, the conditions for their fastening in accordance with the regulatory requirements is investigated [16–18, 21–27]. Setting of the criteria for limit states is based on the results of assessing the actual state, is performed using the feedback coefficient of the structures operating mode (ψ)on the dependencies:

$$N = \Phi/(\Gamma - \psi) \tag{2}$$

$$\gamma_{Sp} = \Gamma - \psi \tag{3}$$

where N is the largest design force in a structural element, kN; Φ is the ultimate force, kN, which an element with a damageability characteristic can take Θ_f; Γ is the ratio of the reliability reserve; γ_{sr}—technological safety factor.

The use of the feedback factor of the operating mode (ψ) ensures the implementation of an analytical approach to the technological safety management. Reliability assurance programs are formed on possible causes analysis and consequences of failures and failure criticality assessment (FMECA). In this case, the criterion of structures technological safety γ_{sr} can be considered as the throughput of resource regulation (η)):

$$\eta = {}^{1}/_{\gamma_{sr}} \tag{4}$$

With the accumulation of defects and damages Θ_f, the feedback coefficient (ψ) characterizes the decrease in the performance indicators of steel structures at the established design value of the reliability reserve ratio (Γ). The effects of negative loads and influences cause the appearance of signs of structures limiting states. The throughput of resource regulation characterizes the permissible change in the design value of the reliability reserve ratio (Γ) to ensure operational state. This operation determines the design and technological constraints for restoring the bearing capacity after repair.

The problem of ensuring technological safety is the “human factor”, which is associated with decision-making, based on the results of monitoring and diagnostics of the steel structures corrosion state. The existing recommendations for the control and renewal of anti-corrosion protection do not regulate the corrosion hazard conditions and construction sites corrosion protection.

Safety management should be carried out on the basis of risk assessment as a comprehensive indicator of the corrosive structures security. In order to eliminate the uncertainty of decision-making, when restoring the objects operational state, the method has been developed for assessing the degree of critical defects and damages to structures. The method that ensures the means reliability and protection methods, take into account the redundancy of the bearing capacity, includes four successive stages: setting the reliability indicators; selection of backup conditions for primary and secondary protection; criterion justification for a single refusal by responsibility category; development of the quality renewal measures specification.

Responsibility categories of structures for corrosion protection are established taking into account a partial decrease in the level of primary protection performance (reliability coefficient γ_{zk}) and secondary protection (reliability coefficient γ_{zn}), a generalized indicator of protective properties Az depending on the risk class.

It is proposed to determine technological safety (*Ri*, score) according to monitoring data depending on the risk class, threat level and vulnerability of corrosive structures (Table 1). At the same time, one of the determining factors for ensuring the effectiveness of measures for primary and secondary protection against corrosion is taking into account the aggressiveness of the effects of the operating environment. Threat levels are set: H—low, O—limited, C—medium, V—high, P—extreme.

Table 1 Risk level for process safety (Ri) [19]

Responsibility group object functions	Level of threat (status category):				
	H(I)	O(II)	C(III)	V(IV)	P (V)
	Damegability (category of responsibility)				
	В,Б,А	В,Б,А	В,Б,А	В,Б,А	В,Б,А
Service. Non production (R5)	1,2,3	2,3,4	3,4,5	4,5,6	5,6,6
Ervice. Industrial (R4)	2,3,3	3,4,5	4,5,6	5,6,7	6,7,7
Auxiliary (R3)	3,3,4	4,5,6	5,6,7	6,7,8	7,8,8
Basic. Serviceable (R2)	4,4,5	5,5,7	6,7,8	7,8,9	8,9,9
Basec. Non-stop (R1)	5,5,6	5,6,7	7,8,8	8,9,10	9.10,10

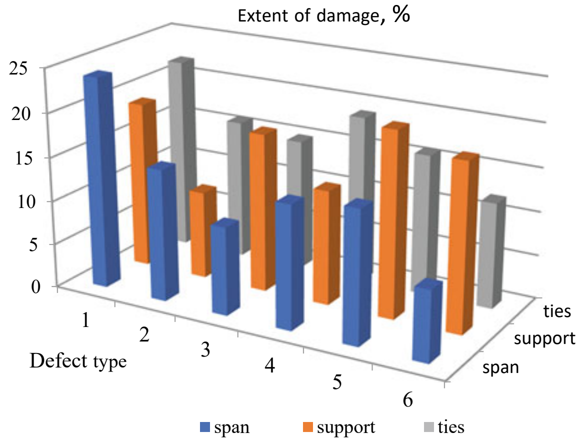

Fig. 1 Defects of the metal structures: 1—lack of surface preparation for applying the topcoats of primer and enamel; 2—corrosion damage to the main bearing structures; 3—destruction of anticorrosive coating layers; 4—defects in the metal structures during installation, welding, and assembly procedures; 5—damage as a result of mechanical stress; 6—other defects and types of damage [20]

5 Results

As a result of the developed procedures, the need to update the regulatory provisions requirements for the maintenance of structures subject to corrosive wear was established. A technique is proposed for using a quantitative assessment of predicting corrosion protection during the structures life cycle.

The approach is based on the assessment of technical and technological risks of restoring the structures operability. It makes possible to minimize the potential damage to the residual risk of facilities corrosion hazard while ensuring reliability based on survey data. Statistical analysis and quantitative assessment of the bridge structures state was carried out on the basis of data from the study of the metal structures preparation and their operation (Fig. 1).

6 Scientific Novelty and Practical Significance

The practical implementation of the proposed methodological approach has led to a number of conclusions:

- the operational state of the structure as a whole is characterized by generalizing indicators of the actual structures' corrosion state;
- a functional relationship is established between the operability of the main and auxiliary structures, generalizing indicators values of corrosion resistance and durability;
- control of the actual technical condition is performed by checking whether the values of these indicators are within the permissible limits.

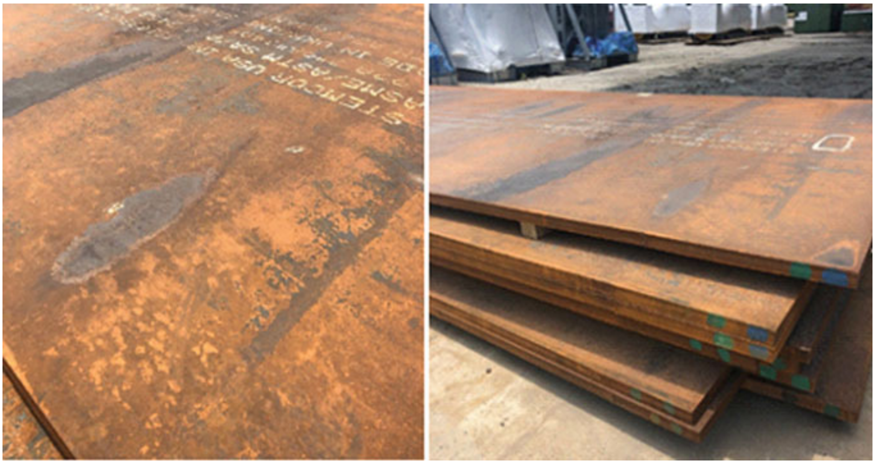

Fig. 2 Surface condition at the stage of preparation for production

The systematization of the signs of the structures operational state is carried out using the classification signs of the database indicators, depending on the level of vulnerability and threats. The categories of responsibility (acceptable—P, low—N, medium—C, significant—Z, high—V, unacceptable—NS) are proposed for the technological safety of buildings and structures, which are characterized by the coefficient of technological safety, γ_{sr} (Table 2, Figs. 2, 3 and 4).

The procedure is the basis for the rational compilation of anti-corrosion protection systems specifications and the display of design and technological equipment in the executive documentation.

Development of specifications for secondary corrosion protection of metal structures during field studies.

Fig. 3 Monitoring of bridge structures

Fig. 4 Evaluation of the effectiveness of the specifications of secondary protection (exposure duration 2 days)

Table 2 Categories of responsibility of technological safety structures

The nature of threat level	P (0)	N (I)	C (II)	Z (III)	V (IV)	NS (X)
Hazard signal colour	Blue	Green	Yellow	Orange	Red	Black
Categories of responsibility	$R0$	$R1$	$R2$	$R3$	$R4$	RX
γ_{sr}	More 1,2	1,15…1,2	1,1…1,15	1,05…1,1	1,0…1,05	Less 1,0

7 Conclusions

The structure of technological safety indicators for the analysis of data from expert diagnostics of the state of structures has been substantiated. It made possible to form a process approach in order to make decisions on operational-tactical (threats 0–IV) and strategic (threat X) values, aimed at reducing the risks of operating facilities. Tactical decisions, based on the diagnostics results of the technical condition of structures (technological safety coefficient $\boldsymbol{\gamma}_{sr} > 0$), are aimed at implementing preventive measures to ensure the operability of structures.

Strategic decisions are made when investigating the causes of accidents and catastrophes (coefficient $\boldsymbol{\gamma}_{sr} \leq 0$),) caused by the creating or not creating conditions for the implementation of preventive measures. The most probable reason for the detected failures of metal structures is the presence of corrosive nature multiple defects. In the absence of mechanical properties guarantees and chemical composition. The technical condition of the structures confirms the need to take additional structural and technological measures to reduce the risks during operationсрока:

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The Development and Calculation of Tanks for Storage of Fuels and Lubricants in the Field

Volodymyr Pents, Vasyl Savyk, Petro Molchanov, Illiashenko Yurii, and Nadiia Ichanska

Abstract There have been considered the main calculations of developed horizontal cylindrical tank for wartime conditions. There have been revealed advantages and disadvantages of constructive solutions in accordance with the principles of simplicity and efficiency. There has been proposed to increase material savings through detailed calculation.

Keywords The horizontal cylindrical tank · The tank wall · Support rings of rigidity · Supports for horizontal tanks

1 Introduction

The storage of fuels and lubricants is a responsible process that requires the proper organization and preparation. In particular, it is necessary to provide the appropriate capacity. Tanks for fuels and lubricants are available in a wide variety of types and are classified according to a number of characteristics.

To save metal and ease of control, it is desirable to make all the joints of the body and bottom sheets butt, regardless of the accepted technology of manufacturing tanks (individual shells, roll method or method of elastic deformation). It is desirable to connect the rings of rigidity with the wall of housing in contact with a double-sided intermittent seam, which is superimposed in a checkerboard pattern with the key length of 100 mm and gap between keys of 200 mm; the leg of these seams is within 4–8 mm depending on the thickness of tank wall and stiffening ring.

In previous works [1, 2], there were accounted sheet constructions, which are the combination of cylindrical, spherical, conical and other shells that are in a biaxial stress state. Also, the problematic issues of construction and operation of steel tanks in

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_21

complex geotechnical conditions are systematized as well as the practical experience of design solutions for highly efficient systems "artificial foundation—foundations—reservoir" for static and dynamic effects [4, 5]. However, in wartime, the dangers of hostilities in the place of tank installation and design features of tanks are different. For such conditions, the modernized design of horizontal tank and the method of calculation of tanks to store fuels and lubricants in the field in order to ensure trouble-free operation of these tanks in extreme situations.

2 Main Body

Recently, conditions of a humanitarian crisis have been created in Ukraine due to the difficulty of logistics and the destruction of the infrastructure of refinery enterprises and the surrounding fuel and lubricants warehouses.

In the current conditions of wartime and the danger of hostilities at the site of the tank, we propose to develop horizontal cylindrical tanks to store liquids and liquefied gases at internal overpressure up to 1,8 MPa and vacuum up 0.1 MPa of the modernized structure. Tank capacity is 75 m^3. The advanced horizontal tank consists of the housing (wall) 1, two bottoms 2, partitions 3 and 4 and supports 5. The horizontal tank consists of the housing (wall), two bottoms, support diaphragms, intermediate stiffeners and supports (see Figs. 1 and 2).

Installed partitions allow you to divide the tank into parts, if one part is damaged, the other will be working. The body of the tank consists of sheets of standard sizes from 1500 to 2200 mm wide with planed edges connected butt. At the thickness of

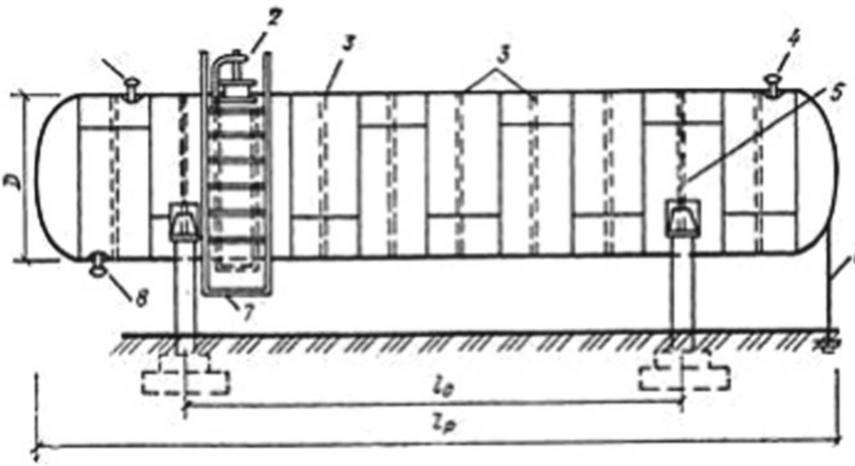


Fig. 1 Horizontal cylindrical tank. 1. the union for loading; 2. the manhole for inspection; 3. the stiffening ring; 4. the fitting for ventilation; 5. the support diaphragm; 6. the grounding; 7. the ladder; 8. the fence union

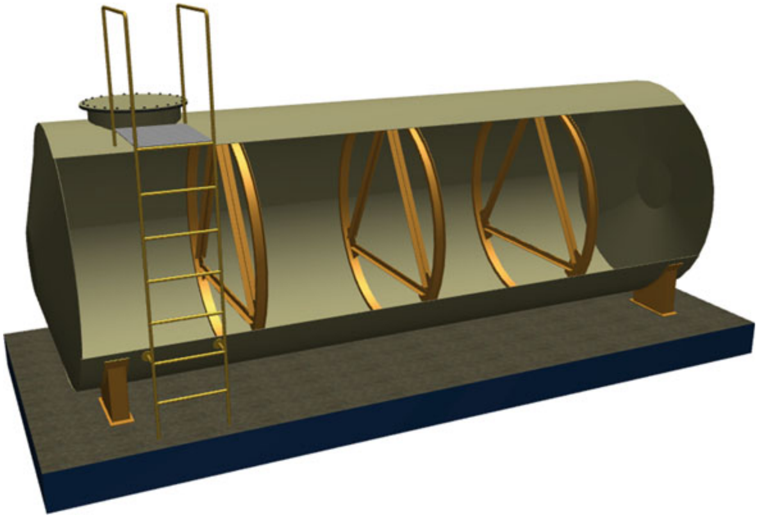


Fig. 2 The tank model to store fuels and lubricants in field conditions

sheets to 12 mm at first a cloth of a wall of tank is welded, and then it is folded and the final longitudinal weld is carried out. With the greater thickness of sheets, separate shells are made of two rolled sheets, which are joined together. In this case, the longitudinal seam is performed in the run. The tank body is equipped with fittings for loading and ventilation, necks with a manhole and the lid for inspection, cleaning and repair, as well as grounding.

When designing advanced tanks, we take such dimensions that would provide the greatest capacity at the lowest material consumption, i.e. the optimal size. Let's make the necessary calculations.

The construction of horizontal cylindrical tanks

These tanks can be above ground or underground. Horizontal cylindrical tanks are designed for storage of petroleum products at excess pressure up to 0.2 MPa and liquefied gases at pressures up to 1.8 MPa and more. At temperature decrease in such tanks vacuum to 0,1 MPas is possible. These tanks are made with a volume of up to 100 m^3 for petroleum products and up to 300 m^3 for liquefied gases. Their length is 2–30 m, diameter—1.4–4 m, wall thickness—3–36 mm.

The body of the horizontal tank consists of several sheet sections that are welded in the form of a ring of one or more sheets. Welded seams for joining sheets and sections are butt. To ensure rigidity in each section it is worth placing the rigidity ring of angles (Fig. 1).

Depending on the pressure, the bottoms of horizontal tanks can be flat, conical, cylindrical or elliptical. Flat bottoms are easy to manufacture, but need to be reinforced with ribs, so they are used in small tanks with low pressures (up to 40 kPa). At pressures up to 200 kPa, spherical or elliptical bottoms with a smooth transition from the bottom to the wall are used. Such tanks are more reliable in operation [1].

Above-ground cylindrical tanks rest on two saddle-shaped supports or on two pairs of racks. The angle of coverage of the support varies between 60 and 1200, Underground tanks rest on a solid saddle-shaped support. In the middle of the tank in the place of support arrange a saddle-shaped diaphragm in the form of a ring of rigidity from the angles welded to a wall. The tank housing is equipped with fittings for loading and ventilation, the neck with manhole and the cover for inspection, cleaning and repair, as well as grounding.

Features to calculate cylindrical horizontal tanks

For the design scheme of the cylindrical tank take a two-cantilever beam of annular cross section. Ring stresses σ_2 have the maximum value in the lower part of the case where the greatest hydrostatic and excess pressure is observed. The calculation is based on the formula

$$\sigma_2 = (\gamma_{f2} p_0 + \gamma_{f1} \rho 2r_2) r_2 / t \le \gamma_c R_y, \tag{1}$$

where ρ—the density of the liquid.

The meridional stresses are defined as for a simple beam

$$\sigma_1 = \frac{M}{W}. \tag{2}$$

Checking the bending strength of the tank is performed with the combined action of bending moment and internal pressure according to the formula

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2} \le \eta \gamma_c R_y, \tag{3}$$

where $\eta = 0{,}9$—coefficient that increases the reliability of explosive vessels.

In addition, it is necessary to check the walls and bottom for stability.

The main features of the design of horizontal tanks

The development of oil and petrochemical industry is associated with the need to build a large number of tanks for storage of raw materials and finished products. Horizontal cylindrical tanks are responsible structures designed for storage of petroleum products at excess pressure up to 0,2 MPa and liquefied gases at pressures up to 1,8 MPa and more. At temperature decrease in such tanks vacuum to 0,1 MPas is possible. These tanks ensure uninterrupted supply of goods through the main pipeline systems. At the same time, tanks are high-risk facilities, accidents which are accompanied by the spillage of huge masses of liquid, which can lead (and have led) to catastrophic consequences with human casualties, violations of regular operation of transportation and storage of oil and petroleum products, and significant pollution of the environment, severe economic consequences, which is also important in modern wartime conditions and the danger of hostilities at the site of the reservoir.

They are completely manufactured at steel plants, and therefore, due to transportation on railway platforms, they must have a maximum diameter of 3,25 m and the length of no more than 15–20 m, depending on their installation on one or two platforms. The volume of the tanks varies from 75 to 400 m^3. With volumes of more than 200 m^3, due to their long length, they are divided into two or three starting blocks, followed by a seam on the construction site.

The body of the tank consists of sheets with standard sizes from 1500 to 2200 mm wide with planed edges connected butt. At the thickness of sheets to 12 mm at first a cloth of tank wall is welded, and then it is folded and the final longitudinal weld is carried out. With the greater thickness of sheets, separate shells are made of two rolled sheets, which are joined together. In this case, the longitudinal seam is performed in the run.

The tank bottoms are designed flat with the overpressure of up to 40 kPa, conical—with the pressure of up to 70 kPa, spherical—with the pressure of 40 to 200 kPa and elliptical (see Fig. 5)—with the pressure of 200 (for light gasoline fractions) to 1800 kPa for liquefied propane.

To ensure rigidity during transportation and installation, the perception of vacuum and wind load, the tank wall is reinforced with support and intermediate rings of rigidity from rolled corners, rolled on a pen and welded with a pen to the wall.

Intermediate stiffeners must be placed at r tw $\geq$ 200 (r—the radius of the tank; tw is the wall thickness of the tank). Since the value of r tw in tanks is often more than 200, the intermediate stiffeners have $1.5 \div 2.2$ м depending on the width of the sheets used for the wall. As intermediate rings of rigidity it is offered to use uneven-shelf hot-rolled corners:

at V = 25…50 $м^3$—corner number 8 5 (⌊80 × 50 × 5);
at V = 75…100 $м^3$—corner number 9 5.6 (⌊90 × 56 × 6).

Rigid support rings have an additional diaphragm, often triangular or cross-shaped. It is desirable to connect the diaphragms with stiffening rings without knotted sheets, which avoids marking when making the details of the supporting diaphragms, simplifies the assembly and welding of diaphragms, reduces metal costs.

Supports for horizontal tanks for petroleum products and liquid chemicals are usually saddle-shaped with the coverage angle of 90°, and for tanks for liquefied gases and for refineries—saddle-shaped with the coverage angle of 120°. In the first case, the supports are made of precast concrete blocks or rubble concrete, in the second—of reinforced concrete or steel. The horizontal tank for liquefied gases is not welded to the steel saddle supports, but connected to them with special slats. On one of the supports the tank is fixed, and on the other it is movable. This is achieved by arranging oval holes in the legs welded to the tank, located in a movable support. When the hole is increased by 25 mm in the direction of movement, it is possible, when the temperature changes by 100°, to assign a distance between the axes of the supports not more than 25/1.2 = 21 м (1.2 мм − elongation of the tank for each meter of its length with increasing temperature by 100°). Vertical load on the support N is the same as for a conventional hinged beam, and the horizontal load is equal to $H = \alpha \cdot N$, where $\alpha = 0.15$—the coefficient of friction between the tank and the support.

At the considerable temperature difference and big span of mobile resistance carry out roller (see Fig. 3). In this case, the coefficient of friction α = 0,04.

If the tank is arranged not on the mezzanine floor, but on the ground, then under favorable soil conditions, horizontal tanks with a capacity of 75 m^3 and more should be rationally installed on racks resting on two strip foundations or on separate foundations. Racks can be prefabricated reinforced concrete, pipe concrete or steel ring, cross or I-section. For tanks of this volume, the support in the form of racks is cheaper than saddles 25–60%.

Regardless of the accepted design scheme of the tank, it is necessary to unambiguously establish the relationship between its volume V and the surface area S and the overall dimensions: diameter D (radius r), length, distance between supports. In general, this link can be provided as:

$$V = \pi \cdot r^2 + K_1 \cdot r^3, \tag{4}$$

where K_1—the coefficient depending on the shape of the bottoms: for flat bottoms $K_1 = 0$; at sloping conical with an angle at the apex 156° $K_1 = 0.762$; at ellipsoidal $K_1 = 2.094$; at spherical $K_1 = 5.33$.

$$S = 2 \cdot \pi \cdot r + K_2 \cdot r^2, \tag{5}$$

where K_2—the coefficient depending on the bottom shape: for flat bottoms $K_2 = 6.28$; at sloping conical with an angle at the apex 156° $K_2 = 6.69$.

When designing tanks, it is necessary to take such dimensions that would provide the greatest capacity at the lowest cost of material. Such dimensions are called optimal. For bulk tanks operating at low overpressure or no overpressure at all (mainly flat and conical bottoms), the optimal tank diameter is determined by the asymptotic expression:

$$\text{Dopt} = 0.8, \tag{6}$$

and for tanks experiencing medium or the high excess pressure (tanks with ellipsoidal and spherical bottoms) according to the formula:

$$\text{Dopt} = 0.6. \tag{7}$$

Formulas (6), (7) indicate the average values of the coefficients of proportionality. As the tank capacity increases, they decrease, and as the tank capacity decreases, they increase.

The distance between the tank supports is chosen so that the equality of flight and reference moments from the action of the transverse load q, evenly distributed over the body length (see Fig. 4). If we denote by n the number of spans of the tank body between the supports, and through α—the coefficient of proportionality in the formula for determining the span bending moments in the n-span beam,

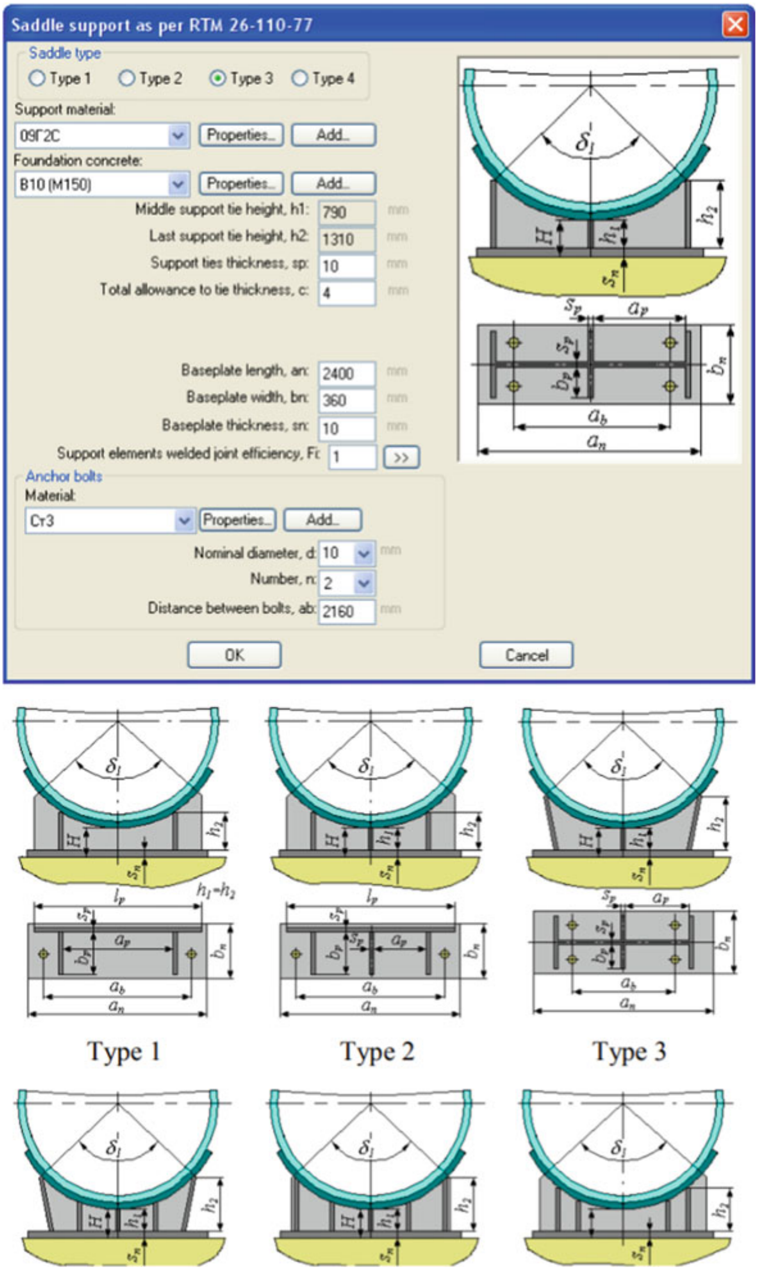


Fig. 3 Saddle support options

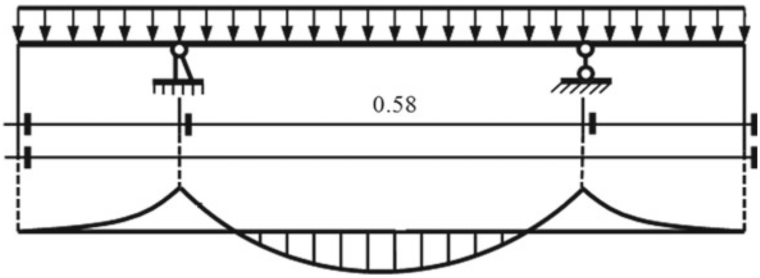


Fig. 4 The calculation scheme of two-console cylindrical tank

$$\zeta = (n - 2\alpha)\left(n^2 - 4\alpha\right). \quad (8)$$

So for the tank on two supports $n = 1$, $\alpha = 0.125$, $\zeta = 0.586$; on three supports $n = 2$, $\alpha = 0.070$, $\zeta = 0.395$; on four $n = 3$, $\alpha = 0.080$, $q\ \zeta = 0.28$.

Tank supports should be designed so that the height from the ground to the bottom of the tank body does not exceed 3,0 m (provided that the supports are unified depending on the operating conditions and terrain). The width of saddle supports for tanks up to 16 m^3 should be at least 200 mm, from 20 to 50 m^3—300 mm, from 63 to 100 m^3—400 mm, from 125 to 200 m^3—500 mm, from 250 to 350 m^3—600 mm.

External and internal loads on the tank body

The elements of the horizontal cylindrical tank are subject to the following loads:

the hydrostatic fluid pressure;
the excess liquid vapor pressure;
the vacuum;
the own weight,
the wind load;

The load in the form of hydrostatic pressure depends on the density of the fluid hp, and the depth of the level for which the pressure is. This load acquires the maximum value at the lowest point of the tank:

$$p_{hp} = 2 \cdot \gamma_{f(hp)} \cdot \rho_{hp} \cdot r \cdot g \quad (9)$$

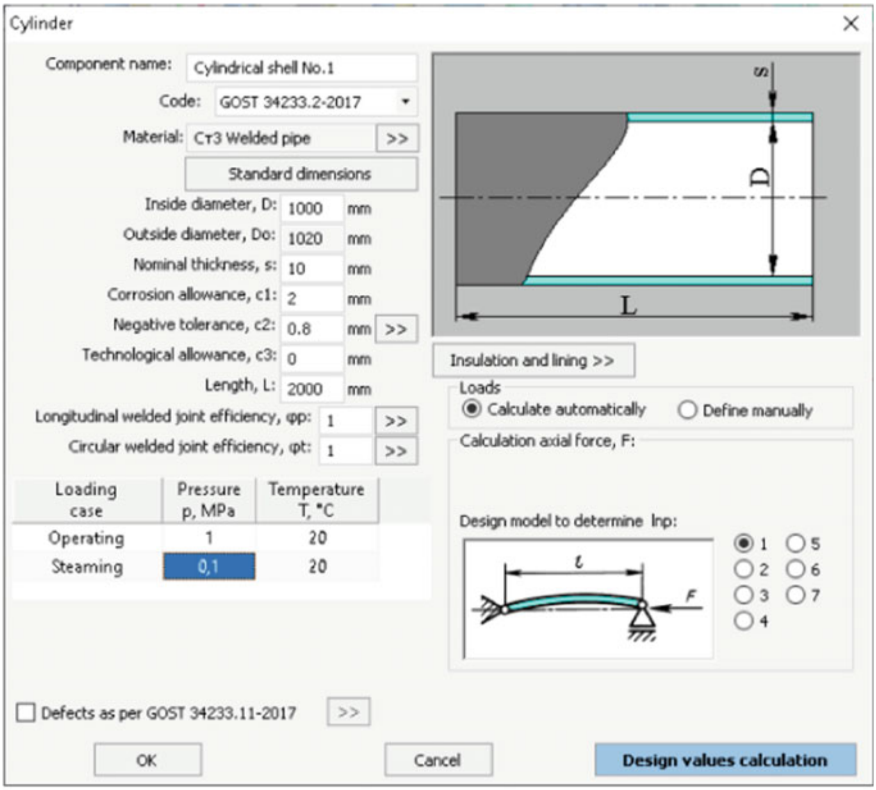
where—f(hp)—1.1—the reliability factor for hydrostatic fluid pressure.

The maximum calculated value of excess fluid pressure is in the form of:

$$p_{sp} = \gamma_{f(sp)} \cdot p_{b(sp)}, \quad (10)$$

$p_{b(sp)}$—the characteristic value of excess fluid pressure (see Table 1); $\gamma_{f(sp)} = 1.2$ the reliability coefficient according to the maximum calculated value of the load from the excess pressure of the fluid.

The calculation of tank wall for strength and stability.



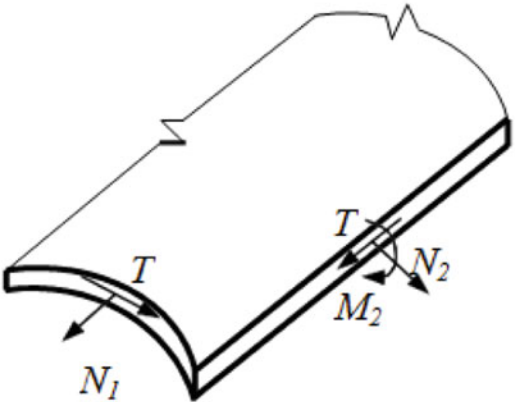


Fig. 5 The distribution of forces in the element of the tank wall

Table 1 The density and overpressure of some types of petroleum products

Product	Density, т/м^3
Aviation gasoline	0.75 … 0.77
Motor gasoline	0.7 … 0.76
Legroin	0.77 … 0.83
Crude oil	0.83 … 1.04
Tractor kerosene	0.82 … 0.89
Kerosene lighting	0.85
Aviation oils	0.90
Diesel oil	0.90
Tractor ink	0.91 … 0.93
Cracked gasoline	0.75
Dark petroleum products	0.90
Refluxed oil	0.90
Oil fuel	1.0
Diesel	0.90

Settlement provisions

The wall of the horizontal cylindrical tank is a closed cylindrical shell of medium length ($0.5 \le l\ r \le 10$), freely supported on two supports. Such shells are calculated on the basis of half-moment theory B.З. Vlasova (bending moments are not taken into account along the generative shell, but are taken into account in the annular direction) and assumptions VV Novozhilova [3].

T—tangential effort.

- neglects the tangential movements of the tank wall in the expression of transverse bending deformation;
- in the differential equation of equilibrium of the elements of the shell does not take into account the component containing the transverse force Q_2.

Taking into account the above assumptions in the wall cross-sections of tlhorizontal tank, the following efforts are taken into account (see Fig. 5):

N_1—the longitudinal (along the generating) force;
N_2—the annular force;
M_2—the annular bending moment;

It should be emphasized that when determining the longitudinal normal force N_1 from the own weight of the tank, hydrostatic pressure of the liquid when the tank is full, wind and seismic effects, the cylindrical closed shell (wall) can be replaced by a beam of annular cross section at any geometric tank parameters.

The wall thickness of tank is determined by the strength condition (should not be less than 4 mm) and checked for stability.

The tank wall at full filling with liquid and the presence of excess pressure receives the highest normal tensile stresses in the meridional σ_1 and in the circular direction σ_2 at the lower cross-sectional point [8] of the tank. Normal stresses σ_1 consist of two components:

$$\sigma_1 = \sigma^A + \sigma^B :$$

stress from liquid pressure and excess gas pressure at the bottom:

$$\sigma^A = 0.5_{hp} \cdot \left(p_{sp} + p|_w\right) \cdot rt^P, \quad (11)$$

where $t^P = t - (c + c + c)$—the estimated wall thickness of the tank is the actual thickness tw except for the additive for the extraction of metal when rolling sheets.

c_1, corrosion additives c_2 and allowances for negative tolerances on sheet thickness c_3;

r—the radius of the tank in cross section.

The numerical value of the first additive can be taken as equal $c_1 = 0.8$ мм. The additive for corrosion during storage of commercial petroleum products can be taken from 0,5 to 1,0 mm. The allowance for negative tolerances for sheet thickness, which is most often used in tank construction, is taken according to the data in Table 2.

The calculation of flat and conical bottoms for the horizontal tank.

Horizontal tanks have bottoms of different structural shapes: flat (ribless and ribbed), conical, spherical and ellipsoidal. The following are methods for calculating these types of bottoms for internal uniform pressure.

The calculation of flat ribless bottoms

The calculation of flat ribless bottoms should begin with the value of the cross section of the stiffening ring and the thickness of the bottom tb. It is recommended to take a stiffening ring in the form of uneven shelves, and the thickness of the bottom within $t_b = 4 \div 5$ мм.

The flat ribless bottom (Fig. 5) is considered as a membrane with elastic fastening on a contour (taking into account deformations of a ring of rigidity to which the

Table 2 Maximum deviations in sheet thickness (Appendix c3)

Thickness, mm	Maximum deviations in sheet thickness for a symmetrical tolerance field at accuracy of VT (high) and BP (increased) at width, mm					
	1500		1500–2000		2000–3000	
	VT	BP	VT	BP	VT	BP
5–10	±0.4	±0.45	±0.45	±0.5	±0.5	±0.55
10–20	±0.4	±0.45	±0.45	±0.5	±0.55	±0.6
20–30	±0.4	±0.5	±0.5	±0.6	±0.6	±0.7

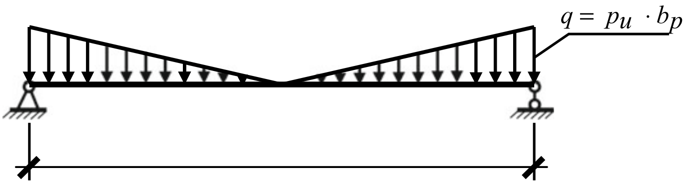


Fig. 6 The estimated scheme of the radial edge of the flat bottom

membrane fastens). The strength of the bottom is checked by comparing the normal radial stresses in the center of the bottom.

Calculation of flat-ribbed bottoms

It is recommended to use a flat ribbed bottom if a thickness of more than 5 mm is required for a ribless bottom. The flat bottom rests on np radially located edges (see Fig. 6). For calculation the strip of unit width which leans against radial edges as an indivisible beam working according to the scheme of a bending-rigid thread is allocated. The number of radial edges [9] np is taken as a multiple of four. The bottom strip absorbs the tensile force H and the bending moment, which will be maximum over the rib (support). The condition of the bottom strength in this case is:

If the strength of the bottom is insufficient, it is necessary to increase the number of radial ribs. The radial rib is checked for strength as a beam on two supports (Fig. 6).

The calculation of conical bottoms

The conical bottom of tank is represented by a momentless flat conical shell under pressure. The bottoms count on the strength from hydrostatic and overpressure and resistance to vacuum. The calculated schemes of the conical bottom are shown in Fig. 7. The strength of the conical bottom is checked [10–14] by the ring normal stresses.

The calculation of spherical bottoms.

Spherical bottoms with the radius of curvature equal to the radius of the tank body r, count on the strength at internal pressure by the formula:

$$\sigma_1 = \sigma_2 = 0.5 \cdot p_u \cdot r/t^p \leq \gamma_c \times R_{wy}. \quad (12)$$

The bottom stability is checked by the expression:

$$\sigma_1 = 0.5 \cdot p_u \cdot r/t^p \leq \sigma_{cr,1}, \quad (13)$$

where $\sigma_{cr,1}$ critical stresses according to the formula (13) at $\xi = 1$ та $t^P \equiv t^P$.

The design and calculation of the conjugation of flat bottoms with the wall of the horizontal tank.

The flat bottom, through the ring of rigidity, which is an integral part of the bottom, extracentrally transmits forces to the area of wall adjacent to the bottom, causing it and

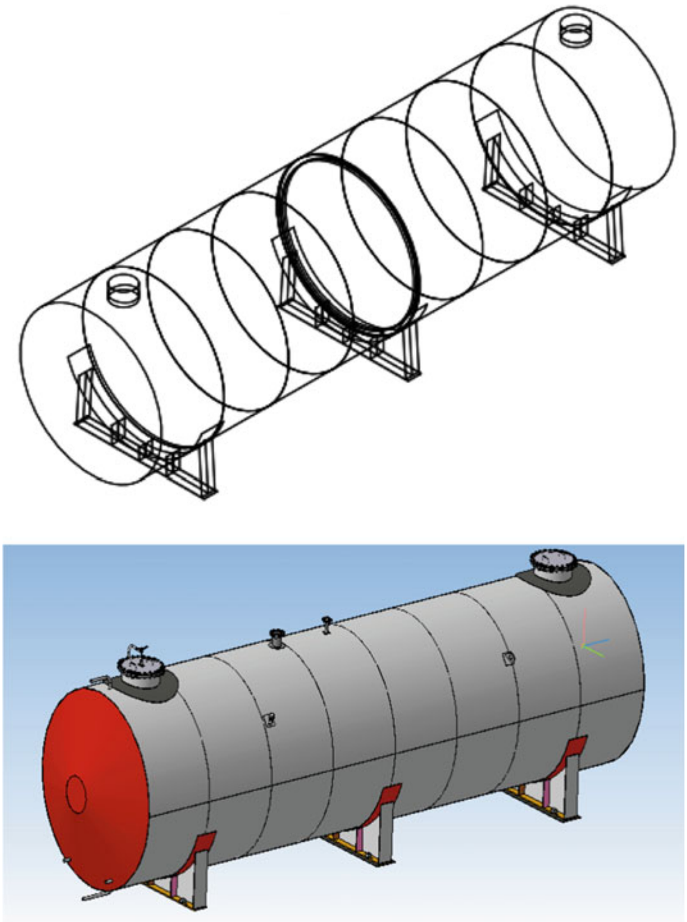


Fig. 7 The optimal design of the tank for storage of fuels and lubricants in the field

the peripheral part of the bottom bending moment. The technical theory to calculate the conjunction node of a flat bottom with the tank wall is schematically stated in the designer's guide [6] from metal structures. However, the specifics of the calculation of the conjugation of the bottom with the wall of the horizontal tank is that in this area does not take into account the bending moment of the edge effect.

Hydrostatic and excess pressures cause the tension in the bottom and compression in the stiffening ring. As shown above, when calculating the bottom take the pressure evenly distributed, which corresponds to the pressure in the center of the bottom. The normal tensile stresses that occur in the center of the bottom are determined by formula (12), and the normal radial stresses along the contour of the bottom will be smaller than in the center. Normal stresses in the wall and bottom from the moment Mw quite significant. The source [16–18] provides recommendations for the use in the calculations of this node of the hinge of plasticity, which occurs in the area of the weld. However, this does not take into account the effect of the moment of the edge effect, similar to the moment in the conjugation zone of the wall with the bottom of the vertical cylindrical tank, which reduces the impact Mw.

To determine the bending moment in the zone of boundary effect as a result of hydrostatic and excess pressures, as in the calculation of the vertical cylindrical tank, strips of unit width cut from the wall and bottom and rigidly connected at the node are considered. The strip is cut from the wall, is considered as a beam on an elastic base, and the bottom strip—as an element of a round thin plate.

The basic system of the method of forces can be obtained by inserting the hinges in the joints of the bottom with the wall (see Fig. 7). The pressure on the bottom is assumed to be uniform and equal to the pressure in the center of the bottom to the formula (13).

Features of tank design

To save metal and ease of control, it is desirable to make all the joints of the body and bottom sheets butt, regardless of the accepted technology of manufacturing tanks (individual shells, roll method or method of elastic deformation) (see Fig. 8).

It is desirable to connect the rings of rigidity with the wall of housing end to end with a double-sided intermittent seam, which is superimposed in a checkerboard pattern with the key length of 100 mm and the gap between the keys of 200 mm; the leg of these seams is within 4–8 mm depending on the thickness of tank wall and

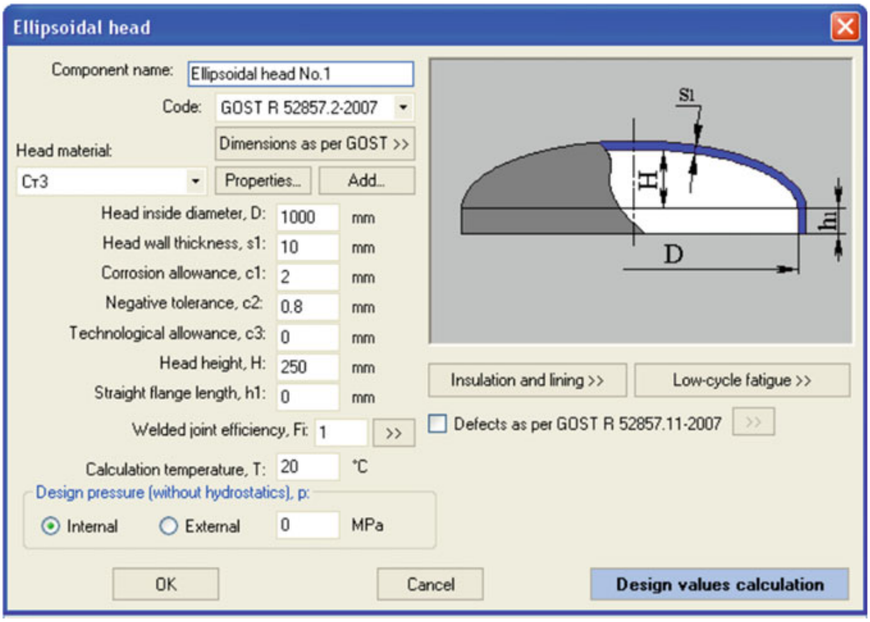


Fig. 8 The calculation of tank part using software

stiffening ring. For internal intermittent seams, which attach the abutment angle to the flat-bottomed tank body and the flat conical bottom board, the key lengths remain the same (100 mm) and the clearance between the keys is halved (up to 100 mm).

The inner support rings of horizontal tanks are rationally made of single corners, bent so that the shelf, which is perpendicular to the plane of the ring, is turned to the center of the cross section of the tank. This ensures the manufacturability of the structure and saves metal.

If the radius of the hull to the wall thickness is more than 200, in addition to the support rings in each shell, an intermediate stiffening ring should be provided to ensure rigidity during the transportation, installation and vacuum and to ensure the required accuracy of measuring the volume of liquid filling the tank. In the lower part of the support and intermediate rings of rigidity is a cut not less than 150 mm wide, required for the drainage of domestic water and sludge. The connection of intermediate stiffeners and support rings must be butt and placed in the place of the lowest stresses to avoid the use of reinforcing pads: in the unsupported ring—in the cross section corresponding to the angular coordinate calculated from the upper cross section of the ring and equal to 45° [18–28]; in rings resting on a saddle support, supported by a triangle, square, straight cross or horizontal rod, located in the middle of the ring—in the cross section corresponding to the angular coordinate of 30°; in a ring resting on a saddle support and supported by a horizontal rod, located at a distance of half a radius from the bottom of the ring—in the cross section $\theta = 45°$; in a ring resting on two struts located against the ends of the horizontal diameter and reinforced with two horizontal rods—in section $\theta = 30°$.

The coupling of reinforcing rods for the diaphragm with the support ring is preferably performed without knotted shapes, which avoids marking in the manufacture of parts for support diaphragms of tanks, simplifies the assembly and welding of diaphragms and reduces metal costs. One of the possible constructive solutions is to weld the corners of the diaphragms directly to the support rings.

3 Conclusions

1. There has been done the construction of horizontal cylindrical tanks for military needs. There have been reviewed features to calculation cylindrical horizontal tanks. There has been calculated the tank wall on the strength and stability.
2. There has been modeled the horizontal tank, namely: the position of flat ribless bottoms, conical bottoms, spherical bottoms. There has been done the design and calculation of conjugation for flat bottoms with the wall of horizontal tank.
3. There has been developed the optimal design and shape of tank for storing fuels and lubricants in the field.

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Layout of Buildings in the Context of Organization the Evacuation of Persons with Disabilities

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Abstract Layout of buildings should be implemented with the comfort and safety of customers' requirements, including customers with special needs due to disabilities. In case of an emergency, the irrational layout of the building, which makes evacuation difficult, can lead to serious consequences in the form of significant damage to human's health or death. Military events in Ukraine have shown that persons with disabilities and other members of groups with limited mobility were vulnerable in case of need for emergency evacuation to safe places during rocket attacks and fires. In addition to limited mobility, the presence of physiological changes in the health state can cause the influence on the increasing of the time of recognition of a signal about the occurrence of danger, the choice of an evacuation route, which leads to an increase of evacuation time and the risk of suffering in case of an emergency. The article analyzes the problems associated with organizing the evacuation of persons with disabilities who belong to vulnerable groups of population, a comparative analysis of layout requirements in the context of organizing the evacuation of persons with disabilities and other vulnerable groups, which are required by the standards of Ukraine and the UK was carried out, and also a comparative calculation of the evacuation time of persons with disabilities. The data obtained as a result of the calculations show that they differ by more than two times, which indicates the importance of taking into account the preparatory period at calculation of the time of evacuation in order to further take this information into account at layout of the buildings with the stay of persons with disabilities.

Keywords Layout of buildings · Disability · Safety · Time of evacuation

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_22

1 Introduction

The problem of ensuring the safety of vulnerable groups of people, including people with disabilities, is very acute in the context of the emergencies. The military events taking place in Ukraine have already led to the need to evacuate about 4 million people from cities where hostilities are taking place. And these data are only for a month and are not final, because the war is still going on. Vulnerable groups in the context of evacuation are people with disabilities in movement, including people with disabilities, the elderly, children, women with baby carriages, etc. [1]. For these visitors at the time of planning public and residential buildings it is necessary to provide planning measures to ensure safety in case of an emergency, as well as in case of an emergency evacuation from the premises to a safe place, such as the basement. Practice shows that there have been many cases when people with limited mobility, due to difficulties in movement, did not go down to the basements of residential buildings during the rocket attacks and thus put themselves in danger. Vulnerable groups of people also had significant difficulties in evacuating, as it was difficult to do so on their own, and there were not always people around who were able to help.

On the other hand, after the end of hostilities in Ukraine, a sharp increase of the number of people with disabilities is expected due to injuries received after traumas, being under the rubble of buildings, etc. Before the military conflict, the number of people with disabilities in Ukraine was about 6% of the population, i.e. more than 2.7 million people [2]. Thus, the problem of ensuring the safety of persons belonging to vulnerable groups, including with disabilities, will become relevant. However, an increase of the number of people with disabilities is observed not only in Ukraine but all over the world. According to the WHO, more than 1 billion people in the world have disabilities, which is about 15% of the total population of our planet [3]. It was noted that the number of people with disabilities will continue to grow due to increasing levels of chronic morbidity, aging, military conflicts, etc. [4].

Another important moment is the fact that on the background of the growing number of people with disabilities in Ukraine as a result of hostilities, a significant number of public and residential buildings were destroyed as a result of rocket attacks. Thus, during the 4 weeks of hostilities only in the city of Kharkiv, more than 1,000 buildings were destroyed, which will need to be restored in the peacetime. It is important to take into account the need to implement the planning requirements for the safety of people with disabilities.

The article provides a comparative analysis of the requirements of standards for layout decisions to organize the evacuation of vulnerable groups, including persons with disabilities, in case of emergency, as well as comparative calculations of evacuation time of persons with disabilities according to national and international standards.

2 Analysis of Problems and Approaches to Layout of Buildings Taking into Account the Needs of Persons with Limited Possibilities

2.1 Analysis of Problems in the Layout of Public Buildings to Take into Account the Needs of Persons with Disabilities and Representatives of Other Vulnerable Groups

The issue of ensuring the safety of people with disabilities during their presence in public buildings through the use of appropriate architectural and planning solutions increases its relevance every year, since the layout decisions of buildings play an important role in ensuring the safety of visitors to institutions and organizations. At the solution of the problem of layout of the buildings, the unaccounting of the needs of visitors, among whom may be persons with disabilities who have persistent functional health disorders, and other vulnerable groups with limited mobility in the rational planning of mechanisms for their orientation in the building and evacuation routes can lead to serious consequences.

The increase of the number of people with special needs is forcing design engineers to take into account the needs of various population groups at the planning of public buildings. At the same time, it is necessary to take into account both the safety and comfort issues of visitors during the normal mode of exploitation of the building, and the situation of an emergency in a public building, for example, a fire, a terrorist attack and other incidents requiring emergency evacuation from the building.

Life restrictions mean the loss by people as a result of illness or injury the ability to self-service, movement, orientation, communication of varying severity, which necessitates accounting of the needs of this category of people at the solving the issues of ensuring their safety in the process of presence in public buildings.

The relevance of the problem of layout of buildings, taking into account the needs of persons with disabilities, is especially increasing for countries in which hostilities took place. In Iran, as a result of the Iran-Iraq war, a significant number of people became disabled, which required from urban planners, architects, engineers to make decisions about improvement of the access for disabled people to urban spaces and services. There are about 1.2 million people with disabilities in the country, whose safety and comfort require the implementation of appropriate architectural, planning, organizational and technical solutions. However, in Iran, despite the adoption of relevant state programs, their implementation has not led to a global improvement in the mobility of persons with disabilities in educational, religious, and sports facilities of the urban infrastructure [5].

Regardless of the type of emergency, persons with disabilities are two to four times more likely to die in natural disasters than people who do not belong to vulnerable categories of the population [6]. One of the main reasons for this situation is unaccounting the special needs of people with different functional constraints in various emergency management methods. In the United States, after Hurricane Katrina, an audit of emergency response plans [7] was carried out, which showed that most plans did not address the critical issues of ensuring effective evacuation, in particular, procedures for tracking the association of people with disabilities, family members, caregivers and durable medical equipment; methods of emergency notification and communication that would be accessible to people with certain disabilities and other key issues.

At the planning of the travel routes for persons with disabilities, there is controversy as to which route is considered the best. The paper [8] considers the problem of finding the best route for wheelchair users in public buildings using BIM technologies. The best route is not meant to be the fastest/shortest route to a safe or designated area, but a route that is primarily accessible and as convenient as possible. Therefore, at the searching for the best routes for the disabled, elements such as the presence of ramps, types of doors and door opening directions are taken into account. However, the best route search model developed by the authors does not take into account factors that complicate evacuation in a real emergency situation. These can be fragments of load-bearing structures, glass from broken windows, smoke in the premises and other factors. It should also be noted that the evacuation of persons with disabilities is carried out, as a rule, in the general evacuation flow, which should also be taken into account at the modeling of these processes.

The work [9] emphasizes that accessible routes should correspond to the physical restrictions of people with disabilities, since the optimal evacuation route may be different for two people with different degrees of functional impairment. At the same time, personal preferences and physical limitations of persons with disabilities who choose an evacuation route can be very diverse and exhaustive, this makes the accounting difficult. In this regard, the tasks of creating spatial models for dynamic modeling of the processes of evacuation of persons with disabilities in case of an emergency are complicated. There is not enough the research on the influence of disability type, surface type, aisle width, exit door width, distance, familiarity with the building and exit doors, crowding, crowd behavior, influence of smoke on the behavior of persons with disabilities at the choosing a route.

There is also the problem of classifying persons with disabilities. In different countries, this classification may be differ, which makes it difficult to develop universal algorithms for calculating the time of evacuation and the further implementation of appropriate architectural and planning solutions. Often, different types of disability are combined into one term “a person with functional impairments”, which reduces the accuracy of evacuation time calculations [10]. In turn, this can lead to insufficient consideration of the special needs of persons with disabilities in the development of planning solutions.

2.2 Requirements of International Standards for Planning Evacuation Routes for Representatives of Vulnerable Groups

In the UK, the safety of visitors to civic buildings, as well as residential buildings, is given increased attention. It notes that successful building evacuation in case of an emergency can be greatly facilitated by comprehensive management of visitor safety, whether or not they have a disability. At the same time, the procedures for managing people with disabilities should include measures to assist people in wheelchairs and people who have mobility restrictions, as well as other restrictions.

British Standard BS 9999 [11] was originally published in 2008, replacing DD 9999 and parts of the BS 5588 [12] codes. The standard provides information on managing fire safety throughout the life cycle of a building and specifies the requirements for a strategy to ensure the safety of people in and around buildings.

There should be no elements on the escape routes that could impede movement. It is expected that there may be some delay in some sections of the evacuation route, which is connected with the waiting for help to use the stairs or the evacuation elevator. Therefore, it may be necessary to create shelters where people with disabilities can wait in comparative safety for a short time before continuing to the final exit. However, the standard limits horizontal displacement distances for means of evacuation, which means that most people with disabilities should make their own way to a safe protected escape route or final exit. At the same time, some people with disabilities, such as wheelchair-bounded, will not be able to use stairs without assistance. For this reason, it is necessary to provide shelters on all floors, except those located in the small buildings of limited height (where the distance to the final exit is so limited that the arrangement of shelters is not advisable), those that provide smooth access directly to the final exit and those which consist exclusively of technical premises.

The physiological state of people who use wheelchairs varies both in type and degree. With these factors in mind, the minimum space provided for a wheelchair in a shelter should be sized to allow maneuvering. If the shelter is a secure stairway, secure lobby, or secure corridor, the wheelchair space must not reduce the width of the escape route. If the wheelchair place is on a secure staircase, access to the wheelchair place must not impede the flow of people moving towards the exit.

For the evacuation of people with disabilities, it is necessary to take into account the design of evacuation stairs. This is due to the fact that they will be the only means of evacuation in buildings not equipped with evacuation elevators, or in case of an elevator failure. Sometimes the presence of the stairs may be unavoidable with a slight change in level. Ramps can be a good alternative to stairs and, to a lesser extent, elevators, but they take up a lot of space and are often impractical for this reason.

As opposed to a conventional passenger elevator, it is important that any evacuation elevator can continue to operate safely in case of a building fire. An evacuation elevator must always be available for evacuation. Therefore, it must be an elevator used regularly as a passenger elevator and not exclusively or occasionally as a freight elevator. The evacuation elevator must have suitable structural, electrical and fire protection and be capable of being operated by an authorized person. It must be connected to the shelter. Any elevator designed for the evacuation of the disabled must be either fire or evacuation elevator.

For each disabled person or group of disabled people located in the building, an Individual fire evacuation plan must be drawn up. Disabled visitors should receive a copy of their personal fire escape plan. If the building is a building with a large number of occupants, staff should, to the extent possible, provide evacuation instructions to visitors with disabilities in case of an emergency.

2.3 Regulatory Requirements of Organizing Evacuation Routes for People with Limited Mobility in Ukraine

Effective evacuation of people, including people with disabilities, is ensured by a complex of space-planning, design and engineering solutions that must be implemented taking into account the category of the building in terms of explosion and fire hazard, the degree of fire resistance of structures, the number of storeys of the building, as well as the characteristics of a possible evacuation flow of people. In Ukraine, in 2018, a new standard DBN V.2.2-40:2018 [13] was adopted, which establishes the requirements for design, construction, reconstruction, restoration, repair, technical re-equipment, as well as the reasonable adaptation of residential and public buildings in accordance with the needs of limited mobility groups of the population, which includes not only persons with temporary or permanent health problems (with disabilities), but also pregnant women, the elderly and visitors with perambulators.

This standard defines the main priorities for the design of public buildings:

– availability of targeted places for people with limited mobility,
– safety of traffic routes (including evacuation routes),
– the possibility of evacuating visitors to a safe area,
– timely receipt of complete and high-quality information both for orientation in space and for the fulfillment of assigned tasks,
– convenience and comfort of the life environment.

Along with the general requirements related to ensuring the accessibility of residential and public buildings for people with limited mobility, the standard provides specific requirements aimed at ensuring the safety of visitors in case of an emergency (fire). The main groups of requirements in this case are:

(1) requirements for the planning organization of buildings and structures,
(2) requirements for the life environment of people with limited mobility,
(3) safety measures, orientation and obtaining information in the process of staying in a public building, taking into account the peculiarities of information perception.

The DBN V.1.1-7:2016 standard [14] provides the main ways to ensure the safety of people who move along evacuation routes, namely:

– timely and unhindered evacuation of people in case of an emergency;
– protection of people who move along the evacuation route from the influence of dangerous factors.

The main elements of the evacuation route are: evacuation exits, evacuation stairs and stairwells. At the same time, elevators and escalators that are used for the movement of groups of visitors with limited mobility are not taken into account.

The width (in the opening) of the sections of the evacuation routes used by the people groups with limited mobility must be at least, m:

- doors from premises where there are no more than 15 people—0.9;
- openings and doors in other cases, indoor passages—1.2;
- transitional loggias and balconies—1.5;
- corridors, ramps used for evacuation—1.8.

It is not allowed to provide for people groups with limited mobility evacuation routes along the stairs of type C3 (external open).

The ramp, used as an evacuation route from the overlying floors in the building or construction being reconstructed, must be directly connected through the vestibule to the exit to the outside. The bearing structures of the ramps should be made of non-combustible materials with a fire resistance rating of at least 60 min.

Materials used on escape routes (stairwells, corridors, lobbies, ramps) must be non-combustible or have high fire hazard ratings.

If it is impossible to provide the necessary (estimated) evacuation time according to the project, then in order to save people with disabilities, a fire-safe zone should be provided on the evacuation routes, from which they can evacuate during a longer time or stay in it until the arrival of rescue units. The fireproof zone should be separated from the other rooms and adjacent corridors by fire barriers. The materials used for siding walls, ceilings and floor in fireproof areas must be non-combustible.

Comparing the requirements for planning and organizing the evacuation of persons with disabilities and other groups with limited mobility, it can be done the conclusion that the fundamental difference is that the standard of Ukraine does not include an individual approach to evacuation planning for persons with disabilities. In this regard, the proper planning of buildings, taking into account the special needs of persons with disabilities, is of great importance, since it is necessary to take into account as much as possible the possible functional states of the persons who are present there and their potential in the context of effective evacuation. At the same time, vulnerable groups are more widely represented.

3 Comparison of Approaches to Calculation the Evacuation Time of Persons with Disabilities for Information Support of Layout of Public Buildings

3.1 Comparison of Data to Calculation the Evacuation Time for Different Groups of Persons with Disabilities

The solution of the problem of layout of the buildings and constructions in the context of evacuation routes largely depends on the initial data, which will be used to calculate the evacuation time. In this regard, the categorization of persons with disabilities and other vulnerable categories of the population play an important role. The normative document of Ukraine—State Building Specifications (DBN) [13] establishes a list of the groups of visitors depending on the mobile characteristics of people in the stream, moving towards evacuation. At the same time, the visitors of public buildings, who are referred to low-mobility groups of the population, divided into 4 groups for mobile activities (Table 1).

The ability of people with disabilities to move at a certain speed influences on the time of evacuation. The data from various sources, which will be used later to calculate the evacuation time from a real premise, are showed for comparison below.

The difference in data on the speed movement and other parameters of the evacuation of persons with disabilities is caused not only by the difficulties associated with obtaining statistical information, but also by significant differences in the functional state of persons with disabilities.

Table 1 Comparison of the speed of movement along the horizontal path of the evacuation route of persons with disabilities of various groups, m/min

Type of life restrictions	DBN [13]	Hashemi and Tomasiello [9]	Robbins and Buckett [15]
Persons with disabilities who do not have mobility restrictions (M 1)	100	75	60
Persons with reduced mobility due to aging, persons with disabilities on prostheses; (M 2)	30	49	–
Persons with disabilities who use additional support while moving (crutches) (M 3)	70	56	56
Persons with disability who move on wheelchairs that are driven manually (M 4)	60	41	–

3.2 Calculation of the Evacuation Time of Persons with Disability on the Basis of the State Ukraine Standard

The estimated value of the speed of people traffic flows of different mobility groups, according to DBN [13], is determined by the formula:

$$V_{D,j} = V_{O,j}\left[1 - a_j \ln \frac{D}{D_{O,j}}\right] \text{ at } \mathrm{D} > \mathrm{D_{Oj}} \tag{1}$$

the intensity of movement of people of different mobility groups is calculated as

$$q_{D,j} = V_{D,j} D \tag{2}$$

$V_{D,j}$, $q_{D,j}$—the speed and intensity of movement of people in the flow on the j-th type of path at the density of the flow D_j;

D—the density of the flow of people at the path of evacuation route, m^2/m^2;

D_{Oj}—the value of the density of the people flow on the j-th type of path, at which the density of the flow begins to influence on the speed of movement of people in the flow, m^2/m^2;

V_{Oj}—the average value of the speed of free movement of people on the j-th type of path at the values of flow density $D \leq D_{Oj}$, m/min;

a_j—coefficient that takes into account the degree of influence of the density of the flow of people on its speed at the movement on the j-th type of evacuation route.

The standard calculation provides for the following types of evacuation route: horizontal path, stairs down, stairs up, ramp up, ramp down.

For practical studying of the possibility of using this method to determine the time of evacuation of people with disabilities who are in a public building, it is determine the time of evacuation for representatives of different groups with limited mobility for the office (Fig. 1), in which are present 2 people who belong to the same mobility group (Table 1), the width of the escape route is 2 m. Suppose assume that in Sect. 3 representatives of all mobility groups (except M4) will choose to move using stairs; representatives of the M4 group will move on the ramp.

The results of calculations for different mobility groups according to Ref. [13] are given in Table 2.

It should be noted that the standard [13] does not take into account the preparatory period preceding the evacuation. It is also important to note that people with disabilities who belong to the same mobility groups have different preparation times for evacuation due to different functional limitations [16].

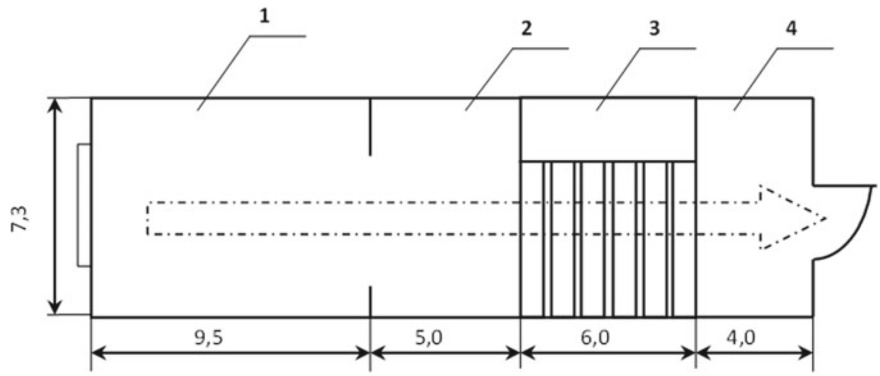

Fig. 1 Calculation scheme: Sects. 1, 2, 4—horizontal path; 3—stairs down, ramp

Table 2 The results of calculating the movement time along the evacuation route of persons with various mobility restrictions, sec

Type of life restrictions	Movement time, calculated using [13]
M 1	15
M 2	49
M 3	34
M 4	22

3.3 Calculation of the Evacuation Time of Persons with Disability on the Basis of International UK Standards

The British approach to calculation of evacuation time [17–18] is based on the determination of evacuation time as the interval between the time when a fire warning is transmitted and the time when all the people can get to a safe place:

$$\Delta t_{evac} = \Delta t_{pre} + \Delta t_{trav} \tag{3}$$

Δt_{pre}—the time before movement—the interval between the time a danger warning is given and the time the first move to the exit is made;

Δt_{trav}—the time in movement—the time required from the start of movement to the exit for all people in the specified part of the building to reach a safe place.

$$\Delta t_{pre} = \Delta t_{rec} + \Delta t_{res} \tag{4}$$

Δt_{rec}—time for a person to recognize a signal about danger;

Δt_{res}—reaction time to a signal, preparation for movement along the evacuation route.

The standard notes that the pre-movement phase can often be the longest part of the total evacuation time. At the same time, it should be understood that when considering the evacuation of persons with disabilities, this period may be even longer comparing to persons without functional impairments, and, accordingly, unaccounting this fact in the Ukraine standard significantly affects at the result of the calculation and further decisions regarding to the layout of buildings and structures decisions.

Characteristics of persons at risk zone that need to be considered in the context of evacuation include [17]:

- number and density of people: the expected number in each occupied premise, including seasonal variations;
- familiarity with the building: depends on such factors as type of premise, frequency of visits and participation in emergency evacuations;
- prevalence and type of activity;
- alertness: depends on such factors as activity, time of day, sleep or wakefulness;
- mobility: depends on such factors as age and the presence of life limitations;
- physical and mental abilities;
- social affiliation: the degree of presence of residents individually or in groups, such as family groups, groups of friends, etc.;
- role and responsibility: includes such categories as member of the public, manager, floor supervisor, etc.;
- location: location in the building concerning to escape routes, etc.;
- response: the degree to which the resident can react to alarms, etc.;
- the state of people: according to the analysis of possible states.

Using formulas (3 and 4), it is possible to calculate the evacuation time of persons with disabilities for the conditions shown in Fig. 1. The calculation is carried out for the conditions described above in paragraph 2.2 (see Table 3).

It should be noted that at the determining of the evacuation time in accordance with the standard [17], it was assumed that the building in which the office premise is located, belongs to level B1, i.e. has a simple planning and a good visual overview.

Table 3 Estimated evacuation rates for representatives of different mobility groups according to the UK standard, sec

Type of life restrictions	Evacuation time along the estimated route
M 1	91
M 2	105
M 3	110
M 4	106

4 Results

Comparative analysis of the obtained results is shown in Fig. 2. It should be noted that the obtained results differ by 2–6 times for different groups of limited mobility, which suggests that in order to layout the buildings taking into account the presence of persons with disabilities who have mobility restrictions, it is necessary to take into account not only direct the time of movement along the evacuation route, but also the preparatory period. It should be noted that the standards being compared do not detail information on the time of evacuation of persons with other disabilities, such as hearing, visibility, etc. Difficulties in obtaining statistically reliable information regarding the preparatory period and the time of direct movement by the evacuation route do not make it possible to determine the evacuation time of persons with various (except motor) disabilities, which creates certain threats for representatives of these groups in case of an emergency.

The standard [17] notes that in many situations the time required to start the evacuation phase (i.e. the time before the start of the movement) and the subsequent movement phase of persons with disabilities is highly dependent on the presence of number of personnel and its level of training in emergency situations.

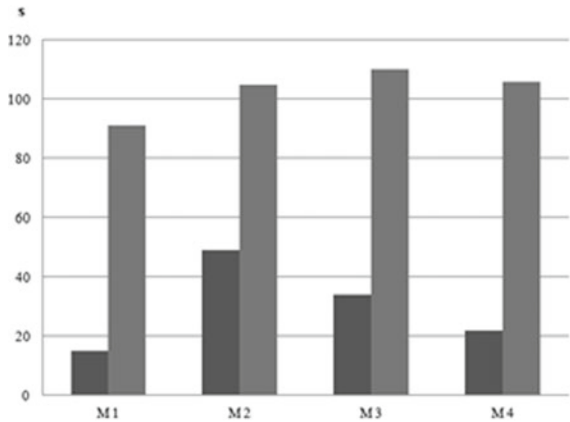

Fig. 2 Calculated time of evacuation of persons with disabilities: M1—persons with disabilities who have no restrictions in terms of mobility; M2—persons with reduced mobility due to aging, persons with disabilities on prostheses; M3—persons who use crutches; M4—persons with disabilities who move on wheelchairs that are driven manually

5 Conclusions

The layout of buildings taking into account the solution of issues of safe staying of persons with disabilities should be carried out both for the mode of normal functioning and in case of possible emergencies. In case of their occurrence, persons with disabilities, as well as representatives of other groups of visitors with reduced mobility, become vulnerable and the risk of their death increases. One of the important criteria for taking safety issues into account at the layout of buildings is the time of evacuation of people, including people with disabilities, in case of danger. However, determining the evacuation time for people with disabilities and other groups of visitors with reduced mobility is connected with certain difficulties due to significant differences in physiological condition among members of one group, not to mention differences in evacuation potential of representatives of different mobility groups.

The article provides a comparative analysis of domestic and international standards devoted to the calculation of the evacuation time and the peculiarities of its organization. Comparative calculations have shown that the unaccounting of the preparatory time that precedes the evacuation and involves the recognition of the danger and the development of an algorithm to respond to it, significantly affects the total evacuation time. Time ranges of movement on the considered evacuation route for various groups of mobility restriction differ in 2–6 times. In this regard, the calculation method presented in the domestic standard should be supplemented by instructions for determining the preparation time for evacuation. This will provide more accurate data on the time required for the effective evacuation of vulnerable groups, and will therefore allow to implement the layout of buildings with a high level of safety.

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Approximation Models of the Method of Design Resistance of Reinforced Concrete for Bending Elements with Double and Multirow Reinforcement

Vasyl Rizak, Dmitro Kochkarev, Anna Azizova, and Tatiana Galinska

Abstract Approximation models of the method of design resistance of reinforced concrete were considered for the calculation of normal sections of reinforced concrete bending elements with double and multirow reinforcement. It is proposed to use approximation dependences of two types—polynomial and linear. Approximation models were developed based on the method of design resistance of the reinforced concrete, which is based on generally accepted theoretically proved assumptions and hypotheses. This method is based on the use of nonlinear diagrams of concrete deformation, acception of the Bernoulli hypothesis, and the usage of the extreme criterion for determining the bearing capacity based on the nonlinear deformation model of calculation. The proposed approximation formulas can greatly simplify the calculation of reinforced concrete bending elements with double and multi-row reinforcement. They eliminate the need for the usage of tables and the performance of complex calculations with iterative methods, as is the case with most existing deformation models. The results of calculations indicate sufficient accuracy for practical calculations of the proposed methods. The authors considered the examples of determining the bearing capacity and area of working reinforcement of normal cross-sections of bending elements from reinforced concrete in double and multi-row reinforcement. The proposed methods of calculation of bending elements, made of reinforced concrete, can be widely used in design practice.

Keywords Nonlinear strain model · Bending moment · Deformation · Reinforced concrete beam · Design resistance · Multi-row reinforcement

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_23

1 Introduction

One of the most common reinforced concrete elements, used in construction practice, is bending elements. The most effective bending elements include elements with single reinforcement. At the same time, quite often architectural and planning requirements determine the low height of the bending elements, which leads to the need of performing double or multi-row reinforcement. In such elements, it is necessary to strengthen the compressive zone of the concrete or to arrange reinforcement on all height of an element. The calculation of such elements should be based on nonlinear diagrams of the deformation of materials, since the stresses in a certain amount of reinforcement on the height of the section, as a rule, do not reach their boundary values. The use of simplified models of calculation [1, 2] of elements with double and multi-row reinforcement is quite complicated. First, this is due to the fact that it is necessary to determine the stresses in the reinforcement using nonlinear or simplified diagrams of the deformation of materials. Such deformation diagrams are given in many deformation models [9–26] and normative documents [3, 4]. However, the calculation of elements with double and multi-row reinforcement should be performed by the method of iterations in the previously developed programs. It is also possible to calculate such elements by the method of design resistance of reinforced concrete [5, 6]. In this case, this method involves the use of tabular values of the design resistance of reinforced concrete. Let's consider an approximation model for the calculation of reinforced concrete elements with double and multi-row reinforcement based on this method.

2 Approximation Model of the Method of Design Resistance of Reinforced Concrete for Bending Elements with Double and Multi-row Reinforcement

The calculation of reinforced concrete bending elements, based on the modified method of design resistances [7, 8] of reinforced concrete is as follows:

1. It is necessary to determine the mechanical reinforcement ratio by the expression:

$$\omega = \frac{\rho_f \cdot f_{yd}}{f_{cd}}, \tag{1}$$

   where ρ_f—the reinforcement ratio of the cross-section with longitudinal reinforcement, f_{yd}—design resistance of the longitudinal reinforcement, f_{cd}—design resistance of compressive strength of concrete.
2. Then the parameter $k_z = f(\varpi)$ is determined according to the relevant graphs.
3. The design resistance of the reinforced concrete is established by the expression:

$$f_z = 6 \cdot k_z f_{cd}. \tag{2}$$

4. The bearing capacity of the element is set by the formula:

$$M = f_z W_c, \quad (3)$$

where f_z—the design resistance of reinforced concrete in bending, MPa, W_c—moment resistance of working cross section of concrete, b·h²/6, m³.

Also, the bearing capacity can be determined by substituting formula (2) in (3)

$$M = k_z f_{cd} \cdot b \cdot d^2. \quad (4)$$

The above formulas were derived using the Bernoulli hypothesis, generally accepted diagrams of deformation of concrete and reinforcement, as well as the failure criterion. Reaching the ultimate deformations of concrete and reinforcement is taken as the main failure criterion.

Let's present the functional dependences of the graphs $k_z = f(\varpi)$ for the bending elements with double and multi-row reinforcement (Figs. 1 and 2). These graphs show the data of the numerical experiment of dependence $k_z = f(\varpi)$ for all classes of concrete and reinforcing steel of classes A400C and A500C.

Let's perform the approximation of the dependence $k_z = f(\omega)$. The dependence approximation for bending elements with multi-row reinforcement will be performed by linear functions and a polynomial of the 2nd degree (Figs. 1 and 2). We will perform a linear approximation in the following form:

$$k_z = 0{,}373 \cdot \omega. \quad (5)$$

The coefficient of variation, determined by the errors of dependence (5), is $\nu = 14.85\%$ in comparison with the true function.

The approximation expression in the form of a polynomial of the second degree has the following form:

$$k_z = 0{,}371 \cdot \omega - 0{,}021 \cdot \omega^2. \quad (6)$$

The coefficient of variation, determined by the errors of dependence (6) and the true function is $\nu = 7.05\%$.

For the elements with double reinforcement when performing a linear approximation, the expression for the definition $k_z = f(\omega)$ takes the following form:

$$k_z = 0{,}94 \cdot \omega. \quad (7)$$

The coefficient of variation, determined by the errors of dependence (7) and the exact function is $\nu = 3.81\%$.

The obtained expressions with the help of linear approximation lead to the following expressions of the bearing capacity:

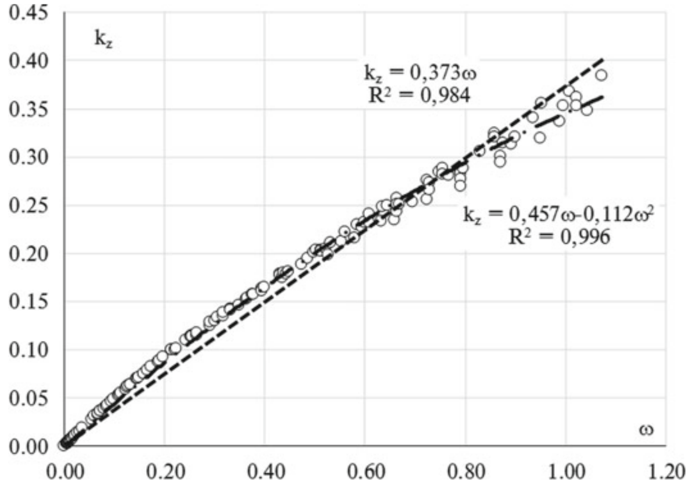

Fig. 1 Functional dependence $k_z = f(\omega)$ and its approximation for bending elements with multi-row reinforcement

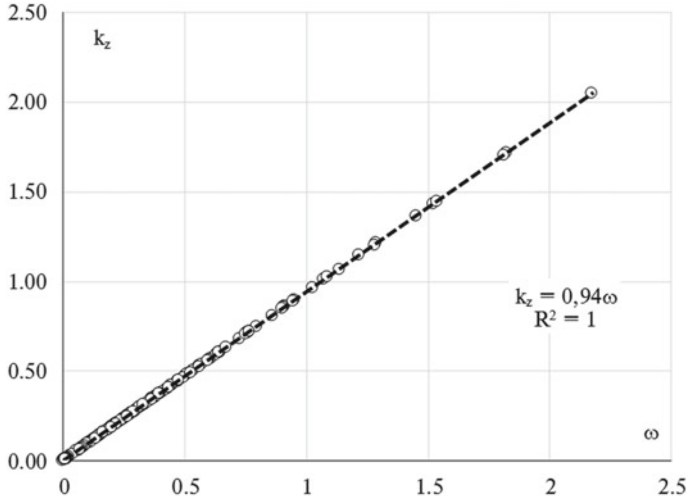

Fig. 2 Functional dependence $k_z = f(\omega)$ and its approximation for bending elements with double reinforcement

– for multi-row reinforcement

$$M_{Ed} = 0{,}373 \cdot A_s \cdot f_{yd} \cdot d; \tag{8}$$

– for double reinforcement

$$M_{Ed} = 0{,}94 \cdot A_s \cdot f_{yd} \cdot d. \quad (9)$$

Expressions (8) and (9) are obtained by substituting formulas (5) and (7) into formula (4) respectively.

It should be noted that expression (9) remains valid in determining the bearing capacity of reinforced concrete bending elements with single reinforcement, in which the failure occurs on the tensile reinforcement.

We shall confirm the validity of the obtained formulas on experimental samples.

3 Examples of Calculation of Reinforced Concrete Bending Elements by the Proposed Methods

Example № 1. Reinforced concrete element of rectangular cross section b × h = 110 × 30 cm is made of concrete class C16/20 and reinforced with steel class A400C, f_{cd} = 365 MPa, placed evenly in five layers along the height of the element. We are going to determine the cross-sectional area of the reinforcement, if the element perceives the calculated bending moment M_{Ed} = 850 kNm.

The solution. Let's accept the arrangement of the reinforcing rod in the section on Fig. 3. The height of the working section is d = 105 cm.

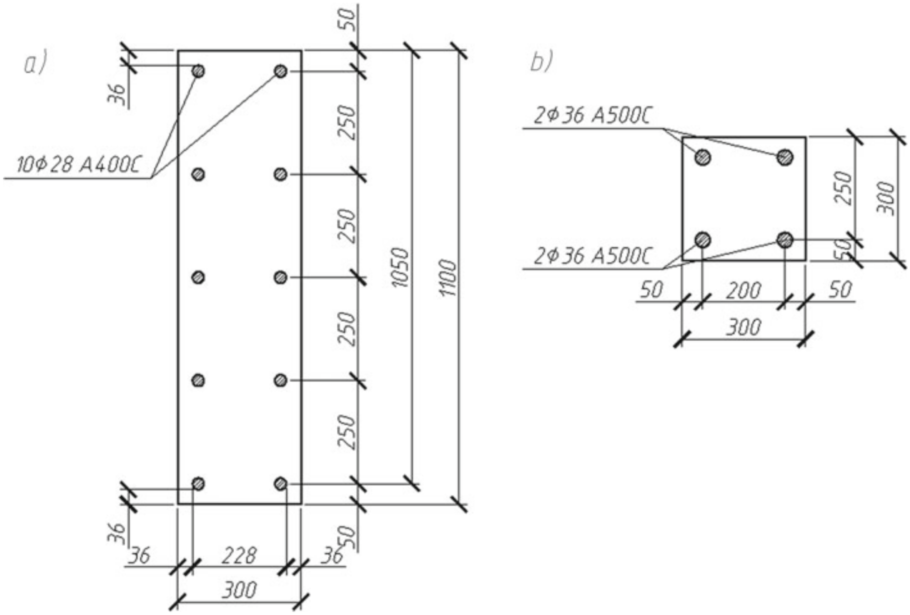

Fig. 3 Illustration of the examples **a** №1; **b**. №2

From the expression (8) we will determine the required cross-sectional area of the reinforcement

$$A_s = \frac{M_{Ed}}{0{,}373 \cdot f_{yd} \cdot d} = \frac{850 \cdot 10^3}{0{,}373 \cdot 365 \cdot 105} = 59,46\ \text{cm}^2.$$

The value of the surface area of the reinforcement area, determined by the nonlinear deformation model, is 55.73 cm^2.

The relative error is $\Delta = \frac{55{,}73 - 59{,}46}{55{,}73} \cdot 100\% = 6{,}7\%$.

Let's check the minimum reinforcement ratio:

$$\rho_f = \frac{A_s}{b \cdot d} = \frac{59{,}46}{30 \cdot 105} = 0.0189 > \rho_{\min} = 0.0013.$$

For the reinforcement we accept 10Ø28 A400C, $A_s = 61{,}58$ sm^2.

Example № 2 Reinforced concrete element of rectangular cross section b × h = 30 × 30 cm is made of concrete class C20/25 and reinforced stell of class 2Ø32 As = 16.09 cm^2 A500C in compressed and stretched zones, $f_{cd} = 415$ MPa, (see Fig. 2). The task is to determine the bearing capacity of the section.

The solution. The height of the working section is d = 25 cm.

The bearing capacity of the cross-section of the element is determined by the expression (9)

$$M_{Ed} = 0{,}94 \cdot A_s \cdot f_{yd} \cdot d. = 0{,}94 \cdot 16{,}09 \cdot 415 \cdot 25 \cdot 10^{-3} = 156{,}92\ \text{kNm}.$$

The value of bearing capacity, determined by the nonlinear deformation model, is 164.43 kNm.

The relative error is $\Delta = \frac{164{,}43 - 156{,}92}{164{,}43} \cdot 100\% = 4{,}57\%$.

4 Conclusions

The considered approximation models of the method of calculated resistances of reinforced concrete give the possibility to check the durability of normal sections of reinforced concrete bending elements at multirow and double reinforcement. The proposed calculation formulas provide an opportunity for rapid checking calculations and can be widely used by students, engineers, and engineering technicians in the practice of design and training.

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To the Determination Transmission Gear Ratios During the BTR-70 Modernization

Volodymyr Sakhno, Akif Gasimov, Oleksandr Dykykh, Anatolii Kryvorot, and Dmytro Yashchenko

Abstract The problems arising on motor vehicles when replacing an internal combustion engine are analyzed and the need to optimize the transmission ratio is substantiated. In determining the transmission vehicle gear ratios, it is considered appropriate to use analytical research methods. The minimum and maximum gear ratios transmission vehicle BTR-70, and the gear ratio of the additional gear are determined. It is shown that when modernizing the studied vehicle with two diesel engines D245.30E2 with a 115 kW capacity, the best individual performance of traction and velocity properties are achieved by different transmissions. According to the present study, the best option is a Mercedes-Benz G 85-6/6.7 gearbox. However, the MAZ-5335 8-stepped transmission can also be recommended. The final choice of the transmission to vehicle BTR-70 needs to be carried out taking into account the fuel efficiency.

Keywords Gear ratios · Traction and velocity properties · Transmission · Vehicle

1 Introduction

Optimization of design parameters—one of the most important ways to improve the technical level, productivity, profitability and efficiency of vehicle and trains. The transmission is a design element, the parameters of which determine the technical and economic vehicle performance. A number of the mechanical transmission gear

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© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_24

ratios significantly affect the vehicle traction and velocity properties and fuel efficiency. When replacing a gasoline engine with a diesel with a different power and a different speed range, it is necessary to determine the gear ratio in such a way as to provide the car with the velocity properties required level in the given operating conditions with minimum fuel efficiency [19]. However, only in some works are unambiguous mathematical dependencies to determine a number of gear ratios in the vehicle designing. At the same time the gear ratios of intermediate stages are determined only by geometric progression. But to improve the vehicle fuel efficiency, the transmission gear ratios which is obtained by geometric progression method, you can only reduce the gear ratio of higher gears by 5 … 15% and increase the density of lower gears by 5 … 15%. [1]. Therefore, it is very important to justify the transmission gear ratios method choosing the when converting gasoline vehicles to diesel, which will improve their traction and velocity properties and fuel efficiency. This fully applies to the modernization of the vehicle BTR-70 conversion is performed replacing gasoline engine ZMZ-4905 to diesel.

2 Review of the Research Sources and Publications

In article [2], were considered the options for retrofitting the BTR-70 by installing two 103 kW General Motors engines on the chassis of this vehicle instead of two ZMZ-4905 engines, or two IVECO Tector P4 engines with a capacity of 110.4 kW, or two D245.30E2 engines with a 115 kW capacity, or two engines of different power—the main engine power DEUTZ TCD 2013 L4 4V is 161 kW and the power of the additional engine DEUTZ D 914L3 is 43 kW. The comparative analysis is based on the main indicators of traction and velocity properties, obtained by solving the differential equation of motion, the initial data for which are the mass and geometric vehicle parameters and operating conditions. Choosing the best option is made by comparing each indicator traction and velocity properties with etalon, which is considered as the best indicator of all possible options. According to the calculations results it is established that vehicle traction and velocity properties with IVECO Tector P4, D245.30E2 engines and two DEUTZ TCD 2013 engines are almost identical and change from the greatest value (two engines D245.30E2) to the smallest (two engines DEUTZ TCD 2013) within 4%, despite their power is changing by 11.3%. Therefore, in the future, when upgrading the BTR-70 transmission, two D245.30E2 engines were taken as a basis.

3 Definition of Unsolved Aspects of the Problem

In determining the transmission vehicle gear ratios, it is considered appropriate to use analytical research methods. The advantages of such methods are that research performance cars can do with a set of special computer programs (MathCad, Microsoft

Ecxel etc.) providing accurate calculations of such parameters as the maximum speed, acceleration time, acceleration path, average speed and so on at the level of 10%.

Analytical methods are based on the vehicle differential equation motion solution. At the same time there is a possibility of the analysis constructive influence the vehicle parameters on indicators of its traction and velocity properties and fuel efficiency. Current analytical methods for determining the indicators of traction and velocity properties and fuel efficiency are based on the work of Litvinov and Farobin [3], Grishkevich [4], Farobin and Shchuplyakov [5], Pilipchuk [6], Pavlenko [7] and others. Thus, in article [8–13, 20] it is proposed to select the best car for a road train with a 38 tons total weight by comparing the traction and velocity properties and fuel efficiency of each individual car with the etalon, which is chosen as a virtual car with the best indicators of all possible cars.

Taking into account the considered approaches to determining the indicators of traction and velocity properties and fuel efficiency, the problem **statement purpose**—to determine a number transmission gear ratios, which provides the best vehicle traction and velocity properties and fuel efficiency.

4 Basic Material and Results

Replacing gasoline engines to diesels with other speed ranges requires not only select and study a number of gear ratios gearbox, but the transmission in general (see Fig. 1).

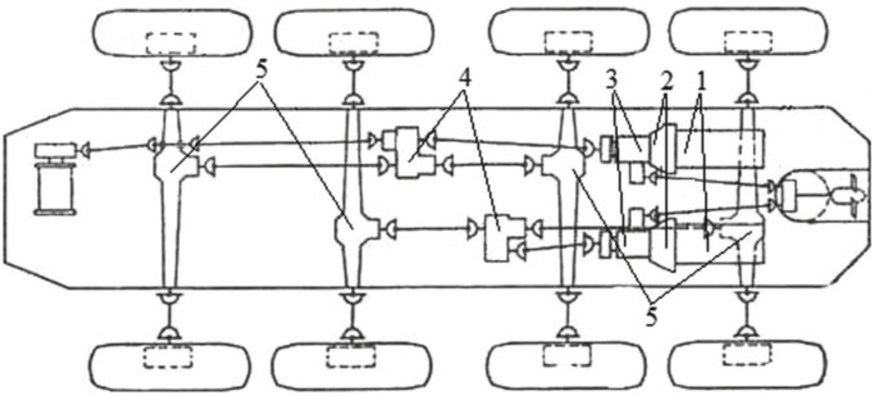

Fig. 1 The BTR-70 vehicle transmission. 1—ICE; 2—clutch; 3—main gearbox; 4—additional gearbox; 5—rear axle

It is well known that the minimum and maximum gear ratios are determined by the vehicle movement at maximum speed and overcoming the maximum resistance of the car. Thus, the maximum speed is determined from the vehicle power balance equation:

$$Ne = \frac{G_a \cdot V \cdot f_v + k \cdot F \cdot V^3}{1000 \cdot \eta_M}, \quad (1)$$

where G_a—the vehicle gravity, $G_a = 117622$ N;

f_v—the rolling coefficient vehicle wheels resistance, $f_v = a_f + b_f(0{,}01V)^{2{,}5}$ [2]

f_0—the rolling coefficient vehicle wheels resistance for speed 1 m/s, $f_0 = 0{,}015$;

k—the air resistance coefficient, $k = 0{,}55$ N·s^2/m^4;

F—the midsection area, $F = 5{,}1\ \text{m}^2$,

η_M—vehicle transmission efficiency, $\eta_M = 0{,}837$ [2].

In Fig. 2 shows the dependence of the power of rolling resistance (Nf), air resistance (Nw), drag (Nf + Nw) and power on the driving wheels (Nek) of the vehicle on the speed.

From Fig. 2 it follows that the maximum vehicle speed is 27,78 m/s (100 km/h). At this speed, the minimum gear ratio is defined as

$$U_{\min} = \frac{\pi \cdot n \cdot r_k}{V_{\max} \cdot 30} = 4{,}2, \quad (2)$$

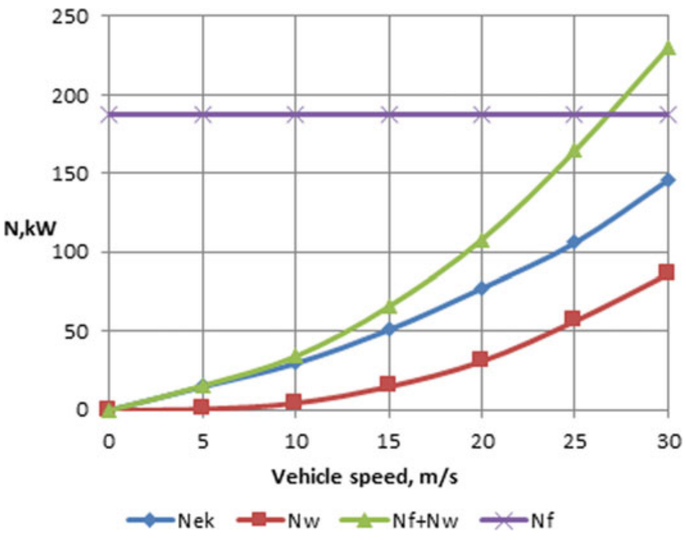

Fig. 2 To determine the maximum vehicle speed

where r_k—wheel rolling radius, $r_k = 0{,}465$ m [2].

For modern cars with diesel engines, the last gear in the gearbox is chosen to accelerate. So, for a Mercedes-Benz gearbox: ZF S5,42/5,72 the gear ratio of the last transfer makes 0,76; for gearbox G 85-6/6,7 – 0,73; for a gearbox with the YaMZ-236 – 0,66; for a gearbox with the YaMZ-238E – 0,71.

We will accept for further calculations $U_{ac} = 0{,}73$. Then the rear axle gear ratio will be defined as

$$U_0 = \frac{U_{\min}}{U_{ac}} = 5{,}76, \tag{3}$$

The maximum gear ratio is determined by the vehicle overcoming the maximum road resistance ψ, and for special vehicles—the maximum lifting angle. According to the technical requirements [15], the value of the maximum lifting angle is 30°. At the same time the lifting force [14, 15] is defined as

$$P_h = G_a \times \sin\alpha, \tag{4}$$

and the resistance of the road

$$P_\psi = P_h + P_f = G_a \times \sin\alpha + G_a \times \cos\alpha \times f = G_a \times \psi, \tag{5}$$

When the lifting angle is 30, the real road can only be a dirt road, for which the rolling resistance can be taken equal to $f = 0{,}05$ (adhesion coefficient 0,4 … 0,5) [2]. Then the resistance of the road and road resistance moment, and hence the resistance movement and moment resistance movement (Pw = 0) will make accordingly $P_\psi = 63433{,}8$ N and $M_\psi = 29496{,}45$ N·m.

The total two engines D245.30E2 torque 1052 N·m.

The maximum transmission ratio is defined as

$$U_{\max} = \frac{P_\psi \times r_d}{M_k} = \frac{M_{\psi\,\max}}{M_{e\,\max} \times \eta_m}, \tag{6}$$

In addition to overcoming the maximum lift, the engine-transmission system must be able to move the vehicle in difficult road conditions, for which the maximum dynamic factor in the lower gear in the main gearbox and additional gearbox must be within $D_{\max} = 0{,}7$–$0{,}9$ [2]. Thus at $D_{\max} = 0{,}9$ the necessary torque on wheels of all axes will be defined as

$$M_{\max} = D \cdot G_a \cdot r_d = 49224{,}77, \tag{7}$$

and the required transmission ratio is defined as

$$U^1_{\max} = \frac{M_{\max}}{M_k} = \frac{M_{\max}}{M_{e\,\max} \times \eta_m} = 55{,}90. \tag{8}$$

The gear ratios $U^1_{\max}$ and $U_{\max}$ ratio will determine the gear ratio of the lower degree additional gearbox, that is

$$U_{\partial\kappa 1} = \frac{U^1_{\max}}{U_{\max}} = 1{,}672. \quad (9)$$

The highest degree gear ratio of the additional gearbox will be equal to 1,0.

The specified range change transmission gear ratios can be achieved with gearbox MAZ-5335 (5-stepped: $U_{k1} = 5{,}26$; $U_{k2} = 2{,}90$; $U_{k3} = 1.52$; $U_{k4} = 1{,}00$; $U_{k5} = 0{,}66$ and 8-stepped: $U_{k1} = 7{,}73$; $U_{k2} = 5{,}52$; $U_{k3} = 3{,}94$; $U_{k4} = 2{,}80$; $U_{k5} = 1{,}96$; $U_{k6} = 1{,}39$; $U_{k7} = 1{,}00$; $U_{k8} = 0{,}71$), and the Mercedes-Benz G 85-6/6.7: $U_{k1} = 6{,}70$; $U_{k2} = 3{,}81$; $U_{k3} = 2{,}29$; $U_{k4} = 1{,}48$; $U_{k5} = 1{,}00$; $U_{k6} = 0{,}73$. At the same time the rear axle gear ratio all variants remains unchanged, $U_0 = 5{,}76$.

The following vehicles traction and velocity properties are recommended in normative documents and technical literature [3]:

1. Speed characteristic "acceleration-runout".
2. Speed characteristic on the last and penultimate transfers.
3. Speed characteristic on the road with a variable longitudinal profile.
4. Maximum speed.
5. Acceleration during racing.
6. Conditional maximum speed.
7. Acceleration time on the way 400 and 1000 m.
8. Acceleration time to the set speed.
9. Minimum stable speed.
10. The maximum lifting angle that can be overcome.
11. Steady speed on long climbs.
12. Traction force on the hook.
13. The length of the dynamically overcome rise.

Each indicator of traction and velocity properties characterizes the vehicle behavior in one of the movement modes, and together they determine the average speed, which is a generalized traction and velocity properties. This speed is used in the comparative evaluation of vehicles when they are converted by replacing the engine or replacing the vehicle transmission.

To choose the best option, will define the BTR-70 traction and velocity properties with the considered options of transmissions. In work [16–18] are present the algorithm for determining the vehicle traction and velocity properties, the basic information is presented in Table 1.

In accordance with the above calculation algorithm, the vehicle traction and velocity properties with different transmission options, are presented in Table 2.

The obtained data in Table 2 show that the best individual BTR-70 traction and velocity properties are achieved with different transmission. However, the best option is to use a Mercedes-Benz G 85-6/6.7 gearbox on the armored personnel carrier,

Table 1 Basic formulas for the vehicles traction and velocity properties determining

Parameter	Calculation formula
The equation of motion during acceleration	$\frac{dV}{dt} m_a \delta_o = a_i V^2 + b_i V + c_i$
Acceleration time, s	$\tau = M_a \delta_o \int_{V_H}^{V_K} \frac{dV}{a_i V^2 + b_i V + c_i}$
Acceleration path, m	$S =$ $m_a \cdot \delta_o \cdot \left\{ \frac{1}{2a_i} \ln\left|a_i V^2 + b_i V + c_i\right| \Big|_{V_H}^{V_K} - \frac{b_i}{2 \cdot a_i} \int\limits_{V_H}^{V_K} \frac{dV}{a_i V^2 + b_i V + c_i} \right\}$
The motion equation at runout	$\frac{dV}{dt} \cdot m_a \cdot \delta_o^{'} = -m_a \cdot g\left(f_0 K_f V\right) - K_B \cdot F \cdot V^2 - P_{fx}$
Minimum steady speed, m/s	$V_{\min y} = -\frac{m_a g f_0 A_i - K_B F C_i}{m_a g K_f A_i - K_B F B_i} + \sqrt{\left(\frac{m_a g f_0 A_i - K_B F C_i}{m_a g K_f A_i - K_B F B_i}\right)^2 - \frac{m_a g (f_0 B_i - K_f C_i)}{m_a g K_f A_i - K_B F B_i}}$
Maximum speed, m/s	$V_{\max} = \frac{-b_i - \sqrt{b_i^2 - 4 a_i c_i}}{2a_i}$
Average speed on the highway, m/s	$V_c = \frac{\sum S_i}{\sum t_i}$
Maximum acceleration during racing, m/s^2	$j_{\max} = \frac{1}{G_a \delta_i}\left(c_i - \frac{b_i^2}{4a_i}\right)$
Average acceleration during racing, m/s^2	$j_{cpi} = \frac{1}{G_a \delta_i}\left[\frac{a_i}{3}\left(V_K^2 + V_K V_H + V_H^2\right) + \frac{b_i}{2}(V_K + V_H) + c_i\right]$
The maximum lifting angle that can be overcome	$\sin\alpha_{\max} = \frac{1}{G_a \delta}\left(C_i - G_a g f_0 \cos\alpha - \frac{(B_i - G_a g K_f \cos\alpha)^2}{4A_i}\right)$
Speed on rise, m/s	$V_{ycm} = \frac{-b_i - \sqrt{b_i^2 - 4 a_i c_i}}{2a_i}$
Traction force on the hook, N	$P_{KP_{\max}} = C_i - \frac{b_i^2}{4a_i}$
Average speed on the route, m/s	$V_c = \frac{0{,}27 N_{y\partial} \eta_m \sum\limits_{i=1}^{n} K_i d_i}{\frac{\gamma_{pi} N \sum K_i d_i}{l_i}}$

(continued)

Table 1 (continued)

Parameter	Calculation formula
The equations coefficients	$a_i = A_i - K_B \cdot F, \quad b_i = B_i - K_f \cdot m_a \cdot g, \quad c_i = C_i - f_a \cdot m_a \cdot g\,;$ $A_i = a \cdot \frac{U_i^3 \cdot \eta_M}{r_\partial r_\kappa^2},\ B_i = b \cdot \frac{U_i^2 \cdot \eta_M}{r_\partial \cdot r_\kappa},\ C_i = c \cdot \frac{U_i \cdot \eta_M}{r_\partial},$ $a = \frac{M_{e\min}}{A_{11}} + \frac{M_{e\max}}{A_{12}} + \frac{M_{eN}}{A_{13}},$ $b = \left[\frac{(\omega_N + \omega_M) \cdot M_{e\min}}{A_{11}} + \frac{(\omega_N + \omega_{\min}) \cdot M_{e\max}}{A_{12}} + + \frac{(\omega_{\min} + \omega_M) \cdot M_{eN}}{A_{13}}\right],$ $c = \left(M_{e\min} \cdot \frac{\omega_M \cdot \omega_N}{A_{11}} + M_{e\max} \cdot \frac{\omega_N \cdot \omega_{\min}}{A_{12}} + M_{eN} \cdot \frac{\omega_{\min} \cdot \omega_M}{A_{13}}\right);$ $\delta_i = 1 + \sigma_1 \times u_{ki}^2 + \sigma_2;$
	$P_{fx} = (2 + 0{,}025 \cdot V) \cdot m_a \cdot g \cdot 10^{-3}, \quad N$ f_0—the rolling coefficient vehicle wheels resistance for speed 1 m/s; f_a—the rolling resistance coefficient at a given speed; K_f—the coefficient that takes into account the increase f coefficient from the speed of movement; K_B—the air resistance coefficient; F—the midsection area; m_a—the vehicle weight; g—free fall acceleration; $V_K,\ V_H$—final and initial speed during acceleration; $N_{y\partial}$—the vehicle specific power; η_M—transmission efficiency; κ_i—the vehicle relative path in the i-th gear; γ_{piN}—the specific traction on the i-th transmission when the engine is running at maximum power; l_i—a factor that takes into account the speed distribution law type on the transmission; $d_i = \frac{V_i}{V_{i-1}},$ $V_i,\ V_{i-1}$—maximum speeds in i-th and i–1 gear

which is slightly inferior to the 8-stepped MAZ-5335 gearbox by increasing the kinematic performance—time, acceleration due to increased gear shift time. However, this gearbox can be recommended for upgrades to the BTR-70. The final choice must be made taking into account fuel efficiency indicators.

Table 2 The vehicle BTR-70 traction and velocity properties

	The name of the indicator	Estimated vehicle transmissions indicators/relative measure			
		MAZ-5335, 8-stepped	MAZ-5335, 5-stepped	Mercedes-Benz: G 85-6/6,7	Etalon
1	Acceleration time to V = 90 km/h, s	61,5/0,89	58,8/0,93	54,9/1,00	54,9/1,00
	Acceleration distance to V = 90 km/h, m	1475,2/0,80	1295,5/0,91	1176,3/1,00	1176,3/1,00
	Runout distance from V = 90 km/h, m	1021,6/1,0	1021,6/1,0	1021,6/1,00	1021,6/1,0
2	Acceleration time in the last gear, s	40,9/0,94	41,6/0,92	38,3/1,00	38,3/1,00
	Acceleration path in the last gear, m	823/0,93	865/0,89	766/1,00	766/1,00
	Acceleration time on the penultimate transmission, s	8,7/0,98	8,9/0,96	8,5/1,00	8,5/1,00
	Acceleration path on the penultimate gear, m	85,9/0,94	88,4/0,91	80,6/1,00	80,6/1,00
3	Average speed, m/s	23,89/1,00	20,06/0,84	22,64/0,95	23,89/1,00
4	Maximum speed according to energy capabilities, m/s	27,9/1,00	27,9/1,00	27,9/1,00	27,9/1,00
5	Max. acceleration during racing, m/s^2	2,72/1,00	2,18/0,80	2,45/0,90	2,72/1,00
6	Conditional maximum speed, m/s	32,1/1,00	32,1/1,00	32,1/1,00	32,1/1,00
7	Acceleration time on the way, with: 400 m	21,98/0,94	22,76/0,90	20,58/1,00	20,58/1,00
	1000 m	49,5/0, 93	48,3/0,95	45,8/1,00	45,8/1,00
8	2000 m	–	–	–	–
9	Minimum stable speed, m/s	1,49/0,93	1,38/1,00	1,52/0,91	1,38/1,00
10	Max. lifting degree overcome, %	54,26/1,00	36,92/0,68	47,03/0,87	54,26/1,00
11	Steady speed on long ascents (3%), m/s	21,43/0,98	21,39/0,98	21,76/1,00	21,76/1,00

(continued)

Table 2 (continued)

	The name of the indicator	Estimated vehicle transmissions indicators/relative measure			
		MAZ-5335, 8-stepped	MAZ-5335, 5-stepped	Mercedes-Benz: G 85-6/6,7	Etalon
12	Max. traction force on the hook, N	90,82/1,00	61,80/0,68	78,72/0,87	90,82/1,00
13	The rise length that is dynamically overcome (3%), m	1325/0,96	1319/0,96	1376/1,00	1376/1,00
	$\sum$Pi	17,22	16,31	17,50	18,0

5 Conclusions

1. Previous studies have considered options for retrofitting the BTR-70 by installing on the chassis of this car instead of two engines ZMZ-4905 two engines D245.30E2 with a 115 kW capacity. However, such a replacement requires the vehicle transmission modernization.
2. In determining the transmission vehicle gear ratios, it is considered appropriate to use analytical research methods. The advantages of such methods are that research performance cars can do with a set of special computer programs (MathCad, Microsoft Excel etc.) providing accurate calculations of such parameters as the maximum speed, acceleration time, acceleration path, average speed and so on at the level of 10%.
3. For typical vehicle operating conditions the minimum and maximum gear ratio transmission car, and also gear ratios of an additional gearbox are defined.
4. It is established that specified range change transmission gear ratios can be provided with 5-stepped and 8-stepped gearbox MAZ-5335 and 6-stepped gearbox Mercedes-Benz G 85-6/6,7. At the same time the rear axle gear ratio all variants remain unchanged, $U_0 = 5{,}76$.
5. Was show that the best individual BTR-70 traction and velocity properties are achieved with different transmission. However, the best option is to use a Mercedes-Benz G 85-6/6.7 gearbox on the armored personnel carrier, which is slightly inferior to the 8-stepped MAZ-5335 gearbox by increasing the kinematic performance—time, acceleration due to increased gear shift time. However, this gearbox can be recommended for upgrades to the BTR-70. The final choice must be made taking into account fuel efficiency indicators.

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Analysis of Influence of Metal Elements of Window and Door Openings in Brick Walls on the Temperature of the Interior Plain of a Wall at the Place of Their Installation

Oleksandr Semko, Olena Filonenko, Oleg Yurin, Petro Sankov, and Nataliia Mahas

Abstract Renovation of buildings often requires the building of window and door openings in the exterior walls. The lintel over the slot is most often made of metal angles that are installed on the edges of the slot. The metal angles are connected by bandages or laths. Horizontal angle legs are connected by metal laths and are established at certain pitches. Metal structures, due to their high thermal conductivity, reduce heat transmission resistance in the place of their application. This leads to a decrease in the temperature of the slope surface on the interior side of the wall and the deterioration in the humidity conditions of this part of the wall. Condensate forms on the slope, if its temperature is below the dew point, in such cases wall material moistens, and mould and fungus form there. The article examines the influence on the slope temperature of the pitch and thickness of the metal laths connecting metal angles, the location of filling the slots with transom bars of windows and/or doors (near the inner and outer surfaces of the wall), the insulation of the slope on the outer side of the enclosure. The authors have proposed methods of avoiding moisture condensation on the slope on the inner side of the wall.

Keywords Heat flow · Insulation · Temperature fields · Window and door openings in brick walls

1 Introduction

Renovation of buildings often requires the building of window and door openings in the exterior walls. The lintel over the slot is most often made of metal angles that are installed on the edges of the slot. The metal angles are connected by bandages or laths. Horizontal angle legs are connected by metal laths and are established at

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_25

certain pitches. Metal structures, due to their high thermal conductivity, reduce heat transmission resistance in the place of their application. This leads to a decrease in the temperature of the slope surface on the interior side of the wall and the deterioration in the humidity conditions of this part of the wall. Moisture accumulates in the enclosure and reduces its heat-insulation properties at the point of use of metal structures. The question of the influence of metal elements on humidity conditions was studied in Ref. [1]. Studies of the influence of heat-conducting inclusions on heat-protective qualities and moisture resistance of external enclosing structures are presented in Refs. [2–5]. Decreasing the temperature of the slope surface, located on the inner side of the room, may also lead to negative consequences. Condensate forms on the slope, if its temperature is below the dew point, in such cases wall material moistens, and mould and fungus form there. Therefore, the study of the influence of metal elements of transom bars on the temperature of the slope surface is relevant. The article examines the influence on the slope temperature of the pitch and thickness of the metal laths connecting metal angles, the location of filling the slots with transom bars of windows and/or doors (near the inner and outer surfaces of the wall), the insulation of the slope on the outer side of the enclosure [6–11]. The authors have proposed methods of avoiding moisture condensation on the slope on the inner side of the wall.

2 Selection of Bench-Mark Data and the Range of Variables for Performing Analysis

The studies were performed for the first temperature zone. The design room air temperature was taken as for a residential building $t_{ind} = 20$ °C, the calculated outside temperature was taken as $t_{out} = -22$ °C (1st temperature zone, [12]). The thickness of the brick wall was 0.25, 0.38, and 0.51 m. The wall was insulated on the outside with a layer of mineral wool with a density of 125 kg/m^3. The thickness of the layer of mineral wool was determined by thermotechnical calculation and was equal to 0.14 m at the 0.25 m thickness of the layer of brickwork, and it was equal to 0.13 m at the thickness of 0.38 and 0.51 m. 75 × 8 metal angles and 60 mm wide laths were used to arrange the slot. The thickness of the laths was taken from 4 to 10 mm, and the pitch of the slots was taken from 300 to 1500 mm.

The research was performed using calculations of temperature fields. The design model of the enclosing structure for the calculation of temperature fields is shown in Fig. 1 [13, 14].

Characteristics of the layers of the enclosing structure are given in Table 1. The numbering of the layers is done from the inner surface of the enclosing structure.

The thermal conductivity of the area, where the batten plate is located, was determined by the following formula:

$$\lambda = \frac{\lambda_{met} \cdot b_{met} + \lambda_{cem} \cdot b_{cem}}{b_{met} + b_{cem}} \tag{1}$$

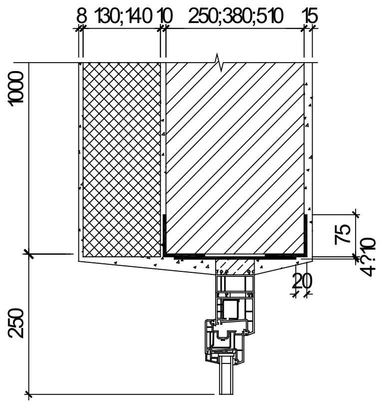

Fig. 1 The design model of the enclosing structure

Table 1 Characteristics of the layers of the enclosing structure

Name	Thickness, m	Thermal conductivity, W/(m · K)
Sand-lime mortar	0.015	0.81
Brick	0.25; 0.38; 0.51	0.81
Adhesive mixture	0.01	0.93
Insulation	0.13; 0.14	0.049
Finishing layer	0.008	0.93

where λ_{met}, λ_{cem}—thermal conductivity, W/(m · K), respectively, of the metal lath and cement-sand mortar $\lambda_{met} = 58$ W/(m · K); $\lambda_{cem} = 0.93$ W/(m · K), b_{met}, b_{cem}—width, m, respectively, of metal lath and cement-sand mortar between the laths.

The width of the cement-sand mortar between metal laths is determined by the formula:

$$b_{cem} = k - b_{met} \tag{2}$$

where k is the pitch of laths, m.

Thus, at the pitch of laths 0.3 m and at 0.06 m width of laths, the thermal conductivity of a place of the enclosure, where the batten plate is located, shall make:

$$\lambda = \frac{\lambda_{met} \cdot b_{met} + \lambda_{cem} \cdot b_{cem}}{b_{met} + b_{cem}} = \frac{58 \cdot 0{,}06 + 0{,}93 \cdot 0{,}24}{0{,}006 + 0{,}24} = 12,344\,\mathrm{W/(m \cdot K)} \tag{3}$$

$$b_{cem} = k - b_{met} = 0{,}3 - 0{,}06 = 0,24\,\mathrm{m} \tag{4}$$

3 Analysis of the Impact of the Pitch and Thickness of Metal Laths, Connecting Metal Angle, on the Temperature Along the Inner Surface of the Slope

Figures 2, 3 and 4 show the temperature fields of the calculated section of the wall with the thickness of 0.25 m at the thickness of batten plates from 2 to 10 mm (every 2 mm) and their pitches of 300 mm, 600 m and 900 mm respectively. For illustrative purposes, the temperature fields are shown only in the location of the reinforcing elements, not of the whole design model.

If the temperature of the slope surface, located on the inner side of the enclosure below the dew point decreases, condensate is formed on it, which moistens the enclosure near the condensation zone. Humidification of enclosure material reduces heat transmission resistance of this area, which, in turn, leads to an even greater decrease in the temperature of the slope surface. In addition, the inner finishing layer of enclosure structures may peel off on damp inner surfaces of enclosure structures, as well as there may occur the formation of mould and fungus, which worsens the sanitary and hygienic conditions, and in some cases leads to diseases.

At $t_{ind} = 20$ °C and $\varphi_{ind} = 55\%$, the dew point temperature will be $t_{dew} = 10.7$ °C.

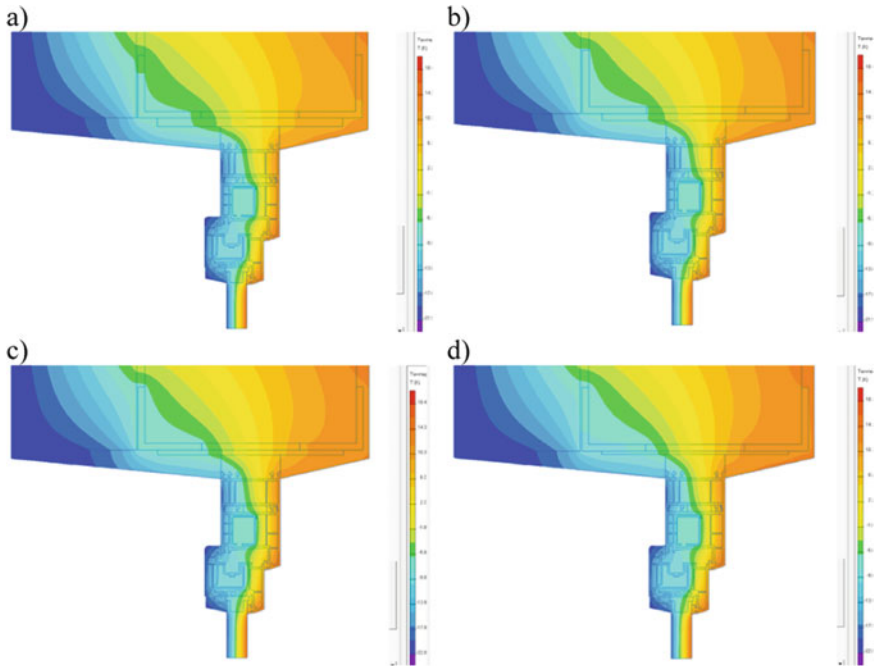

Fig. 2 Temperature fields of the wall with the thickness of 0.25 m, with a 300 mm pitch of batten plates and their thickness: **a** 10 mm; **b** 8 mm; **c** 6 mm; **d** 4 mm

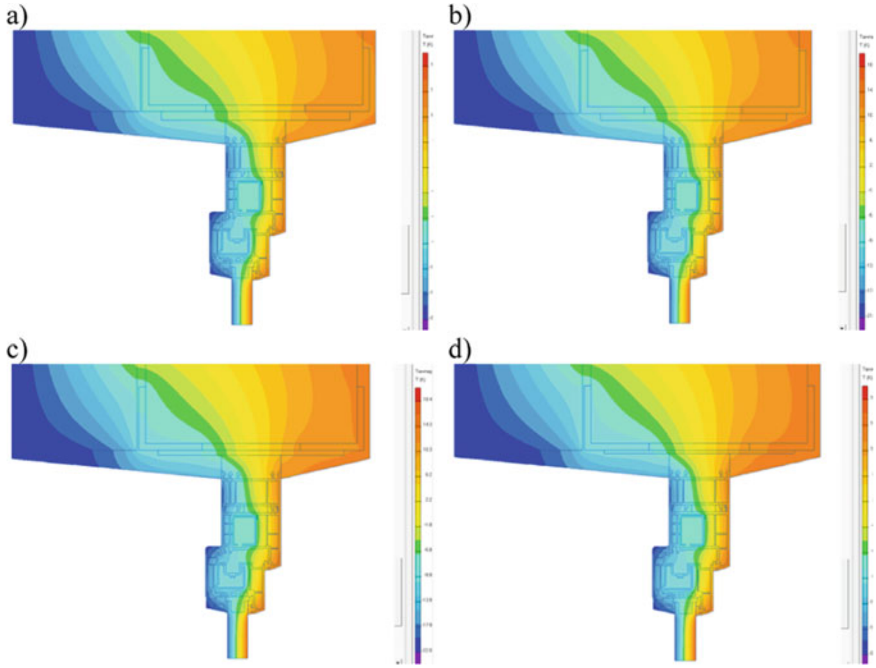

Fig. 3 Temperature fields of the wall with the thickness of 0.25 m, with a 600 mm pitch of batten plates and their thickness: **a** 10 mm; **b** 8 mm; **c** 6 mm; **d** 4 mm

Figure 5 shows temperature curves on the slope surface of the wall with the thickness of 0.25 m, at the thickness of batten plates from 2 to 10 mm, and at their 300 mm pitch.

Figure 6 shows temperature curves on the slope surface of the wall 0.25 m in thickness, at the thickness of batten plates from 2 to 10 mm and at their 600 mm pitch.

Figure 7 shows temperature curves on the slope surface of the wall 0.25 m in thickness, at the thickness of batten plates from 2 to 10 mm, and at their 900 mm pitch.

Temperature curves on the inner surface of the wall (Figs. 5, 6 and 7) start from the junction of the slope surface with the structure of the filling of the window aperture or doorway and end at the upper edge of the inner surface of the calculation area. The minimum temperature is observed at the beginning of the temperature curve at the junction of the slope surface with the slot filling structure.

The minimum slope surface temperature of the 0.25 m thick wall, with the thickness of batten plates from 4 to 10 mm and their pitch from 300 to 900 mm are given in Table 2.

Figure 8 shows graphs of the dependence of the minimum temperature on the inner surface of the enclosure from the pitch of the laths at different thicknesses, for a brick wall of 0.25 m thick.

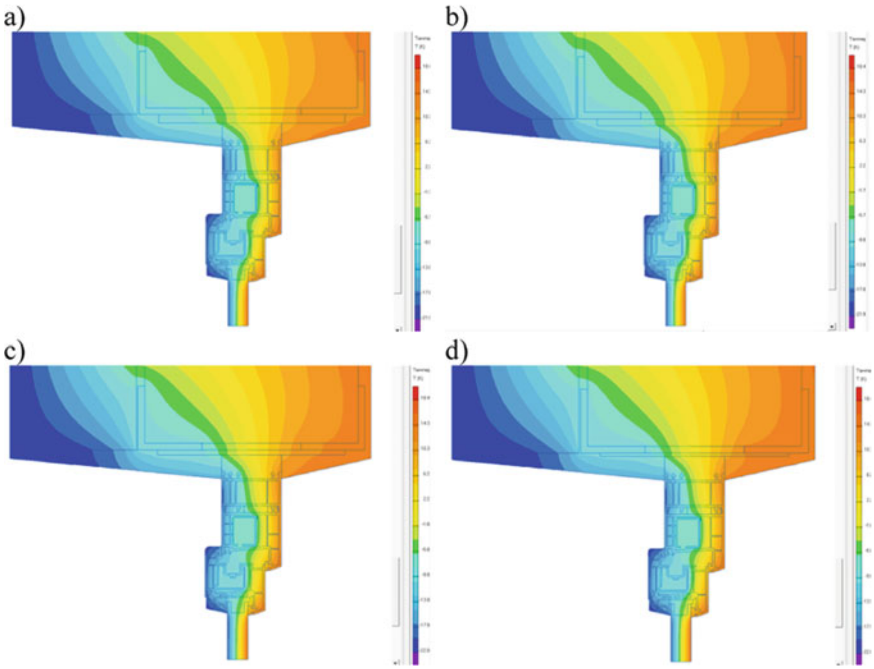

Fig. 4 Temperature fields of the wall with the thickness of 0.25 m, with a 900 mm pitch of batten plates and their thickness: **a** 10 mm; **b** 8 mm; **c** 6 mm; **d** 4 mm

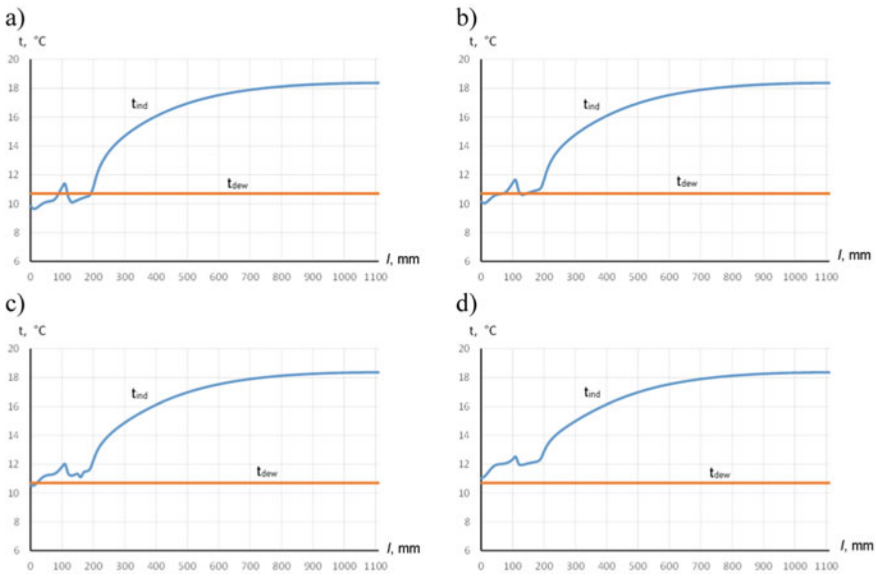

Fig. 5 Temperature curves on the slope surface of the wall 0.25 m in thickness, with a 300 mm batten plate pitch and at their thickness: **a** 10 mm; **b** 8 mm; **c** 6 mm; **d** 4 mm

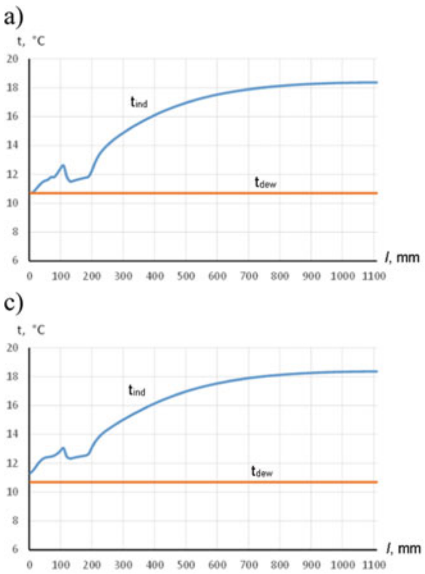

Fig. 6 Temperature curves on the slope surface of the wall 0.25 m in thickness, with a 600 mm batten plate pitch and at their thickness: **a** 10 mm; **b** 8 mm; **c** 6 mm; **d** 4 mm

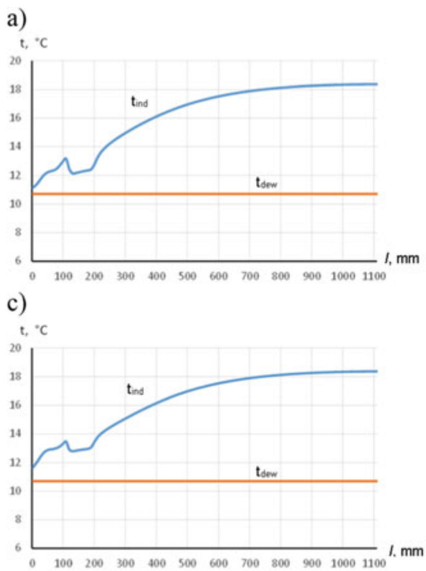

Fig. 7 Temperature curves on the slope surface of the wall 0.25 m in thickness, with a 900 mm batten plate pitch and at their thickness: **a** 10 mm; **b** 8 mm; **c** 6 mm; **d** 4 mm

Table 2 The minimum slope surface temperature of the 0.25 m thick wall

The pitch of the laths	Minimum slope surface temperature, °C at the thickness of the batten plate			
	10	8	6	4
300	9.6	10	10.5	11
600	10.7	11	11.3	11.6
900	11.1	11.3	11.6	11.9

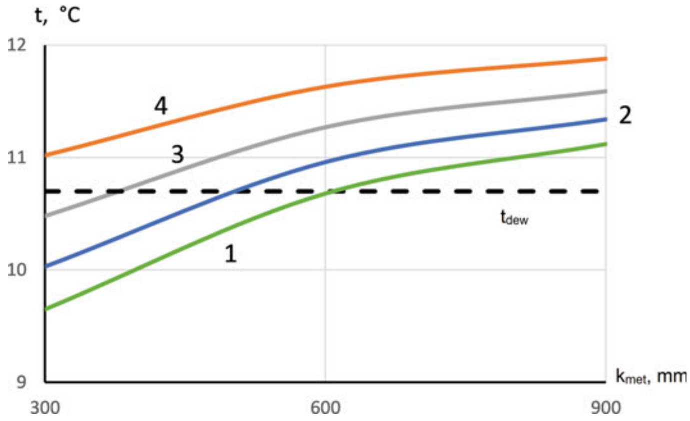

Fig. 8 Graphs of the dependence of the minimum temperature on the inner surface of the slope of the 0.25 m thick wall thickness on the pitch of the laths at their thickness: 1. 10 mm, 2. 8 mm, 3. 6 mm, 4. 4 mm

As can be seen from the graphs, the minimum temperature on the inner slope surface of the wall is higher than the dew point at:

- the lath thickness of 10 mm and their pitches more than 600 mm;
- the lath thickness of 8 mm and their pitches more than 500 mm;
- the lath thickness of 6 mm and their pitches more than 370 mm;
- the lath thickness of 4 mm and their pitches more than 300 mm.

Similar studies were performed for 0.38 and 0.51 m thick walls. For these wall thicknesses, the thickness of the insulation was specified, as well as the thermal conductivity of the area, where the batten plate is located.

The minimum slope surface temperature of the 0.38 m thick wall, with the thickness of the batten plates from 4 to 10 mm and their pitch from 300 to 1200 mm are given in Table 3.

Figure 9 shows graphs of the dependence of the minimum temperature on the inner surface of the enclosure on the lath pitch at their different thicknesses, for a brick wall of 0.38 m in thickness.

Table 3 The minimum slope surface temperature of the 0.38 m thick wall

The pitch of the laths	Minimum slope surface temperature, °C at the thickness of the batten plate			
	10	8	6	4
300	8.8	9.1	9.4	9.9
600	9.6	9.9	10.1	10.5
900	10	10.2	10.4	10.7
1200	10.2	10.4	10.6	10.8

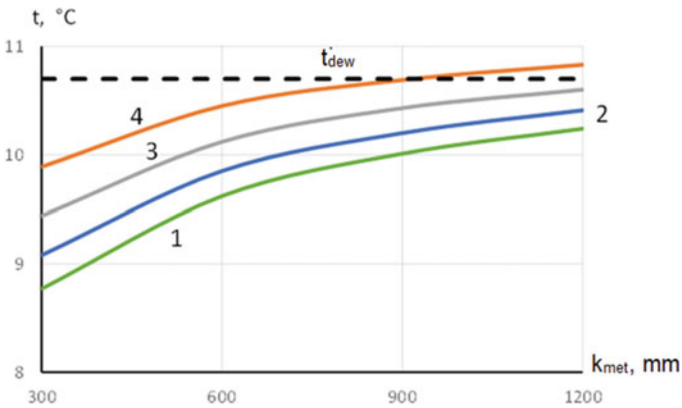

Fig. 9 Graphs of the dependence of the minimum temperature on the inner slope surface of the wall 0.38 m in thickness on the lath pitch at their thickness: 1. 10 mm, 2. 8 mm, 3. 6 mm, 4. 4 mm

As can be seen from the graphs, the minimum temperature on the inner surface of the enclosure is higher than the dew point temperature only when the thickness of the laths is 4 mm and their pitch is more than 900 mm. At other thicknesses of batten plates, the minimum slope surface temperature will be lower than a dew point at the lath pitch up to 1200 mm. In all cases, the minimum surface temperature increases with increasing the lath pitch. It is inexpedient to increase the lath pitch by more than 1200 mm, as an increase in the minimum temperature will be insignificant.

The minimum slope surface temperature of the wall 0.51 m in thickness, at the thickness of batten plates from 2 to 10 mm, and their pitch from 300 to 1500 mm is given in Table 4.

Figure 10 shows graphs of the dependence of the minimum temperature on the inner surface of the enclosure on the lath pitch at their different thicknesses, for a brick wall with the thickness of 0.51 m.

As can be seen from the graphs, the minimum temperature on the inner surface of the enclosure is lower than the dew point temperature in all cases. It is inexpedient to increase the lath pitch by more than 1500 mm for constructive reasons.

Table 4 The minimum slope surface temperature of the 0.51 m thick wall

The pitch of the laths	Minimum slope surface temperature, °C at the thickness of the batten plate				
	10	8	6	4	2
300	8.2	8.5	8.8	9.3	9.9
600	9	9.2	9.5	9.9	10.3
900	9.4	9.6	9.8	10.1	10.4
1200	9.6	9.8	10	10.3	10.5
1500	9.8	10	10.1	10.4	10.6

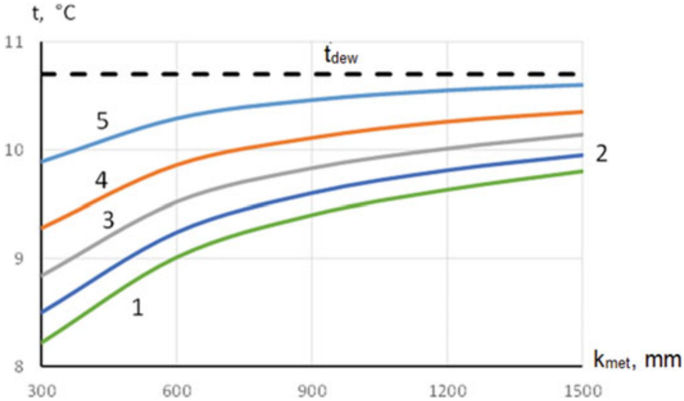

Fig. 10 Graphs of the dependence of the minimum temperature on the inner slope surface of the wall 0.51 m in thickness on the lath pitch at their thickness: 1. 10 mm, 2. 8 mm, 3. 6 mm, 4. 4 mm, 5. 2 mm

4 Analysis of Possible Ways to Increase the Minimum Temperature of the Slope Surface

The lowest temperature on the slope surface is observed at the wall thickness of 0.51 m with the use of batten plates 10 mm in thickness and their pitch of 300 mm. Therefore, in subsequent studies, we have considered this option.

To increase the temperature of the slope surface above the dew point, some methods, described in Ref. [1], were considered, namely:

- displacement of the slot filling with transom bars of windows (doors) to the inner surface of the wall;
- displacement of the slot filling with transom bars of windows (doors) to the outer surface of the wall;
- insulation of the slope on the outside from the slot filling with a layer of insulation 10 mm thick.

Figure 11 shows design models and their temperature fields when shifting the slot filling with transom bars of windows (doors) to the inner surface of the wall (a, b), when shifting the slot filling with transom bars of windows (doors) to the outer surface of the bricklayer of the wall (c, d), when insulating the slope on the outside from the slot filling with a layer of 10 mm thick insulation (e, f).

Graphs of temperature distribution on the slope surface are shown in Fig. 12 when shifting the slot filling with transom bars of windows (doors) to the inner surface of the wall (a), when shifting the slot filling with transom bars of windows (doors) to the outer surface of the bricklayer of the wall (b), when insulating the slope on the outside from the slot filling with a layer of 10 mm thick insulation (c).

When shifting the slot filling with transom bars of windows (doors) to the inner surface of the wall, the minimum slope temperature is $\tau_{ind.min} = 1.4$ °C, which is 9.4 below the dew point.

When shifting the slot filling with transom bars of windows (doors) to the outer surface of the bricklayer of the wall, the minimum slope temperature will be $\tau_{ind.min} = 12$ °C, which is 1.3 °C above the dew point.

When insulating the slope on the outside from the slot filling with a layer of 10 mm thick insulation, the minimum slope temperature will be $\tau_{ind.min} = 11.7$ °C, which is 1 °C above the dew point.

5 Conclusions

The performed research allows us to draw the following conclusions:

1. When increasing the pitch of batten plates, the minimum temperature on the inner slope surface of the wall increases too.
2. As the thickness of the batten plates decreases, the minimum temperature on the inner slope surface of the wall increases.
3. When increasing the wall thickness, the minimum temperature on the inner slope surface of the wall decreases.

When the thickness of the brick part of the wall is 0.25 m, the minimum temperature on the inner slope surface of the wall will be higher than the dew point at:

(a) 10 mm thickness of the batten plates and their step more than 600 mm;
(b) 8 mm thickness of the batten plates and their step more than 500 mm;
(c) 6 mm thickness of the batten plates and their step more than 370 mm;

4. When the thickness of the brick part of the wall is 0.38 m, the minimum temperature on the inner slope surface of the wall will be higher than the dew point temperature only when the thickness of the batten plates is 4 mm, and their step is more than 900 mm.

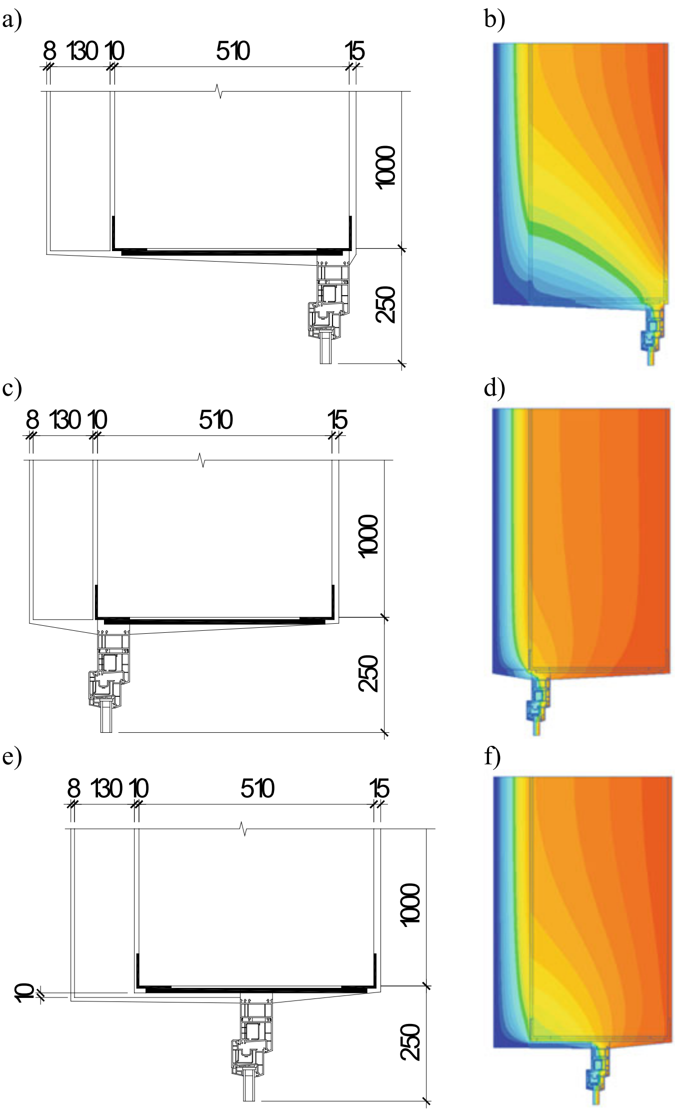

Fig. 11 Design models and their temperature fields when shifting the slot filling with transom bars of windows (doors) to the internal surface of a wall (**a**, **b**), when shifting the slot filling with transom bars of windows (doors) to the external surface of a bricklayer of a wall (**c**, **d**), when insulating the slope on the outside from the slot filling with a layer of 10 mm thick insulation (**e**, **f**)

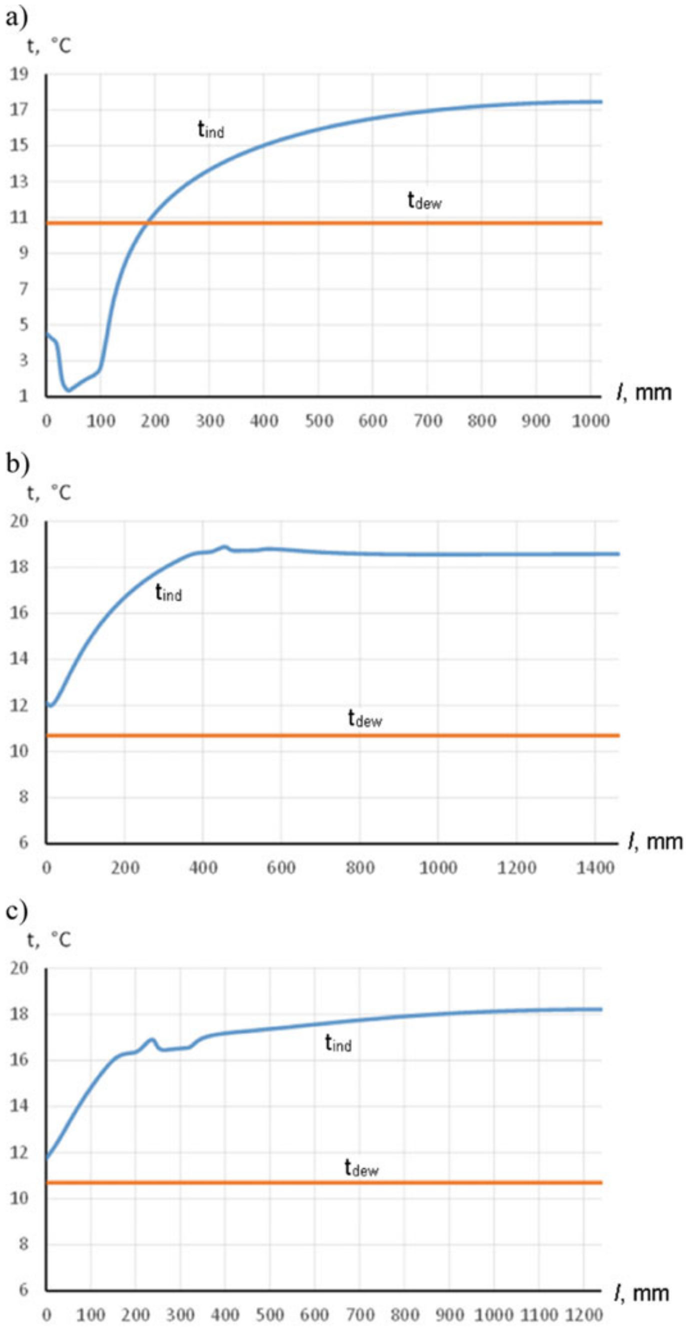

Fig. 12 Graphs of temperature distribution on the slope surface when shifting the slot filling with transom bars of windows (doors) to the inner surface of the wall (**a**), when shifting the slot filling with transom bars of windows (doors) to the outer surface of the bricklayer of the wall (**b**), when insulating the slope on the outside from the slot filling with a layer of 10 mm thick insulation (**c**)

5. When the thickness of the brick part of the wall is 0,51 m, the minimum temperature on an internal slope surface of the wall will be lower than the temperature of a dew point at all considered variants.
6. When shifting the slot filling with transom bars of windows (doors) to the inner surface of the wall the temperature of the inner surface of the wall will reduce significantly.

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Settlements of Buildings on Soil–Cement Base

Yuriy Vynnykov, Roman Razdui, Volodymyr Onyshchenko, and Aleksej Aniskin

Abstract The results of long-term (over 10 years) geodetic observations of a five-section multi-storey building settlement with strip foundations on weak soils reinforced with vertical soil–cement elements are presented. Stabilization of its settlement up to 1–2 mm/year has been recorded. The results of 3D modeling by the finite element method (FEM) of the stress–strain state (SSS) of the system "building—strip foundation—soil–cement base—natural base" and 2D modeling of the FEM in the elastic–plastic soil model of the SSS system "strip foundation—soil cement base—natural base" are analyzed. By comparing simulation data, analytical calculations and field studies, it has been proved that the normative methods for predicting settlements based on the model of a linearly deformed body underestimate their actual values by half, and the accepted FEM modeling methods fairly reliably estimate the SSS of experimental systems.

Keywords River floodplain · Dusty sand · Boring and mixing technology · Soil–cement base · Monolithic reinforced concrete strip foundation · Finite element method · Stress-deformed state · Settlement · Geodetic observations

1 Introduction

According to modern geotechnical experience [1–4] of construction within river floodplains, adverse physical and geological phenomena include: flooding of the territory; annual and seasonal fluctuations in groundwater levels; very significant heterogeneity of the soil mass in both area and depth; the presence of layers (lenses, layers) of weak (very compressible) soils (silt, peat, peat soils, and other deposits with the inclusion of organic matter), the modulus of deformation of which is <5 MPa;

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_26

floating properties of soils; mechanical suffusion, etc. Under such conditions, the design is carried out in compliance with certain tested provisions, in particular: the foundations are simultaneously loaded over the entire area of the building (block, section); reduce the unevenness of settlement; increase the overall rigidity of the building; take into account the structural strength of the soil and its sensitivity to thixotropic rarefaction, etc. [1–4].

Therefore, under multi-storey buildings, cutting through weak soils with various piles or replacing highly compressible soil with a pad of layer-by-layer compacted sand of large or medium size is usually used. However, as geotechnical practice shows, these effective measures have technological limitations (especially in unstable soils) and economic disadvantages. As an alternative to these methods in the last twenty years, due to the versatility and cost-effectiveness of site-based construction technology (even up to a depth of 30 m in weak soils), soil–cement elements (SCE) and piles (SCP), which are made by jet grouting and brown mixing methods gained popularity. Laboratory and field experiments [5–10] proved an increase in time of SCE strength up to 2.5 times and a decrease in settlement of soil–cement base buildings up to 4 times compared to natural.

An important principle in the design of soil–cement foundations of buildings under conditions of very compressible soils is the joint calculation of the system "building—foundation—soil–cement base—natural base" [1–4]. Thus, modern geotechnical software products for the evaluation of finite element method (FEM) stress-strained state (SSS), in particular, and systems "building—foundation—artificial foundation—natural base", which have a powerful library of already tested environmental models, are actively used for comparison results (verification) of field research and numerical calculation and confirmation or refutation of the correctness of methods of calculations and design decisions [10–15].

Note the new original opportunities to improve analytical methods (layer-by-layer summation) to determine the settlement of natural and artificial foundations, which, in particular, are to take into account: changes in the modulus of soil deformation in the stress range; dependences of change of values of the deformation modulus on depth of soil thickness; orthotropic deformation model of the soil; soil compression index, etc. [16–18, 21–25].

To predict the development and stabilization of buildings foundations settlement over time, options for solving the problem of soil consolidation have been tested, including numerical modeling of FEM [19, 20].

2 Defining the Problem

However, the development of design standards for soil–cement base of building foundations requires increasing the reliability of the method for calculating their settlement. A reliable way to solve this problem is to compare the results of modeling, analytical calculations and long-term studies of natural objects settlement.

3 Research Results

3.1 *Object of Field Research*

For more than 10 years, the authors have been performing geometric leveling of accuracy class III of surface grades installed at the level of the basement of a multi-storey five-section brick house (in Poltava, Ukraine) with strip foundations on soft soils, reinforced with vertical SCEs. For this purpose, the method of Prof. M. Zotsenko, tested for observations of long-term settlements of buildings on stuffed piles in punched wells in forest soil conditions [21]. The zero cycle corresponded to the moment of the construction of the basement, the subsequent ones—after each floor and the settlement of the house. In the first two years of its operation, 2–3 cycles were carried out, and in the future—one cycle for 3–4 years.

The house with a basement has a complex shape in plan (sections I, II, IV and V—9 floors, and section III—10). Load-bearing brick walls—both longitudinal and transverse.

Geomorphologically, the site belongs to the floodplain of the Vorskla River. Therefore, the groundwater level is fixed only 2.3 m from the earth's surface. From the surface of the site there was a layer of bulk soil with a thickness of 2.5–2.7 m. Beneath it was a two-meter layer of dusty sand with impurities of organic matter for sections I–III. For sections IV and V, there was a layer of refractory and soft clay under the embankment, as well as a layer of heavy, fluid, highly peat clay 0.3–0.6 m thick. These layers were covered with dusty and fine sands, medium density, saturated with water.

The two-meter layer under the embankment was reinforced with vertical SCEs made using the drilling mixing method. A crushed stone cushion 0.5 m thick was laid on it. Monolithic reinforced concrete strip foundations 2200 mm wide under the outer longitudinal load-bearing walls and 3200 mm under the longitudinal middle load-bearing wall were erected on it. To increase the rigidity of the building, monolithic reinforced concrete belts and reinforcement of the masonry walls were used.

3.2 *Results of 3D Modeling*

Evaluation of SSS system "five-section brick house—strip monolithic reinforced concrete foundation—soil–cement base—natural sand base" was performed by FEM in 3D calculation scheme, taking into account the joint work of aboveground and underground structures, strip reinforced concrete foundation, vertical SCE. The LIRA-SAPR 2020 R3 complex was used for this purpose. For example, elements of the KE51 type were used to simulate the SCE, and elements of the KE56 type were used to model the strip foundation.

During the modeling, the soil conditions corresponded to the engineering-geological section and the location of exploration wells on the site. Complex spatial geometric schemes are simplified by simulating the actual design of the conditional scheme, for example: round-hollow plates are approximated by rods reduced to the axis; monolithic slabs, walls and stairways are conditionally replaced by shells reduced to a certain median plane.

The following preconditions are accepted in the design model of the building: connection of walls with floor slabs—hinged; contact of the strip foundation with SCE—hinged. In the finite element model of the frame, the calculated parameters of strength, rigidity and geometric parameters of the building structures are used. The calculation scheme of 3D modeling of the FEM system "five-section brick residential building—reinforced concrete strip foundation—soil–cement base—natural sand base" is shown in Fig. 1.

When modeling, the shells were divided into quadrangular finite elements (FE). The dimensions of these FEs were taken in accordance with the recommendations of about 0.5 m. The reaction of the elastic foundation is characterized by the stiffness coefficient. When evaluating the SSS of the reaction system, the SCEs were replaced by elastic coefficients determined from the spatial evaluation of the SSS of the building. For each floor, the characteristic load values are taken: constant—2.5 kPa (pressure from the floor and partitions); replaceable long-term—2.0 kPa for residential premises, 3.0 kPa—premises of stores on the ground floor and 0.7 kPa—technical floor. On the roof, the values of permanent loads are assumed to be 0.86 kPa (roof structure), and loads from snow—1.64 kPa. The self-weight of the structure is

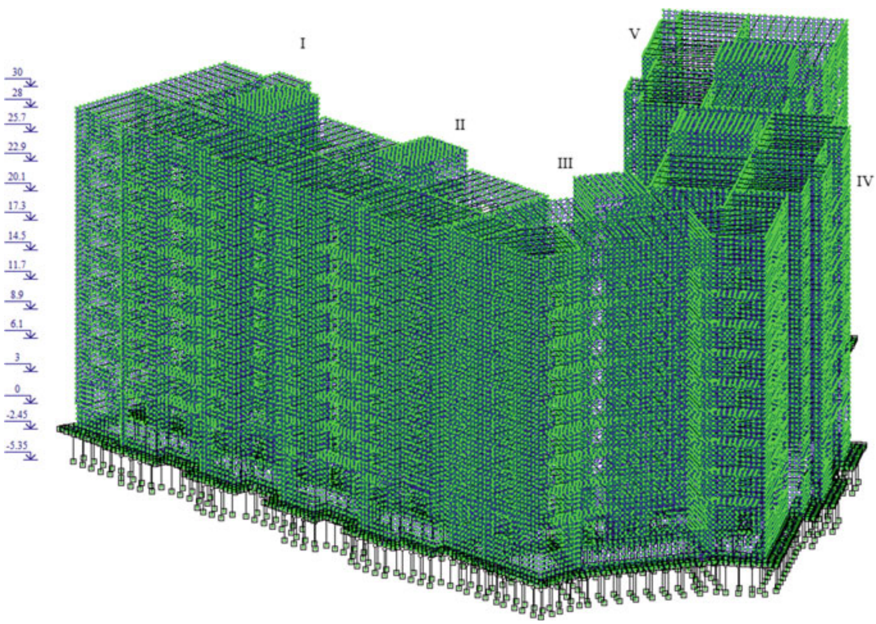

Fig. 1 Calculation scheme for 3D modeling of the FEM system "five-section brick residential building—reinforced concrete strip foundation—soil–cement base—sand base"

Fig. 2 Results of 3D modeling of FEM stresses under the base of the foundation

applied automatically (according to the dimensions of the elements and the density of the material). To determine the stiffness coefficients of the foundation in terms of the strip foundation, calculations were made of settlement in the FE nodes from the action of a uniformly distributed load on the slab. In this case, the plate was taken absolutely flexible. The values of the stiffness coefficients are determined by iterative FEM. According to the surface area of the strip foundation, the stiffness coefficients ranged from 780 to 4770 kN/m^3. The values of hardness coefficients for SCE according to the engineeringgeological section from k = 8800 kN/m (in the zone of the weakest soils corresponding to section V) to k = 13400 kN/m (section I) are calculated.

The results of 3D modeling of FEM stresses under the base of the foundation are shown in Fig. 2, and a similar modeling of stresses in the SCE—in Fig. 3.

They clearly show that under the sections with the best natural soil conditions (sections I and II) most of the stresses are absorbed by the base of the foundation, and in areas of liquid, highly peat clay (sections IV and V)—vertical SCE reinforcement.

3.3 Results of 2D Modeling

2D modeling of FEM using elastic–plastic model of soil with Mohr Coulomb strength criterion SSS system "strip foundation—soil–cement base—natural sand base" was

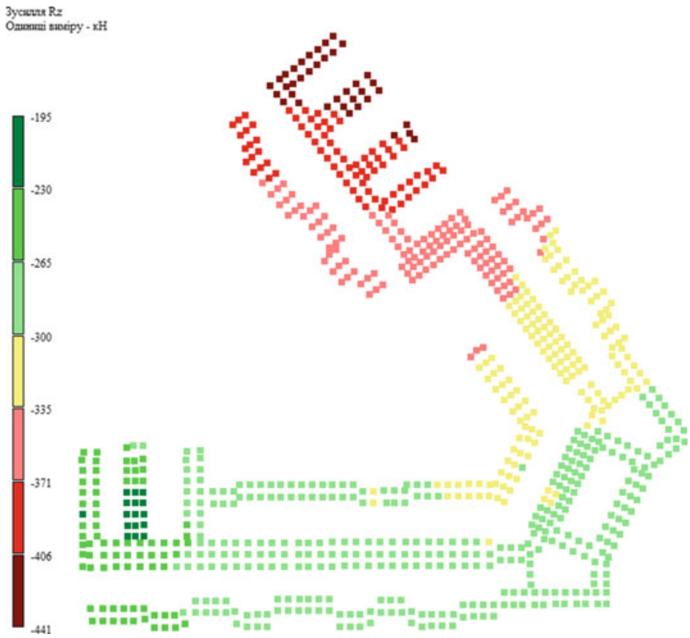

Fig. 3 Results of 3D modeling of FEM stresses in soil–cement elements

also performed. For this purpose, a condition was adopted according to which the modulus of soil deformation in the reinforcement zone was determined as a weighted average depending on the percentage of reinforcement, the values of specific adhesion of soils in the reinforced massif were also taken as weighted average, and the angle of internal friction as natural soils.

Figure 4 shows a 2D modeling scheme for the FEM SSS system "strip foundation—soil–cement base—natural sand base". Figure 5 shows the results (total stresses in the soil mass and deformations in it) of 2D FEM modeling using the elastic–plastic soil model SSS of the same system using section IV as an example (for a foundation load of 650 kN).

In particular, for this system, the corresponding settlement of the foundation was about 250 mm, which has a fairly high agreement with the results of the following long field observations.

3.4 The Results of Long-Term Studies of Buildings Settlement on Soil–Cement Base

The results of long-term geodetic observations of the settlement of a five-section multi-storey building with strip foundations on weak soils reinforced with vertical SCE, in particular, were: plots of settlement of wall marks during the construction

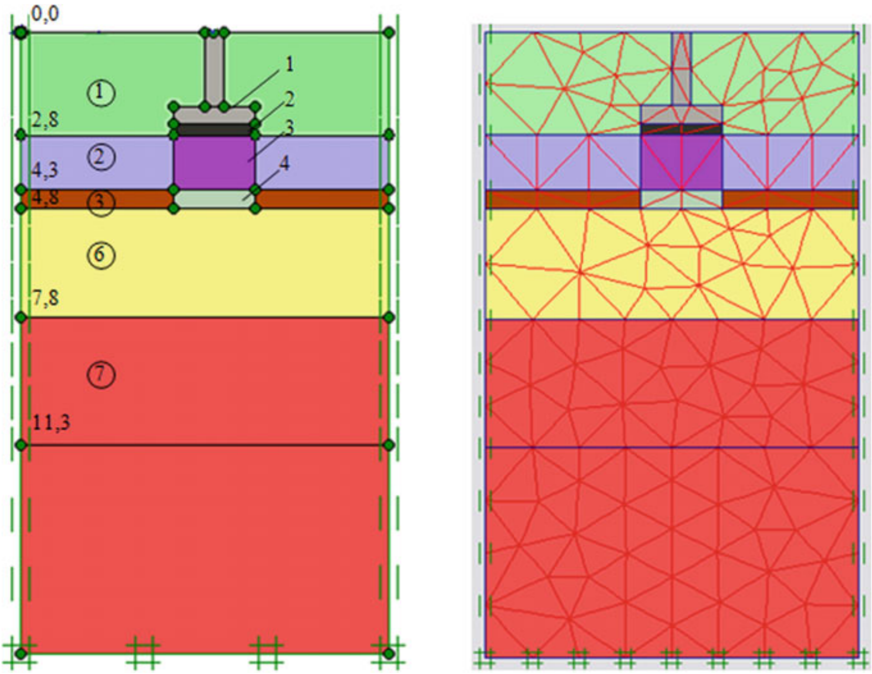

Fig. 4 Scheme of 2D modeling of FEM SSS system "strip foundation—soil–cement base—natural soil base": 1—strip foundation; 2—buffer cushion (crushed stone); 3 and 4—zones of soil layers reinforced with vertical soil–cement elements

and operation of the building; schedules of development of the smallest, average and largest settlement of marks in time; values of absolute and relative settlement of buildings. Figure 6 shows the settling plots of the wall marks of the building (observation data for January 2022). In Figs. 7, 8, 9 and 10 shows the graphs of the development of the smallest, average and largest settlement of marks in time, respectively, for sections I–V.

Geodetic observations, in particular, recorded that as of January 11, 2022, the smallest settlement of the grades of section I–II reached 187 mm, the average—209.6 mm, and the largest—226 mm. Similar results were made for section III, respectively, 235, 245.0 and 256 mm; for section IV—248 mm, 254.2 mm and 264 mm, respectively; for section V—respectively 248, 256.1 and 263 mm.

Thus, the average values of the foundation's settlement exceeded the allowable building norms of 180 mm for all sections of the building, but the values of the relative difference of settlement for any section did not exceed the maximum allowable norms of 0.004. At the same time, no cracks or other deformations were recorded in the constructions of the sections, and the technical condition of the building was assessed as normal. For sections I–II, the so-called conditional stabilization of settlement (1 mm/year) of the base of its foundations has been practically achieved, and for the remaining three sections, there is also a tendency to stabilize the settlement, and so far their development is about 2 mm/year.

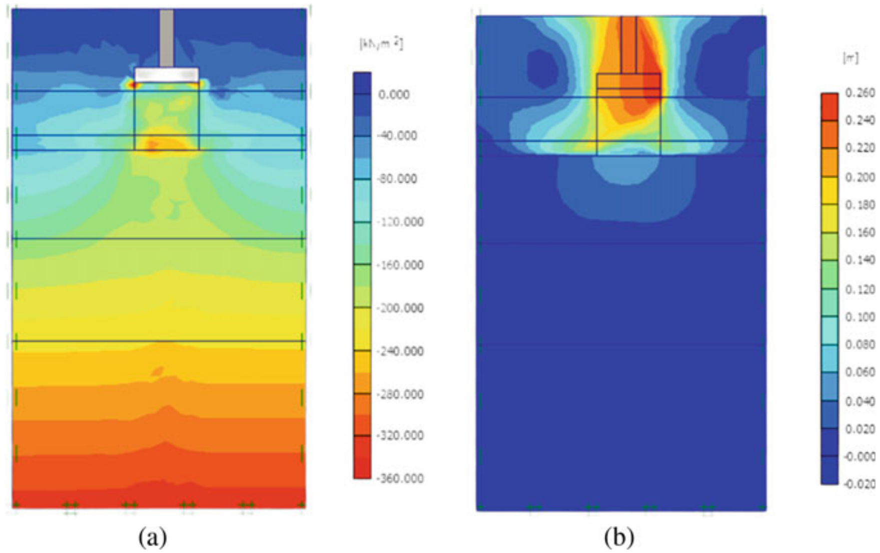

Fig. 5 Results of 2D modeling of FEM using elastic–plastic model of soil SSS system "strip foundation—soil–cement base—natural base": **a** total stresses in the soil mass; **b** deformations in the soil mass

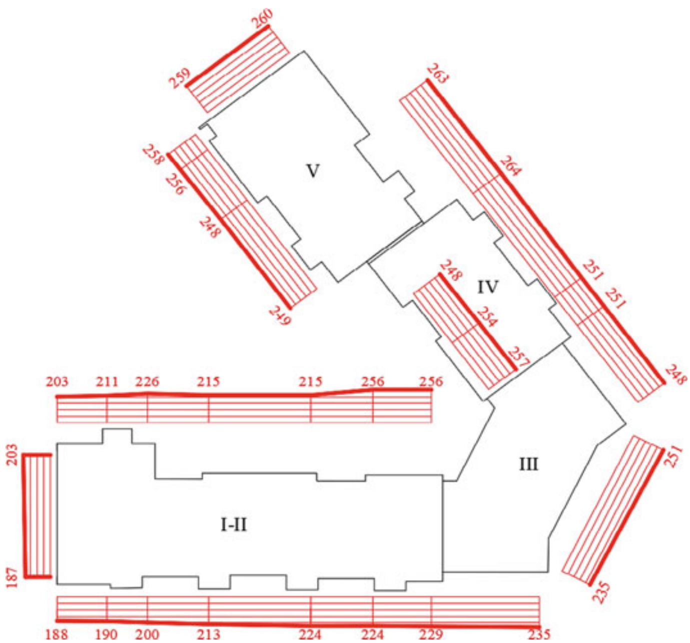

Fig. 6 Plots of building wall marks settlement (observation data for January 2022)

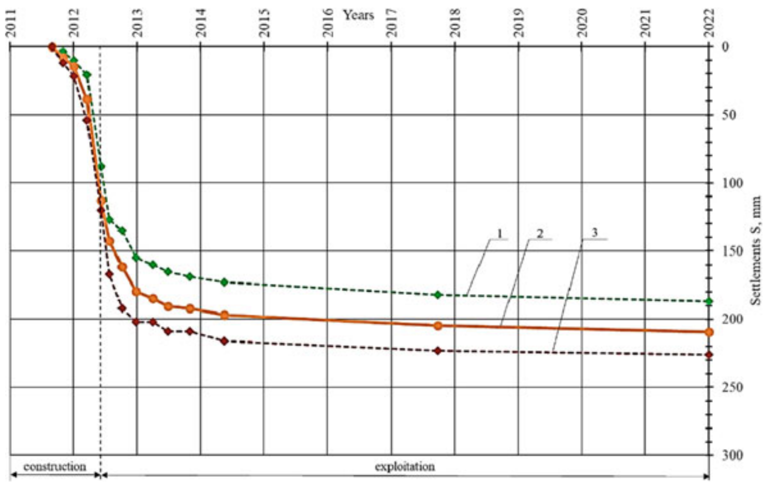

Fig. 7 Development in time of section marks settlement (I–II): 1—the smallest; 2—medium; 3—the largest

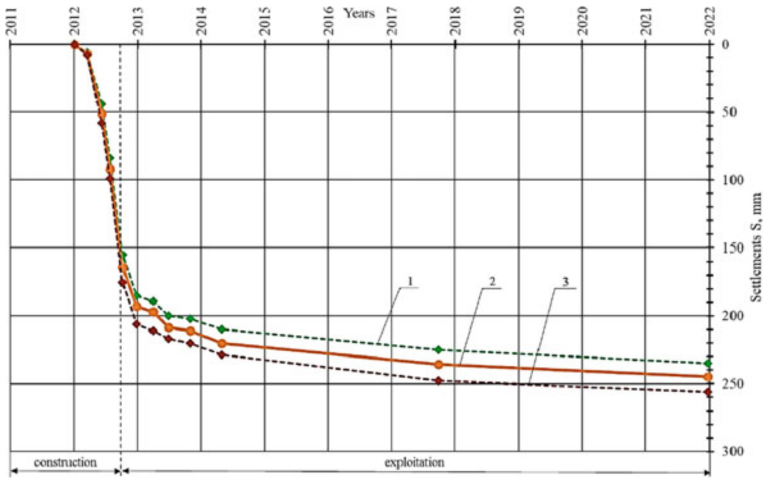

Fig. 8 Development in time of section marks settlement (III): 1—the smallest; 2—medium; 3—the largest

From the diagrams of wall marks settlement and the graphs of their development over time, it is clearly seen that the settlement values of sections I–II are less than three others. Also, conditional stabilization of deformations was fixed for this section. This is logical to explain; that the natural conditions of the soil mass under section I–II are better, and the design solutions and dimensions of the foundations and soil–cement base are the same.

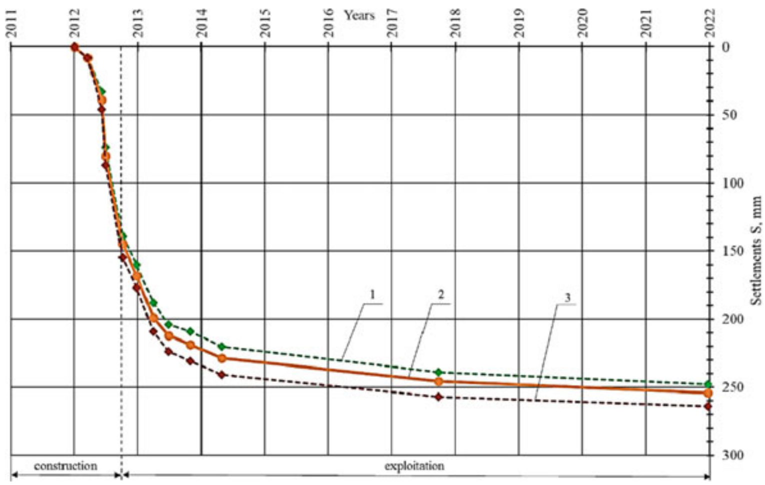

Fig. 9 Development in time of section marks settlement (IV): 1—the smallest; 2—medium; 3—the largest

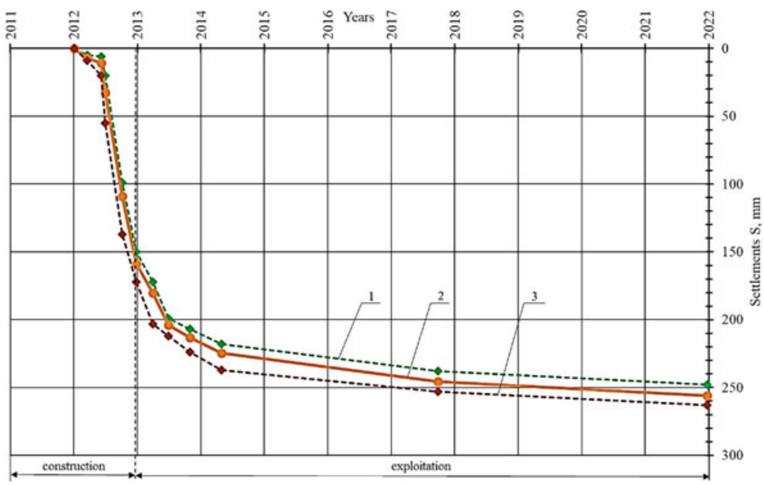

Fig. 10 Development in time of section V marks settlement: 1—the smallest; 2—medium; 3—the largest

Also, analytical calculations of the foundations bases settlement of a multi-storey building sections were carried out using known standard methods (in particular, layer-by-layer summation and I. Rosenfeld), which are based on a model of a linearly deformed medium. However, the values of settlement of the foundations bases of the sections determined by calculations turned out to be more than two times less compared to their actual values according to the results of long-term geodetic observations. Such a significant error is explained by the fact that the basis of the foundations of multi-storey buildings is already in the non-linear stage of deformation.

Therefore, the prediction of settlement of buildings with strip foundations on weak soils reinforced with vertical SCE should be carried out by 3D modeling FEM SSS system “building—strip foundation—soil–cement base—natural base” or 2D modeling FEM using elastic–plastic soil model SSS system “strip foundation—soil–cement base”.

4 Conclusions

1. As a result of long-term (over 10 years) geodetic observations of the settlement of a five-section multi-storey building with strip foundations on very compressible soils reinforced with vertical SCE, new research patterns of actual deformations of such foundations over time. Stabilization of its settlement up to 1–2 mm/year has been recorded.
2. Normative methods for predicting the settlement of such bases, based on the model of linearly deformed medium, approximately underestimate their actual values.
3. A sufficiently high reliability of 3D modeling of the FEM SSS system “building—strip foundation—soil–cement base—natural base” and 2D FEM modeling using the elastic–plastic soil model of the SSS system “strip foundation—soil–cement base—natural base” has been proved.
4. Strengthening the base only within the layer of weak soils, which is less than the width of the strip foundation, is not a sufficient condition for not exceeding the settlement limits. The depth of the reinforcement area of such foundations should be set by simulation.
5. The method of strengthening SCE bases, which is carried out by drilling mixing method, has proved its effectiveness for weak soils with a high content of organic matter.

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Calculation of Overreinforced Concrete Bending Elements Based on Modern Models for Deformation of Materials

Dmitro Kochkarev, Marta Kosior-Kazberuk, Anna Azizova, Andrii Pavlikov, and Tatiana Galinska

Abstract The paper considers the methods of calculating overreinforced normal cross-sections of reinforced concrete bending elements. Overreinforced elements have an interesting characteristic: at the destruction point, the stress in the tension reinforcement does not reach the yield point, which determines the utilization of certain assumptions when using engineering methods for calculating such elements. In particular, in simplified engineering models, one constant value of bearing capacity is obtained when a certain percentage of reinforcement is exceeded, which can lead to certain errors in the design of such elements. The article evaluates the errors in determining the bearing capacity of overreinforced concrete bending elements using various calculation methods for different classes of concrete and reinforcement. The article considers in detail the following calculation methods: a nonlinear deformation model with an extreme criterion; a non-linear deformation model with constant boundary values of deformations of compressed concrete; a method of design resistance of reinforced concrete; engineering methods based on simplified deformation diagrams. The assessment was carried out on the basis of the design resistance of reinforced concrete under bending, which makes it possible to assess not individual elements, but a whole range of elements with the same reinforcement. The article shows the possibility of using the proposed engineering methods to calculate overreinforced normal cross-sections of reinforced concrete bending elements. below.

Keywords Nonlinear strain model · Bending moment · Deformation · Reinforced concrete beam · Overreinforced bending elements · Elements with single reinforcement

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_27

1 Introduction

In bending elements, made of reinforced concrete, destruction may occur under two schemes [1, 2]. The first scheme of destruction involves reaching the ultimate deformations ε_s in the tensile reinforcement, which correspond to the yield point of reinforcement f_y, and the ultimate deformations ε_{cu} in the compressed concrete. It is specific for non-overreinforced bending elements. The second scheme of destruction involves reaching the ultimate deformations in the compressed concrete ε_{cu}, without reaching in the tensile reinforcement of the ultimate deformations ε_s, which correspond to the yield point of reinforcement f_y. The bearing capacity of bending elements that undergo destruction according to the first scheme was described with the help of simplified calculation models [1–5]. In such models, as a rule, stresses throughout the compressive zone of the concrete are constant. When determining the bearing capacity under the second scheme of destruction in simplified models, one constant value of the bearing capacity was obtained when a certain percentage of reinforcement was exceeded. Determination of the bearing capacity in such elements must be performed based on nonlinear deformation diagrams [6–24]. Overreinforced elements significantly concede to non-overreinforced ones by economical indexes. Instead, they are also used in construction practice, under certain aesthetic and architectural requirements, in the cases that demand a minimum height of bending elements. Thus, we offer to estimate the errors of determining the bearing capacity of overreinforced bending elements, made of reinforced concrete, according to different calculation methods for different classes of concrete.

2 Methods of Calculating Overreinforced Bending Elements

The calculation of reinforced concrete bending elements can be carried out according to the following methods:

1. Nonlinear deformation model with extreme criterion.
2. Non-linear deformation model with constant boundary values of deformations of compressed concrete.
3. Methodology of design resistance of reinforced concrete.
4. Engineering methods based on simplified deformation diagrams.

2.1 Nonlinear Deformation Model with Extreme Criterion

This method is based on the following prerequisites [6, 8, 9]:

(1) The bearing capacity of the cross-section of a reinforced concrete bending element is determined by the extreme criterion in the form of:

$$\begin{cases} \frac{dM_{Ed}}{d\varepsilon} = 0 \; npu \; \varepsilon_c \leq \varepsilon_{cu}; \\ \sigma_s \leq f_y; \;\; \varepsilon_s \leq \varepsilon; \end{cases} \tag{1}$$

where M_{Ed} is the bending moment that the cross section can maintain, ε_c is the deformation of compressed concrete, ε_s is the deformation of tensile reinforcement, ε_{cu} – is the maximum possible ultimate deformation of compressed concrete, ε_{su} is the maximum possible ultimate deformation of tensile reinforcement, σ_s is the stress in tensile reinforcement, f_y is the yield strength of tensile reinforcement.

It is also possible to use the extreme criterion in the written form and through other deformation characteristics, like skewness. But in this case, it is necessary to first find the required parameter, and only then the ultimate deformations of concrete. In addition, the skewness, in the cases, when there is a longitudinal force in the section, may have exceptionally large values, which will affect the accuracy of the calculation device. A substantial number of methods also accept in the calculation adjusted skewness, or different values of skewness for compressed concrete and tensile reinforcement, which will also lead to many complications. Therefore, form (1) is more universal, as any extreme criterion will be transformed into it under axial compression in any case.

(2) The Bernoulli hypothesis is accepted as valid, i.e. the distribution of deformations along the cross-section is assumed to be linear, what allows us to formulate the following dependency:

$$\varepsilon = \frac{1}{r} x \; a\delta o \; x = \frac{\varepsilon}{1/r}, a\delta o \; \frac{1}{r} = \frac{\varepsilon}{x}, \tag{2}$$

where ε is the relative strain of the material at a distance x from the neutral line, 1/r is the curvature of the element in the section.

(3) Stresses in the concrete of the compressed zone are described by one of the generally accepted functional relations, which corresponds to the conditions of the parametric points of deformation

$$\sigma_c = f(\varepsilon). \tag{3}$$

(4) The concrete of the tensile zone is not considered in the work of the cross-section.
(5) Stress in the tensile reinforcement is described by an idealized Prandtl diagram

$$\sigma_s = E_s \varepsilon_s \leq f. \tag{4}$$

For further calculations, it is necessary to develop a system of equilibrium equations in the form:

$$\begin{cases} \sum F_i = 0 \; ; N_c - F_s = 0; \\ \sum M_i = 0; +M_s = M_{Ed}; \end{cases} \tag{5}$$

$$N_c = \int_0^A \sigma_c dA; \quad F_c = E_s \varepsilon_s A_s \leq f_y A_s; \tag{6}$$

$$N_c = \int_0^A \sigma_c dA; \quad F_c = E_s \varepsilon_s A_s \leq f_y A_s; \tag{7}$$

The bearing capacity is determined by the method of iterations, as this method allows the most accurate determination of the bearing capacity of reinforced concrete elements.

2.2 Non-linear Deformation Model with Constant Boundary Values of Deformations of Compressed Concrete

In this method, the bearing capacity of a reinforced concrete bending element is determined by the values of the maximum possible ultimate deformations of compressed concrete ε_{cu}, without using the extreme criterion. The method uses similar calculation conditions as previously considered, except for the first one. The main advantage of this technique is that there is no need to perform iterative calculations. At the same time, in some cases, the accepted ultimate deformations will not correspond to the maximum bearing capacity of the element, which was confirmed by numerous studies [8, 9]. This mainly applies to non-overreinforced bending elements, while the maximum possible ultimate deformations of concrete are achieved in over-reinforced elements, as a rule.

2.3 Method of Design Resistance of Reinforced Concrete

This technique is based on all the prerequisites of the nonlinear deformation model with an extreme criterion. When calculating by this method, we used the concept of design resistance of reinforced concrete. The main idea of accepting the design resistance is to separate geometrical parameters from physical and mechanical ones. In the case of composite materials, we have the physico-mechanical and geometrical parameters of each material. In many cases, it is possible to distinguish geometrical parameters in general from all physical and mechanical parameters, but not from each one separately. In this regard, the design resistance of composite materials will depend on the physical and mechanical parameters of all materials that make up the cross-section of the element. For one cross-section of a composite element, there may be a large number of design resistances due to the fact that the strength of the cross-section is determined by the strength characteristics of all the materials that make up the composite element. Therefore, the total design resistance of the composite material is determined by the minimum value of the design resistances. Let us show how to obtain the design resistance for a single bending.

Solving (5) together, it is easy to obtain the following expression

$$M_{Ed} = bd^2 D_i, \tag{8}$$

where

$$D_i = f\left(f_{yd}, \rho_f\right), \tag{9}$$

the mathematical expression D_i is different for each operating condition of the elements.

Let us present the formula (8) in this form

$$M_{Ed} = \frac{bd^2}{6} 6D_i. \tag{10}$$

In the expression (10) $\frac{bd^2}{6} = W_c$ is the elastic moment of resistance of the cross-section of the concrete element with height d, and 6Di is the bending strength of reinforced concrete, which we will denote as f_M. That is, the bearing capacity of a reinforced concrete element under the action of a bending moment can be calculated using the formula:

$$M_{Ed} = W_c f_M. \tag{11}$$

Having made a program for calculating the values of $6D_i$ depending on the factors f_{yd}, ρ_f and having performed the calculations, we will get the value of the bending strength of reinforced concrete as the minimum of the possible parameters. The value of the design resistance for rectangular sections with single reinforcement for steel grades A400C and A500C is presented in the Tables 1 and 2, from the minimum to the maximum percentage of reinforcement.

2.4 Engineering Methods Based on Simplified Deformation Diagrams

Engineering methods for calculating bending elements from reinforced concrete are based on the use of a rectangular stress diagram in the compressive zone of the concrete. In this case, for non-overreinforced bending elements, the system (5) will take the following form:

Table 1 Bending strength of reinforced concrete f_M of rectangular cross-sections with single reinforcement for A400C class of reinforcement, MPa

Class of concrete	Percentage of reinforcement ρf								
	0.13	0.5	1	1.5	2	2.5	3	3.5	4
	$f_{yd} = 365$ MPa (A400C)								
C8/10	2.73	9.18	13.39	14.25	14.80	15.10	15.33	15.45	15.67
C12/15	2.76	9.70	16.95	19.02	19.88	20.47	20.90	21.23	21.49
C16/20	2.78	10.02	18.19	24.19	25.50	26.42	27.11	27.64	28.06
C20/25	2.80	10.21	18.95	26.28	30.61	31.87	32.82	33.57	34.18
C25/30	2.80	10.32	19.38	27.18	33.78	36.13	37.31	38.25	39.02
C30/35	2.81	10.40	19.70	27.90	35.00	40.17	41.59	42.72	43.64
C32/40	2.81	10.46	19.95	28.46	35.99	42.61	45.63	46.95	48.05
C35/45	2.82	10.52	20.18	28.98	36.92	44.01	50.23	51.85	53.14
C40/50	2.82	10.56	20.34	29.33	37.55	44.99	51.64	55.76	57.22
C45/55	2.82	10.59	20.47	29.63	38.07	45.80	52.81	58.90	60.54
C50/60	2.82	10.62	20.59	29.90	38.56	46.56	53.91	60.60	63.39

Table 2 Bending strength of reinforced concrete f_M of rectangular cross-sections with single reinforcement for A500C class of reinforcement, MPa

Class of concrete	Percentage of reinforcement ρf								
	0.13	0.5	1	1.5	2	2.5	3	3.5	4
	$f_{yd} = 415$ MPa (A500C)								
C8/10	3.08	10.17	13.39	14.25	14.71	15.11	15.34	15.53	15.61
C12/15	3.13	10.83	17.63	19.02	19.88	20.47	20.90	21.23	21.49
C16/20	3.16	11.25	20.10	24.19	25.50	26.42	27.11	27.64	28.06
C20/25	3.17	11.50	21.08	28.76	30.61	31.87	32.82	33.57	34.18
C25/30	3.18	11.64	21.64	30.02	34.58	36.13	37.31	38.25	39.02
C30/35	3.19	11.74	22.05	30.95	38.34	40.17	41.59	42.72	43.64
C32/40	3.19	11.82	22.38	31.67	39.71	43.98	45.63	46.95	48.05
C35/45	3.20	11.89	22.68	32.35	40.91	48.36	50.29	51.85	53.14
C40/50	3.20	11.95	22.88	32.81	41.72	49.63	54.00	55.76	57.22
C45/55	3.21	11.99	23.05	33.18	42.39	50.67	56.95	58.90	60.54
C50/60	3.21	12.03	23.21	33.54	43.03	51.67	59.39	61.56	63.39

$$\begin{cases} \sum F_i = 0\ ;\ f_y A_s - f_c b x = 0; \\ \sum M_i = 0;\ f_y A_s (d - x) + f_c b \frac{x^2}{2} =_{Ed}; \end{cases} \quad (12)$$

For overreinforced elements, when using engineering calculation methods, the height value of the compressive zone of the concrete is limited. For simplification, the relative height of the compressive zone of the concrete is used:

– when calculating according to DSTU (Ukrainian national standardization system) [3, 6]

$$\frac{x_{\max}}{d} = \xi_R = \frac{0.8\varepsilon_u}{\varepsilon_u + \varepsilon_{su}}; \tag{13}$$

– when calculating according to SNiP (Ukrainian Construction Standards and Regulations) [4]

$$\frac{x_{\max}}{d} = \xi_R = \frac{0.08 - 0.008 f_c}{1 + \frac{f_y}{\sigma_{sc,u}}\left(1 - \frac{0.08 - 0.008 f_c}{1,1}\right)}. \tag{14}$$

In the expression (13), 0.8 is the coefficient of the transition from a constant epure of the compressive zone of the concrete to a nonlinear one.

When using expression (13) as ultimate deformations ε_{cu}, it is possible to set the maximum possible ultimate deformations of concrete, or the ultimate deformations of concrete, determined by the extreme criterion. Let us conduct a numerical experiment and compare the load-bearing capacity of overreinforced bending sections using different methods. In this way, we will determine the values of the bearing capacity at the boundary of overreinforcement using the expressions (13) and (14), i.e. at $x = x_{max}$, $\xi = \xi_R$. For a relative comparison, we will determine the value of the bending strength of reinforced concrete for rectangular cross-sections $f_M = M_{Ed}/W_c$. The results of the calculations are shown in Tables 3 and 4. The tables show the calculation of the main parameters of the engineering calculation methods on three methodologies. According to methodology 1 [3, 6], the main parameters were determined by the expressions (12) and (13) with the maximum possible ultimate deformations of concrete ε_{cu}. According to methodology 2 [3, 6], the main parameters were also determined by the expressions (12) and (13) with ultimate deformations, determined by the extreme criterion. The main parameters, determined by the expressions (12) and (14), are shown in methodology 3 [4].

The tables present: ρ_{fm1}, ρ_{fm2}, ρ_{fm3}—the limit percentage of reinforcement when exceeding which, according to the appropriate methodology, there is no increase in the bearing capacity; f_{M1}, f_{M2}, f_{M3}—the value of the bending strength of reinforced concrete for rectangular cross-sections according to the appropriate methodology; ξ_{R1}, ξ_{R2}, ξ_{R3}—the limit value of the height of the compressive zone of the concrete according to the appropriate methodology.

The results, presented in the tables, require comparison with the exact calculation methods in order to assess the accuracy of the presented engineering methods. This will confirm the possibility of using the considered calculation of the load-bearing capacity of overreinforced bending elements of rectangular cross-section.

Table 3 Calculation parameters of engineering methods for calculating bending of reinforced concrete elements of rectangular cross-sections, reinforced with A400C class reinforcement, MPa

Class of concrete	Methodology 1			Methodology 2			Methodology 3		
	ρ_{fm1}	f_{M1}	ξ_{R1}	ρ_{fm2}	f_{M2}	ξ_{R2}	ρ_{fm3}	f_{M3}	ξ_{R3}
C8/10	0.885	14.16	0.538	0.760	12.83	0.578	0.959	14.88	0.584
C12/15	1.248	20.00	0.536	1.077	18.13	0.578	1.306	20.58	0.561
C16/20	1.671	26.89	0.530	1.457	24.53	0.578	1.683	27.02	0.534
C20/25	2.076	33.59	0.523	1.837	30.93	0.578	2.020	32.99	0.509
C25/30	2.394	38.95	0.514	2.154	36.26	0.578	2.271	37.61	0.488
C30/35	2.690	44.08	0.504	2.471	41.60	0.578	2.496	41.90	0.467
C32/40	2.971	49.03	0.493	2.787	46.93	0.578	2.696	45.84	0.447
C35/45	3.279	54.62	0.479	3.167	53.33	0.578	2.905	50.13	0.424
C40/50	3.525	59.13	0.468	3.484	58.66	0.578	3.053	53.31	0.405
C45/55	3.755	63.45	0.457	3.755	63.45	0.571	3.179	56.15	0.387
C50/60	4.025	68.53	0.445	4.025	68.53	0.557	3.301	59.10	0.365

Table 4 Calculation parameters of engineering methods for calculating the bending of reinforced concrete elements of rectangular cross-sections reinforced with A500C-class reinforcement, MPa

Class of concrete	Methodology 1			Methodology 2			Methodology 3		
	ρ_{fm1}	f_{M1}	ξ_{R1}	ρ_{fm2}	f_{M2}	ξ_{R2}	ρ_{fm2}	f_{M3}	ξ_{R3}
C8/10	0.745	13.77	0.515	0.632	12.30	0.546	0.819	14.61	0.566
C12/15	1.050	19.44	0.513	0.895	17.42	0.546	1.113	20.18	0.543
C16/20	1.405	26.11	0.507	1.211	23.57	0.546	1.432	26.45	0.517
C20/25	1.744	32.58	0.499	1.527	29.72	0.546	1.716	32.24	0.491
C25/30	2.007	37.74	0.490	1.791	34.84	0.546	1.927	36.70	0.471
C30/35	2.252	42.63	0.479	2.054	39.97	0.546	2.116	40.82	0.450
C32/40	2.483	47.34	0.468	2.317	45.09	0.546	2.283	44.61	0.431
C35/45	2.734	52.63	0.454	2.633	51.24	0.546	2.456	48.69	0.408
C40/50	2.933	56.87	0.443	2.897	56.36	0.546	2.579	51.72	0.389
C45/55	3.119	60.91	0.432	3.119	60.91	0.539	2.682	54.40	0.371
C50/60	3.337	65.66	0.420	3.337	65.66	0.525	2.782	57.16	0.350

3 Comparative Calculations of Overreinforced Bending Elements

We will draw a comparison of the values of the design resistance of reinforced concrete according to the various methodologies described above. Comparisons will be made with the values of design resistance f_M obtained based on a nonlinear

Table 5 Comparison of design resistances of reinforced concrete bending elements of rectangular cross-sections, reinforced with A400C class reinforcement, MPa, by different methodologies

Class of concrete	Methodology 1		Methodology 2		Methodology 3	
	Relative errors $f_{M1/}\,f_M$ at		Relative errors $f_{M2/}\,f_M$ at		Relative errors $f_{M3/}\,f_M$ at	
	ρ_{fm1}	$\rho_f = 4\%$	ρ_{fm2}	$\rho_f = 4\%$	ρ_{fm3}	$\rho_f = 4\%$
C8/10	1.081	0.904	1.021	0.819	1.120	0.950
C12/15	1.087	0.931	1.020	0.844	1.109	0.958
C16/20	1.089	0.958	1.021	0.874	1.092	0.963
C20/25	1.090	0.983	1.027	0.905	1.076	0.965
C25/30	1.087	0.998	1.033	0.929	1.060	0.964
C30/35	1.082	1.010	1.038	0.953	1.043	0.960
C32/40	1.077	1.021	1.043	0.977	1.026	0.954
C35/45	1.067	1.028	1.049	1.003	1.021	0.943
C40/50	1.059	1.033	1.053	1.025	1.019	0.932
C45/55	1.062	1.048	1.062	1.048	1.018	0.928
C50/60	1.080	1.081	1.080	1.081	1.019	0.932
x	1.08	1.00	1.04	0.95	1.05	0.95
σ, %	1.09	5.23	1.90	8.52	3.87	1.40
ν_l, %	1.01	5.23	1.83	8.96	3.67	1.48

deformation model with an extreme criterion. We will compare the design resistance values at $x = x_{max}$, $\xi = \xi_R$ and at the maximum percentage of reinforcement $\rho_f = 4\%$. The results of the calculations are summarized in the Tables 5 and 6.

The conducted calculations indicate the possibility of using the proposed engineering methods. The largest errors correspond to methodology 2 with the maximum percentage of reinforcement $\rho_f = 4\%$. At the same time, at the values of $x = x_{max}$, $\xi = \xi_R$, this methodology allows to determine the bearing capacity most accurately.

4 Conclusions

The article considered the methods of calculating the strength of over-reinforced cross-sections of reinforced concrete bending elements. The most accurate deformation calculation methods using non-linear material deformation diagrams and engineering methods were examined in the study. The possibility of determining the bearing capacity according to the proposed engineering methods was proved, as well as the errors that arise when using them, were estimated by the authors. All methodologies slightly overestimate the bearing capacity at the values $x = x_{max}$, $\xi = \xi_R$. At the maximum percentage of reinforcement $\rho_f = 4\%$ all methodologies,

Table 6 Comparison of design resistances of reinforced concrete bending elements of rectangular cross-sections, reinforced with A500C class reinforcement, MPa, by different methodologies

Class of concrete	Methodology 1		Methodology 2		Methodology 3	
	Relative errors $f_{M1/}\ f_M$ at		Relative errors $f_{M2/}\ f_M$ at		Relative errors $f_{M3/}\ f_M$ at	
	ρ_{fm1}	$\rho_f = 4\%$	ρ_{fm2}	$\rho_f = 4\%$	ρ_{fm3}	$\rho_f = 4\%$
C8/10	1.087	0.882	1.017	0.788	1.132	0.936
C12/15	1.092	0.905	1.019	0.811	1.120	0.939
C16/20	1.094	0.931	1.019	0.840	1.118	0.943
C20/25	1.094	0.953	1.030	0.870	1.086	0.943
C25/30	1.090	0.967	1.031	0.893	1.070	0.941
C30/35	1.084	0.977	1.036	0.916	1.052	0.935
C32/40	1.078	0.985	1.042	0.939	1.034	0.928
C35/45	1.067	0.990	1.047	0.964	1.020	0.916
C40/50	1.058	0.994	1.052	0.985	1.018	0.904
C45/55	1.060	1.006	1.060	1.006	1.017	0.899
C50/60	1.078	1.036	1.078	1.036	1.018	0.902
x	1.08	0.97	1.04	0.91	1.06	0.93
σ, %	1.31	4.54	1.91	8.12	4.54	1.76
ν, %	1.22	4.70	1.84	8.89	4.28	1.90

on the contrary, underestimate the value of the bearing capacity. Generalized statistical indicators of the calculated bearing capacity of overreinforced elements are as follows: methodology 1: $x_1 = 1.03$, $\sigma_1 = 6.09\%$, $\nu_1 = 5.90\%$; methodology 2: $x_2 = 0.99$, $\sigma_2 = 8.09\%$, $\nu_2 = 8.20\%$; methodology 3: $x_3 = 1.0$, $\sigma_3 = 6.89\%$, $\nu_3 = 6.9\%$. The smallest coefficient of variation corresponds to methodology 1.

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Analysis of the Current State of Passenger Traffic as a Component of the Transport System and the Prospects for Its Development

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Abstract The article examines the current state and prospects for the development of transport and the transport system in Ukraine. The study of the state of development of transport and the transport system of Ukraine in recent years shows unstable dynamics, which is mainly related to the economic and geopolitical crisis in the country, the consequences of the COVID-19 pandemic. The level of transport service for the population of Ukraine is significantly inferior to the indicators of developed countries of the world. A necessary condition for effective development and overcoming the consequences of crisis phenomena in the transport industry, in particular those caused by the COVID-19 pandemic, is the development and modernization of Ukraine's transport infrastructure in accordance with modern technological requirements.

Keywords Transport infrastructure · Transport network · Passenger traffic · Pandemic COVID-19

1 Introduction

The efficiency of the transport system, the availability of safe and high-quality transport services, developed infrastructure are indicators of the country's development. Transport is one of the most important branches of material production, which provides production and non-production needs of the economy and the country's population in all types of transportation. The unified transport system must meet the requirements of public production and national security, have an extensive infrastructure for the provision of the entire complex of transport and related services, and provide internal and external communications of Ukraine. That is why there is a

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_28

need to analyze the functioning of the transport system for its further improvement. Particular attention is paid to passenger transportation.

2 Methods and Materials

2.1 Features of the Formation of the Country's Transport System

According to the Law of Ukraine "On Transport" [1], the unified transport system consists of public transport (rail, sea, river, road and air, as well as urban electric transport, including the subway), industrial railway transport, departmental transport, pipeline transport, public transport routes. And the transport enterprises include railways, steamships, business entities in sea ports, automobile, aviation and road enterprises, the main type of activity of which is the transportation of passengers, cargo, luggage and mail, the provision of other transport services, the operation and repair of communication routes, if this is provided by their statutes.

In addition to the concept of "transport complex" [2], scientific sources and legislation use the concept of "transport and road complex" as synonyms [3–5], "transport system", "unified transport system" [5], and under them is understood a complex branch of infrastructure that combines all modern types of transport (railway, sea, river, road, aviation, pipeline, etc.) and road management of Ukraine.

An important feature of transport infrastructure is its long-term life cycle. Buildings and objects of transport infrastructure are characterized by long terms of their design, construction and operation. Also, in connection with the long term of operation of transport infrastructure objects, such factors as the possibility of their development and existing plans for the development of the adjacent territory should be taken into account during their design [6, 7].

2.2 Passenger Transport as a Component of the Transport System

Passenger transportation occupies a special place in the work of transport. This is due to their high socio-economic importance in the life of society and fulfillment of one of the guarantees of the state—freedom of movement. The needs of the population in transportation are related both to labor activities (travel to places of work and business trips) and to cultural and everyday needs (travel for recreation, tourism, excursions) [8–10].

The processing of statistical values of passenger traffic indicators and the number of transported passengers by various modes of transport provide an opportunity to analyze and develop ways to improve the overall transport system [11].

3 Results and Discussion

The COVID-19 pandemic had a significant impact on transport activities in the country, starting with mobility restrictions and a decrease in the level of economic and social activity [12–14]. The transportation sector has been seriously affected by the emergence of this global health crisis and the social distancing norms associated with it. The strict quarantine in Ukraine for 2020–2021 mainly affected passenger transportation. Ensuring safety indicators of passenger transport is one of the main directions of the transport infrastructure as a whole, since the right to life and health of a person is the basis of state guarantees.

According to statistical data, in 2020, the number of passengers transported by all types of transport (railway, sea, river, automobile, air tram, trolleybus, metro) was 2,570,214 thousand passengers, or 60.3% of the volume 2019 In 2020–2021, the transport sector shows a sharper reduction in passenger transportation by all modes of transport [15–17].

The railways have been hit multi-faceted by reduced local travel, restrictions on inter-regional travel, a general drop in tourist demand, and a general avoidance of public transport. In addition, capacity restrictions have been imposed on trains to comply with social distancing rules. In railway transport during 2020, the volume of passenger transportation fell sharply—by 55.7%, or by 86.5 million passes. compared to 2019—mainly due to the effect of the quarantine ban on the transportation of passengers in all types of internal transport (suburban, urban, regional and long-distance) (Fig. 1). Passenger transportation by railway was completely stopped from March 11, 2020, partially resumed in the second half of May. During the quarantine, the number of scheduled trains was significantly reduced, and tickets for these trains were sold for a limited number of seats in the carriages (50% of seats).

In 2020, 40.0% fewer passengers were transported by road transport than in 2019. It should be noted that the trend towards a reduction in passenger-fat transport by road transport was further strengthened due to the introduction of quarantine restrictions (CMU Resolution No. 211 dated 11 March 2020 “On prevention of the spread of the acute respiratory disease COVID-19 caused by the SARS-CoV2 coronavirus on the territory of Ukraine”)—until 22 May 2020, regular and irregular transportation of passengers by road transport in urban, suburban, intercity, intra-regional and inter-regional traffic was prohibited. At the same time, the real impact of quarantine restrictions on road transport was much smaller than on rail transport due to the fact that a significant amount of road transport is carried out by personal transport or is in the shadows (Fig. 2).

Air transport suffers losses due to the introduction of restrictions on crossing the state border in Ukraine and other countries of the world. In 2020, compared to 2019, passenger transportation by air transport in Ukraine decreased by 64.9%, or by 8.9 million passengers (Fig. 3).

After the almost complete suspension of air transport due to the introduction of quarantine restrictions on international passenger air transportation, in the second half of 2020, in connection with the increase in the number of patients with

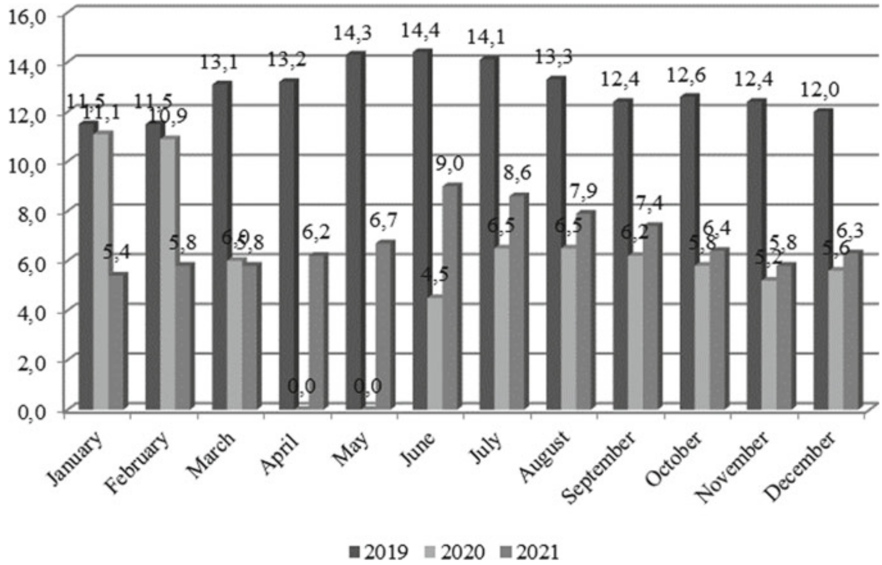

Fig. 1 The number of passengers transported by rail transport in 2019–2021 (million passengers)

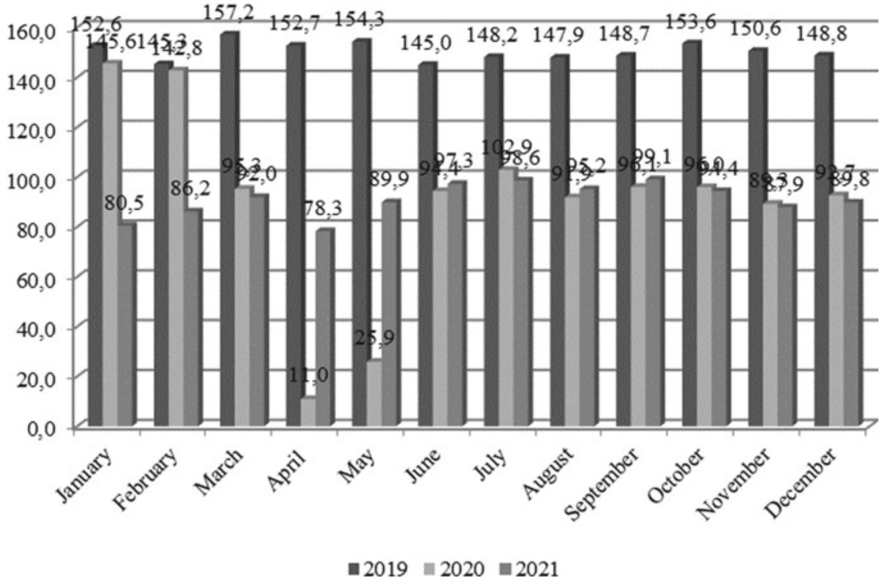

Fig. 2 The number of passengers transported by road transport in 2019–2021 (million passengers)

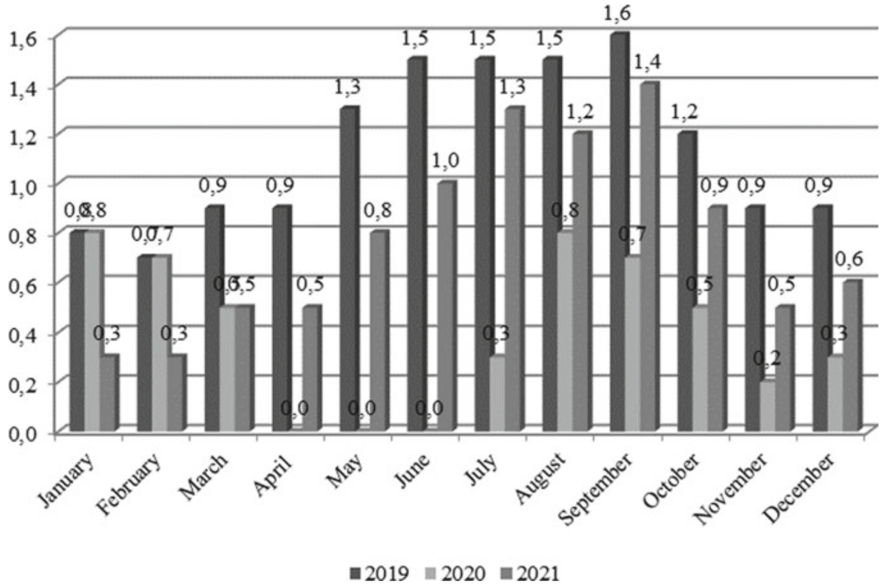

Fig. 3 The number of passengers transported by air transport for 2019–2021 (million passengers)

COVID-19, a ban on entry into Ukraine for foreigners was introduced, which was effective from March 16, 2020 to September 28, 2020. As a result, Ryanair canceled 70% of all its routes in Ukraine in September, and Wizz Air canceled flights from Ukraine on 24 destinations in November 2020. In 2020, passenger traffic at Boryspil International Airport decreased by 34% or 10.1 million passengers. According to the data of the largest Ukrainian air carrier "International Airlines of Ukraine", the total number of transported passengers in 2020 decreased by almost four times compared to 2019 [15].

Due to the impossibility of carrying out their main activities for a certain period of time, the metros of the cities of Ukraine suffered significant losses. During 2020, passenger transportation by this mode of transport decreased by 42.5% compared to 2019. The main factor behind this decrease was the introduction of a quarantine ban on the transportation of passengers by subways in the cities of Kyiv, Kharkiv, and Dnipro (Fig. 4).

Tram and trolleybus transport also experienced a reduction in the volume of passenger transportation as a result of quarantine restrictions—during 2020, it amounted to 36.3% (571.4 million passengers) (Figs. 5 and 6).

The largest losses were recorded in passenger transport due to the introduction of restrictions on transportation by all types of transport, except for private automobiles. In general, during March–October 2020, the number of transported passengers decreased by 51.0%, or by 1398.2 million passports. After the introduction of adaptive quarantine (in May 2020), a gradual increase in the number of transported

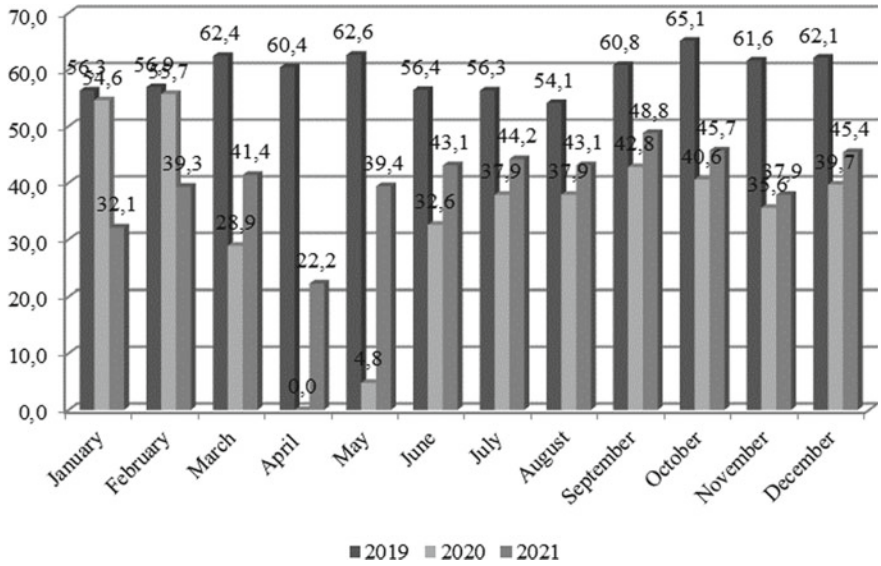

Fig. 4 The number of passengers transported by metro transport in 2019–2021 (million passengers)

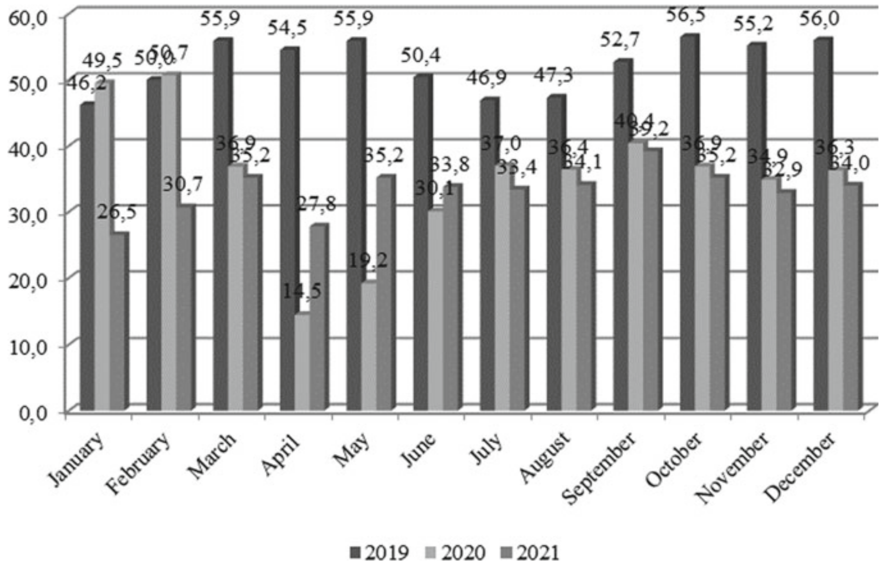

Fig. 5 The number of passengers transported by tram transport for 2019–2021 (million passengers)

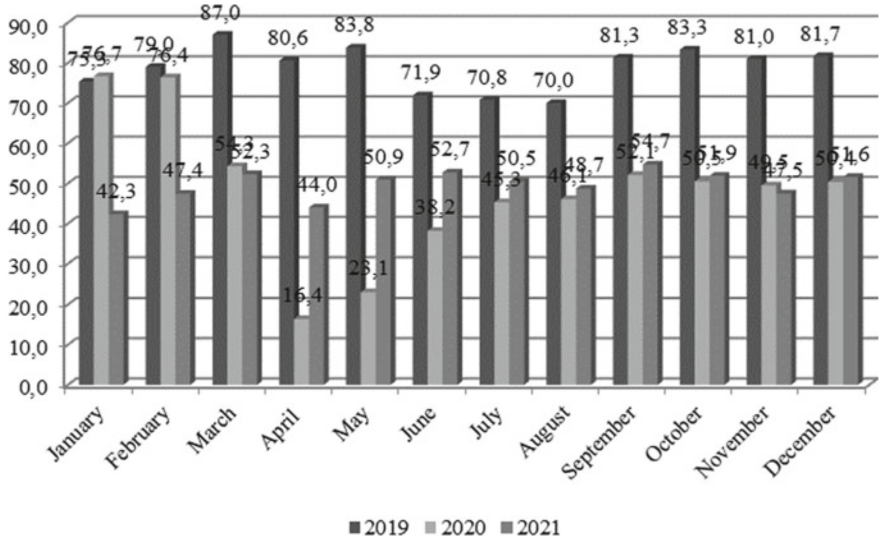

Fig. 6 The number of passengers transported by trolleybus transport in 2019–2021 (million passengers)

passengers was observed. Analysis of statistical data on passenger transportation for the three quarters of 2021 shows an increase in quantitative indicators, but they do not reach the corresponding level of 2019.

From a public transport operator's point of view, it is difficult to balance the decline in ridership during and after the pandemic with timetables and capacity that meet new demand patterns. An additional challenge for public transport is that users expect higher health and safety standards, but fares and prices remain at pre-pandemic levels COVID-19.

Regardless of how soon the threat of COVID-19 passes, uncertainty about the possibility of new waves of the virus or other pandemics will remain in the near term and will likely lead to greater risk aversion to transportation and travel. In addition to a reduction in travel frequency at the individual level, user preferences for transportation modes and travel distances may change. Public transport is particularly vulnerable to changing trends in society and technology.

4 Conclusions

For effective development and overcoming the consequences of crisis phenomena in the transport industry, in particular those caused by the COVID-19 pandemic, it is especially important to improve the attractiveness of passenger transport. First, to upgrade electric transport (trolleybus and tram fleet), which will satisfy the needs of consumers in terms of comfort and speed. Secondly, to optimize traffic patterns, thereby ensuring the need for convenience and intensity of travel. A necessary condition for the effective use of the transport system is the development and modernization of the transport infrastructure of Ukraine in accordance with modern technological requirements.

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Rational Structural System for Roadway Slab of Road Bridges

Valery Shmukler, Yuriy Krul, Vladislav Dushin, and Asaf Aghayev

Abstract The article presents a rational constructive system of steel-reinforced concrete super-structures of road bridges, which can be used in the design of road and city bridges of plate-girder, cable-stayed and suspension systems. The span structure is a spatial two-component system consisting of metal perforated box-section blocks and an effective lightweight reinforced concrete slab of the roadway, put into operation using a shear bracing system. The article outlines the principles for the formation of these systems based on a new bionic-energy method for optimizing structures. It is based on two criteria that ensure that the structure is given positive qualities, such as strain energy and strain-elastic density. As a result os the operation of the method, the solution for perforated beam with variable hole spacing and their sizes that have a given stress–strain state with minimal material consumption. Also developed an algorithm for creating perforated beam with variable hole spacing and their sizes as for linear structural elements so for curved structural elements. The use of non-waste technology to create a metal perforated shell opens up new perspectives for manufacture of these structures.

Keywords Road bridges · Perforated metal box-section blocks · Shear connection system · Lightweight reinforced concrete slab · Bionic-energy optimization method · Strain energy · Strain-elastic density

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_29

1 Introduction

Minimizing the weight of bridges with given bearing capacity is one of the main tasks faces designers. This provides a search for new rational solutions.

At present, steel reinforced concrete span structures of bridges are a modern and promising type of bridge structures, which combine the positive properties of reinforced concrete and metal systems [8, 10–13]. Expanding the range of their use (primarily for spans) encourages the use of lightweight structures as load-bearing metal elements [9]. Perforated elements can be used as one of the variants of lightweight constructions.

However, despite the relatively long term of use, perforated elements are high potential sort of design, leaving a field of action for designers. The main condition for the development of perforated structures is to reduce the cost of materials at a given bearing capacity, or to increase the load bearing capacity at given material costs. Improvement of the characteristics of perforated elements and structures can be achieved by changing the configuration and a hole pitch.

2 Results

The proposed design is a spatial two-component system consisting of metal perforated box-section blocks and included in the work by means of a shear connection system, an effective lightweight reinforced concrete roadway slab (Fig. 1) [1].

This solution can be used in the design of road and city bridges of plate-girder, cable-stayed and suspension systems (Fig. 2).

The metal blocks (Fig. 3) are made of perforated sheet elements by the non-waste technology. The block includes the main beams, transverse diaphragms and the lower plate. All structural elements are joined into a single finished unit at the factory with automatic welding, which, in turn, allows a strict control of the quality of welds. The diaphragms of the block have a ridge on the upper facet, on which a corrugated steel sheet is laid, which is further a permanent formwork for reinforced concrete slabs. The sheet in plan of the upper chord of the structure is immobilized with self-tapping screws or rivet welds (Fig. 4).

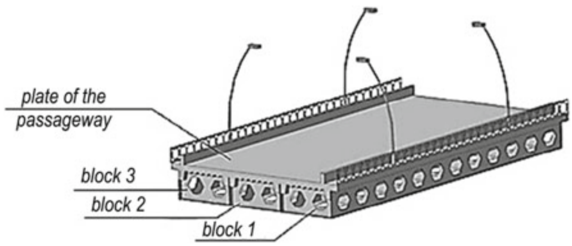

Fig. 1 Fragment of a proposed composite reinforced concrete (CRC) span structure

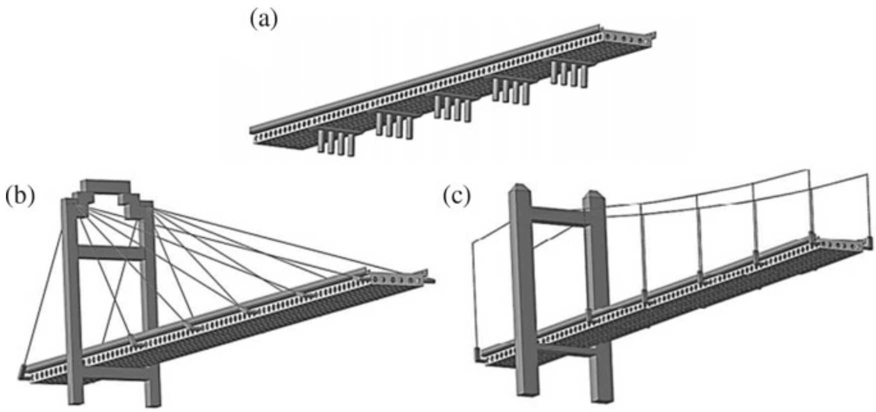

Fig. 2 Variants of bridges of different systems with the proposed span structure: **a** a fragment of the plate-girder bridge; **b** a fragment of the cable-stayed bridge; **c** a fragment of the suspension bridge

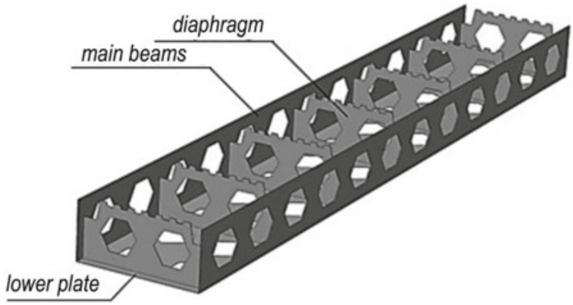

Fig. 3 Metal CRC block of the span structure

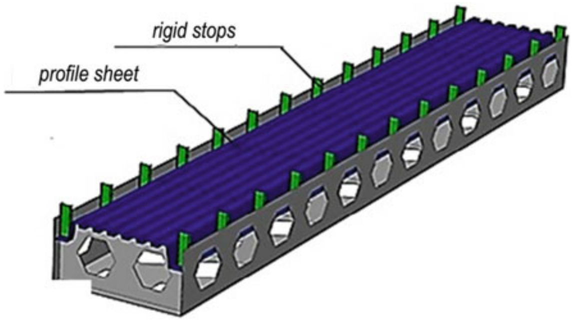

Fig. 4 Factory-built metal block

The blocks are integrated into a single spatial structure, first, by means of HSFG bolts arranged with a calculated pitch along the span length (Fig. 5) and, secondly, by using the proposed connection system connecting the shell with monolithic effective concrete slab of the roadway.

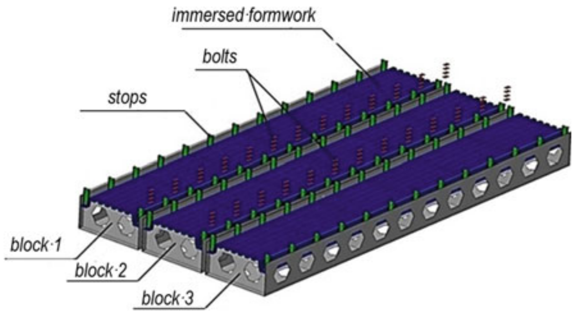

Fig. 5 Joining blocs with HSFG bolts

The aforementioned discrete continuous shear connection system is represented as rigid stops made of segments of the I-beam. To perceive tensile stresses and to prevent the separation of the slab from the metal beams, the stops in two levels, in the transverse and longitudinal directions, are interconnected by reinforcing bars of the deformed section (Fig. 6). The main difference between the proposed system and existing solutions is that the reinforced concrete roadway does not have a metal support element. Reinforcement meshes are laid on the upper and lower rods before concreting, which are a structural upper and respectively lower reinforcement of the reinforced concrete slab (Fig. 7).

The roadway slab is also made of a lightweight reinforced concrete slab (Fig. 8). The upper and lower panels of the slab are made of reinforced concrete, the rest of the height is filled with non-removable foamed polystyrene inserts, between the panels inside the slab along and across the span, stiffeners are made with the calculated pitch. The height of the stiffeners is equal to the full height of the slab. If the design height of the slab increases, so does the cylindrical rigidity, which reduces the cost of reinforcement without increasing the concrete consumption [7].

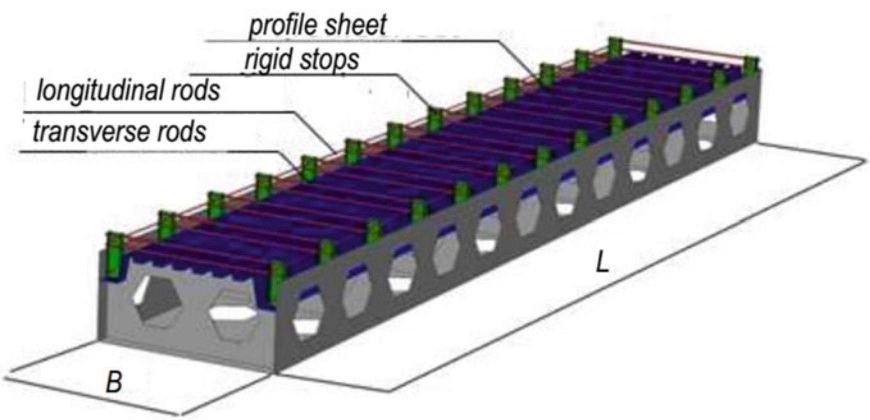

Fig. 6 Discrete continuous shear connections

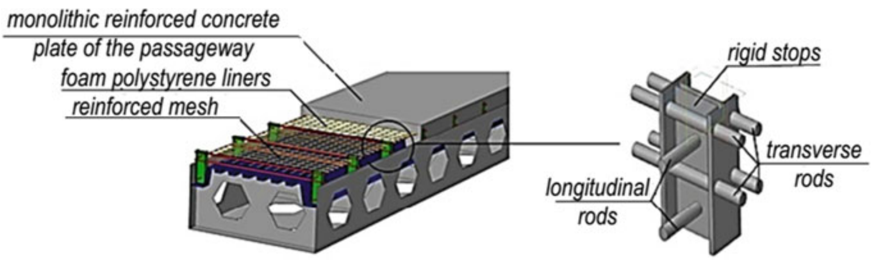

Fig. 7 General view of the discrete continuous shear connection system

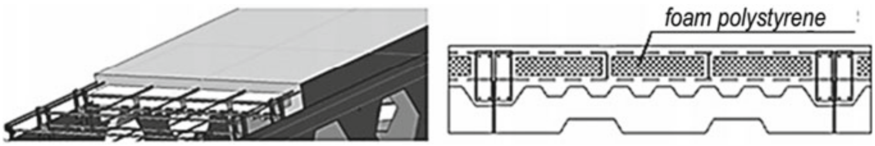

Fig. 8 Roadway slab

In this paper, the principal of a new method for manufacturing such structures are outlined [3]. A feature is fact that the structures themselves are designed on the basis of the bionic-energy optimization (BEO) method [1]. It is based on two criteria that ensure that the structure is given positive qualities [2]:

– the statement that for regulated system with a constant volume of material, the number of external and internal ligaments (external parameters) under the action of static external load—of its own weight, the strain energy after the reconstruction reaches the lower limit on rational combination of geometric parameters values:

$$U = inf\,U(a_k), \quad k = 1, 2, \ldots\ldots..\infty, \tag{1}$$

where U—strain energy (SE); k—number of equation variant; $a \in M$; M—set of admissible values of external geometric parameters [4].

– the requirements of the isoenergetic state of the system (structure), that is, a state in which

$$e|\{x\}| = const \tag{2}$$

where e—strain-elastic density (SED); $\{x\}$—vector of internal parameters [5].

As a result os the operation of BEO-method, the solution for split beams is obtained in the form of a structure with a stepwise changing height of the sections [6]. Further, according to the developed algorithm, this beam is replaced by an equivalent perforated beam with variable hole spacing and their sizes. The essence of the method is as follows.

Solid billets are cut along the vertical beam web into semi-beams with a broken line and connected to each other along the existing ridges. For the manufacture of perforated elements, two solid billets are used, which are cut with an identical cut into two pairs of identical half-beams. They are connected along the existing ridges, having first turned one of the semi-beams at an angle of 180° relative to the longitudinal axis. As a result, two perforated beams with open and closed ends are obtained, which are later combined into a single beam.

In addition, for the production of perforated elements with equal strength, the billets are cut using a beam web cut, which allows varying the size of intermediate ridges and cutouts. This ensures a variable step and variable sizes of holes in the finished beams. At the same time, the sizes of the intermediate ridges and cutouts are arbitrary, and the billets are cut in such a way that the total length of the workpiece is equal to L = 2n + (2n − 1) + 2x(2n − 1)p, where 2n—pair number of intermediate

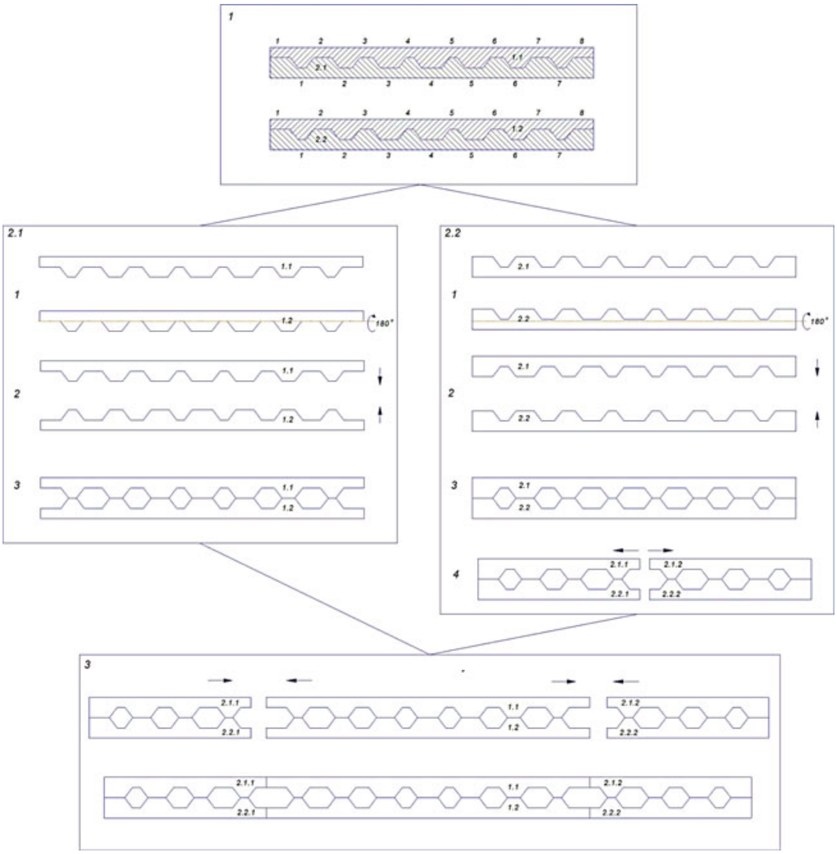

Fig. 9 Principle of forming an equivalent perforated beam (linear structural element)

ridges, (2n − 1)—unpaired number of intermediate cutouts, p—the length of the projection of the inclined part of the hole on the horizontal axis.

Before connecting and welding the finished beam, the beam with closed ends is cut in half. After that, docking is performed on both sides to form a single structure.

For the manufacture of a curved perforated energetically equal strength element and elements of variable height, cut of the beam web of the billets along a curve or at an angle to the longitudinal axis are used. At the same time, for the manufacture of equal-strength perforated elements, the workpieces are cut with a cut, in which the ridges are parallel to the longitudinal axis of the beam, and the cutouts are located at an angle to the longitudinal axis, or vice versa.

Examples of solutions obtained in this way are illustrated in Figs. 9, 10, 11 and 12.

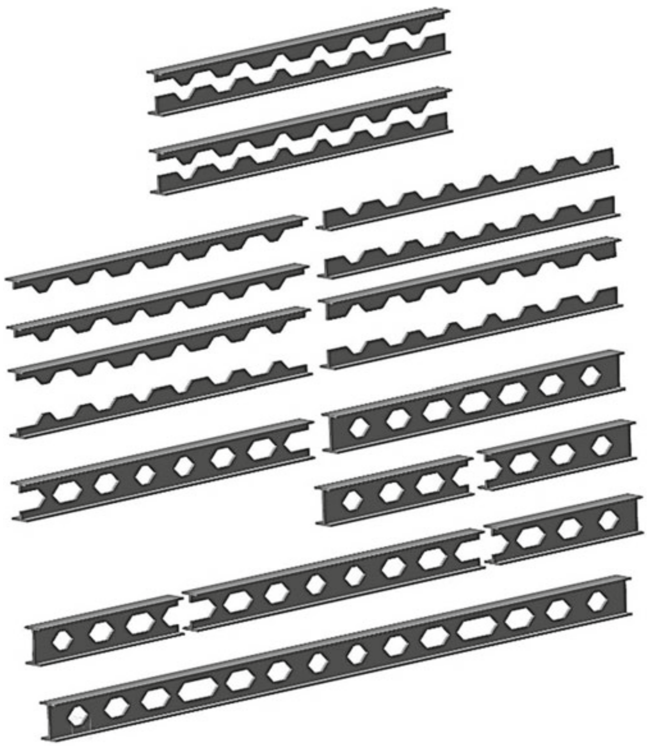

Fig. 10 View of the formed perforated beam (linear structural element)

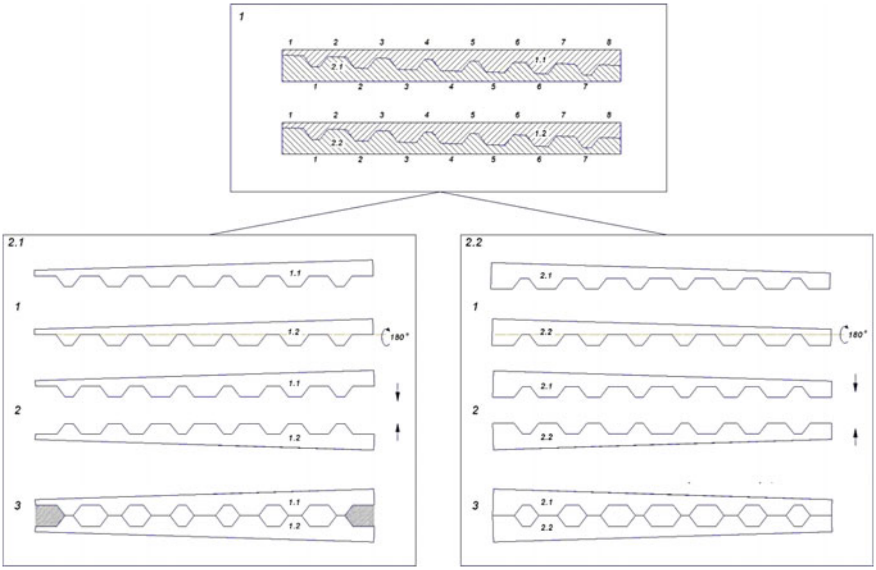

Fig. 11 Principle of forming an equivalent perforated beam (curved stuctural element)

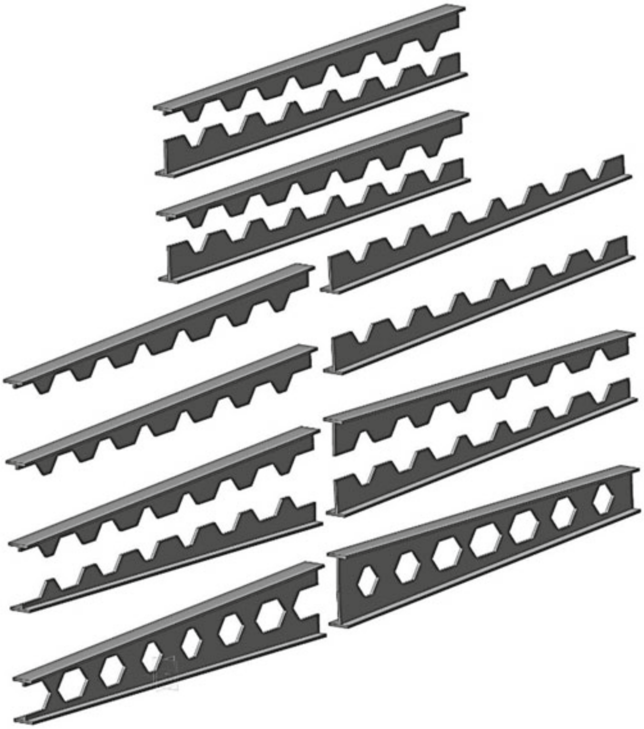

Fig. 12 View of the formed perforated beam (curved stuctural element)

Fig. 13 Composite reinforced concrete bridge in Barvenkovo (author's photo)

3 Conclusions

The priority of the BEO-method is due to the possibility of direct formation of the geometric form and, if necessary, the physical and mechanical content of a large structural system. It can be stated that the final erected construction is a modern efficient system of combining metal girders with the concrete of the roadway slab with discrete continuous shear connections, which minimizes the overall cost and complexity of the process of building steel and steel. The use of non-waste technology to create a metal perforated shell opens up new perspectives for manufacture of structures that have a given stress–strain state with minimal material consumption (Fig. 13). The latter is a consequence of the accepted universal criteria.

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Case Study: Sites for the Drilling and Repair of Oil and Gas Wells

Volodymyr Onyshchenko, Yuriy Vynnykov, Igor Shchurov, and Maksym Kharchenko

Abstract The experience of arranging sites with complex engineering and geological conditions for various technological operations at oil and gas wells is given: installation of drilling equipment, well construction, repair work on it, production intensification, etc. Authors' solutions allow minimizing: excavation work on the construction of the foundation pit; impact on the environment; cost and terms of performance of works; use of special construction equipment. It is proposed, through the use of geosynthetic materials, to strengthen a weak soil mass and create an artificial base for the installation of prefabricated slabs, which in turn act as prefabricated foundations for the corresponding technological equipment and cover the platform for the movement of equipment. After the completion of technological operations at the well, the prefabricated elements of the foundations and the geosynthetic coating of the site are removed, and with minor reclamation work, the territory is used for agriculture. The level of reliability of the proposed solutions is substantiated depending on the time of technological operations and the level of complexity of engineering-geological conditions.

Keywords Oil and gas well · Technological operation · Drilling equipment · Geosynthetic materials · Level of reliability · Stress-strain state of the system "weak base—geosynthetic coating—prefabricated foundations and coatings"

1 Introduction

Innovative engineering projects for the construction of new wells and repair work to restore the operation of existing wells require the latest solutions with a high level of reliability and a low level of technological, environmental and economic risks. Most of the work of specialists is focused on creating technologies for minimizing

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_30

emergency situations during basic technological operations: rock destruction, well casing, ensuring that well trajectories do not cross in space, tripping operations, opening a productive horizon, offshore drilling [1–4].

At the same time, there are quite a few scientific works on technologies for minimizing emergency situations caused by uneven deformations and loss of stability of the soil base when performing technological operations on wells on land under difficult engineering and geological conditions, since most of the norms [5, 6] and studies [7–10] are aimed at creating effective artificial foundations and foundations for capital buildings (multi-storey residential, shopping and entertainment, etc.), structures (reservoirs, bridges, roads, etc.) and engineering networks (various pipelines, etc.). In particular, it makes sense to distinguish from them the following design and technological solutions that have been tested for complex engineering and geological conditions: cutting through weak soils with pile foundations [11–14]; improving the geotechnical properties of massifs by vertically reinforcing them with rigid elements (the so-called “stone pillars” [15, 16] and soil-cement elements [17–19]); replacement of non-building soils with a layer-by-layer compacted sand cushion [20]; horizontal reinforcement of such cushions with spatial geogrids and geotextiles [21–24]. To assess the stress-strain state (SSS) of the systems “structure (building)—foundation base” or “foundation—base” created in this way, modern geotechnical software products of 3D or 2D modeling by the finite element method (FEM) with an elastic-plastic soil model are used [25]. However, the most reliable criterion for the reliability of structural and technological solutions and the correctness of their calculation methods are geodetic observations of long-term subsidence of buildings and structures [26–33].

The fundamental difference between these studies and those presented in the article is the term of operation of artificial basis and foundations. Therefore, the search for a reliable and effective arrangement of sites for technological operations at oil and gas wells is an urgent task.

2 Defining the Problem

However, decisions on the arrangement of sites for technological operations at wells in difficult engineering and geological conditions require justification of the required level of reliability, taking into account the life of artificial basis and prefabricated foundations. The most proven way to solve such a problem is to accumulate research results and positive experience of using a certain number of technologies in various engineering and geological conditions.

3 Research Results

3.1 Object of Research

An oil and gas well is an extremely complex innovative engineering project for the arrangement of mining production. Modern technologies make it possible to construct ultra-deep wells (over 6,000 m) with a complex and constantly original trajectory in space (inclined-directed with a deviation of the hole from the vertical of more than 10,000 m and horizontal sections with a length of more than 12,000 m), and sometimes even a whole system of wells made from one point (multi-wells, including wells with branched wells, etc.). Examples of the appearance of a multihole well are shown in Figs. 1 and 2. At the same time, the process of their construction takes place in difficult mining and technological conditions (abnormally high and low reservoir pressures, high temperatures, complex geological conditions, which very often lead to complications and accidents). But thanks to a set of proven design solutions and their observance during the construction of wells, it is possible to build them in a fairly short time (sometimes even less than six months for a directional well with horizontal completion at depths of more than 6000 m).

The following technological operations during the operation of wells (underground repair, intensification of production, etc.) occur even faster—from several days to several weeks. One of the conditions for the successful execution of the listed operations is the placement of special equipment (drilling machine, drilling pumps, equipment for cementing, coiled tubing installation, hydraulic fracturing

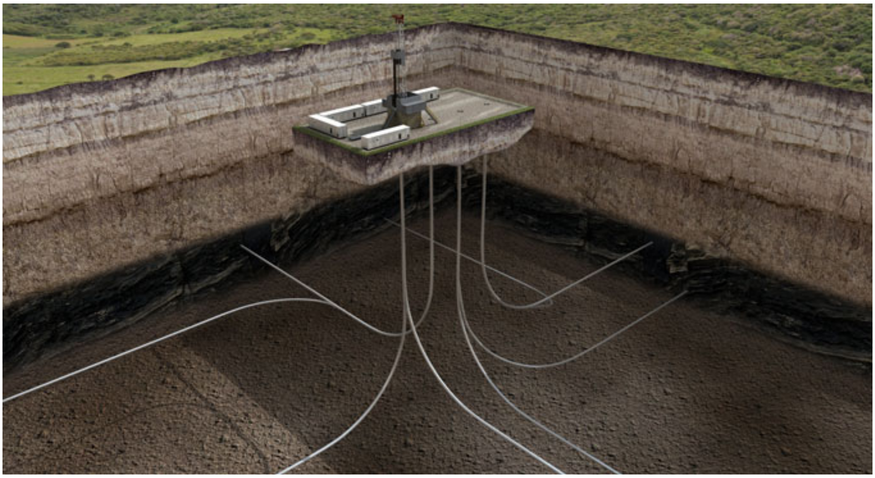

Fig. 1 An example of the spatial view of a multihole well (https://www.hartenergy.com/exclusives/unlocking-production-multilateral-wells-31250)

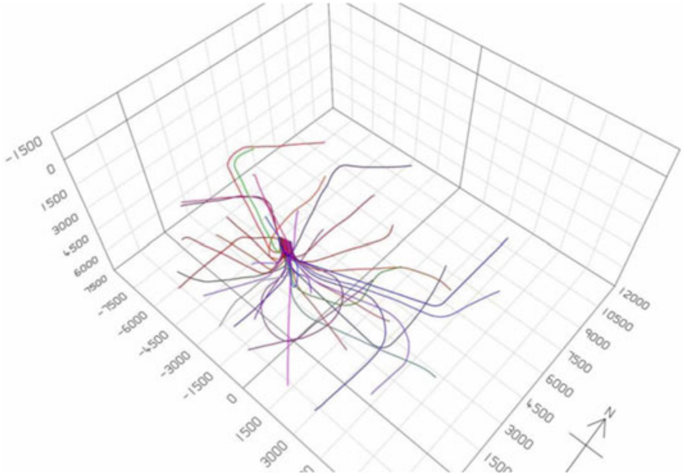

Fig. 2 An example of a plan of a multihole well [1]

fleet, etc.) on the surface of the site and ensuring their trouble-free operation. Examples of arrangement of sites for drilling wells and their repair are shown in Fig. 3 and Fig. 4 respectively.

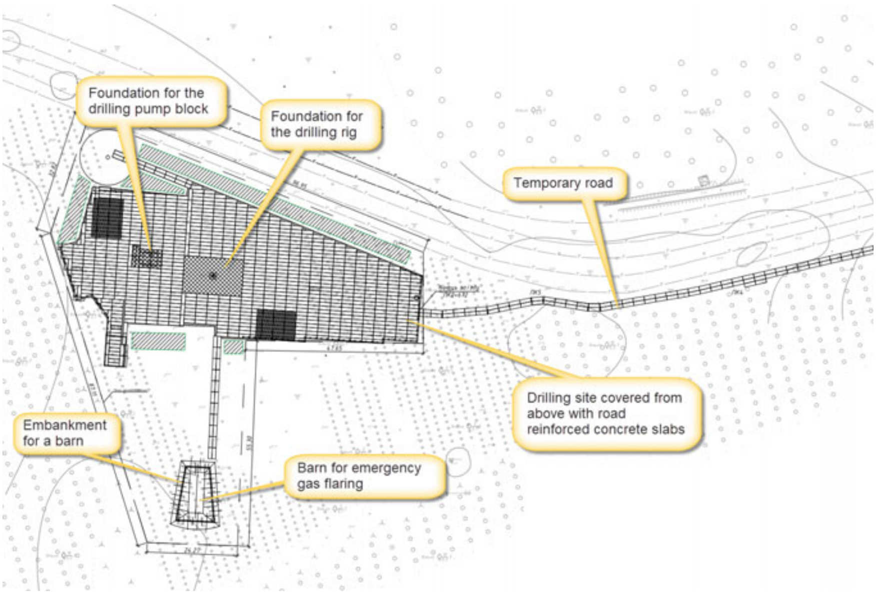

Fig. 3 An example of the arrangement of a drilling site for the construction of one of the wells of DTEK Naftogaz

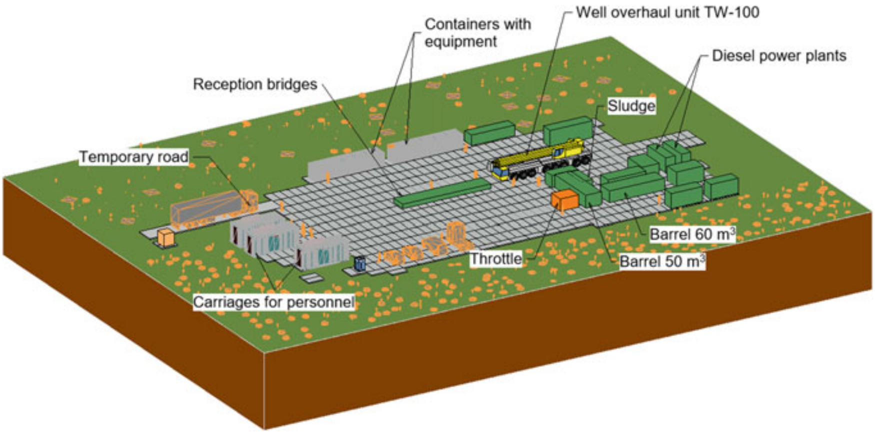

Fig. 4 An example (calculation model) of the arrangement of the site for major repair of one of the wells of JV Poltava Gas-oil Company

Very often, especially in the conditions of Ukraine, sites for work on wells are referred to as complex engineering and geological conditions (in particular, floodplains, wetlands with a high level of groundwater, thick strata (more than 5 m) of peaty and weak soils, fluid-plastic and flowing loams or sandy loams with thixotropic properties, etc.). Such conditions require special preparation of the territory for its further exploitation as a drilling site, and then as a site for other technological operations.

The weight of the technological equipment reaches 450 tons (the carrying capacity of a modern drilling rig). Such drilling rigs, when constructing wells of a complex profile, include extremely high criteria for movements and rolls of the above-ground part of the equipment during their operation, which can be caused by absolute and relative uneven subsidence of the soil base under their foundations. If it is not possible to reach a reliable decision regarding the arrangement of drilling sites, then this causes additional difficulties in the operation of all technological equipment, and sometimes even leads to emergency situations.

Since the terms of work are quite short, and the loads are relatively small, then repeat the classic design and technological solutions for transferring loads from process equipment and mechanisms to the soil massif (massive monolithic foundation slabs, reinforced concrete piles and other capital types of foundations), which usually prevail in construction sites, is impractical for many reasons (economic, environmental, the need for complete dismantling after completion of drilling, etc.).

It is often also unprofitable to arrange artificial basis by vertical reinforcement or by pouring powerful compacted embankments under these conditions.

In addition, there are requirements for minimizing the impact on the environment, in particular, it is advisable to use such technologies that will allow the use of surface lands between technological operations on wells as fertile lands, as well as with minimal impact on their fertile properties.

Therefore, solutions will be effective, in which it will be possible to achieve the most convenient and technological solutions with the minimization of: (1) carrying out earthworks for the construction of the pit; (2) impact on the environment; (3) cost and terms of performance of works; (4) use of special construction equipment.

The authors substantiated effective solutions for sites for the construction and repair of oil and gas wells, the purpose of which is to strengthen the weak soil mass through the use of geosynthetic materials and create an artificial basis for the installation of prefabricated slabs (usually reinforced concrete), which in turn play the role of prefabricated foundations for the corresponding technological equipment and the function of covering the platform for the movement of equipment. These decisions are justified from the standpoint of reliability during a relatively short period of operation.

After the completion of technological operations on the wells, all prefabricated foundation elements and geosynthetic covering of the site are quickly and completely removed, and with minor reclamation works, the territory can be returned to rural lands.

Certain generalizations have been made from the analysis of a sufficient sample of data on engineering-geological conditions of sites for well construction.

So unfavorable physical and geological processes and phenomena for many sites include: (1) a powerful (from 4.5 to 5.6 m) thickness of non-building (soil and vegetation layer, peat at the bottom of the layer is silty, humus, with organic residues, fluid, very heterogeneous) and weak soils (fill soil, loam (bottom silt) light silty, from fluid-plastic to fluid, with interlayers of sand, layered; soil deformation modulus is <5 MPa), i.e. when using them as a natural basis for the foundations of the deformation of the soil mass; (2) soils capable of thixotropic liquefaction under dynamic loads; (3) significant heterogeneity of the soil mass—different thicknesses of soil layers, the presence of numerous interlayers and lenses; (4) flooding of the territory.

Figure 5 shows a photo of one of these sites, which is characterized by flooding of the territory and a significant thickness (more than 5 m) of peaty and weak soil massif.

For the area with such conditions, for the reliable operation of a drilling machine with a load capacity of 450 tons, it is advisable to either cut through a weak layer with deep (for example, piled) foundations, or perform engineering preparation by installing an artificial foundation with the desired elevation of the top of the platform in case it is flooded with surface water.

Figures 6, 7, 8 and 9 present possible geotechnical solutions for the engineering preparation of the territory or effective foundations for specific engineering and geological conditions.

To carry out work on all the above options, it is additionally necessary to provide for the preparation of a base for the movement of construction equipment on the surface of swampy and flooded areas.

Therefore, for the conditions described above, the fastest and cheapest solution is to improve the soil mass by installing crushed stone horizontal drains (Fig. 9).

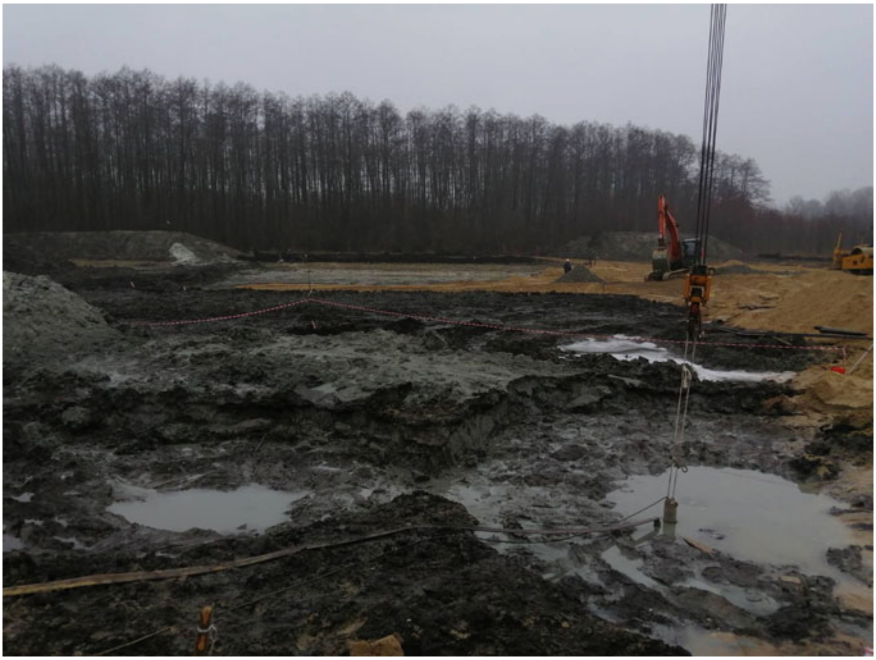

Fig. 5 A photo of a typical wetland site in the process of work before the installation of a drilling rig for the construction of an operational inclined-directed well with a depth of more than 5000 m

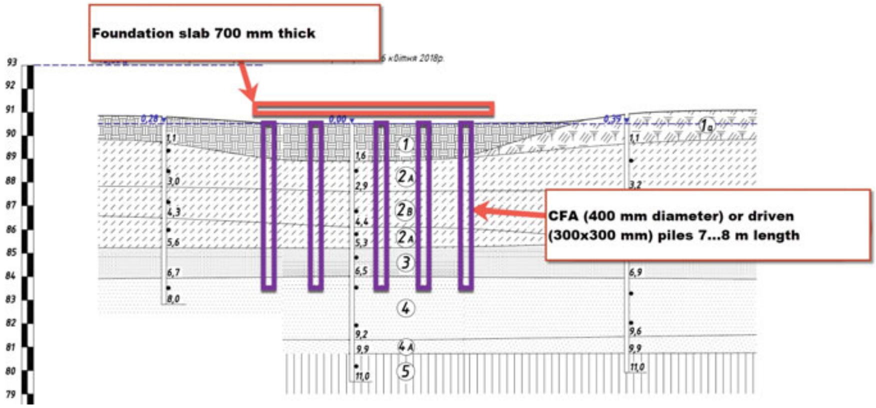

Fig. 6 A variant of cutting through weak soils with pile foundations

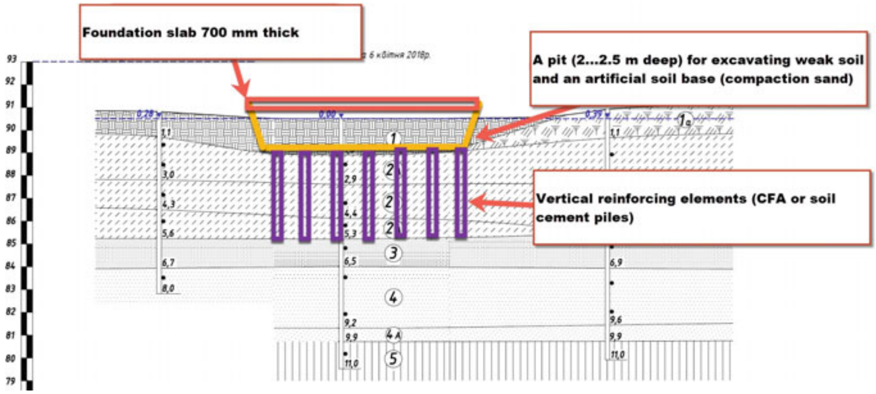

Fig. 7 An option to improve the soil base by vertically reinforcing weak soils with rigid elements and replacing the top layer with a compacted sand cushion

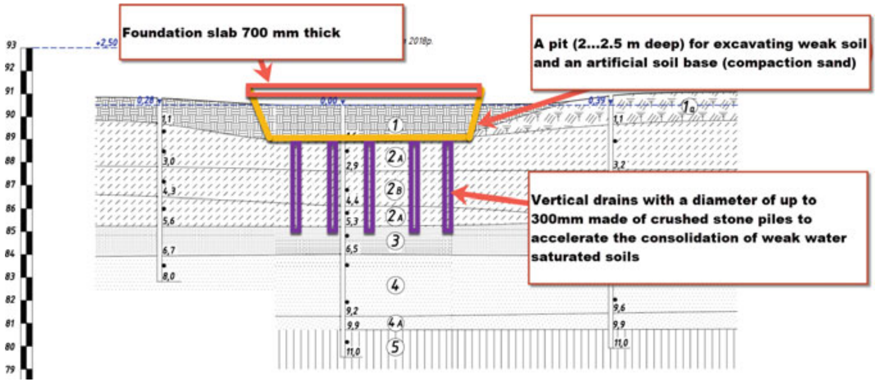

Fig. 8 An option to improve the base by installing vertical crushed stone drains within water-saturated weak soils and replacing the top layer with a compacted sand cushion

The main disadvantage of this solution is the fact that peaty and weak soil is not completely removed, but remains under the artificial base as a weak sub-layer. This causes additional risks regarding uneven deformation of the foundations during the operation of the drilling rig.

Therefore, for such a solution, before installing the equipment, it is necessary to carry out artificial loading to accelerate the consolidation of the weak water-saturated soil massif.

According to the process of soil consolidation of the massif, it is advisable to organize geodetic observations, and after the stabilization of the base subsidence, the proposed construction is a completely reliable option.

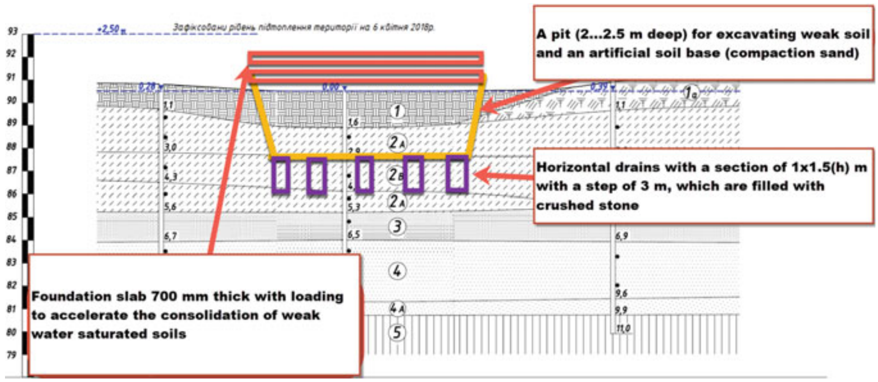

Fig. 9 An option to improve the soil base by installing horizontal gravel drains and replacing the top layer with a compacted sand cushion

As the foundations of drilling machines, it is advisable to arrange a foundation slab with the dimensions of approximately 20 × 32 m and a thickness of 700 mm from the calculation conditions of ensuring the spatial stability of the machine against overturning during its operation in the most loaded mode.

For the convenience of carrying out technological operations, the upper face of the foundation slab must coincide with the level of the site, that is, the immersion of the slab is equal to its thickness, which necessitates the correct calculation of the overturning system.

For the convenience of dismantling this slab after the completion of the well construction process, its design is provided by a team of laid 5 rows of road slabs (for example, dimensions 2 × 6 × 0.16 (h) m) with appropriate dressing and interconnection by clips of steel channels.

The spatial view and photo of the prefabricated foundation slab are shown in Fig. 10.

If the well construction process will take more than a year, then the probability of the coincidence of the worst factors is much higher than if this process will be carried out in a maximum of six months. This, in turn, causes the need to take appropriate measures to increase the level of reliability of the constructive solution for the engineering preparation of the territory and foundations for the drilling rig. In particular, in this case, according to the results of the numerical modeling of the SSS of the soil base, taking into account the fluctuations of groundwater (the possibility of significant flooding of the territory), the option with shallow drains is possible only if the capacity of the embankment on top of it is significantly increased and, accordingly, the surrounding area is raised. Therefore, the economically best options will be solutions with complete cutting of the weak massif by reinforcing elements (Figs. 7 and 8).

Therefore, the period of technological operations in the well is taken as an important criterion of the scientific problem.

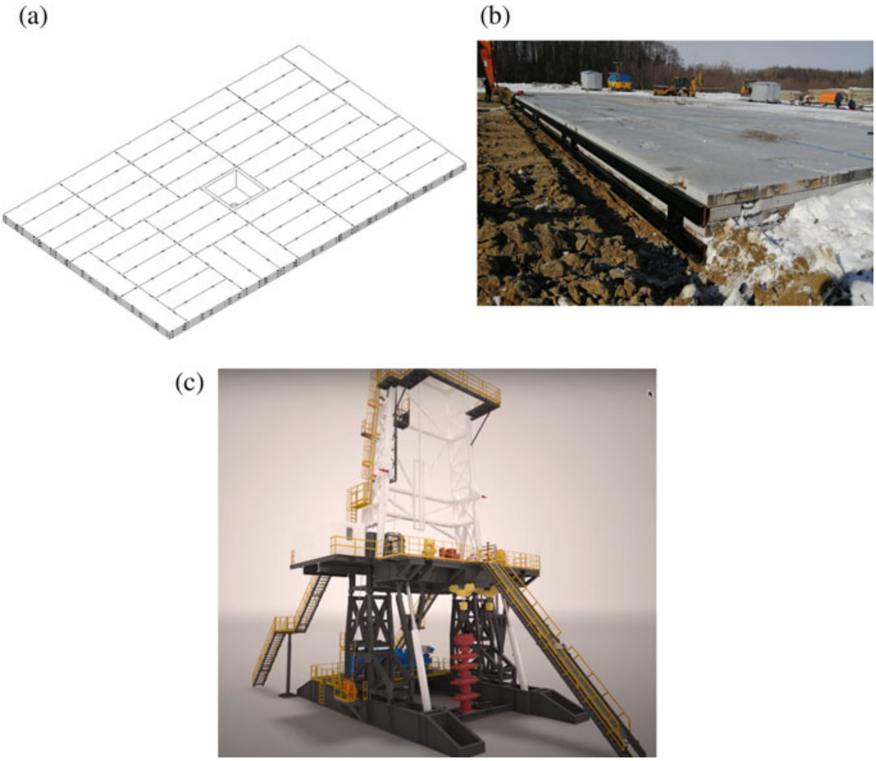

Fig. 10 Spatial view (**a**) and photo of foundation (**b**) and drilling rig (**c**)

In the case of technological operations for the capital repair of wells, for example, a coiled tubing installation or production intensification operations, in particular, hydraulic fracturing, the terms of these processes vary from several days to several weeks. In addition, the mass of technological equipment is much lower than when constructing a deep well. This makes it possible to make even more optimal decisions on the arrangement of the site, in particular, to minimize the impact on the existing soil cover for the smallest measures for its further reclamation around the well. Analytical calculations and modeling of the stressed deformed state of the base of the site for repair work (the calculationscheme is shown in Fig. 4) justified the construction of the base reinforcement with geosynthetic materials. At the same time, two options are offered.

Option 1. Roll out a geotextile sheet on the surface of the soil, install a spatial geogrid on it (cell height 100 mm, diagonal size 200 mm) with its cells filled with washed crushed stone of a fraction of 25–60 mm (a principle photo of this solution is shown in Fig. 11a. Reinforced concrete road slabs with a thickness of 160–180 mm are mounted on top. After completion of technological operations on the well, the protective covering should be removed. At the same time, the lower layer of geotextile performs the function of protecting the ground cover from the penetration of crushed stone into it.

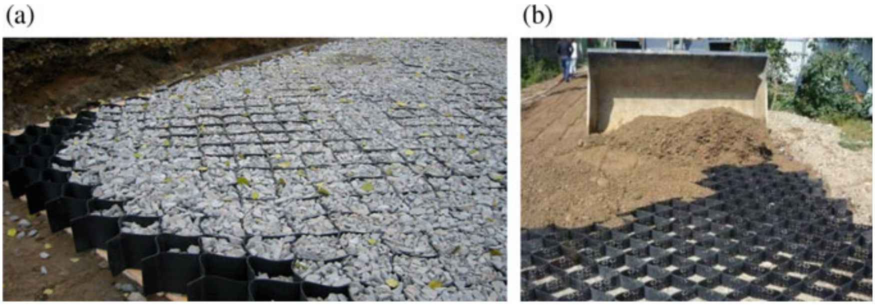

Fig. 11 Principal decision on the arrangement of the base under the protective coating for carrying out technological operations on the well: **a** option 1; **b** option 2

Option 2. Laying out a spatial geogrid (the geometric parameters are the same) immediately on the surface of the soil layer, filling its cells with soil (a basic photo of this solution is shown in Fig. 11b. 160–180 mm thick road slabs are mounted on the top. After completion of technological operations on the well, it is necessary to remove the protective covering.

3.2 Theoretical Principles of Assessing the Bearing Capacity of the Site Covering for Technological Operations on Wells

The effectiveness of the use of geosynthetic materials (geogrids, geonets, geomembranes, etc.) is achieved by increasing the bearing capacity of the base, increasing the tensile strength of the soil through its horizontal reinforcement, separation of different soil environments with different conditions and composition (allows to avoid mixing or penetration of bulk dispersed and weak base soils) etc. That is, the geogrid performs the function of increasing the tensile strength of an incoherent crushed stone massif of the subgrade by means of its horizontal reinforcement. After installation, a reinforcing element or a system of them must create additional force reactions with permissible deformation, which are absent without reinforcement, and in this regard, the required level of reliability is not ensured. The principle of interaction of the geosynthetic reinforcing element with the soil of the natural base or bulk compacted soil is ensured due to the friction and adhesion of the geosynthetic material with them. The interaction and "transfer" of the force factor into the overall system is characterized by the coefficient of friction and the necessary displacement deformation to activate the friction. In the case of direct contact of reinforcement elements made of geosynthetic materials located one above the other, the value of the coefficient of friction is set as the friction between these reinforcement elements.

These parameters were determined in the laboratory.

Reinforcement with geosynthetic materials increases the cohesion of the soil, the conditional value of the modulus of deformation and the coefficient of lateral expansion, changes the stressed deformed state of the base under force effects. The reinforced massif can be considered as a slab on the subsoil layer of unreinforced weak soil.

In general, the geosynthetic material for reinforcement is selected in such a way that the stability of the embankment on a weak foundation is ensured both at the construction stage and under the action of tensile stresses that are realized during the entire life of the structure.

However, even in this case, subsidence is not excluded, although due to the reinforcing element, it passes more evenly, decreasing in size. Volumetric geogrids make it possible to significantly increase the load on a weak foundation (almost twice as much as compared to a flat one). The criterion of the general reverse deformability of the layered coating, which takes into account the sum of the reverse deformations of the layers, is adopted as the general criterion for the strength of the site covering

$$K_u = u/|u|;\; K_u^{dyn} = u^{dyn}/\left|u^{dyn}\right|;$$

$$K_u = \frac{P \cdot D}{|u|}\Big/\frac{P \cdot D}{u};\; K_u^{dyn} = \frac{P_{dyn} \cdot D_{dyn}}{\left|u^{dyn}\right|}\Big/\frac{P_{dyn} \cdot D_{dyn}}{u^{dyn}};$$

$$u = \sum_{1}^{M} u_j;\; |u| = \sum_{1}^{M} \left|u_j\right|, \tag{1}$$

where u, u^{dyn}—respectively, the total inverse static and dynamic deflection of the surface of the constructions of the site covering;

$|u|$, $\left|u^{dyn}\right|$—permissible static and dynamic deflections of the surface of the site covering, at which the quality of operation during technological operations does not deteriorate;

P, P_{dyn}, D, D_{dyn}—specific static and dynamic pressures from the wheel load of the technological equipment, which are distributed among circles with a diameter D at rest and D_{dyn} when moving;

K_u, K_u^{dyn}—calculated strength coefficients (static and dynamic) of the structures covering the site.

A condition for ensuring the static and dynamic strength of structures is the calculation and determination of the thickness and properties of the layers within

$$K_u \le K_u^{\min};\; K_u^{dyn} \le K_u^{dyn,\min}, \tag{2}$$

where $K_u^{\min}$, $K_u^{dyn,\min}$—strength coefficients (static and dynamic), which are established experimentally, if they are exceeded, the structure of the covering needs to be repaired.

As partial criteria for the strength of individual layers of the structure (coatings, base, sub-layers), the criteria for the tensile direction during bending and active shear stress, the values of which are greater than one, mean that the limit states in the layer for these types of coatings have been reached

$$K_{\sigma_r} = |R|_u/\sigma_r; \quad K_\tau = |\tau|/\tau_\sigma, \tag{3}$$

where σ_r, τ_σ—tensile during bending and shear stresses in the layer from the load;

$|R|$, $|\tau|$—calculated resistance of the tensile material during bending or displacement, taking into account endurance or multiple loading.

The given theoretical provisions were also analyzed by modeling the FEM of the SSS of the system “weak base—geosynthetic covering—prefabricated foundations and covering”.

In the Table 1, in particular, the physical parameters of the components of the calculation scheme for such modeling are given.

An interface (interface strength) is used to simulate the interaction of the soil model with the geogrid.

The Coulomb criterion was used to draw the boundary between the elastic behavior of the interface, in which small movements are possible inside it, and its plastic behavior.

In order for the interface to remain elastic, shear stresses must satisfy expression (4), and for plastic behavior—expression (5).

$$|\tau| < \sigma_n \tan(\phi_i) + c_i; \tag{4}$$

$$|\tau| = \sigma_n \tan(\phi_i) + c_i, \tag{5}$$

where ϕ_i and c_i—angle of interface friction and adhesion.

The strength characteristics of interfaces are related to soil strength parameters. Each data set has its own strength reduction factor at the interfaces R_{inter}.

The characteristics of the interfaces are determined on the basis of the soil properties from the appropriate data set and the strength reduction factor according to the following rules

$$c_i = R_{inter} \cdot c_{soil}; \tag{6}$$

$$\tan(\phi_i) = R_{inter} \cdot (\phi_{soil}) \le \tan(\phi_{soil}), \tag{7}$$

$\psi_i = 0^0$ $R_{inter} < 1$ and in other cases $\psi_i = \psi_{soil}$.

The described tensile truncation criterion, which is used for the Coulomb criterion for shear stress, also applies to interfaces (if the corresponding option is enabled)

Table 1 Physical parameters of the calculation scheme components for the analysis of the design solution for covering the site for technological operations during the overhaul of wells

Cluster	Model	Specific weight, kN/m^3	Modulus of elasticity/deformations, MPa	Specific adhesion, kPa	Angle of internal friction	Poisson coefficient
Weak ground base	Elastic-plastic with Mohr-Coulomb strength criterion	Appropriate value for soil	Soil deformation module	Appropriate value for soil	Appropriate value for soil	Sand 0.3 Sandy loam 0.32 Loam 0.35 Clay 0.37
Rocky subgrade	Elastic-plastic, Mora-Coulon strength criterion	25	63.7	100	60	0.25
Geogrid	Elastic	Axial rigidity at 3% elongation is set to 700 kN/m				
Geomembrane	Elastic	Axial rigidity at 3% elongation is set to 1000 kN/m				
Road wear	Elastic	25	1000000	–	–	0.15
Interface	0.9	Interface	0.9	Interface	0.9	Interface

$$\sigma_n < \sigma_{t,i} = R_{inter} \cdot \sigma_{t,\,soil}, \tag{8}$$

where $\sigma_{t,\,soil}$—tensile strength of the soil.

The reinforcing geosynthetic material is modeled using the Geogrid model. This element is characterized by the axial rigidity of EA.

The Geogrid geosynthetic material model perceives only tensile forces. The axial stiffness EA of a geosynthetic material is determined as the ratio of the tensile axial force to the relative axial strain according to the formula

$$EA = \frac{F}{\Delta l / l}, \tag{9}$$

where F—axial tensile force, kN;

Δl—elongation of geosynthetic material under tension, m;

l—basic length of geosynthetic material, m.

The results of simulation of FEM of SSS of the system “weak base—geosynthetic covering—prefabricated foundations and covering” in the parking area of the heaviest equipment (well overhaul unit TW-100 adopted) are shown in Fig. 12.

So, it was found that the maximum vertical movements can reach 1.5 mm.

The probability of local destruction of the coating and subgrade from a spatial geogrid filled with crushed stone or soil is practically impossible.

Tangential tensile forces in the pavement and subgrade are fully absorbed by the geogrid.

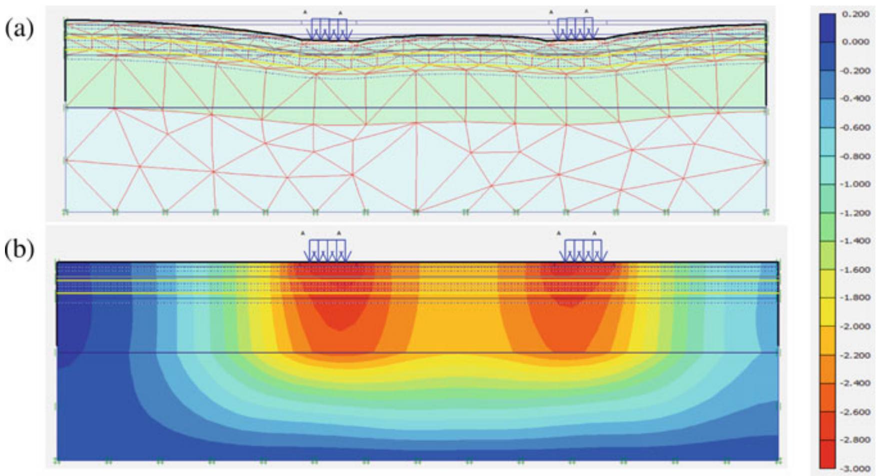

Fig. 12 Deformed scheme (**a**) during operation of the covering with a geogrid layer (conditionally magnified 200 times) and vertical movements (**b**), mm

3.3 Results of Field Studies

Physico-mechanical properties of the base soils were evaluated in laboratory and field conditions using standard methods.

Thus, to determine the mechanical parameters of the formed artificial foundations, field tests of trench-type drains filled with crushed stone were carried out (similarly for filling the grids of the spatial geogrid). The tests were performed with a soil density meter "Terratest 3000 GPS". As a result, the dynamic modulus of elasticity was obtained at points: No. 1 $E_{vd,1} = 63.7$ MPa; #2 – $E_{vd,2} = 86.2$MPa; #3 and #4 – $E_{vd,3} = 75.6$ MPa. For FEM calculations and simulations, the smallest of the obtained values $E_{vd} = 63.7$ MPa was taken.

Control of the arrangement of compacted soil cushions was carried out by taking samples of compacted soils. At the same time, soil samples and monoliths were taken from different horizons with an interval of 0.3 m. The sampling sites were designated in such a way as to cover the entire area of the compacted massif. The average value for the massif of compacted soil is $\rho_d = 1.667$ t/m^3, which is in the range of normalized values of dry soil density for compacted foundations ($\rho_d =$ 1.65–1.7 t/m^3).

During laboratory studies, it was established that the bearing capacity of the soil base increases with an increase in the number of horizontal layers of geomaterial. The loss of base stability mainly takes place according to three schemes: (1) with a large percentage of reinforcement (more than 4 layers), the geomaterial elements of the upper layers break; (2) the loss of stability is associated with the sliding of the reinforcing elements relative to the soil of the base, which is accompanied by the pressing of a stamp into it; (3) the soil is squeezed between the stamp and the upper layer of reinforcement (this effect was observed when the upper layer of reinforcement was placed at a distance of 3/4 of the width of the application of the load from the stamp).

The maximum bearing capacity corresponds to the distance from the sole of the foundation model to the upper layer of reinforcement, equal to half the width of the stamp. An intensive increase in the load-bearing capacity of the base takes place in the presence of three layers of reinforcement. A further increase in the number of layers has little effect on the load-bearing capacity of the base as a whole.

An important confirmation of the author's results is also research [24]. In particular, in this work, from the graphs of resistance to pull-out-displacement of the plate during experimental tests and obtained by FEM simulation with and without a granular trench, the significant influence of the presence of a geogrid, as well as the presence of crushed stone trenches in weak soil, is clearly visible. The ultimate pullout load for different number of geogrid layers at different relative densities of sand was obtained experimentally.

Thus, the deformations of the ground base reinforced with geogrids are significantly reduced, and the presence of trenches in weak soil creates an additional effect of the joint work of the geogrid with the base.

Constructions based on geolattices and geogrids when reinforcing the soil in one layer show an increase in the modulus of the general deformation of the base by 22–35% compared to the option without its reinforcement and by 79–115% when reinforcing in several layers. The use of geogrids leads to a decrease in the modulus of general deformation of reinforced soil structures with coarse-grained aggregate.

To confirm the calculated data, full-scale static tests were carried out by loading the arranged foundation slab under the drilling machine with road slabs to achieve the design loads and impacts during well drilling. The experimental load on the foundation slab was selected from the conditions of the most unfavorable combinations of loads and influences during the operation of the drilling rig.

According to passport data, the weight of the drilling machine in total with technological loads when drilling wells is 680 t (weight—6800 kN).

The mass of the foundation slab is $260 \times 4.2 + 208 \times 0.0184 = 1096$ t (where 4.2 t is the mass of the road slab; 260 is the number of road slabs in the foundation; $208 \times 0.0184 = 4$ t is the mass of the channel bracket). Thus, the total weight of the foundation with technological equipment is $680 + 1096 = 1776$ t.

During static tests, it was decided to use the maximum number of available road slabs, 156 pcs. At the same time, their placement is provided similarly to the load transfer scheme from the drilling rig.

The total mass during the tests was $156 \times 4.2 = 655.2$ tons, which is 96% of the maximum possible value of the load.

The scheme of loading the foundation slab and its photo are shown in Fig. 13.

The results of geodetic measurements are included in the Table 2, as well as in Fig. 14.

Therefore, field tests recorded maximum vertical settlement of 6 mm, while the rise of the slab did not exceed 4 mm, and the roll -3.3×10^{-4}. These values are less than the maximum permissible according to the requirements of the operation of the drilling machine, the roll will also not affect the normal, accident-free operation of the machine.

In the process of unloading the slab, the elastic component of the deformations of its base was recorded, the rise of the slab was 1 mm.

4 Conclusions

Thus, as a result of research, the optimal solutions for arranging sites in difficult engineering and geological conditions for carrying out technological operations on wells have been substantiated.

1. For drilling equipment (with a load capacity of up to 450 t) on weak foundations, the best option is a prefabricated foundation slab made of road slabs, which can be quickly assembled and dismantled. In order to avoid excessive subsidence and tilting during the installation of such slabs, engineering preparation of the base should be performed by arranging a system of shallow drainage trenches, which

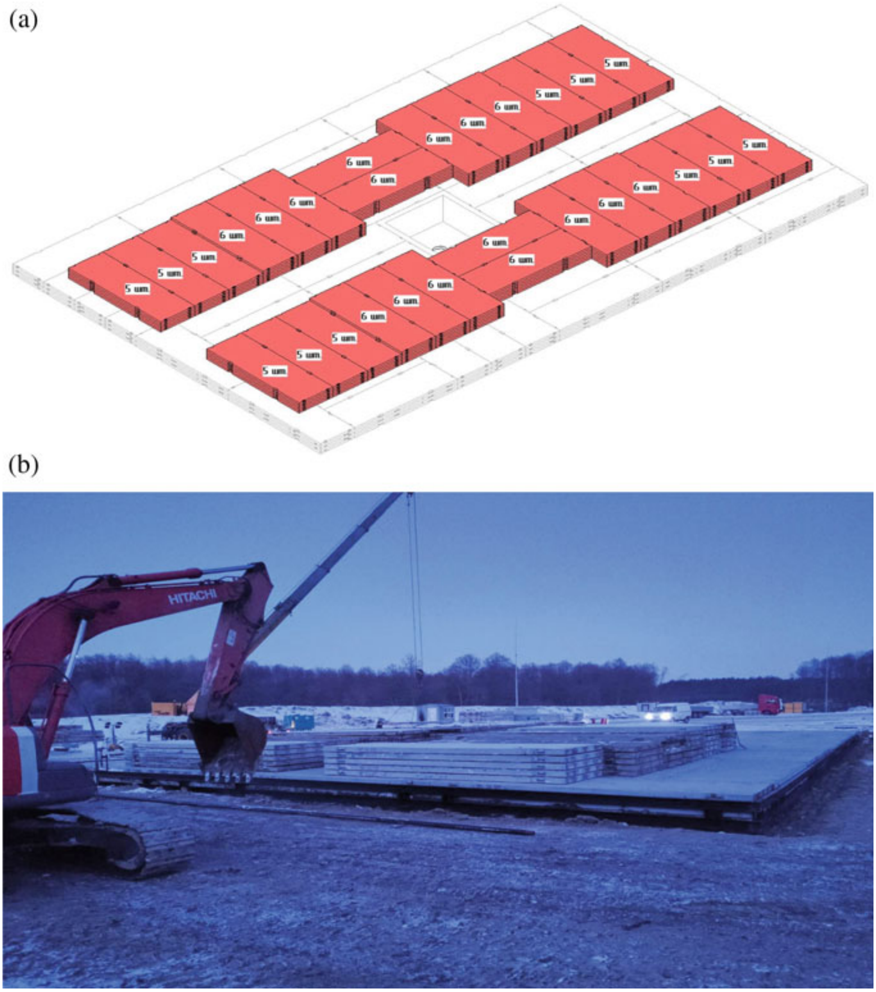

Fig. 13 Scheme of loading the foundation slab (**a**) and photo of the loaded slab (**b**)

are filled with crushed stone, and a geogrid is laid on top. When performing work for a period of up to six months, the level of reliability of such a solution fully satisfies the operational safety of works on the construction of wells of any complexity. In the event of an increase in the time of the works, additional justification is required, for example, it is possible to increase the depth of reinforcement of a weak base with vertical rigid elements or to create a more powerful embankment with several rows of geogrids.

2. With a large thickness of the weak water-saturated base of the foundations of drilling rigs, the effectiveness of the method of loading the finished foundation with the weight of the future equipment in the maximally loaded state with

Table 2 The results of geodetic measurements during full-scale tests of the foundation slab on an improved soil base by arranging horizontal crushed stone drains

No points	Date of measurements (percentage of load)/value of subsidence, mm									
	15.02 (0%)	16.02 (65%)	17.02 (100%)	18.02 (100%)	19.02 (100%)	21.02 (100%)	22.02 (100%)	23.02 (100%)	26.02 (51%)	28.02 (0%)
T1	–	+4	0	−1	0	0	0	0	−1	−1
T2	−2	+2	−2	−2	−2	−1	−1	−2	−2	−2
T3	+3	+5	+3	+2	+2	+3	+3	+3	+3	+2
T4	−2	−3	−8	−7	−7	−6	−4	−6	−4	−3
T5	−3	0	−6	−6	−4	−3	−3	−3	−3	−2
T6	−8	−4	−10	−10	−10	−9	−9	−9	−9	−8
T7	−7	−4	−11	−11	−10	−10	−10	−10	−11	−10
T8	−6	−5	−10	−10	−10	−10	−10	−10	−9	−8

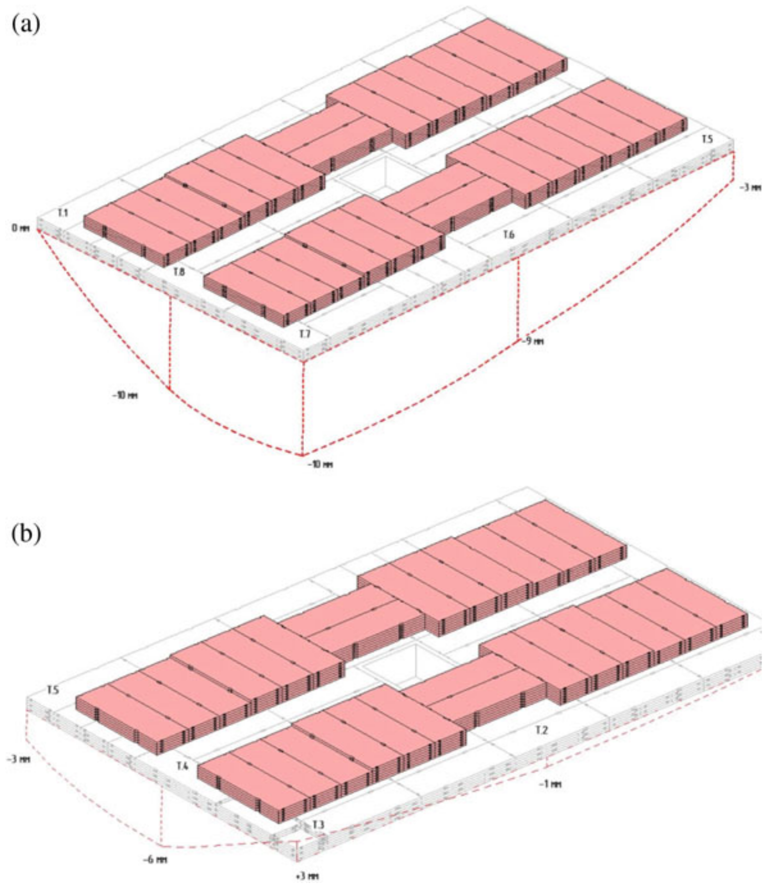

Fig. 14 The results of geodetic measurements of road slab loads on the base and foundation slab of the drilling machine for: **a** grades 1, 5, 6, 7, 8; **b** point 2, 3, 4, 5

geodetic control of such static tests was experimentally confirmed. This approach makes it possible to speed up the consolidation of trench-reinforced weak soil and to confirm the stabilization of the foundations of already prepared foundations before installing drilling equipment.

3. It is possible not to arrange drainage trenches and prefab foundations for the equipment during major repair of wells with a term of up to 1 month. It is enough to place one layer of a spatial geogrid on the existing surface, and on top—a covering of road slabs.
4. It was established that the bearing capacity of the soil base increases with an increase in the number of horizontal layers with geomaterial. Its maximum bearing capacity corresponds to the distance from the base of the foundation to the upper layer of reinforcement, equal to half the width of the foundation.

The maximum appropriate number of layers of geomaterial is three, and a further increase in the number of these layers has little effect on the bearing capacity of the foundation as a whole.

5. Constructions based on geolattices and geonets when reinforcing the soil in one layer show an increase in the modulus of total deformation by 22–35% compared to the option without reinforcement and by 79–115% when reinforcing in several layers. The use of geogrids leads to a decrease in the modulus of general deformation of reinforced soil structures with coarse-grained aggregate.

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Planning of Cities

Visitors’ Terraces as Components of the Urban Environment of Airports

Galyna Agieieva

Abstract The paper covers the results of research on the urbanization processes of airport territories. Ways to remove social barriers and ensure universal access to road infrastructure, recreation and local culture have been explored. The paper represents the experience of arranging visitors’ terraces as components of social and cultural space at the territory of airports. Events and places worth seeing are categorized in 5 parameters. Areas where potential visitors concentrate and attracting sights (3) are defined. Characteristic features of visitors’ terraces intended for attendance, factors (6) for evaluating the arrangement, siting (3) within the system of spatial organization of terminal cities and airports are defined. For the system of spatial organization of the international airport “Boryspil”, 3 options for arrangement of visitors’ terraces are proposed. Each of the options has its advantages and disadvantages. Suggestions are given in order to satisfy the social demand for the visual accessibility of a number of workflow operations in the airports and the environment.

Keywords Airport · Terminal city · Spatial organization · Sustainable development · Non-aviation · Visitors’ terraces

1 Problem Statement

Modern trends in the development of airports are based on the spread business model, which turns airports into a kind of urbanized area [1–3]. This transformation effects airports not only spatially but also functionally. In particular, the expansion of additional services for air passengers and visitors which is 200–250 contributes to the growth of non-aviation revenues up to 46% of the total income of the airport [4]. Even today, even for small airports, the quantity and quality of non-aviation services are among the main selection criteria for potential airport users (passengers, visitors, etc.).

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_31

The concept of sustainable development of countries defines the ways of urban development of territories especially those which are close to airports, and the principles of safe urban area where social barriers are removed, public access to road infrastructure is ensured; safe, accessible and open green areas and public places are widely available particularly for women, children, elderly and disabled people. Such urban areas create favorable conditions for the development of tourism, recreation, local culture, which are also relevant for airports.

The airport as a part of urban areas needs a good solution for a number of relevant problems, in particular, spatial planning, integration of transport infrastructure, social and economic changes, etc. [5].

In a crisis caused by the COVID-19 pandemic, airports can lose up to 40% of passengers and up to 50% of revenue according to ACI Word experts. Therefore airports address the issues of economic development and promote energy efficient, environmental and social projects, which will affect their spatial organization [6].

2 Analysis of Research and Publications

The works of Güller and Güller [2], Kasandra [3], Veretennikova and Vilensky [7], Stangel [8], Bosma and Nikolaeva [9], Timchenko et al. [10] are devoted to the tackling problematic issues related to the urbanization of airports and the arrangement of city airports.

Conditions for generating urban processes in the area of influence of airports are considered in the works of Baburov [11], Bondar and Solodilova [12].

Works of Agieieva [13, 14] are devoted to special issues related to the transformation of the architectural environment of airports into a social and cultural space with relevant conditions, restrictions and requests.

This paper contains the results of the author's research of urbanization of airports and mostly the satisfaction of social demand for visual accessibility of a number of workflow operations in the airports and the environment.

Purpose of the paper:

- to determine features of spatial organization of terminal cities (henceforth TC) in particular the arrangement of visitors' terrace (henceforth VT) with regard of sustainable development of airports and urbanization of their territories;
- to define VT characteristic features for areas where visitors concentrate, criteria for evaluating the arrangement and siting within the system of spatial organization of terminal cities and airports;
- to give proposals on how to arrange VT in the system of spatial organization of Boryspil International Airport.

Research Methods

The research includes the study of cartographic, photographic and design documents and draws on released information on the history of construction and operation of the study objects.

The main research methods are comparative and critical analysis, a systematic approach to the study object as a complex, identification of properties and environmental effects of the study object.

3 Urbanization of the Airport. Events and Places Worth Seeing

In the context of sustainable development, airports develop the relevant strategies and implementation of these strategies contributes to addressing political, economic, operational, environmental and social problems. The social problems include accessibility of airport and its parts; maximum access to aviation transport system and individual destinations; spread of non-aviation services, creating new vacancies, etc. [15].

This leaves an imprint on the TC spatial organization, contributes to the emergence of new types of buildings and structures and requires the retrofitting of landside areas, transport roads and pedestrian walkways and so on.

All this leads to changes in planning strategies in order to transform a significant part of airport into a creative/social and cultural space that is attractive to users [13].

The key to creating this space is the establishing centers in the airport structure, generating opportunities to identify the airport as part of a tourist destination; provision of educational, cognitive and entertainment services; getting positive impressions; handling economic issues, with basic workflow as backdrop.

Exceptions are aerodrome and other flight safety zones. However the airfield is the most attractive point to be this center. On the one hand, it is the main part of the airport which is a specially equipped plot of land. On the other hand, the airfield has a significant territorial potential such as huge areas, interesting landscapes and simple terrain due to special technological processes related to industrial transport. This is why the airfield is attractive for visual perception, watching and evaluation of workflow when you see it from the air and from visitors' terraces which are well-located and have picturesque landscapes and interesting static and dynamic observation objects.

From the air one can clearly see general layout of the airport and built up areas, which are located in the aerodrome approach area; there are beautiful landscapes of adjacent areas that have preserved their naturalness or have been changed, etc.

Aviation has had a great number of supporters throughout its existence. Demonstration flights of aircraft within the framework of world, international and regional aviation events still gather big audience and fans of different ages, professions and hobbies.

Recently, spotting, a new kind of hobby has appeared and it has its fans, professional photographers and amateurs. Airports are interested in holding official spotting competitions and organize them several times a year placing temporary plane spotting on the territory of the airfield, platform or near terminals, hangars, etc. [16, 17].

VT is not a mass phenomenon, but allows to provide additional services to passengers and visitors who observe and visually perceive the most interesting, from their point of view, moments when aircraft moves on the platform, airfield, air, without any interruptions of airport routine.

VT load can vary from single visitors to several thousand people (Berlin Tempelhof Airport, [18]). VTs are created according to town-planning, architectural and design decisions which consider layout features of the relevant airport (Budapest Ferihegy International Airport, Vilnius Airport, Warsaw Frederic Chopin Airport, Los Angeles International Airport, Belgrade Nikola Tesla Airport, Hamburg Airport, Zurich Airport, Helsinki Airport ets).

In the context of transforming the architectural environment of airports into creative / social and cultural space, many years of experience in VT construction and operation requires analysis, systematization and dissemination. In this case, the study objects of this paper are VTs designed for mass service of visitors and having free access without time restrictions.

VT design, construction and operation requires relevant knowledge of the details of workflow and principles of spatial planning solutions of airport cities, standardization of requirements, current trends and prospects for airport construction, urban planning and etc.

According to the **scale** of demonstration events and the interest of actions in the airport routine, we can offer the following hierarchy of events and places worth seeing categorized as follows:

1. display flying of aircraft (air show);
2. takeoff and landing of aircraft;
3. ground movement of aircraft;
4. panoramas of the whole airport taking into account surrounding areas;
5. panoramas of the airport buildings (local areas) taking into account / without taking into account surrounding areas.

It is these events and places that affect the VT type.

4 Characteristic Classification of Visitors' Terraces

By the use Visitors' terraces are divided into plane spotting (hereinafter—PS) and VT.

By **volume-planning** parameters:

– single-storey and multi-storey;
– point; linear-extended; curved in plan;

– simple and complex by shape;
– open and covered areas;
– with restrained or increased architectural characteristics;
– temporary or permanent with long-term operation.

VTs are divided by the **level of availability**:

– mass use by passengers and visitors of the airport;
– limited use (passengers only or airport staff only).

These VTs include departure waiting rooms where windows are oriented to the platform and airfield and have a window ensuring the quality of panoramic views. Several modern airports offer access to open visitors' terraces connected to the waiting rooms.

VT public (large-scale) access can be **temporary** (during the air show, in consultation with airport management) and **permanent** (stationary).

Temporary VTs can be placed in high-risk areas for visitors, in particular, in areas of air approaches, end safety lanes, etc. [17]. Such VTs need approval from the airport administration, air traffic control services, flight safety, etc. and are not the study subject of this paper.

The placement of **permanent VTs** cannot be spontaneous, they must be safe for visitors and do not disrupt the workflow of the airport.

By **human load** VT can be divided into:

– small (several people);
– medium (up to several dozen people);
– large (up to several thousand people).

The quality of VT behavior is influenced by its location on general plan of airport; height of the placement and linear dimensions; human load; viewing angles available (360° or less); protection from atmospheric precipitation, excessive insolation; safety of visitors and maintenance of the facility, etc.

5 Factors Influencing the VT Arrangement

When arranging VT one should take into account the following factors that determine the sustainable development of the urban environment:

– social;
– natural, climatic and ecological;
– urban planning;
– structural and technological;
– aesthetic and informational;
– economic.

5.1 Social Factors

The creation of socially important facilities that integrate cognitive, educational, aesthetic and special functions, recreation and entertainment helps to improve the want-satisfying quality of the airport environment and contributes to its competitiveness. Therefore, VT is, first of all, the result of satisfying a social demand.

5.2 Natural and Climatic Factors

Natural and climatic factors affect the functional and spatial organization, VT architectural solutions, the comfort of visitors. The following characteristics of the climate need to be taken into account: wind, aeration and temperature and humidity conditions, excessive insolation, amount and intensity of precipitation. Environmental factors are also assessed, in particular, the impact on the environment, the ecological balance of the territory.

5.3 Urban Factors

Urban factors determine the possible VT areas on the airport territory, accessibility for potential users, comfort, protection from the adverse effects of aviation noise, dust, gas pollution, etc.; the use of VT for concept solutions for the airport architecture.

By the nature of the location on the territory of the airport VT can be attributed to the facilities that have the appropriate restrictions associated with the airport activity (flight safety, accessibility modes, etc.).

Taking into account the categories of potential users (passengers and visitors) and the need to meet the conditions of walkability [19], VT areas are localized and tend to the places of concentration of users in the terminal city, namely to:

- passenger terminals / stations;
- landside area;
- transport interchanges,

and facilities that are either part of terminals/stations, transport interchanges, or are located on the landside area (parkings, airfield control towers, etc.).

By **height** VT may be arranged at ground level, on the upper floors and operated roofs of buildings and structures.

5.4 Design and Technological Factors

VT design solutions and engineering equipment should ensure its basic functions, and take into account design indicators of architectural and planning solutions (human load, height and quality of visual perception of places worth seeing), strength, stability of building, sanitary and environmental qualities, accessibility to low-mobility groups of visitors, long duration, maintainability, energy efficiency and safety of operation of Visitors' terraces [20].

5.5 Information and Aesthetic Factors

On the one hand, these factors affect the quality of basic functions, such as to get visual information when using VT. On the other hand, these factors influence the parameters which help create a VT positive visual perception in the airport architecture.

There is a well-established practice of forming individual architectural and planning solutions for VTs using modern building materials, structures, technologies. Various options of engineering equipment, improvements and planting are introduced.

5.6 Economic Factors

Economic factors should be taken into account when finding reasons for VT arrangement, selection of design solutions and operational measures [1, 15, 20]. VT visitor service can be attributed to commercial or non-commercial non-aviation services of the airport, and this in combination with advertising can be a source of significant additional income [15].

6 Methods of Location at Airports

Taking into account a number of these factors one can get fixed architectural and planning solutions for PS (Vilnius Airport, [16, 21]), and also unique structures that have become accents of build up and symbols of airports (Los Angeles International Airport, [22]).This largely depends on the urban situation, the spatial organization of terminal cities and methods of VT arrangement (see Table 1).

Table 1 Methods of VT location at the airport

Methods of VT location at the airport	Examples/airport
A. Detached facilities not joined to passenger terminals	
A.1. Multifunctional	Los Angeles International Airport
A.2. Monofunctional	Vilnius Airport
B. Detached facilities joined horizontally to passenger terminals	Vienna International Airport
C. As part of other buildings:	
C.1. Isolated floor of aerodrome control tower	Vienna International Airport, Istambul Airport
C.2. Extension to airport buildings	Boryspil International Airport
C.3. Operated roof of airport buildings	Berlin Tempelhof Airport, Vienna International Airport

7 Examples of VTs built from 1936 to 2019

7.1 Berlin Tempelhof Airport

The most famous, large in size and human load is a VT at Berlin Tempelhof Airport (Fig. 1a). This is an open tribune with the load of up to 80,000 seats located on the roof of the terminal city which is curved in plan and has the length of 1.23 km (Fig. 1b). It was intended for accommodation and service of numerous visitors and observers of demonstration and regular flights of aircraft at the aerodrome [18]. The airport has not been operated for a long time for its main functions. In the near future it is planned to carry out reconstruction with transformation into a multifunctional public center and VT will get back its designed functions [23].

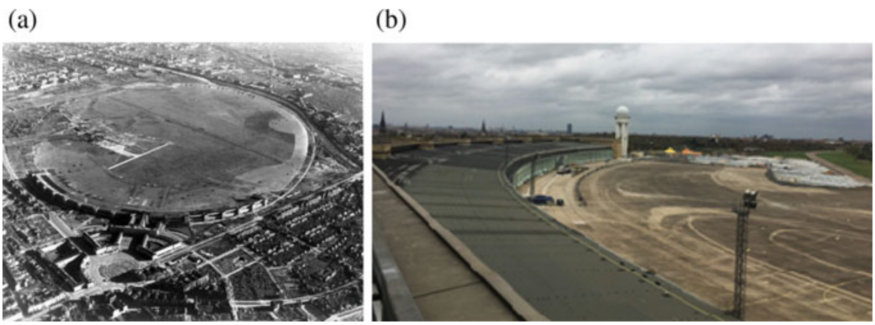

Fig. 1 Berlin Tempelhof Airport: **a** is a general view [24], **b** is a VT fragment [25]

Categories of events and places worth seeing (according to the proposed hierarchy)—1, 2, 3, 4, 5.

7.2 Vienna International Airport

An interesting example is several VTs at Vienna International Airport taking into account many years of experience in arrangement and maintenance [22, 26].

Stage 1 (1960). After commissioning of the Flughafen Wien passenger terminal (1960), the airport received a series of facilities to observe the processes that took place on the platform and on the aerodrome (lane 11/29). The facilities had free access from the landside area and were interconnected. The facilities included:

- VT-1, open four-storey building of tower type with a penthouse (on the left side of the platform [26]) for observation of the circle (airfield, platform, landside area);
- VT-2, linearly extended open-type walking terrace located at some distance along the entire facade of the terminal [26]. Four rectangular VTs-3 for spectators crossed the terrace and were located on the operated roof of the assembly point [26].

Stage 2 (1972–1995). The construction of the second airport runway (16/34) was accompanied by the reconstruction of the TC and the reorganization of the airport general layout. A part of the "Flughafen Wien" passenger terminal, VT-2, VT-3 were dismantled. Over time, two curved satellites were added to the Flughafen Wien terminal from the platform—Pier Ost (1986) and Pier West (1989–1995) [27].

The VT-1 four-level tower-type structure was reconstructed as an administrative building [26].

An isolated floor of the new 109 m high building of aerodrome control tower [28] and the operated roof of the multi-storey parking (VT-5) both built on the territory of the landside area during 2004–2005 started to use as VT-4.

As a result, VT locations, categories of places worth seeing, as well as load, availability, and operation mode have changed (Fig. 2).

Stage 3 (after 1996). Further development of the airport was accompanied by the construction of new buildings and structures, in particular, the "Skylink" terminal which was curved in plan and had "Pier Nort", rectilinear satellite (2006–2012).

The location of the "Skylink" terminal made it possible to use this location for the construction of an open-type VT-6 along the north-east facing façade towards both airport runways and platforms [28, 29]. The length of VT-6 is about 300 m, what ensures the high human load [30].

Categories of events and places worth seeing are as follows VT-1, VT-4, VT-5, VT-6—1, 2, 3, 4, 5; VT-2, VT-3—1, 2, 3, 5.

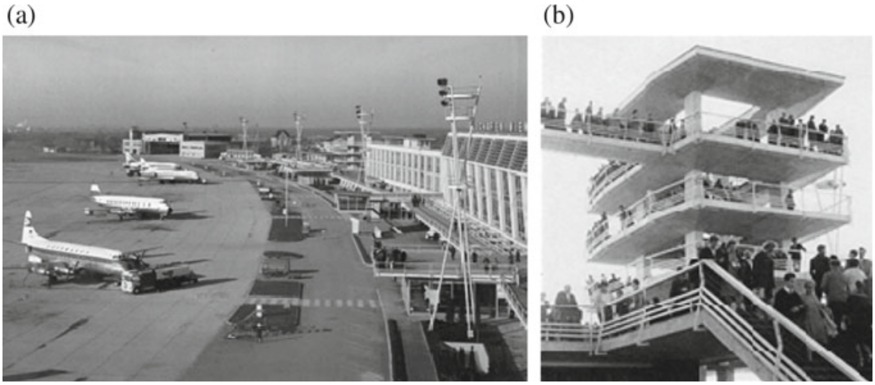

Fig. 2 Vienna International Airport: **a** is a "Flughafen Wien" terminal [26]; **b** is a VT, 1960 [26]

7.3 Vilnius Airport

In 2019, an open-type VT located outside the airport was built at **Vilnius Airport** [16, 17]. It has a fixed architectural and planning solution, transparent fencing, landscaped area, free access for users. There is a children's playground nearby.

Categories of events and places worth seeing are as follows 1, 2, 3, 4, 5.

7.4 Los Angeles International Airport

An interesting VT solution was implemented at Los Angeles International Airport in 1965 [22]. The terminal city includes 8 (7 at the time of construction) passenger terminals which are located around the perimeter of the landside area [31]. Parkings, administrative buildings and engineering structures are situated on the landside area. The highlight of the facilities is the building of the airfield control tower and the tower with a restaurant inside which includes a VT with a cafe for visitors [32].

The unique architectural and spatial design of the tower with a restaurant inside—"Spider"—is a kind of business card of the airport [32]. This is what is taken into account during the reorganization of design concept of the landside area and the construction of new facilities. VT accessibility for visitors is ensured by elevators and horizontal connections i.e. crossings with each passenger terminal equipped with stairs for descent/ascent to the parking lots.

Categories of events and places worth seeing are as follows 1, 2, 4, 5.

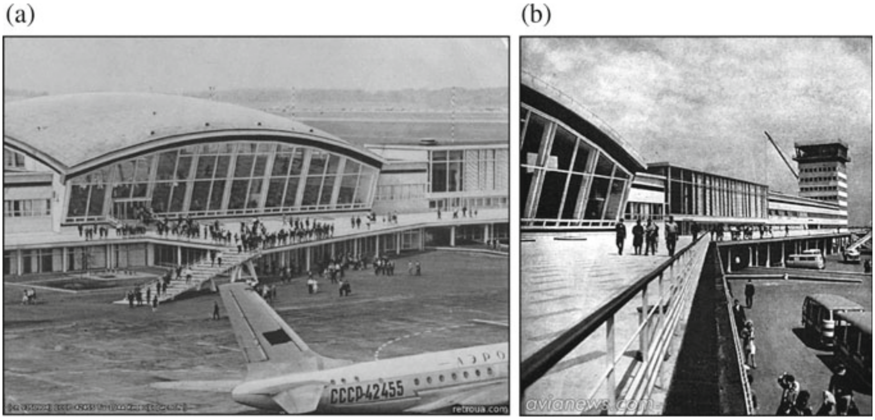

Fig. 3 VT, Boryspil International Airport: **a** is a general view [33]; **b** is an element [34]

7.5 Boryspil International Airport

The VT solution implemented during the construction of Terminal B at Boryspil International Airport in 1960 is indicative of the domestic practice of airport construction. It was an open-type VT attached to the terminal from the platform side at the second floor level (Fig. 3a). For many years, Terminal B was a kind of business card of the capital of Ukraine. Architectural and urban planning, engineering and technical solutions ensured the terminal the role of the dominant building and made it attractive for visiting by aviation fans. The size, human load and accessibility of the VT provided the concentration of visitors. There were entrances/ascents from the landside area, the platform and exit from the waiting room of Terminal B which were removed over time (Fig. 3b). During the reconstruction of Terminal B at the beginning of the XXI century the VT was dismantled.

Categories of events and places worth seeing are as follows 1, 2, 3, 5.

8 Conceptual Proposals for the VT Arrangement at Boryspil International Airport

8.1 Current Status

The airport has several passenger terminals and each one has waiting rooms to provide additional services for passengers, such as the chance to observe takeoff, landing and maneuvering of aircraft in ground handling and so on. But this is a restricted area with an access for departure and transfer passengers only. These areas are not available for mass visits. There are currently no other permanent VTs at the airport.

The details of spatial organization of the airport are due to the fact that it has a dual-base aerodrome, two parallel runways; service and technical area which is located between the runways (see Fig. 4); the last railway stop close to terminal D. Every year spotting is held in the airport as there is a constant need for organization, production and technical support of educational and informational activities. The most popular for professional photographers and amateurs are the four zones [17], which are used for spotting between times (Fig. 4).

The arrangement of permanent VTs requires investigation of the current situation and finding places of maximum attraction in the system of spatial organization of the terminal city [35].

The airport's strategic development plan includes reconstruction of the runway, further construction of Terminal D in the direction of Terminal B, construction of a platform, extension of non-aviation services and so on.

Reconstruction and commissioning of the second runway will increase the airport's acceptance rate, tighten the aircraft schedule and, as a result, increase the attractiveness of the airport as an object of creative social and cultural space. Densification of the built-up area does not exclude the possibility of arrangement of a VT to meet the visual needs of airport visitors. Currently, free access area is the landside

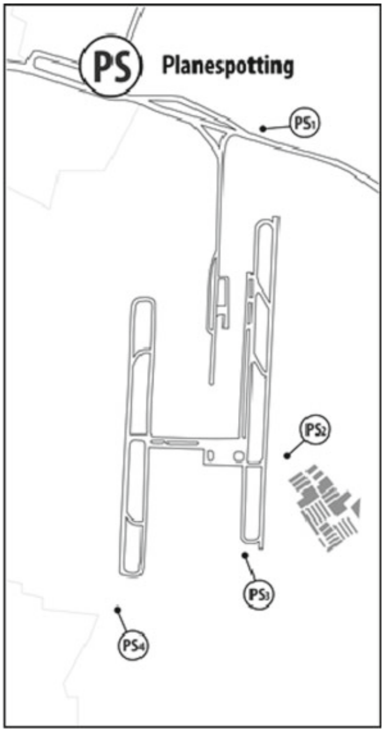

Fig. 4 Layout of temporary plane spotting

area and area with limited access is the multi-storey car park roof, but they do not meet the requirements to the quality of information perception. The development plan of the State Enterprise UkSATSE envisages the construction of a new aerodrome control tower [36], and this building may be multifunctional, in particular, it may include VT areas on one or more floors (by analogy with the aerodrome control tower of Vienna International Airport, [28]).

8.2 Proposals for the Arrangement of a New VT

When choosing a VT location, one need to take into account the details of the landside area which is the area where land transport, passengers and visitors concentrate. This is an area complicated in shape and square, its part borders on terminals B and F and another part–in the zone of terminal D–has two levels. The established traffic arrangement and presence of a viaduct are attractive dynamic pictures for observation, too. At the same time, the implementation of "*…life-supporting manifestations"* [37], i.e. "*meeting the needs of today, which should not undermine the ability of future generations to meet their own needs*" [37] requires careful intervention in the existing system of airport buildings and related structures. The analysis of the general and site layouts of the airport, traffic plan of motor and railway transport, passengers and visitors allowed to offer three options of VT location:

1. VT1 arrangement on the floor of a multi-storey car park;
2. construction of a new VT2 close to terminal D from the north side and the end station of the railway;
3. transformation of the existing aerodrome control tower into VT3 with additional functions (restaurant, advertising, etc.) after the construction and commissioning of a new aerodrome control tower. A similar practice already exists at Stapleton International Airport, Stockholm Arlanda Airport [38–40].

Terminal D with the acceptance rate of 3,000 passengers/hour and the last stop of railway transport are chosen as main places of attraction that supply VT services to users (Fig. 5).

The main 9 criteria for selecting VT locations are:

- the possibility of influencing the workflow of the airport;
- no high-altitude obstacles;
- the possibility to organize a visual observation of 360° and its quality;
- the possibility to organize horizontal connections with the rooms of passenger terminals;
- walkability from the last stops of motor and railway transport;
- categories of events and places worth seeing;
- human load.

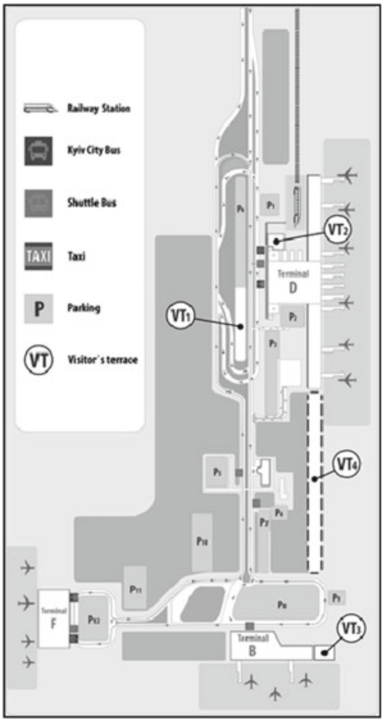

Fig. 5 Layout of permanent VT, design proposals

Each of these three options has its advantages and disadvantages (Table 2).

This indicates that the optimal decision can be taken during the reconstruction of the terminal city, i.e. when expanding Terminal D. The new part of the Terminal may include VT4 which will best meet the established evaluation criteria (Fig. 5).

9 Conclusions

1. In the conditions of sustainable development of society, urban development of areas close to airports has the relevant limitations associated with the details of airport workflow. Airports promote the practice of removing social barriers and providing public access to road infrastructure, recreation and local culture. For this purpose it is offered the VT arrangement in the system of spatial organization of terminal city for mass attendance.

2. Best practice of world experience of the VT arrangement in the airports made it possible:

– to identify categories (5) of events and places worth seeing;

Table 2 The results of evaluation of VT locations according to the selected criteria

Evaluation criteria	Option		
	VT1	VT2	VT3
Influence the workflow of the airport	Minimum	Minimum	Minimum
High-altitude obstacles	Yes (terminal D)	–	–
Organization:			
A visual observation of 360° and/or sufficient height	Yes / No	Yes[a] /Yes[a]	Yes/Yes
horizontal connections with the rooms of passenger terminals (covered)	Yes (terminal D); No (terminals A, B, C, F)	Yes (terminal D); No (terminals A, B, C, F)	Yes (terminals A, B, C); No (terminals D, F)
Walkability (up to 150 m) from the last stops of motor (MT) and railway transport (RT)	Yes / No	Yes / No	Yes / No
Categories of events and places worth seeing	1, 2, 3	1, 2, 3, 4, 5	1, 2, 3, 4, 5
Additional services	No	Yes	Yes
Human load	Need to be agreed with the management of parking	Design documentation need to be taken into account	Restricted by planning solution of the building of aerodrome control tower

[a]Taking into account the height of Terminal D

– to find places where potential consumers concentrate and define places which attract the most (3);
– to determine the VT main types, factors for evaluating the arrangement and siting within the system of spatial organization of terminal cities and airports.

3. For Boryspil International Airport, three options for VT of different types are proposed with each option taking into account details of the spatial organization of the existing terminal city. All options have their advantages and disadvantages. They may be taken into account when finalizing the strategy of economic development of the terminal city and promoting measures aimed at meeting the social demands of airport users.

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Innovations in Architectural Design Based on Integrated Urban Development and Participative Planning

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Abstract The text describes the innovative learning processes of students of NU "Poltava Polytechnic named after Yuri Kondratyuk" in the specialty 191 "Architecture and urban planning", specialization "Urban planning". The experience of international cooperation on integrated urban development and participatory planning is described.

Keywords Workshop · Educational process · Participatory planning · Integrated urban development

1 Introduction

In Ukraine, state policy in the field of urban planning is aimed at ensuring high living standards, creating effective financial, economic, technical, organizational and legal mechanisms to improve the socio-economic and spatial development of the state, regions and settlements.

These tasks are provided by legislative and regulatory acts, the main of which are the Law of Ukraine "On Regulation of Urban Development" and the Law of Ukraine "On Amendments to Certain Legislative Acts of Ukraine on Land Use Planning" [4–7], which were adopted with amendments in recent years in connection with the implementation of new approaches to management in the field of urban planning.

Decentralization reform, aimed at expanding the powers of local governments to manage territories is being implemented slowly and inadequately due to a lack of spatial planning documentation, lack of experience, shortage of qualified staff and difficult access to information.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_32

The level of informal influence of the public and business on decision-making on spatial planning should be taken into account both at the stage of decision-making by public authorities and officials, and at the stage of development of urban planning documentation.

Thus, the further development of architectural and urban planning professionalism in Ukraine needs to be improved taking into account the new socio-economic conditions, which involve various stakeholders. The deployment of a series of studies in the field of architecture and urban planning concerning the attitude to social changes seems to be long overdue; forms of own thinking and organization of activity, modernization of forms of education.

The growing number of urban initiatives reinforces the importance of informal planning. There is an urgent need to create a number of communication platforms for government, business, civil society and professionals to resolve and agree on decisions, actions with all stakeholders involved in urban development. As a result of decentralization, city budgets are gradually growing, the number of urban development initiative projects is being implemented, which are implemented at the expense of "participation budgets", crowdfunding, crowdsourcing or grants. In this way, a demand is formed for participatory planning, for specialists capable of providing it, and for relevant knowledge that accompanies these processes and promotes the integration of Ukrainian urbanism into the world space.

Currently, strategies in Ukraine are traditionally referred to as informal planning, especially in spatial development. In this area, the uncertainty of the relationship and interaction of master plans as documents of formal spatial planning and development strategies of settlements as documents of informal planning causes inconsistencies and conflicts.

Development of the Territorial Development Strategy—can be considered as the first step in the development of an informal document in the implementation of formalized documentation on spatial planning.

The concept of urban development [5]—a plan for the development of the territory, which determines the final functional purpose and the main parameters of development of the territory. It should include a comprehensive solution for architecture (may include sketches of buildings using three-dimensional visualization), infrastructure, transport and engineering networks, as well as justification of economic efficiency of financial investments and investment attractiveness of the territory, taking into account the possibilities of its development.

The example of Germany shows that the concept of urban development planning (informal, which is neither substantive nor substantive) cannot usually be separated from spatial planning, as the development of a city or part of a city is already a spatial one. solutions and vice versa, the land use plan (master plan) contains strategic elements of city development.

One of the main goals of training the future architect-urban planner is to form his creative worldview, to teach him the creative method, exploratory constructive thinking, thoughtful and sound decision-making, etc. But in times of changes in the paradigm of social thinking, the issue of educating professionals, especially in the field of urban planning, adapted to today's needs [2]. Design is filled with a fundamentally new content, based on which—man. The main purpose of architectural design is to create public spaces focused on the comprehensive satisfaction of the needs of each person or community living in a particular area. That is why the training process needs to be rethought.

Rethinking the learning process is a very difficult and painful issue for classical scientific schools and due to international cooperation this process is tolerant and gradual and most importantly at a high professional level [3].

Establishing and further developing relations with world schools is a necessary condition for building a modern system of multilevel vocational education in Ukraine and accreditation of domestic universities abroad. Educational programs of European and Ukrainian schools (double degree program, other programs) must also be created and agreed upon.

2 Main Part

It is for this purpose on June 30, 2017 Poltava National Technical University. Yuri Kondratyuk (now the National University "Poltava Polytechnic named after Yuri Kondratyuk") and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH sign a cooperation agreement. Its purpose is to develop and introduce at Poltava University a semester course of educational qualification level "Master" in specialty 191 "Architecture and City-Building", specialization "Urban Planning" with in-depth study of disciplines "Integrated Urban Development". This course is coordinated with the University of Applied Sciences in Lübeck (THL) https://www.th-luebeck.de/en/, consists of separate training modules and is implemented in accordance with the European Credit Transfer and Accumulation System and high EU educational standards (see Figs. 1 and 2) (Tables 1 and 2).

According to each module the thematic content of the course was developed:

As a result of students' study of theoretical modules, which were reflected in the development of practical tasks for urban reconstruction in the last module, conceptual projects for the reconstruction of a residential area in an urban environment were performed. They were presented by students at the final stage of studying the modules at the end of the semester (see Figs. 1, 2 and 3).

For the quality implementation of the above-mentioned educational process, an international exchange tool was used in the framework of the existing partnership with the University of Applied Sciences in Lübeck, with which joint research on energy efficiency of buildings is currently being carried out. Thus, in June 2019, a three-day workshop was held at the University of Lubeck on the topic of integrated design by 8 international teams of residential students per 5,000 inhabitants in Lubeck with the participation of 4 teachers and 6 5th year students of Poltava Polytechnic. And the practical results were consolidated by a professional excursion to Hamburg–HafenCity (see Figs. 4 and 5).

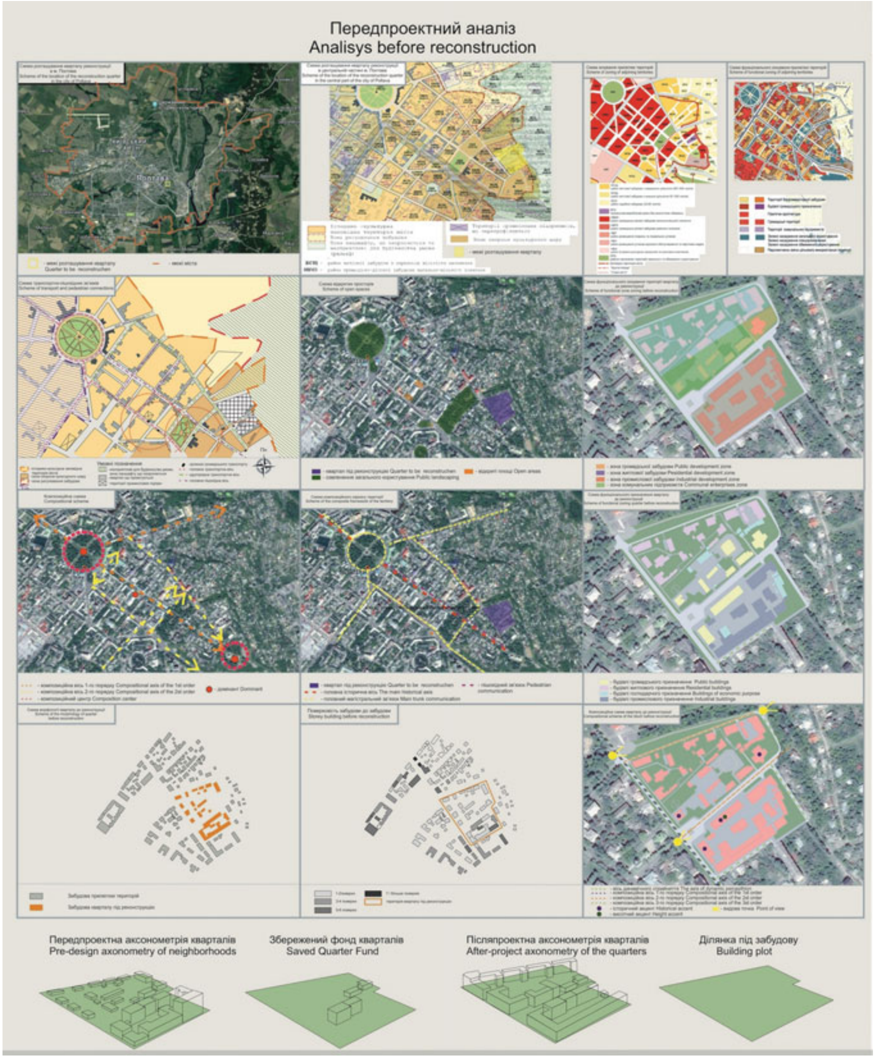

Fig. 1 Schemes of analysis before reconstruction

As a result of such international events, the possibility of cooperation with other foreign universities and international donor organizations (eg Brandenburg Technical.

University, Cottbus, German Academic Exchange Service (DAAD), Gdansk University of Technology, etc.) is not ruled out.

In parallel with the cooperation of the German Free Economic Zone of the Poltava Polytechnic named after Yuri Kondratyuk, the Inna Przestrzeń Foundation (Warsaw) has the support of the Polish non-governmental organization. So in the spring of

Fig. 2 Schemes of urban reconstruction

Table 1 Content of the training course of educational and qualification level “Master” in the specialty 191 “Architecture and Urban Planning”, specialization “Urban Planning” with in-depth study of disciplines “Integrated Urban Development”

№	Module name	Number of credits
Module 1	Urban development and urban planning	6
Module 1	Urban improvement. Typology of urban space	6
Module 3	Integrated urban planning. Sustainable urban planning, general planning and planning of transport networks	6
Module 4	Urban planning. Integrated Urban Planning and Development Project	9 + 3 = 12

Table 2 Short description of modules

Modul	Thematic content
Module 1 Urban development and urban planning	Features of urban development. Modeling and driving forces of urban development. Urban development in international comparison Features of urban planning. Types of planning. Strategic planning
Module 2 Urban improvement. Typology of urban space, buildings and structures	The concept of urban systems as objects of study of urban theory. The city as the main object of urban theory. Typological classifications of settlements, their main features and examples of cities. Planning classifications of cities. Functional classification of the city territory General provisions and classification of buildings and structures
Module 3 Integrated urban planning. Sustainable urban planning, general planning and planning of transport networks	Basic concepts of sustainable development. Principles of sustainable urban planning Foreign experience, history of formation, development, current state and current trends in sustainable urban planning
Module 4 Urban planning. Integrated Urban Planning and Development Project	Urban tours. Development of the architectural project "Concept of reconstruction of the territory of the quarter in the historical environment"

2019 on the basis of PoltNTU. Yu. Kondratyuk (now NU "Poltava Polytechnic") held two workshops, during which students-architects underwent a 6-day training on participatory planning of public spaces, conducted a training event on participatory planning of the courtyard of NU Poltava Polytechnic. The event was attended mostly by 3rd and 4th year students. The gained experience was qualitatively reflected in the further works of students and is a great basis for studying the integrated development of cities at the master's level.

In the field of architecture and urban planning, participatory measures in relation to public places and territories are gaining popularity, and in some countries are enshrined in law: Portugal, Greece, Poland, Georgia. And thanks to the development of the project "Integrated Development of Ukrainian Cities" patricative measures increase and increase their presence in Ukraine.

3 Conclusion

Thus, for effective planning of city development and creation of proper living conditions for its residents, a comprehensive, integrated approach to planning processes of both construction and social, economic development is needed. Therefore, there

Fig. 3 Three-dimensional images of urban reconstruction of the quarter

is a question of training specialists with relevant specialized education in the field of urban planning and interdisciplinary knowledge and professional experience. Yuri Kondratyuk Poltava Polytechnic National University has already taken the first steps to meet today's requirements. Given current trends in the development of informal design of settlements, residential areas, public facilities and participatory planning

Fig. 4 Workshop in Lubeck with Professors of University of Applied Sciences (THL)https://www.th-luebeck.de/ and Technical University Cottbus https://www.btu.de/

Fig. 5 Urban tour in Hamburg—HafenCity district with Professor of Brandenburg Technical University Cottbus https://www.b-tu.de/ Christoph Wesling

skills, together with the basics of integrated urban development are very important in preparing a future architect or urban planner who will work on modern integrated urban development, public spaces, as the result of the design should not satisfy the investor (municipal government), but the end consumer (resident, tourist, etc.).

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Implementation of Folk Housing Traditions in Modern Individual Housing Construction

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Abstract Talking about the traditional look of individual housing is now becoming increasingly difficult. More and more old houses are being rebuilt according to the modern system; less and less archaic houses are preserved. The ancient settlements abandoned by the inhabitants are being destroyed. Buildings are destroyed not only by weathering, but also by locals using preserved traditional buildings as ready-made building materials. That is why it is important to have time to record, survey and bring into the system all the most characteristic, original and artistically significant elements of traditional housing, created by folk architects. Approaches to the organization of individual housing are currently being standardized around the world. This is mainly due to the production of similar building, finishing and decorative materials on a large industrial scale. The same can be said about household items and furniture. In addition, the last century itself is characterized by increasing influence of industrialized countries on various aspects of life in all regions of the world. As a result, new solutions appear in the field of individual housing design. The article deals with the possibility of implementing the traditions of the subject-spatial environment of public housing in modern individual housing construction. The article will also be of interest to researchers in the fields of art history, construction, ethnology and design.

Keywords Subject-spatial environment · Traditional architecture · Folk housing · Individual construction · Eastern Ukraine

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© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_33

1 Introduction

Today we see the expansion of the areas of individual housing construction, which uses the heritage of traditional folk architecture. This historical heritage was formed long ago and was of different styles. The study of traditional housing is interconnected with other areas of research. It is important for the researchers to comprehend and evaluate the trends in the formation of traditional areas of housing for the development of local and global architecture. Ethnographic themes are one of the leading directions in the formation of the spatial image of modern residential architecture, in particular the interior. The popularity of this area can be explained by several factors. For a long time, people preferred to use modern materials in interior design, ignoring deep cultural traditions. Recently, we can see the desire of people to search for primary sources, the desire to return to those forms that are natural to humans.

The role of the ethnographic component in cultural and social processes is especially increasing, and interest in national identity is being revived. That is why there is a growing desire to bring new elements of life and principles of space organization into everyday life. Therefore, the style of furniture and three-dimensional compositions of interiors are the expressive visual means that designers use when they recreate the atmosphere of different ethnic cultures. Another important factor in the popularity of ethnic design is its environmental friendliness. Mostly natural materials are used to decorate ethnic interiors—wood, rattan, leather, stones, clay, metal, fabrics. Manufacturers try to emphasize the natural properties of these materials [1].

First, we consider the formative and decorative means expression of style ethnographic in modern construction. We want to pay attention to the use of constructive and decorative elements borrowed from the traditional art of a particular ethnographic region. These elements are formative and decorative means expression of ethnic style in modern construction. Most often, modern Ukrainian architects appeal to the colorful folk art of the regions of Hutsul, Boykiv region, Podillya, Dnieper.

The relevance of the research topic is supported by the principles of the world-famous "Athens Charter". This "Charter" says about the development of local architectural features. Moreover, folk traditions of construction are one of the main factors that can help develop local architectural features.

1.1 Analysis of Recent Research and Publications

Many scientific works of domestic and foreign researchers analyze the historical path of traditional architecture development in the context of the evolution of individual housing [2–8], of structural schemes of residential building as a whole [9]. Also of great interest for researchers from different countries are the traditional components of the subject content of home furnishings of different times—carpets and woven products, furniture, ceramics, etc. [10–12]. Previous authors' scientific papers were devoted to the folk housing traditions, too [13–16]. However, all these studies are quite specialized. At the same time, the general, historically formed principles of traditional housing formation have not been considered yet. Such principles, which provide for the organization of housing, were not fully considered. The principles that take into account modern architectural and construction approaches, the properties of the main components of the subject space were not fully analyzed. Little has been done on the formation of a general image of folk housing, which reflects the influence of folk traditions and local customs.

1.2 Materials and Methods

The methods of compilation, environmental approach, methods of comparative analysis, retrospective methods and methods of empirical modeling were used as research methods.

1.3 The Purpose of the Study

The purpose of the study in the article is the analysis of the probability of applying the traditions of the subject-spatial environment of public housing in modern individual housing construction.

2 Research Results

Traditional construction technologies and the subject-spatial environment of traditional housing in Eastern Ukraine have been developing for a long time. They acquired a familiar appearance around the nineteenth century. However, its beginnings are lost in the depths of millennia [18]. The factors that influenced the formation of the traditional environment were very diverse. It is not always possible to completely single out any one factor.

The word "implementation" comes from the Latin word *implere*, which means, "to fill, achieve, perform, and carry out". This word is mostly used in jurisprudence and programming. In architectural activities, this term is rarely used. However, in this case we can safely use such terminology. After all, we need to describe the phenomena of traditional features realization of public housing in modern individual housing construction. The building materials for traditional individual housing were most often wood and clay, less often stone. Traditional folk housing has absorbed all the well-known design solutions—from a pure massive log house to a frame-clay wall. Monolithic clay walls were widely used in the folk construction of Ukraine. Wall designs are quite diverse. Depending on the building traditions of a particular region, folk dwellings used clay walls, cast clay walls, clay roller walls and adobe wall constructions.

Clay walls were built mainly in Central Ukraine, *cast clay walls* were built in the eastern regions of Ukraine, and *clay roller walls* were built in the western regions of southern Ukraine, as well as in a large part of the forest-steppe zone.

Clay walls are made of a mixture of clay (this clay has natural moisture) and straw chips. Builders stack this mix in a timbering in layers and carefully ram. The first layer was stuffed to a height of one meter. After drying of this layer, boards of a timbering raised to height of the first layer and covered the following layer. Each subsequent layer of walls was built up after drying of the previous layer—and so finished a wall to the necessary height. The wooden frame inside the clay mold strengthened the clay mass of the walls, forming a solid structure of the building.

To build *cast clay walls*, builders laid a layer of crushed straw in the formwork and filled the formwork with a liquid clay solution. The further process repeats technological methods of erection of adobe walls (ramming, layering, drying).

The *walls of clay rollers* have two design options—ordinary clay rollers and clay rollers "in the shape of a Christmas tree". In the first case, the builders use large rollers of clay-straw mass, which are stacked across the walls in rows, close to each other.

To build walls of clay rollers "in the shape of a Christmas tree", builders use smaller rollers. Each layer of rollers masters stack on the wall not horizontally, but at an angle of 45°.

Adobe is a small block (brick) of clay-straw mass. As a building material, adobe is widely used in the folk construction of southern Ukraine, as well as in the western part of the forest-steppe zone. The main advantage of adobe walls over other clay structures—the walls dry quickly and do not sag too much.

Thus, the use of clay in construction is one of the most characteristic features of traditional housing of Ukrainians. Clay is usually combined with a wooden frame. The traditional decoration of the house and the architecture of the building are due to the presence of clay (as a building material).

Today, the construction technologies of traditional Ukrainian folk housing are largely forgotten. Such technologies are used sporadically, in modified versions or in museum construction. An urgent phenomenon that has a high demand is the construction of individual housing with elements of the traditional environment, traditional technologies or materials.

The main directions of implementation of the traditions of folk housing in modern individual housing construction are as follows: (1) reed roof (sometimes it is shingled roof, wooden roof); (2) whitewashed walls (walls are whitewashed with chalk, lime, and now more often with various facade and interior finishing paints); (3) wooden furniture; (4) elements of the interior (textiles of traditional style, utensils, paintings, decorative and applied arts, etc.; (5) wall paintings (walls are not always painted); (6) traditional anthropocentric proportions; (7) environmental friendliness of housing; (8) frequent use of energy efficient housing technologies.

Having analyzed these areas in detail, we can note that only the application of all these points forms the image of traditional Ukrainian housing, the image of the "Ukrainian house". The names of these images often exist in society, such as "grandmother's house", "Taras house", "Shevchenko house", "Cossack house" and so on.

However, today in modern individual housing construction we observe the use of only certain areas or elements of the application of traditions. For example, the use of only a thatched roof in construction (without using traditional planning and proportions)—gives the effect of "decorative" or "fairy tale" housing. In particular, the so-called "Dutch" method of covering roofs with reeds has recently become widespread (see Fig. 1). There are no leaves in the Dutch reed roof, and the whole technology is quite different from the traditional Ukrainian technology (see Fig. 2). There are also English, Danish, Polish and other roofing technologies.

Unfortunately, the "Ukrainian" way of covering the roof is not almost now used. This method also has several types of laying reeds on the roof. This technology is used sporadically and mostly in temporary structures. This method of roofing is not

Fig. 1 "Dutch" method of covering roofs with reeds. *Source* [17]

Fig. 2 Traditional Ukrainian technology of covering roofs with reeds. *Source* Scheme—by authors, photo—[18]

officially developed as a construction technology. This method is mostly used only in museums of folk architecture. We mentioned this problem in previous works [10]. It should be noted that the technology of roofing has a significant impact on the formation and the final architectural image of the building. Therefore, the development of methods of application of "Ukrainian" technology (reeds with leaves, without metal) will open new perspectives for the application of this type of roof in the work of architects and builders.

Speaking of whitewashed walls, it should be noted that builders sometimes ignore this method of decorating buildings. Because such builders are not familiar with true traditional architecture. After all, whitewashed walls are a distinctive feature of traditional Eastern Ukrainian housing. The use of whitewashed walls among individual construction (new or during renovation) is rapidly disappearing. Taras Shevchenko's expression: "houses are like children in white shirts"—has unfortunately become history. However, in the new individual housing construction, while searching for the "ethnic image", we again see an attempt to apply Western European architectural features, and not to take into account local (native) Ukrainian features. This is, in particular, a widespread imitation of half-timbered German wall structures. Half-timbered beams are sometimes simply painted on a white wall.

The use of deliberately curved and untreated boards in the design of «ethnographic» interiors further creates the impression of artificiality and "theatricality". This approach does not encourage residents to perceive space naturally. Exaggerated curved shapes keep residents' attention in suspense. This is a negative phenomenon in the reproduction of Ukrainian "ethnographic housing". A positive trend is the reproduction of copies of traditional furniture, and the use of furniture in the interior and exterior of individual housing. Unfortunately, such cases are not common.

It is also a common trend to use traditional style textiles, utensils, paintings, arts and crafts, etc. in interiors. This is a positive point, especially if it is a reproduction of traditional style samples. Sometimes homeowners overdo it by using antiques in the interior. These residents fill the house with any samples of antiques, regardless of the function of the object. In such cases, the architectural image of the home disappears, and instead there is the impression of a museum, a shop of old things, or just a pantry where antiques are stored (wheels, fragments of wooden machines, etc.). Only the balance between the functionally related interior objects will create the image of "traditional ethnographic housing".

Regarding wall paintings, we should note that this painting is often made completely unconventional. There is a transition from the style of decorative painting to an almost "photographic" image of people and objects. Due to the popularization of the specific "Petrykivka painting", its reworked versions began to be widely used in all areas of application of the "ethnographic style". However, recently this "Petrykivka" tendency has significantly decreased. Traditional murals, if properly reproduced, can be an important element in creating an "ethnographic environment".

The most complex building traditions, which are almost never used today, are the traditions of applying human proportions in the structures and components of the living environment. Individual production of building structures with a non-metric system of dimensions is an extremely expensive technology. This technology is not available to a wide range of people. However, you can use human proportions in the formation of floor plans. In addition, the system of human proportions can determine the height and size of walls, windows, doors. However, even these features of the proportional system are not actually used today. Only sporadically (when creating an exact copy of traditional housing) can we see individual housing of the correct, traditional proportions. The authors of this article once proposed one of the options for the proportional scheme of individual traditional housing [12]. It is possible that in the future, this situation will be gradually changed, and we will see professionally designed proportional samples of individual housing.

Environmental friendliness of traditional housing is an important indicator. But this figure is not always achievable for builders who are trying to make a traditional, "ethnographic" house.

About thirty percent of the world's individual housing is not environmentally friendly. The atmosphere inside such buildings is harmful to health. This is due to the use of plastic, polymers and toxic substances in home decoration. Therefore, the ecological direction in the field of individual housing construction appeared very timely. Ecological construction is becoming more and more popular.

There are several options for ecological housing. It is worth listing these options. The first option: an adobe house. Such buildings are built in two ways: either the builders first make adobe bricks, or put formwork and tamped adobe there. The second option: the hut is the most typical housing for the inhabitants of Central and Eastern Ukraine of the past centuries. In these areas, many building materials are used for such structures. To make huts, you need clay, wood of different quality and fillers: reeds and straw. The house is strong, very warm and quite durable, if properly cared for. There are several types of huts, depending on the material used by the builders. One common design technique common to all types of huts is a wooden frame.

The third option: a house made of straw. This is a new invention of builders. Such a house is not a traditional home. A straw house requires baling machines that press the straw into very dense blocks. These blocks are stacked on top of each other like bricks and coated with clay. Clay protects straw from rot, burning and serves as an antiseptic. However, the walls should be protected from precipitation. After all, clay absorbs moisture and passes it to the straw. Therefore, a number of features of straw construction must be carefully studied to avoid mistakes.

The fourth option: an adobe house or a farm house—a very old method of construction, which was used in many countries. Clay casting is a technology that is typical of areas with poor vegetation but rich in clay. These are mainly East Asian countries. Such buildings are very durable, but Asian countries are poor in the rain, and this can be a problem in Ukraine. To prevent the clay from rotting, the exterior walls should be plastered or lined with wood or other materials. In ancient times, such houses were burned from the inside—a fire was lit inside the house and the walls became as strong as bricks. Such walls did not emit dust into the air; they were not "smeared". An adobe burnt in the middle is as a ceramic bowl burnt in a furnace. Fifth option: a sack house. This is a non-traditional type of building. This is a somewhat modernized type of adobe construction. Instead of formwork, builders use polypropylene «sleeve» (sometimes it's just construction bags). Builders fill this "sleeve" with any available soil and lay it out in the required shape (mostly round buildings), before compacting this "sleeve" tightly.

The sixth option: a house made of fuel wood is an unconventional, newest type of house made of natural materials. Seventh option: a wooden house. In areas where there is a lot of timber, wooden houses have long been built. This is a long-known technology that requires carpentry skills in builders. The eighth option: a house made of stone—it is advisable to build where there are many stones. For example, in the south of Ukraine (in particular, in the Crimea) it is often built of shell rock. A natural material retains heat well and is easy to handle. Granite stones are mainly used only for the manufacture of foundations or strong fences, garages or outbuildings [18–20].

The technology of construction of ecological housing, which is developing today in Europe, requires very high material costs. In Ukraine, such technology will probably not be introduced soon. An example of a newly created house according to folk building traditions is the house of Andriy Bobrovytsky. The building is made of homemade adobe, with a thatched roof (see Fig. 3). The biggest disadvantage of adobe construction, according to Bobrovytsky, is great physical effort. In ancient times, people kneaded clay with their feet, then tried to do it with the help of horses. To make adobe, Bobrovytsky poured two bodies of clay on the ground, a layer of 40–50 cm. Then he filled the clay with water, and began to lead the horse in a circle, giving the horse a rest. From the third event, the horse was already trying to follow in the footsteps. So kneading clay for traditional adobe is difficult if you do not do it with your feet. If you use, for example, a mortar mixer—then you need to grind straw. We must not forget about the protection of houses made of adobe from moisture, which can destroy the walls, and from rodent pests (mice). In particular, in folk architecture there is an interesting way to control rodents: if you put a layer of buckwheat husk on the top floor, the mice do not appear [16].

Fig. 3 Bobrovytsky's house in Poltava region. *Source* [11]

Fig. 4 House-mazanka in the village of Kotseba (Eastern Podillya, Ukraine). *Source* [11]

A similar example of the implementation of certain folk technologies is the house of Dmytro Lvov in the village of Kotseba (see Fig. 4). Dmytro Lvov decided to make a hut, knowing about the current popularity of ecological settlements. These are, for example, ecological hostels, where people can come and enjoy life in the village. Preparations for the repair lasted a month; another two months were spent on major repairs. It also took a long time to work inside the house. Everything was done without additional reinforcement of structures and foundations.

For almost four months, Dmytro came to the village to sculpt the house from the inside. The budget for the creation of this "mazanka" house is about two hundred dollars. This is the cost of wood, paint, final spackling. The technological process of creating such a structure has partly traditional processes. First, the masters drive wooden sticks into the wall and weave the frame. Then the builders knead adobe (a mixture of clay and straw). With this adobe, people fill the formed framework of the house, giving it the necessary form. The structure is reinforced with wooden sticks [17].

3 Conclusions

Public housing is one of the most important and brightest indicators of ethnic culture. However, no area of national culture has been studied as little as folk architecture. First, the architecture of individual housing is unexplored. The diversity of types of public housing is inextricably linked with the diversity of climatic, social, economic, religious and other factors. These factors determine the formation of a culture, as well as these factors shape the type of public housing. It should be noted that the most important are not only the mechanisms of economic development of the population, but also the local characteristics of its territory. This determines the possibility of interregional contacts, and cultural exchange. Moreover, the degree of their development (as historical facts show) can stimulate the development of life and culture of public housing.

According to the results of the study, exceptional diversity and richness of both architectural and artistic forms and technological methods of construction characterize the folk architecture of housing. That is why the study of the development of traditional housing is of great importance for the formation of the future appearance of the settlements of a particular region. Centuries of experience of the ethnos are concentrated in housing. Housing was a creative laboratory of architects and met the basic needs of protection from climatic influences. Traditional housing reflected the psychology of society, the tastes of the inhabitants of an individual house and the level of skill of the builders.

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Settlements Preparation to Future Transport Progress

Tetyana Lytvynenko, Lina Hasenko, Mohamed Elgandour, and Iryna Tkachenko

Abstract The creation of bicycle infrastructure is the settlements preparation to future progress in the field of vehicles. The investigation is devoted to individual environment-friendly means of transportation, which can be used in a street-road network of settlements. The history of settlements planning in the context of street and road infrastructure development is studied. The priorities changing in transport network planning are researched. The benefits that accrue from the use of individual environment-friendly vehicles in the areas of medicine, environment, economy and the social sphere are analyzed. The examples of individual environment friendly means of transportation, the most common of which for now is a bicycle, are presented. The examples of cities that have already implemented priorities changing in transport network planning are given. The particularities of individual environment-friendly vehicles and requirements that must be applied to the infrastructure for their comfortable and safe movement are formulated.

Keywords Individual environment-friendly vehicles · Street and road network · Urban planning principles

1 History of Settlements Planning in the Context of Street and Road Infrastructure Development

Transport systems are very diverse across cities and facilitate very wide-ranging experiences of life. Walking was a dominant means of travel in most cities before 1900, alongside some limited use of public transport. Cycling, too, was popular in many contexts, reaching 60% of trips in some cities in the 1940s [1].

From the 1950s onwards in the United States, and later as it spread to wider contexts, the private car became the aspired mode of travel for many—and the modernist dream of dispersed urban development and motorization was sold and

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_34

implemented in many countries. Street spaces has been given to one dominant mode: the private car. It was done by a complex set of processes, institutions and leaders. The engineering discipline, for example, has helped to shape our streets and cities for the dominant use of the car, through street widening, street space allocation, spatial segregation and suburbanization, etc., and this has adversely affected our cities and urban areas. This has been justified in terms of supporting individualized travel, but ignored the very significant adverse impacts on society [2]. The settlements infrastructure expansion, aimed at satisfying, in the first place, the needs of car drivers, is accompanied by great negative changes in the conditions of inhabitants' life [3]. In recent times more and more urban planners use the term «Automobile Dependency» [4].

The counter movement towards sustainable urban mobility, where public transport, walking, the public realm and cycling are given much greater priority, has only just begun (see Fig. 1).

The Coronavirus crisis in 2020 gave us a glimpse of what life could be like in cities and on our streets without high levels of traffic, and particularly high levels of car usage. Traffic levels fell and it became much easier for walking and cycling. Air pollution reduced and we could even see the blue skies again. It is imperative that we capture the benefits of more active travel as mobility levels return—and the majority of travel in many contexts can be by public transport, walking and moving by individual environment-friendly vehicles (IEFV) the most common of which today is the bicycle.

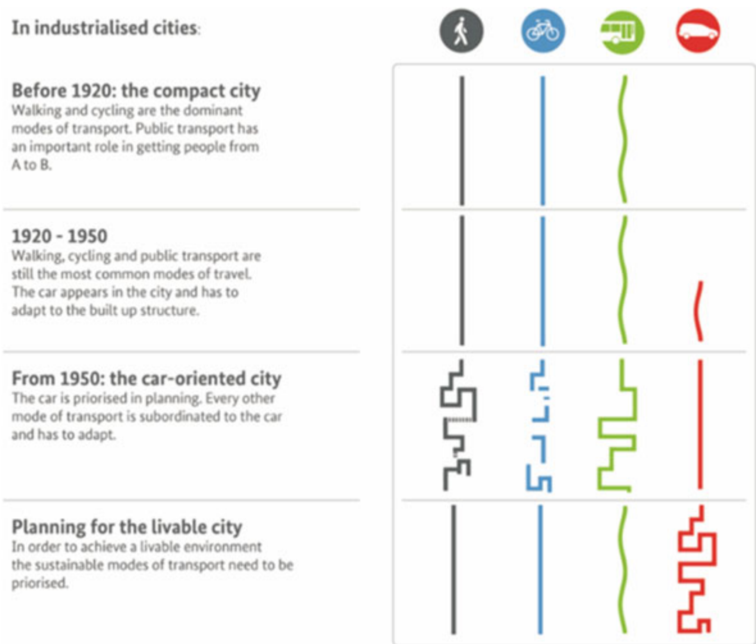

Fig. 1 A short history of traffic engineering [5]

2 Priorities Changing in Transport Network Planning

Although the use of the private car is often associated with positive terms—such as convenience, comfort and even freedom—we can see that this is simply the imagery sold through advertising, funded by the motor manufacturers. The reality is often very different when many people choose to drive.

Traffic congestion follows from too many vehicles on the streets—and it means that even the journey experience in the car is unpleasant, in addition to the negative impacts on pedestrians and other street users. Hence there are very significant adverse impacts associated with motorization: energy depletion; carbon dioxide (CO_2) emissions; traffic casualties; local air quality; obesity and wider health impacts of inactivity; loss of street space to the car [6].

The scale and importance of these differ by context, but they are all likely to increase as car-based mobility increases. Experience of many countries shows that even investing a lot of money in the street and road network (SRN) development, the solution of road transport services composite problems, it is impossible to solve the problem of transportation in large cities by creating comfortable movement of cars. A big problem is also the high speed of cars, which significantly increases the risk of death in a collision (see Fig. 2) [7, 8].

The best in terms of transport cities in the world (such as Berlin, Copenhagen and others) guided by «pyramid of priority» and apply it making decisions in urban planning.

Taking into account the pedestrian movement mass (almost every inhabitant with one or another frequency use the walking to move) and its safety for the environment, pedestrians are on the highest step of this pyramid. The cycling transport is on the second step, because it has the same advantages and problems as pedestrian movement, but occupies a separate place in the pyramid because it lets to overcome much larger distances (as usually distance that is easily overcome by cyclists of different physical abilities is 5–7 km), needs parking spaces and, on separate streets, cycling infrastructure.

Both the sustainable transport hierarchy and the separate sustainable investment hierarchy (see Fig. 3) are inverted pyramids. It emphasizes that previous approaches have been turned upside down.

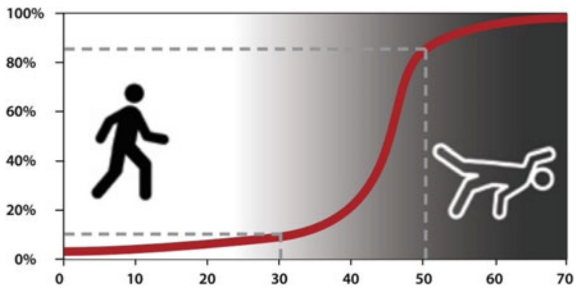

Fig. 2 Probability of fatalities for pedestrians depending on the speed (km/h) of car collision

Fig. 3 The sustainable transport hierarchy (left) and the separate sustainable investment hierarchy (right)

The «sustainable investment hierarchy» places «reducing the need to travel unsustainably» at the top of its inverted pyramid, with «maintaining and safely operating existing assets» the second.

The third is «making better use of existing capacity», with «targeted infrastructure improvements'» in fourth and last place and very clearly feeling the squeeze [9].

3 The Features of Individual Environment-Friendly Vehicles (IEFV)

The creation of infrastructure for bicycle traffic, in our opinion, is the settlements preparation to future progress in the field of vehicles. Meanwhile scientists of the world are now working actively on the creation of individual environment-friendly vehicles (IEFV). Various types of such means of transport designed to replace or minimize the use of individual cars in settlements.

For example, the individual vehicle Segway is already actively used. It is a small platform on two wheels with an electric motor (Fig. 4a). It is controlled by moving the center of weight [10].

The Segway-Ninebot press service published the announcement of a new vehicle called S-Pod. It is an unusual model of a hovercraft: comfortable egg-shaped chair (Fig. 4b). It has the same gyroscopic self-balancing system as previous products of the company's. Distinct all other models, this vehicle is driven using a physical joystick on the armrest.

YikeBike—the little electric bike (Fig. 4c) that has 450-W motor and can develop speed of 14 miles/hour. It is anti-skid regenerative brakes and built-in LED lights.

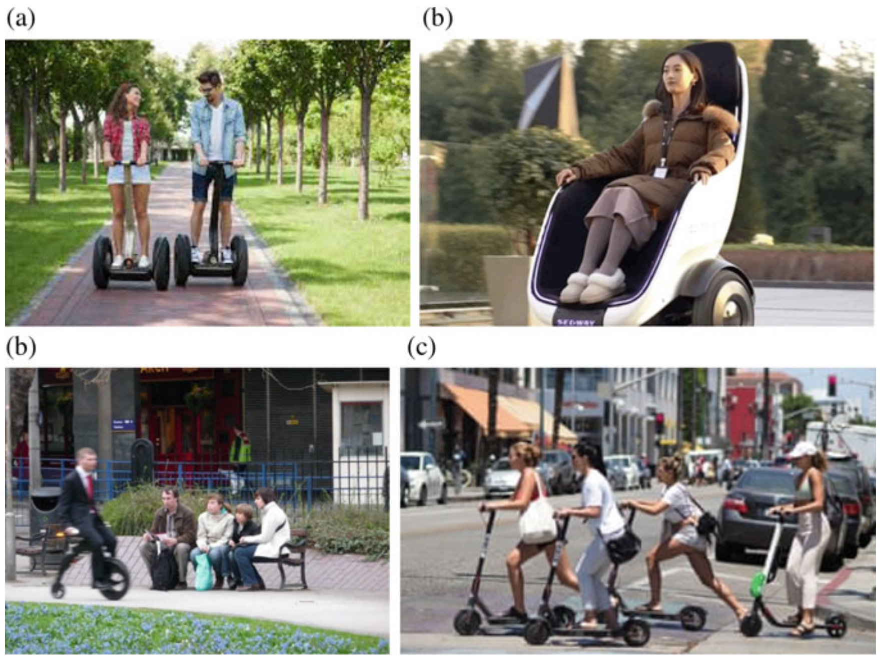

Fig. 4 Individual vehicles: **a** Segway; **b** S-Pod; **c** YikeBike; **d** e-scooters

Also e-scooters (Fig. 4d) recently have become a common sight in many cities of the world [11–13]. Their popularity has grown and scooter-sharing schemes now operate in more than 100 cities including San Francisco, Paris and Copenhagen.

Among the features that combine the above IEFV and other similar modes of transport, the following peculiarities can be distinguished.

Advantages

- environmental friendliness: the use of such transport modes does not harm the environment and does not create noise;
- mobility: in places where a car according cannot pass, the IEFV can drive without troublesomeness;
- compactness: such transport modes occupy much less than cars space on roads and parking lots.

Disadvantages

- low speed in comparison with the car;
- shakiness: the area of the IEFV contact with a road surface is smaller than that of the car, what leads to less IEFV stability;
- protection of a driver from rain and snow.

4 The Features of Infrastructure Design for the IEFV Movement

Let's consider the experience of cities that have already implemented this priorities changing in transport network planning. The photos below were taken while watching training videos as part of an online course Transforming Urban Mobility: Introduction to Transport Planning for Sustainable Cities from University College London.

One of examples is San Paulo, a huge city and wider metropolitan urban area in Brazil, with recent urban growth sprawling over a large area and giving rise to inequitable living conditions. The city gives priority to bicycle and pedestrian traffic (Fig. 5), as well as public transport.

In the Netherlands the VINEX strategy (supplement to the Fourth National Policy Document on Spatial Planning), was published in 1993, where housing development was planned in a 10-year program across multiple cities in a polycentric and compact form.

One of such cities is Houten (Fig. 6). It is perfectly adapted to the high number of cyclists. Houten is built around a system of car free public space combined with the infrastructure for slow traffic. A large network of bike paths makes it convenient to cycle to various destinations and within the town the bike is the most popular means of transport.

Spoorzone Delft (also called Railway Zone Delft) is a big redevelopment project, covering 40 hectares. It has been implemented around the central railway station in Delft (Fig. 7). The impetus for the project was the removal of the old railway viaduct, putting the railway into a tunnel, and then using the new space to build a new railway station and municipal office, around 1200 dwellings, offices, a city park, water features and landscaping, bicycle parking and new road access.

Based on the above properties of IEFV, as well as on world experience, we can formulate the features of designing infrastructure for the movement of such vehicles:

1. While designing such infrastructure attention should be paid to protection the driver from harmful exhaust gases of cars and the noise they generate.

Fig. 5 Priority to bicycle and pedestrian traffic on San Paulo streets in Brazil

Fig. 6 Houten city in the Netherlands built around a system of car free public space combined with the infrastructure for slow traffic

Fig. 7 Reconstructed railway zone in Delft, the Netherlands

2. The comparatively low speed of requires the shortest ways of communication, which will allow reaching the final points within the time limit not exceeding automobile, as well as routes completeness and consistency.
3. The area of IEFV and road surface contact is small. That is why special attention should be paid to the roughness, evenness and adhesion of these surface.
4. Most IEFV do not provide protection of driver from precipitation, it must be taken into account when designing the infrastructure. For example, it can be installed special coverings in front of traffic lights, in bike rental locations and in bicycle parking lots.

5 Conclusion

So, to ensure the comfortable IEVF movement, in addition to laying special routes (complex, with convenient exits, road connections and comfortable surface), a number of issues still needs to be resolved:

– to create special infrastructure for IEFV (to develop a rental system for such vehicles, to arrange convenient parking lots, to build service stations);
– to organize traffic flow (to set up traffic signs and lights, to build special overpasses, junctions, tunnels etc., to coordinate the intersection of paths for IEFV movement with passenger boarding and landing points for public transport, to provide "green waves");
– to coordinate the work of services system (to organize the work of snow machines and constant control by the serviceability and cleanliness of such paths);
– to provide social protection for drivers of IEFV (to regulate their rights as full-fledged participants of road traffic, to guarantee the possibility of IEFV transporting in public transport).

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Automation of the Selection Committee for the Specialty «Construction and Civil Engineering»

Tetiana Dmytrenko, Andrii Dmytrenko, Tetiana Derkach, Lina Klochko, and Emil Mammadov

Abstract The work of the selection committee is the enormous amount analysis of statistical information. In the case of manual processing, errors cannot be avoided, which ultimately distort the real picture of the opening company results. The problems of informatization of the selection committee work, requires the modern information systems construction for electronic document management, are considered. The theoretical and methodological aspects of improving document management in higher education institutions are analyzed. Particular attention is paid to a detailed description and analysis of existing information systems used in the selection committee work for recruitment for engineering specialties. The creating necessity an information system that will allow the analysis of statistical information has been identified and justified. The main directions of the information system analysis are given. The selection committee activities analysis of a higher educational institution is given. The robots' functions from the documentation implemented in the information system are presented. The requirements for the implementation of the information system in the Web application form are envisaged. The diagrams Use Case Diagram and Activity Diagram are presented on the decomposition of some activity into its component parts. The relational database scheme is given. The system provides processing applications for admission by the selection committee of a higher educational institution. The developed information system enables to generate documentation for admission on the basis of complete secondary education and on the

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_35

basis of the bachelor's level. The system provides the ability to view general statistics, such as the number of applications, the average score, data on exam results, etc.

Keywords Intellectual system · Semantic analysis of the text · Scientific activity of the department

1 Introduction

The applicants selection for higher education is a complex task that does not always give the expected results. Entrants have difficulties with choosing a specialty. Great responsibility for the provision of information lies with the higher education institution management. The number of students applying for admission is increasing in the institution of higher education where prior education and experience issues are considered [1, 2].

The entry process, as a rule, is based only on the institution requirements, that are expected from applicants to meet the conditions of admission. However, the reception processes are mutual in nature. Often, the applicant's point of view regarding the requirements that universities apply when attracting potential students is often not noticed.

Currently, the applicant has the right to apply for entry into several higher educational institutions and several specialties, but ultimately only one that meets their personal and academic needs.

Various factors can influence the decision-making process (see Fig. 1), selection criteria, and a selection method are also implemented.

One of the important factors in encouraging a future student is the qualified and competent selection committee work. Currently, applicants are applying for entry online. It enables to reduce the burden on the selection committee, as well as to make the process of processing applications faster and more accessible for applicants [3].

For more effective selection committee work, it becomes relevant to develop an information system that could meet the requirements of a higher educational institution. First of all, the developed information system tasks should reflect the main tasks of the selection committee (see Fig. 2).

In accordance with the tasks of the selection committee, the general directions for the information system development "Selection Board" are defined [4, 5].

- Providing information on the list of specialties for which the institution announces the documents acceptance;
- Publication of a external independent evaluation and entrance examinations certificates list for each specialty;
- Formation of a submitted applications list (data import from the "Vstup-info" information system);
- Formation of a list of ratings by specialty (each applicant should see a rating by specialty for which he has applied);

Fig. 1 Factors affecting the decision of the future student

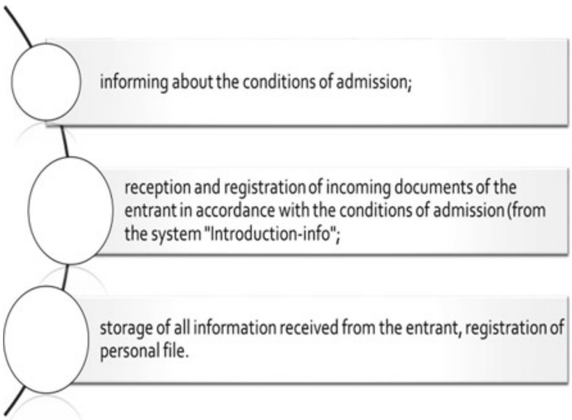

Fig. 2 The main tasks of the selection committee

– Reporting on the progress of filing applications and analyze the opening company progress;
– Examination sheets formation;
– Students' personal files preparation.

2 Main Body

2.1 The Analysis of Recent Research Sources and Publications

One example of the selection committee automation is an automated complex developed by the software development center “Softreactor” [6].

The introduction of an automated complex from Softreactor minimizes possible errors, reduces the time it takes to work with an applicant, generates various reports, however, at the same time it reduces the number of employees involved in the selection committee, thereby creating savings in the payroll fund.

The proposed software supports all popular operating systems and therefore is easily integrated into the existing local network above educational institutions.

The program is implemented in a client–server architecture, it also enables to increase the reliability of information storage and speed up its processing when several commission members work simultaneously.

The analysis is carried out in different directions (see Fig. 3).

The final composition and functions of a program product are being finalized to the particular educational institution requirements. The system is easily scalable and can be used both in a regular technical school and in a large university.

Entrant Admissions Automation Program, developed by Landgraph [7].

With the program help, a database of applicants is managed, the entrance tests results are entered. The program accompanies the applicant from the moment of documents submission until the enrollment moment in universities. The program enables

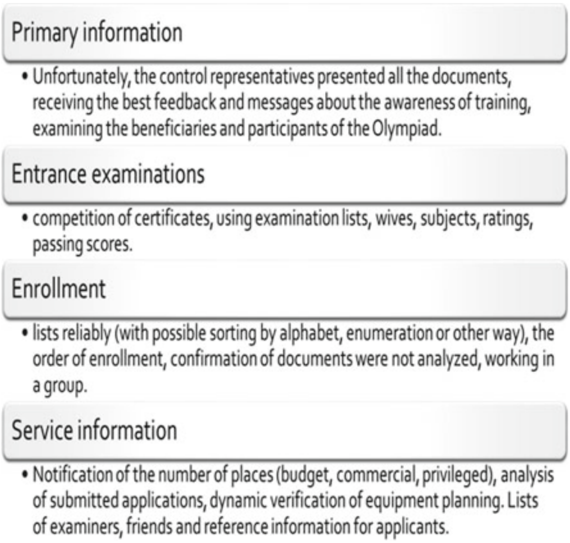

Fig. 3 Directions for analysis of the automated complex developed by the software development center “Softreactor”

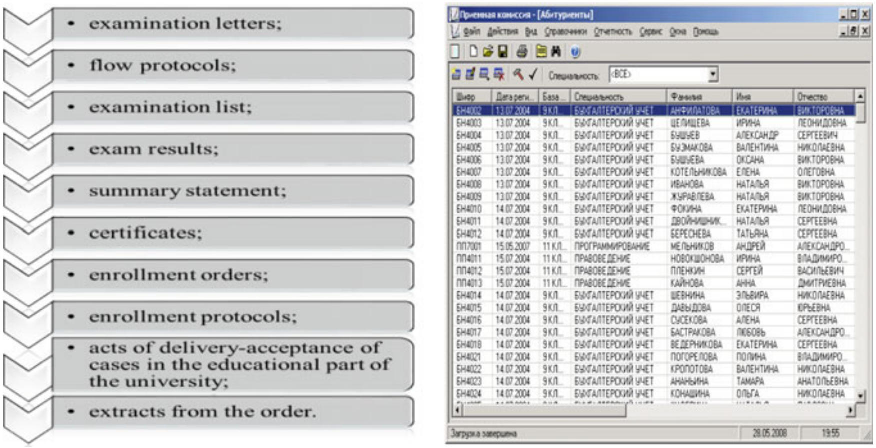

Fig. 4 The list of documentation in the Entrant selection committee automation program and the unit for working with the applicant

to generate many documents that accompany the admission universities campaign: from public statistics and ending with protocols for admission of applicants.

As a work result, the program enables the necessary documents formation of the selection committee (see Fig. 4).

The program itself is a modular engine, on its basis including university information system, modules are executed in the form of dynamic libraries, can be integrated both in the program menu, and contain their own printed forms, windows, etc.

VM Glushkov Institute of Cybernetics of NAS of Ukraine has developed an automated system “Admissions Committee”, which enables to automate the admissions committee work and ensure the applicants personal files formation [8].

The program has the ability to access a educational documents database, enables to verify most of the applicant information and automate most of the selection committee members functions:

- Maintenance of electronic cards of entrants (considering privileges and special categories of entrants);
- Processing of information on the current status of documents admission from applicants (considering the submission of applications for various specialties and faculties);
- Accounting for the results of entrance tests (including the results of external testing) and export of data to the IS “Competition”;
- Formation of competitive lists of entrants according to the scored points;
- Providing recommendations for enrollment not only individually but also in groups with the name of study groups and numbers of enrollment orders;
- Creation of standard, analytical and statistical reports in the form of lists, tables and charts.

– Interaction with the Unified State Electronic Database on Education in accordance with the conditions of admission to higher educational institutions of Ukraine in 2012, approved by the Order of the Ministry of Education and Science, Youth and Sports of Ukraine for №1179 from 12.10.2011.

The system is easy to operate, maintenance does not require special training and complex software and hardware; due to an intuitive interface, user training is carried out in a short time.

2.2 The Selection of Previously Unsolved Parts of the General Problem

Necessity to automate the selection committee work of a higher educational institution arises to optimize the reporting process, reduce organizational costs, reduce the selection committee workload.

2.3 Problem Definition

The main objective of this study was to analyze the selection committee activities of a higher educational institution, to develop documents models included in the personal file and reporting and automate the reporting process.

2.4 The Main Material and Results

In the working process on the study, entities were identified that must be stored in the database (see Fig. 5) [9]:

After defining the entities, ER Diagram was built. A face-to-face relationship diagram, also known as an ERD, ER Diagram, or ER model, is a type of structural diagram for use in database design. ERD contains various symbols and connectors that visualize two important information:

– Basic entities within the system;
– The relationship among these entities.

As a result, it's got an ER diagram of the following form (see Fig. 6).

As a analysis result, it's got a UML following form diagram (see Fig. 7).

The model consists of two actors:

– Administrator;
– Selection committee.

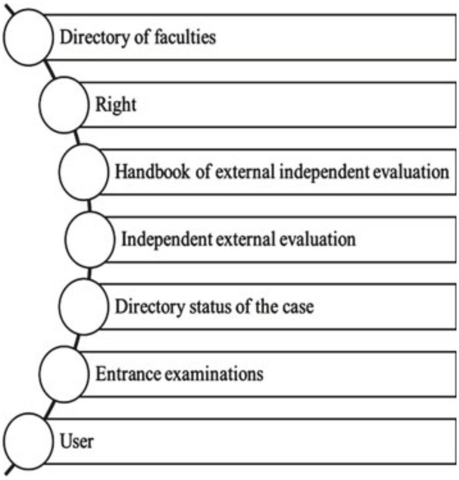

Fig. 5 Entities that must be stored in the database

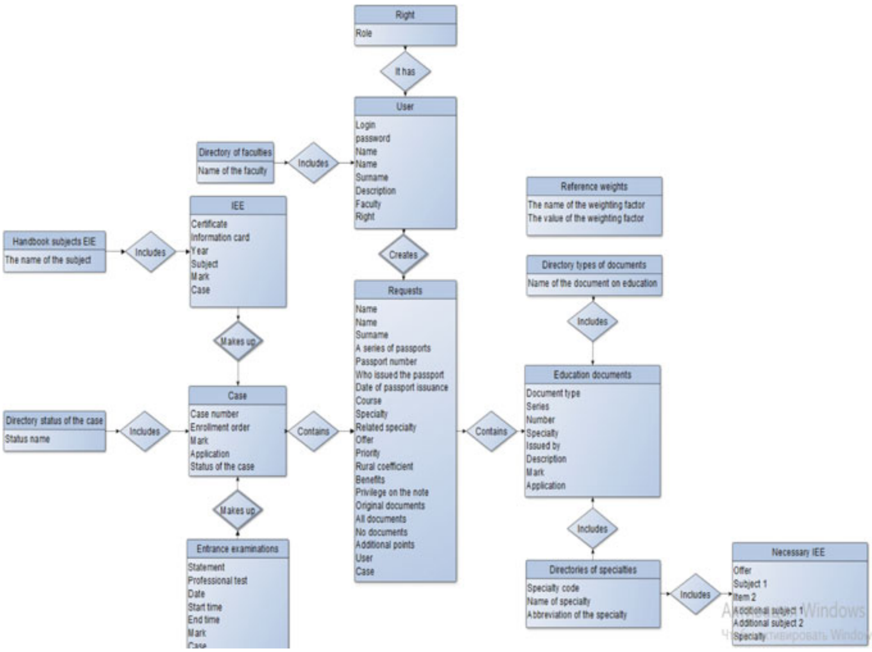

Fig. 6 ER- subject area diagram

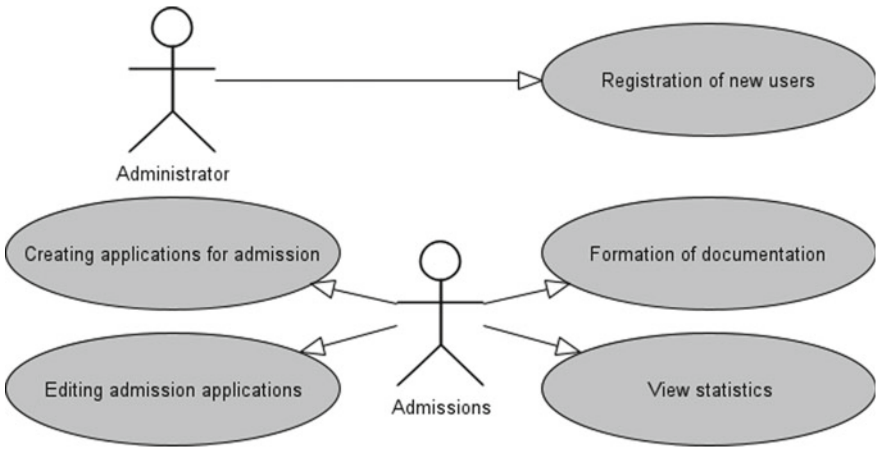

Fig. 7 Use case diagram

Each of the actors is responsible for special actions.

- Administrator—registration of new users in the system;
- The selection committee—the creation of applications for entry, editing applications for entry, the documentation formation and viewing statistics.

As a result of the simulation, a class diagram was created.

Modeling is customary to express (name) an entity as a noun or noun with an adjective characterizing it, and a connection is a verb that combines two or more nouns.

Entities and relationships can have their own attributes. For example, the entity citizen has the attribute passport number, and the relationship among the entities of the player and the notebook has the attribute last entry.

Each entity (if it is not a weak entity) has a minimal set of unique attributes, called a primary key [10].

As a result of the design, a database should be available, the scheme that has the following form (see Fig. 8).

The database is an absolutely integral part of software systems [11–16]. The full use of ER-diagrams in database engineering guarantees us the high-quality database design creation, database management and maintenance. The ER model also provides a communication means.

The information system was developed for the selection committee. It implemented such functions as (see Fig. 9):

- Adding applications for entry into the undergraduate program on the basis of the CCD/Associate;
- Adding applications for admission to the magistracy on the basis of the bachelor;
- Accounting and editing opening statements;
- Applicants registration;

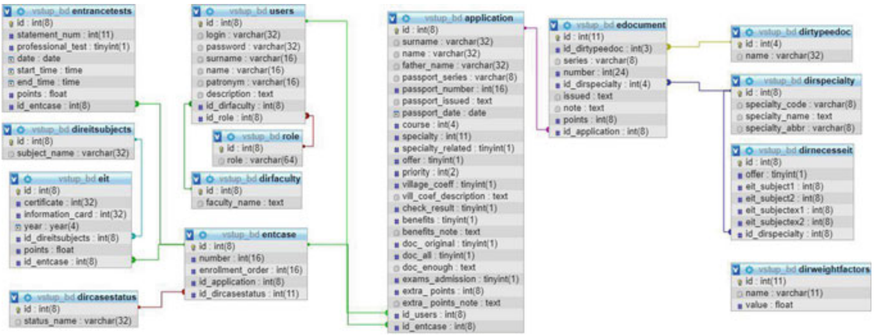

Fig. 8 Scheme of the created database

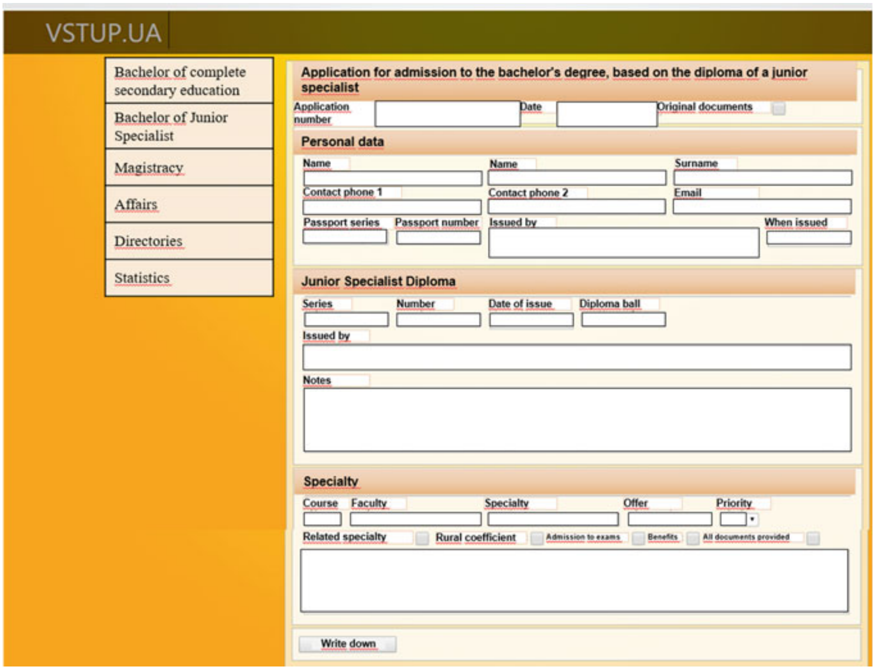

Fig. 9 Application for entry into the undergraduate program, based on an associate

- Documentation generation (orders, certificates, etc.)
- Applicants rating formation;
- User authorization.

The information system has the ability to generate the following documents:

- Personal file description;
- Message;

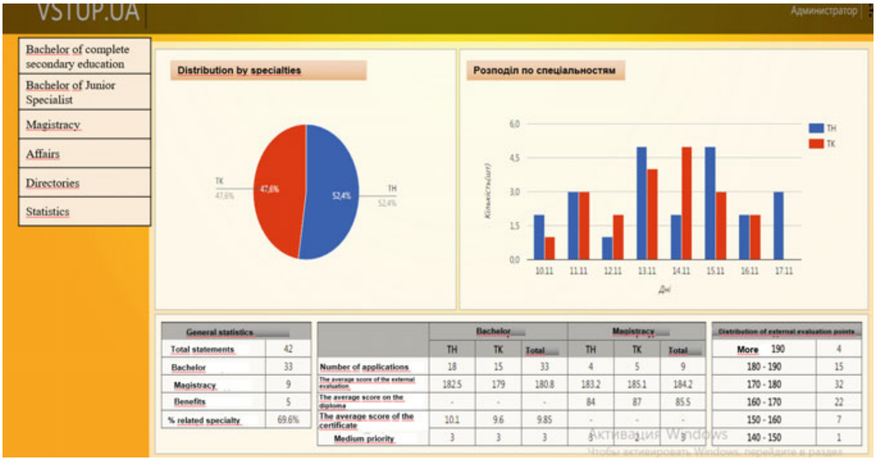

Fig. 10 General statistics

- A results sheet of entrance examinations for an additional exam;
- Results A sheet of entrance examinations without an additional exam;
- Extract.

The information system enables to view general statistics (see Fig. 10):

- Total stats;
- Number of applications;
- Average score of independent external evaluation;
- GPA of the diploma.

3 Conclusion

An intelligent information system has been developed for processing applications for admission by the university selection committee, which differs from the existing ones by a sufficient functionality amount, with a simple and intuitive interface, which reduces the system development time.

As a work result, the subject area was analyzed. The intelligent information system “Admissions Committee” was designed and developed, which includes a database containing information:

- About entrance examinations (code sheet, professional test, date, start time, end time, ball, case code)
- About items of independent external evaluation (code, name of the item)
- About independent external evaluation (code, certificate, information card, year, item code, ball, case code)
- On the status of the case (code, status name)

- About users (code, login, password, l
- ast name, first name, middle name, description, faculty code, law code);
- About the role of users (role code)
- About faculties (code, name of faculty)
- On cases (case code, case number, transfer order, application code, application status code)
- About applications (code, surname, name, middle name, passport series, passport number, who issued the passport, date of issue of the passport, course, specialty, related specialty, offer, priority, rural rate, benefits, privileges notes, original documents, all documents whose documents are missing, additional points, user code, case code)
- About documents on education (code, document type code, series, number, specialty code, who issued it, description, score, application code)
- About the types of documents on education (code, name of the document on education);
- About the specialty (code, specialty code, name of the specialty, abbreviation of the specialty);
- On the necessary independent external evaluation (code, proposal, subject 1, subject 2, additional subject 1, additional subject 2, specialty code);
- O weights (code, name of the weight coefficient, value of the weight coefficient).

The system generates documentation for entry on the basis of complete general secondary education and on the basis of the bachelor's level.

The site was tested, the results were not identified errors in the program.

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A Unique Historical-Architectural Monument-The Village of Khynalyg

Gulchohra Mammadova, Aliya Alieva, Mahammad Nurmammadov, and Sabina Hajiyeva

Abstract Khynalyg is a mountainous village in Azerbaijan, where a small nationality (ketsh khalkh) lives, which has its own language, culture and traditions. The array of the village, picturesquely located on a slope surrounded by the mountains of the Caucasus Range, creates the impression of a single architectural ensemble, harmoniously integrated into the harsh mountain landscape. The unique building traditions, constructive and aesthetic features of the village were formed on the basis of natural and climatic factors, features of local building materials, lifestyle and worldview of the people living here. The architectural value of the monument lies, first of all, in the integrity and organicity of the structure, the skillful use of the relief, the use of traditional, centuries-old architectural and construction techniques that correspond to the conditions of the mountainous area. In recent years, Khynalyg has faced a number of socio-economic, demographic and other problems that require measures to ensure the sustainable development of the village, preserve its unique heritage and architectural appearance. The article devoted to the historical and architectural features of the Khinalyg village provides recommendations for its protection, restoration and development as a potential tourist site, as well as a proposal to include it in the World Heritage List.

Keywords Architectural heritage · Alpine village · Unique building traditions · Organic connection with nature · Conservation issues · Tourism

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_36

1 Introduction

The village of Khynalyg is located at an altitude of 2,300 m above sea level in the north-eastern part of Azerbaijan. The inhabitants of this mountainous village are Khynalygians, or as they call themselves *qettsh khalkh*, a small ethnic group with its own language, culture and traditions.

Little is known about the history of this ancient settlement. Ancient Roman historian Pliny mentions this tribe, belonging to the Shahdag ethnic group, with their own language, traditions, and customs [1]. Musa Kalankatuklu, who lived in the seventh century, also refers to the tribe "*heni*" in his "History of the Albanians" [2]. Some historians identify this name with the Khynalygians.

It has to be kept in mind that Khynalyg is located in an isolated mountainous region. It is surrounded by magnificent mountains of the Greater Caucasus Range, covered with snow and glaciers. On the north side, near the village, there is Mt. Khynalyg (3715 m). Locals call this mountain as *Gyzylgaya.* In the northwest one can see the snow-capped peak Shahdag (4,250 m), in the west stretches the Tufandag ridge (4,191 m) [1] and the Salavat mountains (3,640 m); in the south the village is surrounded by the Garagaya ridge (Fig. 1).

Note that the population of the village of Khynalyg is over 1,800 people. Khynalygians are a special ethnic group with their own language which is not spoken outside this village. The main occupation of the population is cattle breeding. Various kinds of arts and crafts, especially carpet weaving, have been developed since ancient times. The massif of the village built on a mountain slope creates the impression of a single architectural ensemble. Over 150 houses have survived in the old *mahallas* of

Fig. 1 General view of the Khynalyg village [3]

Khynalyg that arose hundreds of years ago. At the same time, outside the historical part, on the bank of the river Khynalyg there was built a new housing estate in which a part of the population lives [4].

Socio-economic and natural-climatic conditions primarily influenced the layout and formation of residential houses of Khynalyg. Khynalygians were engaged in cattle breeding, carpet weaving, and wool products manufacturing. These peculiarities of their economic life were also reflected in the structure of their dwellings. The dwellings and household constructions are striking in their adaptation to environmental conditions and natural solutions to functional problems.

2 Main Part

2.1 Investigation of the Dwellings

The houses in the village are built of local building material–river stone and rock fragments. In masonry, the stones were most often used in their natural, that is, in unprocessed form. The walls are of three-layer construction. The outer and inner layers were made of stone material, while the inner part was filled with clay and small stone fragments. In this construction technique, the mortar dries and joins the facing stones and the inner filling to form a monolithic mass. The mortar is clay mass obtained by mixing a cleaned layer of soil with water. This masonry is a simple and accessible construction that has been used in many regions of Azerbaijan since ancient times and is still in use today [5].

Research conducted in 1954 revealed that 72% of homes at the time had no windows. Light into the rooms came from circular or rectangular light-sky openings in the ceiling. Three or four of these openings illuminated a room of 50 square meters or more. In the surveyed houses the illumination ratio was 1: 100 [1]. At present, most rooms have windows, but traditional skylights remain in many homes [4].

Rooms are usually 2.40 m high. Wooden beams were placed on the stone walls, and wooden slats or simply fragments of twigs cleaned of leaves were placed on top of them. On the floor there was a layer of compacted straw (10–15 cm). This not only preserved heat inside, but also to some extent prevented flooding during the rains. A layer of greasy clay was placed on top of the straw, as in masonry walls. This layer of clay completely insulated the building from water. A similar arrangement was made for the roof: the soil-soil layer was covered with greasy waterproof clay. The houses, built very close to each other of traditional river stone, give the impression that the village was literally carved out of the rock. The houses were staggered from the foot to the top along steep slopes, and the flat roof of the house below often served as the yard of the house above.

Unique construction traditions, constructive and aesthetic features of the village of Khynalyg were formed over a long historical period. These processes took place on the basis of natural and climatic factors, peculiarities of local building materials, as well as lifestyle and worldview of people living here.

As a result of demographic processes, since the last decades of the twentieth century, there has been a gradual resettlement of some inhabitants of remote mountain villages to more favorable living conditions in the plain villages. Some houses were abandoned and fell into disrepair. Ruins appeared in place of the collapsed abandoned houses, and the cleared areas began to be used as courtyards (Fig. 2).

The study of dwellings in the village of Khynalyg is of scientific interest from the point of view of studying the history of folk housing architecture in remote mountain villages characterized by such features as organic connection with the surrounding landscape, skillful placement of houses on the relief, compact layout of buildings, use of local materials in construction, the simplest structural solution–beam and column system and a peculiar solution of interiors. In the construction practice of Khynalyg one can observe the evolution process from a one-room *karadam* to a developed multi-room village house [4].

Fig. 2 Colourng of Khynalyg [6]

2.2 Problems of Khynalyg Village Preservation as Peculiar Historical Ensemble

It ought to be noted that Khynalyg is a peculiar historical ensemble with the structure similar to the structure of mountain villages of the Caucasus [7]. To our thinking, its architectural value lies, above all, in its integrity and amazing organic structure. Here we have skillfully used the relief and applied traditional, time-tested architectural and construction techniques appropriate to the conditions of mountainous terrain. It is an example of spontaneous solution to artistic tasks of architecture and urban planning. Thanks to this evolution, however, the result is a harmonious ensemble that blends perfectly with its surroundings and is in organic unity with nature. The interrelation of architectural forms, the formation of a single residential and economic space, created a functional, adapted to the harsh conditions, comfortable and harmonious living environment for people.

Khynalyg is distinguished by its special coloring. This flavor is specified by the use of local stone, the colors of which are in harmony with the natural background. Artificial forms, created by man, repeat the natural configuration of the relief, becoming part of the environment. Ensuring the necessary conditions for human life, a kind of aesthetic understanding of the surrounding nature and its reflection in the architectural forms is the main value of the historically established structure of the village. Any unprofessional interference in the architecture of the village, the use of new materials, colors and modern forms disturbs the harmony of the appearance of the village Khynalyg.

The essential point to remember is that the architectural appearance of Khynalyg has been mostly formed, apparently in the last 200 years. At each new stage, individual volumes included in the single composition have changed, new elements have been added; however, the appearance of the village which organically blends into the mountain landscape has largely retained its defining characteristics.

Since the 70-s of the twentieth century, there have been processes aimed at improving living conditions, expanding the area of houses, the use of more efficient building materials. This manifested itself, for example, in the replacement of earthen roofing in some houses with asbestos-cement or metal sheets. From a practical point of view, this roof is more convenient, since every year the earthen roof has to be lubricated with a new layer of clay, patch cracks. Later the wooden window frames were replaced by plastic ones. Other parts of the buildings were also changed. In many of the houses the open eaves were glazed, bringing new elements into the architecture of the houses.

It has to be noted that the problem of enlarging the house was solved by additional construction. New walls were often made of cube-stone, which was brought from Absheron, destroying the characteristic look and color of the village. In the harsh conditions of the mountain climate, the structures needed constant care and renewal. Homeowners often use new building materials and elements in the old structures during repairs. All of the above and even minor changes made to the houses certainly affect the overall architectural appearance of the village (Figs. 3 and 4).

Fig. 3 Historical masonry [photo by authors]

Fig. 4 Capitals in the old dwelling [4]

In recent years, Khynalyg has faced numerous problems. A part of the rural population left their native village and moved to more comfortable villages closer to the regional centers. Some old houses of historical value now lie in ruins. Almost all of the houses are in need of serious repair. If the problems that forced the population to leave Khynalyg are not resolved quickly, it is likely that the houses we see now in good condition will also be in danger of collapse in ten to fifteen years.

The Khynalyg Master Plan has now been drafted which is aimed at the sustainable development of the village and the preservation of its original culture and architecture. It provides for comprehensive measures for the sustainable development of the village and the preservation of its cultural, historical and architectural heritage. The project provided for the restoration of the historical part of the village and the creation of better living conditions while preserving the village image and the basic parameters of the historical environment.

It cannot be forgotten that to succeed in preserving and developing the village, all the residents of Khynalyg should understand the problem, take an active and creative part in this process. At the same time, it is important to instill in the population an awareness of the value of the historical place where they live. It is impossible to ensure effective protection of the historical monument of architecture without community participation. The protection of the village as a monument is important to protect the Khynalyg ethnos, its language as well as the Khynalyg culture as a whole.

It should be recognized that the village's protection plan is based on a balanced harmonious relationship between the needs of residents and the protection of the historic environment. The integrity of the cultural and natural environment will be a quality that ensures the development of the community through budget-funded restoration works and increased local income from agriculture and tourism. Such a strategy will lead to the effective implementation of the Master Plan, protect the historical and cultural heritage and serve to strengthen patriotic feelings as well as a sense of responsibility for the protection of the village.

2.3 Results

The protection of the historical and architectural monument Khynalyg includes the protection of its individual buildings. These are issues related to the restoration of existing monuments, reconstruction of houses, preservation of their interaction with the environment, as well as the modernization of utilities and landscaping. As a result of measurement and research works implemented by the design group of the Azerbaijan University of Architecture and Construction, architectural, structural and decorative solutions have been studied in a number of houses. As a result of the survey the state of their construction and the measures necessary for restoration and reconstruction have been determined. The study of individual houses and historical monuments made it possible to identify the following specific tasks, relevant to the majority of buildings in Khynalyg:

- Elimination of defects and deformations of bearing structures of buildings, restoration of their stability;
- Installation of buttresses and other measures related to the strengthening of structures that have lost their strength;
- Overhaul of houses, the constructions of which are in need of it with the use of local traditional building materials;
- Removal of innovations that spoil the appearance of houses;

- Modifying or "hiding" the new materials used by the residents that are not characteristic of the architecture of Khynalyg as much as possible;
- Clearing the area of debris and collapsed parts of old buildings;
- Implementation of measures to improve the area.

It should be added that all these issues will be addressed in accordance with the developed project and the management plan of the monument. Timely preventive and conservation work increases the service life of the monument. In the future, the condition of the buildings will depend on proper regular maintenance. At present, these works are financed by the state budget. But in the future, income from the development of economic activities and tourism should help the community to cover part of the costs.

Also, Khynalyg has great potential for tourism development, and it is necessary to use this potential to preserve this unique historical and architectural monument. A hotel complex should be built in the new district of Khynalyg to receive and serve tourists. Consideration should be given to the reconstruction and use of old houses as part of small hotels, creating normal living conditions for tourists. Finally, the rehabilitation of the village should take into account the improvement works, such as paving the road, creating engineering and communications network, providing all houses with water, sewerage, heating, telephone and other household services.

It should be emphasized that Khynalyg is a unique historical village with ancient traditions. Its protection is important not only as a monument of a peculiar building culture, but also in terms of preserving the entire cultural, ethnographic and natural complex. Along with the houses here it is necessary to restore the historical environment, to create conditions for the Khynalyg people to continue their artistic traditions. Khynalyg should continue its life as an architectural and ethnographic reserve, where small people live and demonstrate their original culture and ancient crafts. At the same time, the creation of more favorable living conditions, increasing the level of comfort of the inhabitants are necessary conditions to ensure the longevity of the village.

It is necessary to create conditions for the villagers to live a normal life, engaged in their usual economic activities, because the preservation of the unique village is closely connected with the support of productive activities of the population. Only through the simultaneous solution of these two tasks–preservation and development of historical environment and socio-economic development of Khynalyg can get rid of degenerative processes, revive and continue its life in new conditions.

The protection of the village of Khynalyg as a monument of urban planning and architecture implies the preservation of not only the existing religious and defensive structures, but also the entire planning structure–houses, the grid of streets and connections between parts of the village. Given that the village has no utilities (water supply, sewerage), a project will be developed to lay the appropriate communications, without harming the local color. It is necessary to create a protective zone of the monument in order to protect the historic environment and landscape.

It should be acknowledged that the implementation of the reconstruction plan will allow to fully preserve the urban and natural environment of the village, rich in architecturally and ethnographically interesting buildings, and to present it as an open-air museum. This multi-faceted architectural and ethnographic museum will reflect both the material culture typical of this ethnic group and the construction art and architecture.

3 Conclusion

The complex research involving architectural, historical and ethnographic information about Khynalyg allowed revealing the architectural planning of the village and the architectural peculiarities of its buildings. Extensive material obtained during the study shows the value of the historical village and the importance of its preservation. The research material allows us to draw the following conclusions.

It is worth reminding that the history of the village Khynalyg goes back to ancient times. For almost 2000 years of its existence, Khynalyg, unlike other mountain villages, has always been a relatively independent territorial unit. The settlement owes its special position to its traditional economic life, location on an isolated and well-protected territory. These two factors also contributed to the preservation of historical architecture and unique material culture.

It should be remembered that Khynalyg is located in a mountainous and rugged terrain, but this has not prevented the viability of the ancient village. This viability was achieved by choosing the right location of the village, taking into account factors important for life–the availability of water, defensive potential, favorable orientation and the economy of land.

Khynalyg is an example of harmony of landscape and human creations. The settlement was created and developed in this harmony. This harmony was achieved by adapting the entire structure of the village and its buildings to the existing topography and the use of local building materials.

What is important to notice is that the village of Khynalyg, which has significant value in terms of history, ethnography, art, architecture is a unique phenomenon of architecture, demonstrating the unity and connections with nature. Khynalyg is included in the list of cultural heritage protected by the state as a historical, architectural and ethnographic reserve. I believe that it is of interest not only to Azerbaijan, but it could be included in the world heritage list under the 3rd criterion as a unique and unrepeatable object of the existing cultural tradition.

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Palace of Sheki Khans: Some Aspects of Preservation and Use

Gulchohra Mammadova and Sabina Hajiyeva

Abstract The palace of Sheki khans, an architectural monument of Azerbaijan, located on the territory of the state historical and architectural reserve "Yukhari Bash" in the town of Sheki of Azerbaijan, had been included in the UNESCO World Heritage List on July 7, 2019 at the 43rd session of the World Heritage Committee. The richness and brightness of the architectural and artistic decoration, the skill of using traditional building materials and techniques against the backdrop of the magnificent picturesque nature attract the attention to the Sheki Khans' Palace. Preservation of the Sheki Khans' Palace, correct assessment of its significance, as well as timely work to maintain its safety is an indispensable guarantee of its existence and use. It is necessary to draw up and implement a management plan for the preservation of this monument at the present stage. The article discusses various aspects of the architectural, planning and decorative solutions of the Palace, as well as issues of preserving its features and using it today.

Keywords Palace architecture · Historical and architectural reserve "Yukhary Bash" · Sheki Khanate · Preservation of tangible and indelible heritage

1 Introduction

The palace of Sheki khans, an architectural monument located on the territory of the state historical and architectural reserve "Yukhari Bash" in the town of Sheki of Azerbaijan was included in the UNESCO World Heritage List along with the historical part of Sheki, on July 7, 2019 at the 43rd session of the World Heritage Committee.

The richness and brightness of the architectural and artistic decoration, the skillful use of traditional building materials and techniques against the background of the

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_37

magnificent picturesque nature–these are the features that invariably attract the attention of visitors to the Sheki Khans' Palace. This monument had attracted the attention of numerous researchers. However, among the publications dedicated to Palace, it is necessary to highlight the extensive and comprehensive study of the history, artistic characteristics of the palace, carried out by the prominent Azerbaijani scientist Bretanitsky in his dissertation work, which had been defended in 1945 [1]. One could mention detailed analysis of the architecture of the palace in the context of its connection with the traditional folk architecture of Sheki as the special merit of Bretanitsky's research, which made it possible to scientifically refute the previously superficial opinion about the palace of the Sheki khans "as a monument of the late Safavid ("new Iranian") architectural style and epigone of Iranian country palaces. [1].

The detailed works of Weimarn and Miklashevskaya, dedicated to the murals of the palace, are also very important, provided with a large number of illustrations [1, 2].

2 Main Part. Architecture of the Shekikhans' Palace

2.1 Architectural and Planning Solution of the Monument

The architectural image of the Palace is associated in its genesis with the ancient traditions of local folk residential architecture, which reflected a complex of socio-economic and natural conditions. This palace is harmoniously located at the highest point of the town, at the end of the main street. The deeply thought-out clarity and integrity of the architectural and planning solution of the palace does not oppose it to the surrounding buildings, but is its logical conclusion. This was influenced, of course, by the general integral image of the town of Sheki, which was formed as a result of the simultaneity of its emergence in a new place. After a strong mudflow in 1772, the town of Sheki was moved to a new location and rebuilt on the site of the historical city of Nukha, connected in the works of researchers as the historical town of Niga [3]. Therefore, the town was officially called Nukha until 1968. The town, created in a new place, was limited by mountain spurs on one side and the Gurjanachay River on the other. That fact influenced the elongated character of its urban planning structure, which has survived up to day. Therefore, mosques, caravanserais, baths and other important public buildings characteristic of a traditional Islamic city are located here along the main town street, which led to the dominant town-fortress where the Sheki Khans' Palace placed. The formation of the structure of the town of Sheki was also influenced by the fact that during its centuries-old history it was one of the most important silk-breeding and trade-handicraft centers in Azerbaijan. As Bretanitsky notes: "The integrity of the ensemble was also facilitated by the well-known equal scale of the buildings, organically connected with the general town silhouette. All this is united by the greenery of the gardens, merging with the forest surrounding the city and the rice fields of the suburbs, giving Sheki a somewhat romantic and picturesque character. Against this background, the small expressive volume of the Sheki khans' palace with its polychrome facades, deeply shaded stalactite niches on the southern facade and the lacy pattern of lifting windows does not stand out in harmony with it" [1].

The palace of the Sheki khans is located on a high hill rising in the northeastern part of the Sheki fortress. The palace is located inside the fortress walls in a complex with other buildings. But the Palace also has its own courtyard, enclosed by a wall with a gate. Inside the courtyard, in addition to the building of the Palace itself, there is a park built according to the oriental principle of geometry and two magnificent century-old plane trees. Fortunately, the building of the Palace itself has not undergone significant changes throughout its existence. The entire planning composition of the building has been preserved with the arrangement of rooms enfilade, along the axis, with a symmetrical arrangement of rooms on both floors. However, the overall composition of the complex was grossly violated at the beginning of the nineteenth century, after the conquest of the Sheki Khanate by the Russian Empire. The disbandment of the Russian military garrison on the territory of the fortress caused the destruction of buildings belonging to the palace complex, which Major Lisanevich wrote about in 1819. According to the descriptions, the complex of the Palace included: the building of the palace (now existing), the khan's mosque, the premises of the harem, numerous chambers, a bathhouse, a prisoner's room, storerooms, stables, barns and other services. But the military demolished all the buildings of the complex, apparently built of raw bricks, and built stone buildings-barracks, prisoners, existing today: "In the fortress, in addition to the palace, there were barracks, a treasury, a prison and an Orthodox church converted from a khan's mosque in 1828" [4].

Most often, the Palace is called the summer pavilion in the sources. Russian journalist of the nineteenth century Nikolai Bersenov wrote that Palace, being the residency of the khan, also served as a court building [5]. After the annexation of the Sheki Khanate to the Russian Empire, the palace was under the jurisdiction of the local administration and was repaired several times [4]. At the same time, an inventory of the real estate of the Sheki khans was carried out [6]. Judging by the old plans, it was once part of the complex, from the former splendor of which only the pool and ancient trees had been survived. According to the surviving materials, the ensemble "was very significant, including a large number of structures for various purposes: the building of the palace (now existing), the khan's mosque, the harem room, numerous "chambers" that belonged to relatives and confidants, a bathhouse, a prison, a storeroom, stables, barns and other services. All these structures were located inside the walls of the fortification and occupied a significant part of it" [1, p. 385].

In the scientific literature, there are several dating of the palace. The earliest of them is 1730. Many sources repeat the date–1762, 1765, 1792 or 1797. This is due to the presence of different assumptions about the time of the construction of the palace. According to one version, after the flood of 1772, the town was moved to a new place, where in 1790 "… Usein Khan built an extensive stone fortification … in the form of an irregular rectangle …". A little later, in 1797, during the reign of Muhamad Hasan-khan, the Palace of the Sheki Khans was built [1, p. 389; 7]. According to another version, it was built in 1762 on a hill, away from the town [2] by order of Huseyn-khan Mushtag, the third khan of Sheki, who ruled the khanate in 1759–1779. Ten years later, the town was destroyed by floods and was rebuilt in a new place–around an already existing palace. This version is also supported by the epigraphy on the ceiling of one of the rooms on the 2nd floor, where the date 1175 was captured by the master Abbas Quli. (1761/62) [8, p. 94]. According to the architectural historian M. A. Useinov, "inscriptions about the time of the palace construction have not survived and at present the most probable date of its construction is considered to be 1797, which was on the reign of the Sheki khan Muhammad Hasan-khan. In any case, the date of the construction of the palace is limited to the time from 1762 to 1797 " [9]. He also notes that the palace was completed by Muhammad Hasan-khan, the great-grandson of the founder of the Sheki Khanate, Haji Chelebi Khan [10]. The architecture of the Sheki khans' palace, as well as almost all types of buildings in the town of Sheki, including religious ones, was influenced by the traditional and typical for this town type of dwelling house. The palace has all the features characteristic of a residential building: the rooms are located on one longitudinal axis, there are *"ref"* -shelves under the ceiling along the entire perimeter of the premises and wall niches, small and large, for storing household items. The main decoration of the interiors of the ceremonial rooms is the richly decorated "*Bukhara*"–a fireplace that emphasizes the longitudinal or transverse axis of the room. All elements of such a house are functionally justified, laconic and artistically expressive. As the defining details of the region's housing, it should be noted carved wooden columns with beams and the filling of window openings—"*shebeke*".

The palace of the Sheki khans is a relatively small two-storey building "richly decorated along its main southern facade with carved, currently polychrome-colored ornamentation over mud" [1] (Fig. 1). The interior space was solved very simply and clearly: the layout of the two floors of the building was solved symmetrically and identically. The main premises are the central halls of the first and second floors, which stand out not only for their place in the general plan of the building and for their size, but also for a more complex organization of internal volumes and a more ceremonial character of the decoration.

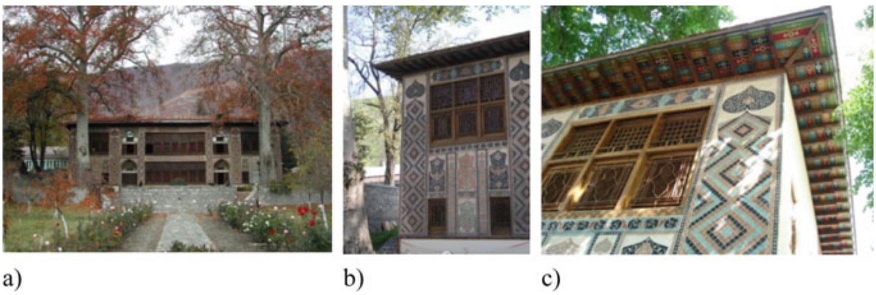
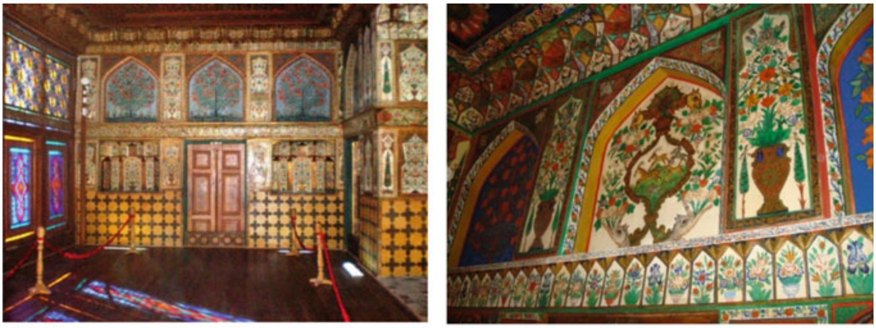


Fig. 1 Palace of Sheki khans. General view and detailes of façade ornamentation



a) b)

Fig. 2 Interiors decorations

The principle of mirror symmetry, clearly visible in the entire architecture of the building, remained in force in the resolution of the interior of the hall (Fig. 2). Compositionally, its divisions are subordinated to the central transverse axis by an accentuated niche, in the depth of which "Bukhara" is currently located, and in the middle, there was once a fountain [1]. The planes of the walls of the hall (excluding the southern one, which is essentially a continuous window opening) are dismembered in height by a "ref" into two tiers. There are also small niches - "*takhcha*"–widespread in the Sheki dwelling and intended for storing household items are sunk into the walls.

History has preserved the names of five artists who painted the palace of the Sheki khans at different times. These are *Ustad*-master Abbas Quli, ornamental artist Mirza Jafar from Shemakha, who created a number of murals on the first floor in 1895–1896, Ustad Gambar from Shusha, who created most of the patterns on the second floor, Ali Quli and Qurban Ali from Shemakha.

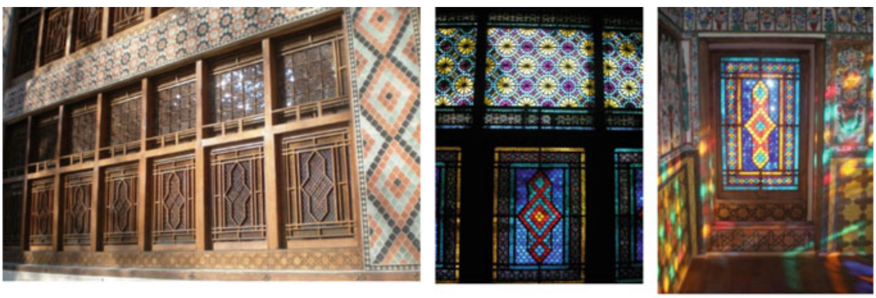
The walls of the palace, which, regardless of whether they are internal or external, are one meter thick, are made of baked bricks on a widespread *gyaj*-mud solution. The material for the preparation of the solution is local raw materials–a natural mixture of gypsum and clay, called "gyaj". It should be noted that the widespread use of that solutions is undoubtedly associated with their anti-seismic properties. In addition, in a harsh continental climate, large wall thickness is an excellent protective measure against excessive heating and cooling of premises.

2.2 Decoration of the Palace

The southern, main facade of the palace is the most interesting, since the central part of it is designed in the form of continuous glazing with windows covered with a geometric wooden "*shebeke*" filled with colored glass (Fig. 3). The extraordinary artistic characteristics of the palace have been described several times. It should be especially noted the skill of the architect, who managed to create the illusion of high rooms with decorative means at a low floor height (only 3.35 m) [11, p. 74]. Of particular interest are the interiors of the monument, famous for their paintings of the eighteenth-nineteenth centuries [2].

The surface of the walls of the hall, including niches and stalactite cornices, is covered with rich bright paintings. Band friezes and numerous panels, located on separate planes, are not simultaneous and are not the same in quality and manner of writing. However, the quality of the paintings in this room is higher than the paintings of the rest of the palace interiors. This is obviously due to the fact that the hall, which was overhauled in 1848–1851, was subsequently much less subject to minor repairs and alterations than, for example, the premises of the upper floor [1].

The murals are located in the halls of both floors and in the two side rooms on the second floor. They occupy the planes of walls, niches, stalactite transitions from the walls to the plafond, as well as plafonds. Researchers distinguish among the murals of the Sheki Khans' Palace murals of subject, geometric and plant patterns, sometimes with images of birds. Particularly interesting are the murals depicting various scenes of hunting and battles, placed in the hall on the second floor in the form of a frieze between niches (Fig. 4). The murals of the Sheki Khans' Palace are characterized by rich color and wide use of golden color. Unfortunately, the secret that the ancient masters used when creating paint for panels has been lost. Modern paints used during the restoration of partially lost paintings are only approximately able to repeat the once created splendor. As noted by Miklashevskaya [2, p. 484], who devoted a number of her studies to wall paintings of Azerbaijani architectural monuments, the first sign that Azerbaijani wall paintings were filled with egg paints, and not glue paints. As she explained the transparency and elasticity of the paints of the paintings are evidence of that. In addition, glue paint always remains sensitive to water, and egg paint only becomes stronger over time and after several years completely loses its sensitivity to water. Despite the technically high complexity of the execution of wall paintings and, especially, plafonds, almost all paintings are distinguished by the complexity of the ornamental compositions and the richness of colors.



a) b) c)

Fig. 3 Wooden "shebeke" filled with colored glass


a)

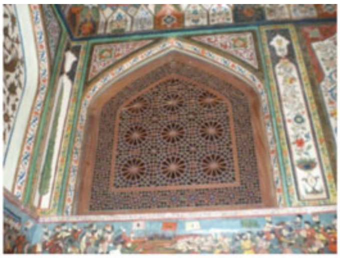
b)

Fig. 4 Murals of the Palace of Shekikhans

Miklashevskaya divides all the paintings according to the place they occupy in the interior on painting panels, niches, piers, "*bukhara*", friezes, plafonds, stalactites, doors, etc., highlighting the subject paintings in different groups [2, p. 0.486] (Fig. 5). One can find geometrized carpet-type ornaments, composed of multi-ray stars and polygons; panels, covered with patterns of a vegetative nature, in construction and motives are very similar to the patterns of ornamental interior design, but differ from the latter in some static and more stylized elements [2, p. 485].

One of the dominant places in the composition of the facades is occupied by such a strong accent as shebeke, a traditional type of geometric ornament that has found wide application in Azerbaijani national architecture. Shebeke are most vividly presented in Sheki's residential buildings: in window frames, in door frames, internal partitions, in the solution of plafonds, "*eyvan*'-lodjias, balconies, etc.

Of particular interest is the technique of assembling the bindings of these lifting frames, which easily slide up and down along the grooves, in the supporting posts of the overall structure of the window system. The entire complex pattern of bindings


a)

b)

c)

Fig. 5 Murals on Bukhar- fire placei, takhcha- nich and stalactite cornice of stained-glass windows was mounted exclusively on thorns, without the use of any additional clips, nails or glue. Similar elements were also used in the Shekihanovs' house in Sheki, in the Panakh-khan's palace in Erivan, in the Kerimbek Mehmandarov's dwelling house in Shusha, etc. [12, p. 88–95]. The material for the main strapping and individual small components was carefully finished beech, apparently impregnated with unknown compounds and polished.

2.3 Restoration and Renovation Work in the Palace

Since its construction, the building of the palace has undergone many repairs and reconstructions, which have not seriously affected its external appearance [13]. The archival and literary materials that have survived to our time make it possible to restore the process of organizing repair work and find out how they found their concrete expression in the general architectural image of the structure. Report on "the renewal of the khan's house, consisting of a Nukha fortification with the preservation of an Asian view inside and out", which began according to the report of the Shemakha military governor in August 1848 and completed in September 1851 is of special importance [1].

"Some of the surviving documents testify to some of the repairs, marking their general volume and character, while some of the works could only be guessed at from individual fragmentary references. In some cases, they tried to preserve at least some of the premises of the palace in their original state, in other cases, especially when the building was adapted for "public places", this principle was not used" [1].

In 1848–1851, the restoration of the palace was carried out by the poet Kerim aga Fatehi, the grandson of Huseyn Khan Mushtag. Shemakha military governor (1848) Vorontsov was informed in his report that the palace was inspected by the Shemakha provincial architect Cambiagio [1]. The work concerned only the finishing of the building, and mainly on the lower floor. This is confirmed by A. Dumas: "… The interior was renewed according to ancient drawings for the arrival of the great dukes who stayed in it. Whole building was not renewed, but only the lower houses" [1]. The act does not say anything about any significant, major alterations in the building. According to the old drawings, the carving on the gyaj of the southern facade was corrected, and the decorations of the entrance niches decorated with stalactites were also repaired. In the premises of the lower floor, the walls were replasted and the wall paintings were re-executed, mainly according to the old drawings. During one of the restorations of the late nineteenth century, the side ceiling of the palace was also changed. From the covering that preceded it, only traces have come down in the form of several ends of the rafters covered with floral ornament, which once supported the overhang of the roof [1]. There is also interesting information about the renovation of the roof of the khan's house, … which was again: battened and covered with oak shingles painted by the Swedish solution" [1].

Regular repair and restoration work was carried out in the Palace of Sheki Khans by Azerbaijan Center for Monuments Protection during 1938–1940. The author and direct leader of the restoration project was Baranovsky [1]. The Azerbaijani scientist Bretanitsky, who later devoted his scientific research to the palace, also took part in the measurement and restoration work. Extensive restoration work was carried out in 1955–1965 according to the project and under the direction of the architect Rzayev; the artist F. Hajiyev and the master on shebeke A. Rasulov worked in the palace [14]. Historical part of the Sheki town "Yukhary Bash", where the palace is located, was declared a historical and architectural protected area in 1968. In 2002–2006, within the framework of the "Protection of Cultural Heritage" project, a new stage of restoration work was carried out, and the palace was restored anew [15, 16] and others [17, 18].

It should be noted that no similar monument or similar decoration has survived in other places in Azerbaijan. Sardar's palace, erected in Erivan, the Mehmandarovs' House in Shusha, a number of residential buildings in Lahich, painted in the manner of the Sheki palace, have not survived. Thus, the Sheki Khans 'Palace acquired the significance of unique monuments for the Republic of Azerbaijan.

3 Conclusion

Today, the Palace celebrated its 250th anniversary, is used as a museum. It hospitably opens its doors to everyone who wants to get acquainted with this striking monument of Azerbaijani architecture. Preservation of the Sheki Khans' Palace, correct assessment of its significance, as well as timely work to maintain its safety are an indispensable guarantee of its existence and use. At the present stage, it is necessary to draw up and implement a management plan for the preservation of this monument. Taking into account the above-described characteristics of the Palace, preservation requires the coordinated work of specialists in many areas-architects-restorers, masters of paintings and shebeke, landscape architects and many others.

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Use of Different Geodesic Methods for Determining Heights

Svitlana Nesterenko, Roman Mishchenko, Grygoriy Shariy, and Vira Shchepak

Abstract The issue of the effectiveness of using various geodetic methods for determining vertical displacements of the earth's surface, including the use of satellite technologies, is considered. The vertical displacements of the benchmarks located on the geodetic polygon of the Poltava Gravimetric Observatory were determined for a period corresponding to 0.5 calendar year. It has been analyzed the advantages and disadvantages of using network RTK in GNSS technologies. Measurements were made at the geodetic polygon with a GNSS receiver. The accuracy of determining normal heights in RTK mode is calculated. It was found that only 30% of measurements have high geodetic accuracy, but such errors are acceptable for topographic surveying. To compare the results, a remote satellite radar method was developed for the same period. A map of relief deformations on the geodetic polygon was obtained, which confirms the results obtained by the traditional ground method of geometric leveling. The satellite radar is effective over large areas, when a general trend of displacement can be observed. Further, having identified dangerous areas, having in the arsenal the most available technologies and means for determining deformations of the earth's surface, it is possible to obtain fairly accurate geodetic results for individual points.

Keywords Displacements of the Earth's surface · Geodetic methods · Geometric leveling · Geodetic accuracy · GNSS-receiver · Satellite radar

1 Introduction

Technological evolution in geodetic production has led to ample opportunities for the implementation of various engineering and geodetic work. Most of them associated with determining the coordinates of points on the ground in a certain coordinate system. For the territory of Ukraine, the following is possible by transforming them into the Ukrainian State Geodetic Reference Coordinate System USK-2000, since

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_38

the processing of survey materials during land management works is carried out precisely in this coordinate system or in the local coordinate system, which is uniquely connected to the USK-2000 coordinate system. When performing high-precision geodetic works, for example, evaluating the geodynamic processes of movements of the earth's crust and displacement of soil masses [1], the stability of geodetic points must be determined in the world coordinate system ITRS (International Terrestrial Reference System) and the European coordinate system ETRS (European Terrestrial Reference System). Factors that can affect geodynamic phenomena are diverse: planetary scale (movements of the Earth's poles, displacement of the Earth's rotation caused by the influence of the gravitational forces of the Moon and the Sun, unevenness of its rotation [1], etc.), regional (earthquakes, variations of geophysical fields within one tectonic plate or shield), of a local or local character, when vertical and horizontal changes in the position of the network of points are caused by geological and hydrological conditions, features of zoning, in particular, the presence of technogenically loaded territories, hydrometeorological factors [2].

Monitoring of deformations of the earth's surface of a local nature can be performed by various traditional ground geodetic methods, while achieving sufficient accuracy. The land surveying has undergone a significant transformation with the advent of high-precision electronic and robotic theodolites, tacheometers and levels, laser scanners, multistations, cameras and stereophotogrammetric devices. And with the development of global navigation satellite systems [3], it has been appeared a new method—the ground–satellite surveying, conducting topographical and geodetic measurements using GNSS–receivers. However, often the modern generation of surveyors, neglecting the regulatory framework, use modern geodetic technologies in violation of control measures. For example, according to [4], when using GNSS satellite geodetic receivers to determine points of survey justification and survey of geospatial objects using RTK technologies, it is necessary to check the differential field of coordinate corrections, which are set by GNSS networks. That is, when performing geodetic surveys using GNSS receivers, one should be aware of the likelihood of gross deviations due to a number of factors: ephemeris and time errors, satellite configuration geometry, multipath propagation, the influence of the ionosphere and troposphere, and the like [5, 6].

In addition to the geodetic methods listed above, the method of satellite radar can be used to detect displacements of the earth's surface, which is based on the processing of Sentinel-1 space images, interferometric processing of remote sensing data of the Earth, and construction of terrain deformation maps.

The purpose of the work is to determine the accuracy of finding normal heights using various geodetic methods, based on a stable network of leveling points, to analyze the effectiveness of using satellite technologies to determine vertical displacements of the Earth's surface.

2 Page Layout

Scientists all over the world are constantly studying the effectiveness of using various geodetic methods to determine the spatial coordinates of points. With the wide implementation of satellite technologies, scientists began to comprehensively consider the possibilities of global navigation satellite systems for the needs of the geodetic sphere. Among those who studied satellite navigation technologies, such domestic and foreign scientists as Gray Jim et al. [7], Soloviev et al. [8], Litinsky et al. [9]; engaged in researches of modern geodynamics in Ukraine, including vertical ones,– Tretyak [10], Pavlik [11] and others. The results of the possibilities of using radar interferometric methods were studied in the works of Buraka et al. [12], and others.

Traditional ground geodetic methods for determining vertical displacements of points on the earth's surface include geometric and trigonometric leveling, calculation of spatial linear-angle networks, ground laser scanning and ground photogrammetry. A wide selection of constructive solutions led to the transition from the use of optical-mechanical devices to the use of electronic (digital, laser) equipment.

High-precision coordinate-time provision of a significant share of geodetic, land management and other works significantly increases the efficiency and pace of their execution.

However, most of the modern complex software and hardware complexes are not available to a wide range of consumers due to the high price policy. For example, laser scanners, which cost 0.85–3.0 million hryvnias (30–100 thousand euros), have a limited number on the market due to low consumer demand. Errors in the scanning process with laser scanners have not been sufficiently studied, and the data provided by the manufacturing companies may be biased due to the small number of production tests.

To carry out a truly high-quality and most accurate geodetic survey, it is necessary that it be carried out using the correct instruments that have been tested for quality and reliability. Moreover, the tools for performing such work must pass not just a check, but state certification, and their re-certification is carried out annually. The shooting process itself must be carried out according to all geodetic rules and according to a certain algorithm.

At the geodetic range of the Poltava Gravimetric Observatory of the Institute of Geophysics named after Subotina has been observing geodynamic processes for 30 years. A network of riparians of various depths with known stability indicators is laid on the landfill. The location of the GNSS station on the territory of the geodetic polygon (POLV) greatly simplifies the task of determining the quantitative characteristics of its vertical dynamics under the influence of local hydrothermal factors. At a distance of 75 m from the station, there is a benchmark A1 with a depth of 6 m, which is characterized by high stability throughout all the years of observations. There are no slow and seasonal movements in the dynamics of this sign [11]. This benchmark was chosen as the starting point when determining the characteristics of the possible vertical dynamics of all other benchmarks on the geodetic polygon.

Vertical displacements of geodetic points after six months (in autumn and spring) are determined by the classic method—geometric leveling—using the H-05 level. This type of leveling does not lose its relevance today due to obtaining highly accurate results with relatively small costs for operating the device. Such levels are designed for leveling of the I and II classes, the mean squared error of measurement of the excess per 1 km of a double stroke is 0.5 mm.

During one of the observation periods (October 2020–April 2021), results were obtained that indicated seasonal dynamic movements (Fig. 1).

Analyzing the obtained results, it can be noted that the investigated geodetic points for the specified period (October 2020–April 2021) had minor vertical displacements in the range of $-1.70 \div +1.75$ mm. These results will be considered as reference for further research.

Taking into account that satellite technologies are widely used in geodesy, urban and land cadastre, land inventory, construction of engineering structures, geology, etc. [13, 14], it is necessary to compare the results of "fast" satellite surveys with traditional ones. One of the oldest problems in human history was the problem of precise positioning. Positioning methods were based on the observation of celestial bodies. The field of positioning and navigation has undergone a dramatic evolution, which has led to the use of radio frequency signals and led to the emergence of GNSS with global coverage, high accuracy, and the absence of complex equipment for the user [15]. GNSS receivers for surveying are specially designed for the precise determination of the coordinates of point objects [16]. To create and develop a plan-high-altitude justification, to perform topographic surveys of all scales, dual-frequency GNSS receivers are used, which allow working at large distances from the base station.

To correct GNSS data on the territory of Ukraine, DGPS and RTK correction methods from ground base stations are used. Differential DGPS mode provides

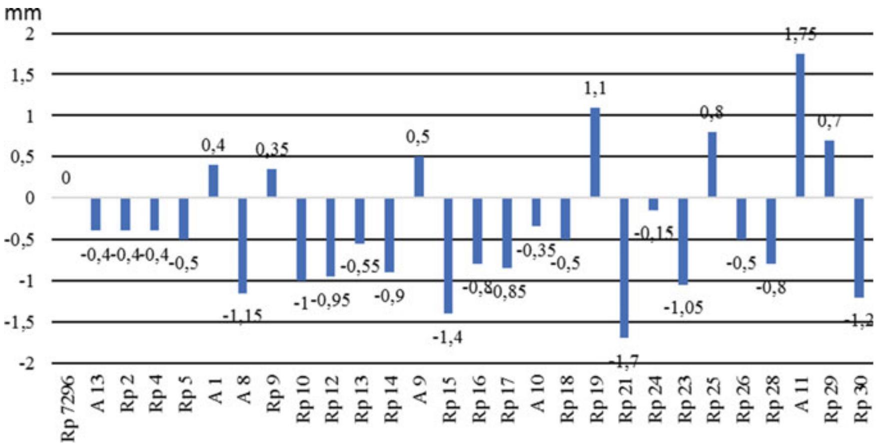

Fig. 1 Vertical displacements of benchmarks located at the geodetic poligon of the Poltava Gravimetric Observatory for the period October 2020–April 2021

decimeter accuracy (1–3 m) in determining the location of the object [17]. This method is quite simple and economical, since single-frequency antennas are used in the work. For high-precision coordination, finding the plane coordinates and heights of the points of the topographic surface with centimeter accuracy, the RTK mode is used. For RTK operation, dual-frequency antennas are required that allow mapping areas of the territory with geodetic accuracy throughout the entire territory of the RTK network coverage.

GNSS receivers have the ability to receive signals from multiple satellite systems, reduce operating time and improve the quality and accuracy of measurements. GNSS receivers with RTK–in this configuration, the devices are equipped with transmitting and receiving radio or GSM modems [18], make it possible to obtain the final measurement result and assess the accuracy directly in the field in real time (RTK) with centimeter accuracy in a network of permanent reference GNSS stations.

The world practice of using active permanent stations began in 2000 [8]. Such reference stations are combined into a local/national network and work to implement RTK technologies [9]. In the geodetic sense, an active network of reference stations is a network of condensation from a network of permanent stations, although they differ in their functions, accuracy, and infrastructure.

In Ukraine, the technological equipment and software to ensure the determination of coordinates in the RTK mode is at the modern level. Today, there are networks of active reference stations that transmit differential corrections [19–24]: System.net, Geoterrace, RTK HUB, NGC.NET, UA-EUPOS/ZakPOS, System of coordinate-time and navigation support of Ukraine (Table 1). Each of them uses special software from Leica, Trimble, Topcon and ground GNSS stations. The UA-EUPOS/ZakPOS network and System.net are fully automated.

A network of RTK base stations is a certain number of permanently operating GPS/GNSS receivers, it is recommended to have a minimum of five base stations that combine accumulated satellite data and form RTK corrections for rovers. The distance between stations should not exceed 70 km, the overlap radius should not exceed 50 km for dual-frequency receivers. The observations made were based on the System.net network. This is a network of active permanent stations that issue corrections in the USK-2000 coordinate system indicating the accuracy of measurement results.

In general, all the necessary conditions for determining coordinates in RTK mode were created in the Poltava region. There are three separate services for transmitting corrections in real time: UA-EUPOS/ZakPOS, RTK HUB, System.net. Each of them uses special software from Leica, Trimble, Topcon and ground GNSS stations. The networks are fully automated.

The RTK HUB system provides 24/7 access to RTK correction service and satellite raw data. The following services are offered: 24/7 access; work from a network solution RTK; work from the nearest station; work from the selected station; per minute RTK access packets [22]. The cost of one hour in real time (RTK) depends on the chosen subscription and ranges from 0.65 UAH up to UAH 3.75 [5].

The EUPOS/ZakPOS network is fully built on the principles and requirements of EUPOS. Used hardware and software from Trimble. The cost of one minute of

Table 1 List of Ukrainian networks of permanent GNSS stations

No line number	Network name	Organization	Founded, year
1	System.net	PrJCK «System Solutions», c. Kyiv	2011
2	Geoterrace	Institute of Geodesy of Lviv Polytechnic National University, c. Lviv	2012
3	RTK HUB	Company «TNT-TPI» (TOPCON Representative Office in Ukraine), c. Dnipro	2005
4	NGC.NET	SPI «Navigation and Geodetic Center» (official dealer of Leica Geosystems, Switzerland), c. Kharkiv	2010
5	UA-EUPOS/ZakPOS	Company «ZakPOS» (ZakPOS Company (Trimble Representative Office in Ukraine), t. Mukachevo, Transcarpathian Region)	2009
6	System of coordinate-time and navigation support of Ukraine	National Center for Space Management and Testing, c. Kyiv	2010

observations of base and virtual stations (post-processing) is 0.036 €, which at the exchange rate is 1.18 UAH. The cost of one minute in real time (RTK) for 1 min is 0.06 €, which at the exchange rate is approximately 1.2 UAH [20].

The System.net network provides services for any consumer who has a GNSS receiver with the ability to receive RTK corrections from the Internet via a GSM/GPRS connection. RTK corrections are transmitted as standardized messages in various formats: RTCM v2.x, v3.x, Leica, Leica 4G, CMR, NMEA, etc. Networked Transport of RTCM via Internet Protocol (NTRIP) communication. You can register online and subscribe to the real-time service package through the service management system [19]. RTK is a basic package for operation, which includes functions of operation from a single base station–"nearest" and network solutions–Automax, I-Max, VRS. The System.net network provides a program in Telegram and Viber, with which you can find out the coordinates of the desired station or see the status of the nearest to us.

Today, there is a growing need in Ukraine to deploy a network of permanent reference GNSS–stations that accumulate data with the necessary accuracy characteristics of position, navigation and timing (PNT) around the clock. The presence of a network of GNSS stations in any region allows for centralized information support for users' geodetic work throughout the region. At the same time, in the network coverage area, users get the opportunity to achieve centimeter accuracy when using one geodetic receiver of satellite navigation signals [25].

But when determining absolute heights in a certain coordinate system, it is necessary to take into account the annual movement of reference stations. For example, for the POLV permanent network station, which is located on the territory of the Poltava Gravimetric Observatory, ITRF2014 velocities are VZ = 7.83 mm/year (relative to the center of mass of the Earth) [26], which takes into account movement of the Eurasian tectonic plate [1].

The necessary measurements on the geodetic polygon were performed by the Trimble R8 GNSS RTK receiver, which is specially designed for solving geodetic tasks using GPS by Trimble Integrated Surveying™ (USA). The Trimble R8 GNSS receiver has 72 channels for receiving signals: L1 C/A code, L2C, L1/L2/L5 carrier, GLONASS L1 C/A code, L1 P code, L2 P code and L1/L2 carrier. All SVs enabled.

It is possible to write data to an external controller for further processing of the received data. Technical characteristics of Trimble R8: vertical accuracy in RTK mode ±20 mm +1 mm/km; vertical accuracy in static mode with post-processing ±5 mm +1 mm/km.

Shooting with a GNSS receiver took place in April 2021. The obtained results are summarized in the Table 2.

The root-mean-square error of one measurement of a given series is calculated using the Gauss formula

$$m = \sqrt{\frac{\sum \Delta^2}{n}} = \sqrt{\frac{0.0922}{28}} = 0.057\,\text{m} \tag{1}$$

where Δ–true errors; n–number of measurements.

3 Results

Service [19] under favorable conditions makes it possible to determine the location within a few seconds with an accuracy of 10–20 mm in plan and 15–30 mm in height. Analyzing the data obtained, we see that six dimensions (second, fourth, sixth, twenty-first, twenty-fourth and twenty-fifth) have large deviations–from 35 mm to 21 cm (Fig. 2). In our case, this is about 20% of measurements. The origin of such deviations is excessive shading, which causes attenuation when the signal propagates directly through the leaves of the trees. 50% of measurements are within acceptable limits, but not ideal for accurate geodetic measurements (deviation is 1–3 cm). And only about 30% of the measurements have deviations of 1 cm.

Discard the «rough» results obtained at points A 13, Rp 4, A1, Rp 26, Rp 28, which arose mainly as a result of excessive shading. We get a graph of deviations with an average trend of 0.008 m (Fig. 3). These results provide a holistic characterization of the use of GNSS technologies to determine normal point heights.

The instruction for topographic survey [27] (п. 1.1.18) indicates that the average errors of the relief survey relative to the nearest points of geodetic justification should not exceed in height: 1/4 of the accepted height of the relief section at tilt angles up

Table 2 Comparison of the coordinates determined by the traditional method and as a result of the GNSS receiver

No line number	Item name	Height, m	Average height determined GNSS receiver	Deviation, Δ	Δ^2
1	Rp 7296	148.207	148.231	+0,024	0,0006
2	A 13	148.425	148.215	−0,210	0,0441
3	Rp 2	149.371	149.398	+0,027	0,0007
4	Rp 4	150.071	150.217	+0,146	0,0213
5	Rp 5	150.651	150.661	+0,010	0,0001
6	A 1	149.811	149.918	+0,107	0,0115
7	A 8	150.565	150.557	−0,008	0,0001
8	Rp 9	150.535	150.532	−0,003	0,0000
9	Rp 10	148.473	148.499	+0,026	0,0007
10	Rp 12	146.962	146.937	−0,025	0,0006
11	Rp 13	147.671	147.657	−0,014	0,0002
12	Rp 14	145.967	145.959	−0,008	0,0001
13	A 9	144.368	144.379	+0,011	0,0001
14	Rp 15	144.370	144.341	−0,029	0,0008
15	Rp 16	143.319	143.325	+0,006	0,0000
16	Rp 17	141.269	141.284	+0,015	0,0002
17	A 10	139.009	139.001	−0,008	0,0001
18	Rp 18	139.507	139.512	+0,005	0,0000
19	Rp 19	137.352	137.343	−0,009	0,0001
20	Rp 21	135.597	135.580	−0,017	0,0003
21	Rp 24	134.211	134.246	+0,035	0,0012
22	Rp 23	132.417	132.446	+0,029	0,0008
23	Rp 25	134.432	134.422	−0,010	0,0001
24	Rp 26	135.173	135.107	−0,066	0,0044
25	Rp 28	137.172	137.112	−0,060	0,0036
26	A 11	139.787	139.801	+0,014	0,0002
27	Rp 29	141.074	141.057	−0,017	0,0003
28	Rp 30	139.181	139.186	+0,005	0,0000
			$\sum$	−0,024	0,0922

to 2 degrees; 1/3 at angles of inclination from 2°. up to 6°. for plans of scales 1: 5000, 1: 2000 and up to 10°. for plans of scales 1: 1000 and 1: 500; 1/3 when the relief is cut through 0.5 m on plans of scales 1: 5000 and 1: 2000. In a forest area, these tolerances increase by 1.5 times.

In areas with tilt angles over 6°. for plans of scales 1: 5000 and 1: 2000 and more than 10°. for plans of scales 1: 1000 and 1: 500, the number of contour lines must

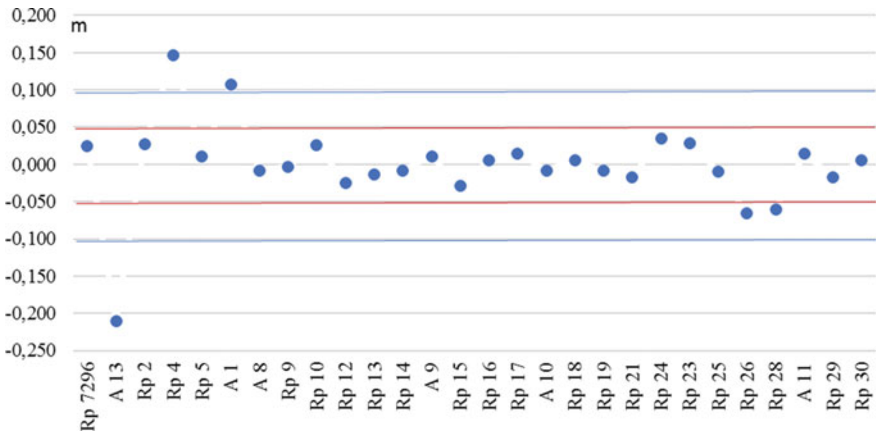

Fig. 2 Deviations in determining the normal heights of benchmarks using a GNSS receiver (according to Table 2)

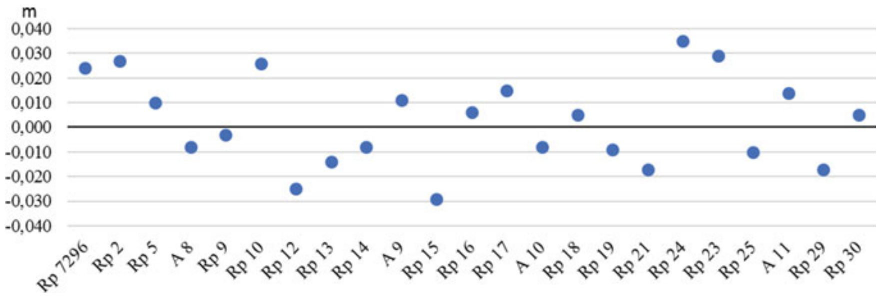

Fig. 3 Deviation in determining the normal heights of benchmarks using the GNSS receiver (excluding gross errors)

correspond to the difference in heights determined at the inflections of the slopes, and the average errors of heights determined at the characteristic points of the relief should not exceed 1/3 of the accepted height of the relief section. So, depending on the angles of inclination of the relief, respectively, and on the height of the relief section, the average survey errors can be different (Table 3).

However, such errors are permissible only for topographic surveys and are too large for accurate geodetic measurements. Taking into account the requirements [27], the vertical accuracy of the device in RTK mode (±20 mm) and the accuracy of the service [19] (up to 30 mm in height), the results of surveys at the geodetic test site are positive–all values are contained within the maximum permissible limits (Figs. 3 and 4).

Satellite radar can be used for geodetic monitoring of deformations of the Earth's surface. Today, this method of distance research is only becoming more widespread.

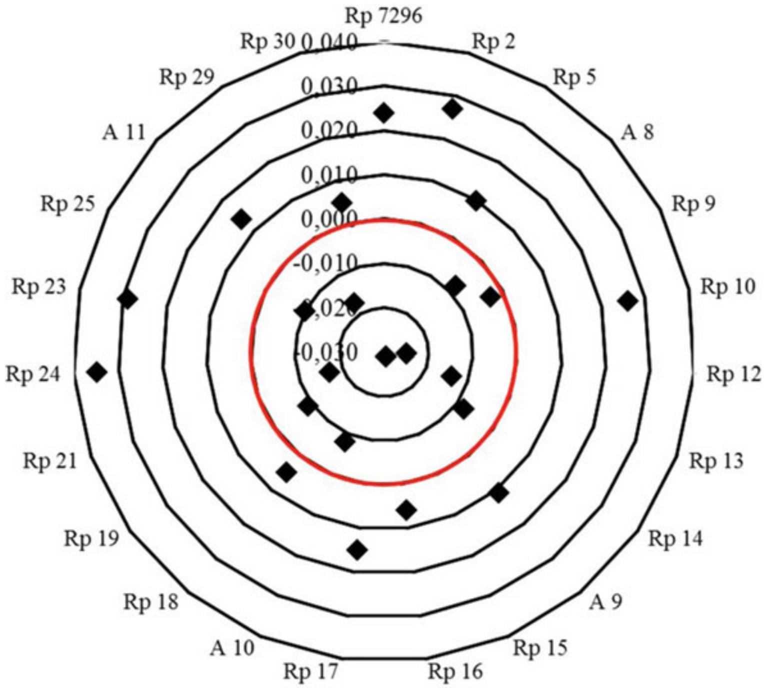

Fig. 4 Pie chart displaying deviations when determining the normal heights of benchmarks using a GNSS receiver (excluding gross errors)

The technological possibilities of obtaining space images of different spatial resolution have appeared–from 0.3 to 30 m [28]. However, the interferometric processing of Sentinel-1 data in the SNAP (Sentinel Application Platform) software allows obtaining the results of vertical displacements with millimeter accuracy. Radar images uploaded to the Copernicus Open Access Hub web platform, which was developed by the European Space Agency under the Copernicus program [28], are most often used for work. SNAP program can also process snapshots uploaded to the Vertex ASF Data Portal and SSARA. The capture range of one space image is 250 km. For geodetic purposes, we download Synthesized Instrument Radar (SAR) data in IW (Interferometric Wide Band) mode using the Terrain Observation with Progressive Scanning (TOPSAR) visualization method. Interferometric SAR (InSAR) uses the phase difference between two complex SAR radar observations of the same area taken from different sensor positions [29] and others [30, 31].

Be sure to check the meteorological reports for the specified dates, as snow, rain, ice, and so on can affect the results of the research. It was found that neither on October 8, 2020 nor on April 6, 2021 there were sub-zero temperatures and precipitation, and therefore the remote sensing data are suitable for further use.

Uploaded images go through very complex stages of processing: TOPSAR–Split—splitting the Sentinel–1 product into strips of selected parameters

Table 3 Average errors of survey of the relief relative to the nearest points of geodetic substantiation [27]

Relief characteristics and maximum prevailing tilt angles	Survey scale					
	1: 5000		1: 2000		1: 1000 1: 500	
	Relief section height, m	Average errors, m	Relief section height, m	Average errors, m	Relief section height, m	Average errors, m
1. Plain, with slope angles up to 2°	0,5	0,167	0,5	0,167	0,5	0,125
	1,0	0,250	1,0	0,250		
2. Hilly, with slope angles up to 4°	1,0	0,333	0,5	0,167	0,5	0,167
	2,0	0,667	1,0	0,333		
3. Intersected, with inclination angles up to 6°	2,0	0,667	1,0	0,333	0,5	0,167
	5,0	1,667	2,0	0,667	1,0	0,333
4. Mountain and foothills, with slopes of more than 6°	2,0	0,667	2,0	0,333	1,0	0,333
	5,0	1,667				

(swath, polarization, bursts); Apply–Orbit–File—update of orbit metadata; Back–Geocoding—conversion of GNSS coordinates into geometric parameters with finding the location of the object; Enhanced–Spectral–Diversity—assessment of constant azimuthal shift between radar images, elimination of phase gaps in bursts; Interferogram—combining the phases of two images, creating an interferogram; TOPSAR–Deburst—merging of adjacent subbands with the same time tag, polarization of the "burst" product; TopoPhaseRemoval—removal of various topographic deviations relative to a number of evenly spaced strips; Multilook—averaging values stored in neighboring image pixels, increasing pixel sizes, decreasing resolution; GoldsteinPhaseFiltering—restoration of the quality of the bands of the phase image (signal/noise) using a specialized Goldstein phase filter; SnaphuExport—export of the received products to SNAPHU, an application with which interferogram phase unfolding is carried out.

The last algorithmic step of Phase Unwrapping involves unwrapping the filtered interferogram outside of SNAP using the SNAPHU application.

The expanded results should be interpreted as the relative vertical/horizontal displacements between the pixels of the two images.

The Export operator will create a directory with the files "Consistency", "Collapsed phase", "Expanded phase", "Configuration file".

It is uploaded the resulting product with the *kmz extension to the Google Earth application, combining the results of vertical displacements of the Earth's surface with a 3D satellite image (Figs. 5 and 6).

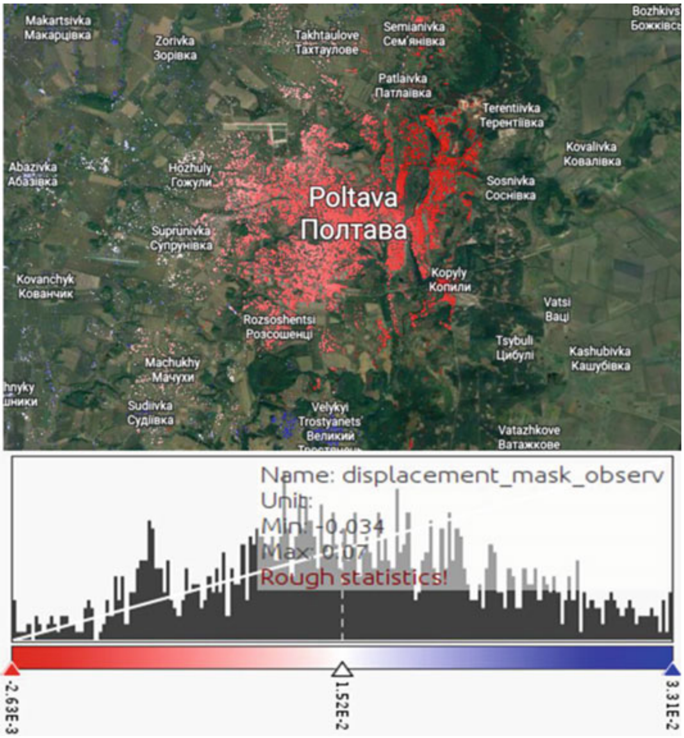

Fig. 5 General view of the city of Poltava (Ukraine) on the Google Earth map with display of vertical displacements (m) between two pictures for 08.10.2020 and 06.04.2021

Fig. 6 Geodetic polygon (□) of the Poltava Gravimetric Observatory (city of Poltava, Ukraine) on the Google Earth map with the display of vertical displacements between the two images from 08.10.2020 to 06.04.2021

The satellite radar technology has its advantages and disadvantages. Radar surveying does not depend on the cloudiness and illumination of the territories, the time of day. It allows to obtain global and local information about objects, perform retrospective processing due to the use of archival photography, which cannot be done with traditional geodetic methods. But at the same time, we must take into account the resolution of the images we use. The higher the resolution, the more precisely the processing result is superimposed on a planar surface.

The map of terrain deformations, which was obtained as a result of the processing of radar images in the SNAP software, confirms the reference data taken by the traditional ground method of geometric leveling. According to the color palette, the maximum displacements of the Earth's surface on the geodetic polygon were within 1–2 mm (Fig. 6).

To determine the vertical shifts of the relief on the territory of the Poltava gravimetric observatory, it has been used the publicly available satellite methods of studying deformations of the earth's surface. To obtain high-precision point results, there are commercial proposals that allow obtaining spatial relief displacements with high plan accuracy (which depends on the resolution of the images) [12].

4 Conclusions

Observations and research conducted on the territory of the Poltava gravimetric observatory of the Institute of Geophysics named after S.I. Subotina, showed complementary results. The satellite radar is convenient to use, since with the help of remote monitoring, without leaving the area, it is possible to detect terrain shifts of various kinds and types. It is possible to constantly carry out operational research, especially in places of man-made hazardous areas or in urbanized areas, where sudden dangerous situations for people may arise. The satellite radar is effective over large areas, when a general trend of displacement can be observed. Further, having identified dangerous areas, having in the arsenal the most available technologies and means for determining deformations of the earth's surface, it is possible to obtain fairly accurate geodetic results for individual points.

The use of network RTK has a number of advantages compared to individual base stations: higher accuracy, simplicity, economy, speed of shooting, versatility, the ability to work at almost any point. And the vast majority of surveyors in Ukraine are guided by this motivation. However, the main technological and legislative "obstacles" should be singled out.

First of all, the main legislative document in this area is the Instruction on topographical surveying at the scales of 1:5000, 1:2000, 1:1000 and 1:500, which has been in effect since 1999. The Instruction does not yet specify the possibility of using GPS/GNSS technologies with RTK corrections for topographic surveying. According to the order of the State Geocadastre, a working group was created until August 2, 2021 to develop the project of the Order of topographic survey at scales of 1:5000, 1:2000, 1:1000 and 1:500. The new regulatory document should contain provisions on the use of the latest geodetic, including satellite, technologies.

Secondly, one should keep in mind the permissible accuracy of the received data. The geometry of the satellite configuration with such a number of satellites in the visibility zone (in our case 8–14) practically does not affect the planned position of the points, but it has a significant impact on the accuracy of determining normal heights. Therefore, today the main and most accurate method of finding the heights of points is geometric leveling.

Thirdly, it is necessary to follow the instructional recommendations regarding topographic surveying in the built-up area. Conducted studies have shown that multi-beam propagation and shadowing phenomena may occur when GNSS is captured by receivers, when a multi-beam signal is reflected from another building or object, the path of the direct path may be densely shadowed, and the receiver can only track multi-beam signals. Therefore, the most appropriate use for topographic surveying in a settlement is a mixed method using a total station and a GNSS receiver.

Acknowledgements Special thanks to the employees of the Poltava Gravimetric Observatory of the Institute of Geophysics National Academy of Sciences of Ukraine by S.I. Subbotin, in particular V.H. Pavlik, for the opportunity to conduct research on this territory.

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Reliability Comparison Method of Rural Settlements Water-Supply

Valeriy Novokhatniy, Oleksander Matyash, Gulnar Feyziyeva, and Sergiy Sadovyi

Abstract The paper presents a method that allows to compare the reliability of rural settlements water-supply with a branched water-supply network. First of all, it is needed to choose the main reliability indicator. It should be noted that the range of possible reliability indicators is significant. The main reliability indicator for comparison is the readiness coefficient C_R. To calculate this value, it is needed to calculate the average operating time for failure T and the average recovery time T_R. The failure criterion is the situation when at least one of the water-supply network sections or well is not operational. The implementation of the method is shown by comparing the water-supply reliability of two rural settlements according to the water-supply networks and wells plans. As a result of calculations of the reliability quantitative indicators values are received. They showed that the faultlessness of water supply in the village "A" is 10.5% higher than in the village "B". Thus, it is shown that the proposed method allows to perform a comparative analysis of any number of water-supply systems with branched networks.

Keywords Water-supply system · Reliability · Faultlessness · Repairability · Readiness coefficient

1 Introduction

The water-supply system of a rural settlement usually includes a well, a water tower and a branched water-supply network. In the case of high quality groundwater, it is supplied by submersible pumps directly into the water-supply network. If the water-supply network is branched, then there is only one way to supply water to the consumer. In this case, the water-supply reliability to consumers can be determined

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_39

by assessing the reliability of the elements that are connected in series on this path—from the well to the final consumers. But in this way it is impossible to compare the water-supply reliability of settlements among themselves. This paper proposes a method for such a comparison.

2 Problem Statement

Providing the population with drinking water is one of the priority tasks, the solution of which is necessary to maintain health, create conditions for quality activities and the appropriate level of cultural and household services. However, the current state of water-supply systems in Ukraine is assessed as inefficient, given the significant wear of technological equipment, the use of outdated water treatment technologies, drinking water-supply and distribution facilities, which leads to high energy consumption and reduced water-supply reliability. However, some issues of preventing further deterioration of this situation, even at the design stage of new and reconstruction of existing systems, can be achieved without significant capital investment. For example, the issue of the water-supply reliability assessing in the variant design of individual structures, including water-supply networks. But this requires the appropriate methods development and, based on them, waterworks reliability calculating methods.

3 The Aim of Research

The supply and distribution complex (SDC) of rural settlements water-supply systems is based on branched type water-supply networks. In this case, it caould be determined the water-supply reliability in each water-supply direction to ultimate users [1]. But if it is necessary to compare the reliability of settlements water-supply systems, it is impossible to do so. The purpose of the article is to present the method developed by the authors to compare the water-supply reliability in rural areas by the readiness coefficient.

4 Recent Research Analysis

The problem of water-supply systems reliability is so complex and multifaceted that it does not leave without the attention of both scientists and practitioners in the field of water-supply. This is due to the fact that: first, the concept of reliability is complex and includes three main components [2]: faultlessness, repairability and durability. These technical characteristics are probabilistic, and therefore it is necessary to use statistics on individual waterworks and equipment operation. And only after that to develop methods and to make techniques for constructions and systems reliability quantitative indicators calculation. Secondly, the mathematical modeling of the waterworks functioning is quite complex due to the fact that these are streams of random events. Scientists use a wide range of methods—from classical [3–5] to modern genetic algorithms [6]. Third, the water-supply reliability to the population with drinking water depends not only on the water-supply reliability, but also on the quality of water reaching consumers. This is due to the possible deterioration of drinking water quality during its transportation to consumers. A number of works, including by foreign scientists [7], evidences this aspect of reliability.

5 Main Material

5.1 Failure Criterion

Water-supply systems work for different consumers, who have different requirements for the water-supply reliability level. Quantitative indicators of reliability, namely—reliability, repairability and durability, quite a lot. Durability issues are considered when choosing pipes or waterworks material. In the operation water-supply systems process of, reliability and maintainability come to the fore.

Experts in the reliability theory recommend [8] to choose the main reliability indicator for faultlessness and repairability, taking into account, first of all, the failure consequences. Professor, D.Tech.Sc. Novokhatniy in his study [9] proposed to group water consumers depending on which factor is dominant in assessing the failure consequences. He noted that the dominant factors, which are fundamentally different in assessing the water-supply failure consequences, can be distinguished only two: the risk of interruption in water-supply and the break duration, and therefore all water consumers were divided into two groups. The first group—productions with a continuous technological process in nuclear energy, metallurgy, petrochemical, chemical, medical industries, with the use of explosives, toxic substances, nuclear and missile fuels, etc. The danger of interruption in water-supply is dominant, as it can cause death or environmental catastrophe. All other consumers who are not included in the first group are assigned to the second group. Dominant for them is the water-supply break duration, which leads to the usual material or moral losses for consumers. This group also includes centralized water-supply systems of settlements (Table 1).

It is known that the faultlessness operation probability P (t) is the probability that the water-supply system will work without failure from the beginning and for a certain time (for example, one year). The readiness coefficieny $\boldsymbol{K_R}$ determines another probability, namely—the probability that at any time the water-supply system is in operating mode. To calculate the readiness coefficient, it is needed to know two basic reliability indicators—the average operating time to failure $\boldsymbol{T}$ and the average recovery time $\boldsymbol{T_R}$.

Table 1 Classification of consumers and water-supply systems by reliability

Consumer groups	Groups and categories of water-supply systems	Values of main and basic reliability indicators		
1	First group			
	Subgroup A—water-supply systems of hazardous industries	Maximum of the faultlessness operation probability during the service life max $P(T_{sl})$		
	Subgroup B—fire water-supply systems	Maximum of the readiness operational coefficient for 3 h of fire localization max $K_{RO} = K_R \cdot P(\tau)$		
2	Second group			
	Centralized water-supply of settlements with the number of inhabitants	Operating failure time T, hours	Average recovery time T_R, hours	Readiness coefficient K_R
	1 category			
	Cities N ≥ 50 thousand inhabitants	T≥ 2160 h (3 months)	$T_R \leq 3$ h	0,99,861
	2 category			
	Towns 10 thousand ≤ N ≤ 50 thousand inhabitants	T≥360 h (0,5 months)	$T_R \leq 6$ h	0,98,361
	3 category			
	Villages N < 10 thousand inhabitants	T≥360 h (0,5 months)	$T_R \leq 24$h	0,93,750

The rural settlement water consumer intuitively assesses the reliability of the water-supply system through the house water-supply. That is, the water consumer evaluates 2 factors: how often there is no water in the house and how long the water-supply break lasts. Therefore, the reliability of water-supply as a technological process is determined by the water-supply system reliability and should be assessed by the average time between water-supply breaks T and the average duration of such T_B breaks. In other words, reliability calculations should answer two questions—how often and how long there will be no water in the consumer's house. If we are talking about a separate settlement with an extensive water-supply network, then this problem is solved [1] by the reliability determination of water-supply from the source to the final consumers in certain water-supply directions. But it is impossible to compare the water-supply reliability in settlements in this way—you need a "convolution" of indicators.

It is proposed to introduce the following failure criterion, which allows to obtain one specific value of the readiness coefficient for the water-supply system as a whole. We will consider a working water-supply system only when all structures and all sections of the water-supply network are in operational mode. Given that the readiness coefficient is the probability, the introduced criterion is the product of the well readiness coefficient and the readiness coefficient of the network individual sections. It can be calculated by Eq. (1)

$$K_R = K_R^w \cdot \prod_{i=1}^{n} K_{Ri}, \tag{1}$$

where K_R—the readiness coefficient of the i-th network section;

K_R^w—well readiness coefficient;

$\boldsymbol{n}$—the number of the water-supply network sections.

$$K_{R_i} = \frac{T_i}{T_i + T_{R_i}}, \tag{2}$$

$\boldsymbol{T_i}$—average operating time for failure of the i-th water-supply network section, hours;

T_{R_i}—average recovery time of the i-th water-supply network section, hours.

Average operating time for failure of the section

$$T_i = \frac{1}{\omega_i} = \frac{1}{\omega_0 l_i}, \text{ hours} \tag{3}$$

where $\omega_{\mathbf{i}}$—failure flow parameter of the i-th section, 1/hour;

l_i—the section length, km;

ω_0—specific parameter of the pipeline failure flow, 1/hour·km.

The reliability calculations implementation in accordance with the above method will be shown for the plans of two rural settlements. Due to the fact that both villages water-supply system has a water intake well, we first calculate its reliability.

5.2 *Reliability of the Well*

The well design includes a filter, well casing, pump unit, water-riser pipe, control unit, valve and back pressure valve (Fig. 1). Failure of each well element leads to well stop. Therefore, in terms of reliability, these elements are connected in series. The mathematical model for the well reliability calculating adopted the chain of these series-connected elements.

Well faultlessness is estimated by the failure flow parameter, which is calculated as for series-connected renewable elements according to Eq. (4)

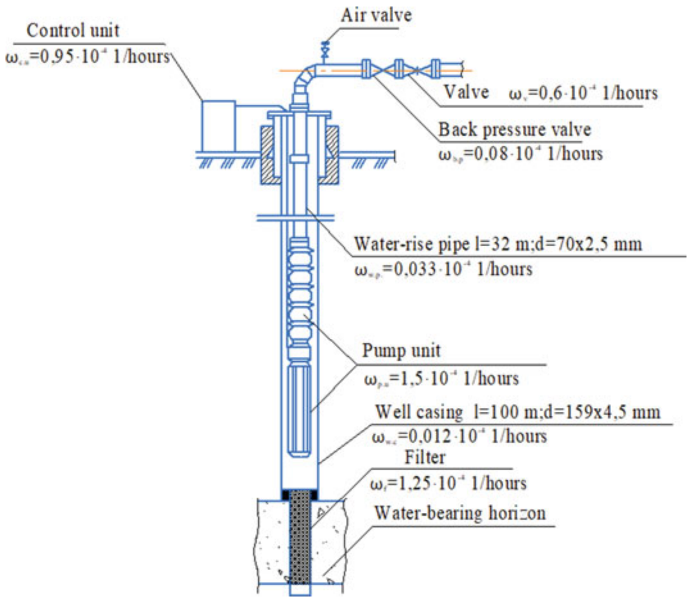

Fig. 1 Well scheme with reliability indicators

$$\omega = \omega_f + \omega_{w\cdot c} + \omega_{p\cdot u} + \omega_{w-r\cdot p} + \omega_{c\cdot u} + \omega_v + \omega_b,\ 1/\text{hour}, \quad (4)$$

where $\boldsymbol{\omega_f}, \boldsymbol{\omega_{w.c}}, \boldsymbol{\omega_{p.u}}, \boldsymbol{\omega_{w\text{-}r.p}}, \boldsymbol{\omega_{c.u}}, \boldsymbol{\omega_v}, \boldsymbol{\omega_b}$—flow failure parameters of filter, well casing, pump unit, water-riser pipe, control unit, valve and back pressure valve, 1/hour.

Use the Ilyin YuO reliability data [10] of the water intake well individual elements and perform calculations.

Flow failure parameter of well casing steel pipe with a diameter of 159 mm

$$\omega_{w.c.} = \omega_0 l_{w.c.} = 0,12 \cdot 10^{-4} \cdot \frac{120}{1000} = 0,00000144 = 0,0144 \cdot 10^{-4}\ 1/\text{hour}$$

where $\boldsymbol{l_{w.c.}}$ = 120 m—well casing lenght;

$\boldsymbol{\omega_0}$ = 0,12·10^{-4} 1/hour·km—specific parameter of the pipe failure flow.

Flow failure parameter of water-rising steel pipe with a diameter of 70 mm

$$\omega_{w-r.p.} = \omega_0 l_{w-ree.P} = 0,12 \cdot 10^{-4} \cdot \frac{85}{1000} = 0,0000086 = 0,086 \cdot 10^{-4}\ 1/\text{hour}$$

where $\boldsymbol{l_{w\text{-}r.p.}}$ = 85 m—water-rising pipe length;

$\boldsymbol{\omega_0}$ = 1,02·10^{-4} 1/hours·km—specific parameter of the pipe failure flow.

Flow failure parameter of water intake well

$$\omega = (1,25 + 0,0144 + 1,5 + 0,086 + 0,95 + 0,08 + 0,6) \cdot 10^{-4} = 4,48 \cdot 10^{-4}\ \text{1/hour.}$$

Average operating time for failure of the well

$$T = \frac{1}{\omega} = \frac{1}{4,48 \cdot 10^{-4}} = 2232\ \text{hours}$$

The average recovery time of the well will take, according to the operation data, $\boldsymbol{T_R}$ = 12 h.

Well readiness coefficient

$$K_R^w = \frac{2232}{2232 + 12} = 0,994652$$

5.3 Plans of Villages Water-Supply Networks

Next, calculate the reliability of water-supply networks. After performing hydraulic calculations, the water-supply network is designed, which is presented in Fig. 2 (village "A") and in Fig. 3 (village "B").

Polyethylene pipes with a diameter of 63, 75, 90 and 110 mm are accepted for a water-supply network. According to Khramenkov SV data [11] specific failure flow parameter for polyethylene pipes $\omega_0 = 0,44$ 1/year·km or 0.00005 1/hour·km, which corresponds to approximately one failure per 2 years of a polyethylene pipe with a length of 1 km. The average recovery time of the pipe section will take 8 h. Assuming the exponential distribution laws, interval estimates are obtained using confidence limits coefficients [12–14] with confidence probability $\alpha = 0,095$.

5.4 Network and System Reliability

Water-supply reliability calculations in both villages are performed in tabular form (Tables 2 and 3).

With almost the same average recovery time of the village water-supply system (Table 2), we have a significant difference in faultlessness (Table 1). The operating time for failure in the village "A" T = 1765 h is 10.5% more than the operating time for failure in the village "B" T = 1573 h.

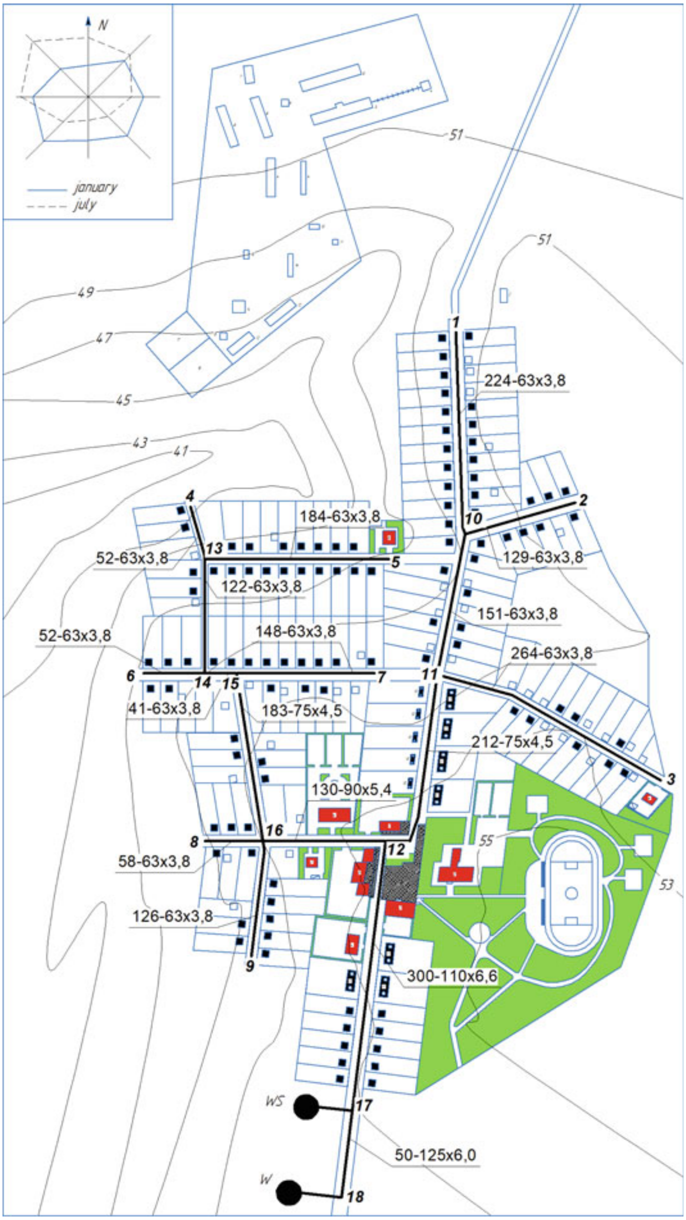

Fig. 2 Plan of the village “A” water-supply network

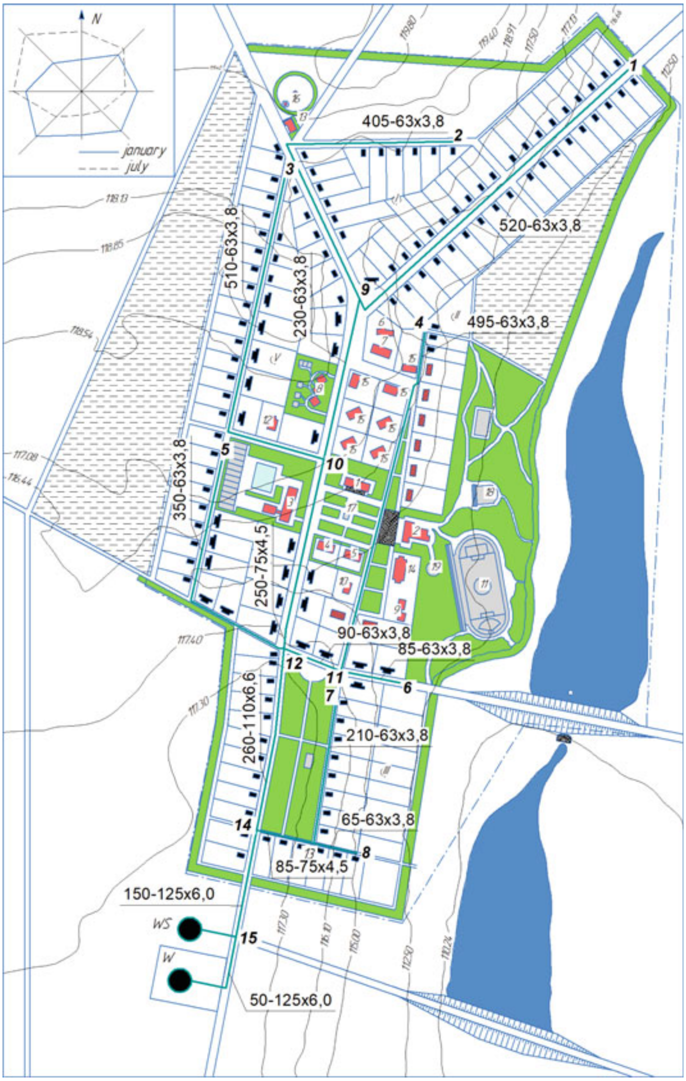

Fig. 3 Plan of the village “B” water-supply network

6 Conclusions

1. The main reliability indicator for the rural settlements water-supply systems should be the readiness coefficient $\mathrm{K}_{\boldsymbol{R}}$, and the basic reliability indicators are the average operating time to failure $\boldsymbol{T}$ and the average recovery time $\boldsymbol{T_R}$.

2. The water-supply reliability comparative analysis in two rural settlements showed that in the village of “A” the water-supply system faultlessness is 10.5%

Table 2 Faultlessness calculations

Total length of the pipes ***L***, m	Failure flow parameter				Average operating time for failure			Interval assessment ***T***, hours	
	Specific ω_0, 1/hour·km	Network $\omega_m = \omega_0$, 1/hour	Well ω_{c_6}, 1/hour	System ω = ω_{c_6}, 1/hour	Network T^m, hours	Well T^{c_6}, hours	System T, hours		
Village "A"									
2426	0,00,005	0,0,001,213	0,000,448	0,0,005,693	8244,0	2232,1	1756,5	1111,7…	2583,0
Village "B"									
3755	0,00,005	0,0,001,817	0,000,448	0,0,006,357	5327,6	2232,1	1573,0	953,3…	2247,1

Table 3 Readiness calculations

Readiness coefficient			Average recovery time of the system $T_R = \frac{T}{K_R} - T$, hours	Interval assessment T_R, hours
Network K_R^n	Well K^w	Water-supply system $K_R = K_R^w \cdot K_R^n$		
Village "A"				
0,99,903	0,994,652	0,993,688	11,1	7,0…16,3
Village "B"				
0,9985	0,994,652	0,993,161	10,8	6,5…15,9

higher than in the village of "B". Calculations have shown that in village "A" water-supply breaks should be expected about 1 time per 2.5 months with duration 11.1 h, and in village "B" water-supply breaks should be expected about 1 time per 2 months with duration 10.8 h.

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The Organization of the City Pedestrian Network in the Conditions of the Development of Individual Transport Types

Halyna Osychenko, Boguslaw Podhalanski, Olga Tyshkevych, and Volodymyr Toporkov

Abstract The rapid development of alternative means of individual transport creates great opportunities for free movement of residents within the city, but also threatens the expansion of new types of transport to the pedestrian areas of the cities. New alternative types of individual transport and the possibility of their combination with pedestrian traffic are analyzed in the article. The main criterion for the safety of individual traffic for pedestrians is a body momentum. The principles, corresponding approaches and methods of pedestrian network formation in the city in the conditions of development of alternative types of individual transport are defined (the principle of differentiation, the principle of coherence of road infrastructure networks, the principles of conformity, concentration and succession).

Keywords Body momentum · Individual transport types · Organization of the city pedestrian network · Pedestrian and walking network of the city · Safety

1 Introduction

The actuality of the topic and the problem. The modern period of urban development is connected with the ideology of ecological urbanism and involves the formation of a pedestrian environment in cities, which is apt to natural development and can adapt to local conditions. Pedestrian spaces are seen as means of creating new socio-cultural connections in the city and as an important factor in solving social problems of the city, formation of a healthy social climate and the development of social communication between city residents. The emphasis in the urban design is shifted

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_40

to the need to provide walking in cities, which leads to the improvement of residents' health. In urban planning a new design object–pedestrian and walking spaces of the city (PWS) is defined. The COVID 19 virus pandemic has revealed a lack of urban public spaces for recreation and walking, as the citizens had been displaced by cars. It also highlighted the need to develop a network of pedestrian and walking spaces in cities.

In turn, the rapid development of alternative types of individual transport creates great opportunities for free movement of residents within the city. It also improves the environmental situation. However, it is necessary to analyze the consequences of mass use of individual transport taking into account its impact on urban use and to reconcile the needs of all participants of urban traffic. Nowadays there are not any clear criteria for assessing the level of danger that is made by different types of vehicles in the urban environment and in particular in the areas provided for pedestrians.

Thus, the relevance of the research topic is determined by the lack of pedestrian and walking spaces in cities and there is a need for theoretical reflection on the peculiarities of the urban network formation of PWS in connection with the development of new alternative types of individual transport.

The analysis of recent research and publications. The theoretical basis of the research is the works of domestic scientists of the 1980s by Bezrodny [1], Bug [2], Valeev [3], Lieberman [4], Pronin [5], who studied and analyzed the historical experience of the organization of pedestrian zones in cities. The concept of a pedestrian-friendly city adopted by the Charter of Pedestrian Rights (1988) was updated in the late XX–early XXI century. In the Charter the study of the urban level of the single network organization of PWS in the city was taken into account. It was highlighted in the works by Sotnikova [6], Shesterneva [7], Osychenko [8] and in the European concept of a *walkable city*, which was formulated by the followers of "new urbanism" [9]. Fruin [10], Gejl [11], Kolman [12], Cambra and Moura [13], Anciaes and Jones [14], Watkins et al. [15] studied the issues of assessing the quality of existing pedestrian spaces.

The approaches to the formation of pedestrian spaces were analyzed in the works by Hussein [16], Özdemir and Selçuk [17]. They studied the strategies for the priority of pedestrian traffic in the city; the strategies for differentiating pedestrian traffic from automobile one horizontally [18] and vertically [19]; the strategies for integrating pedestrian traffic with other road users–shared space [20, 21 22]. The analysis and the strategy of the development of underground pedestrian spaces of the city were presented in the work by Jianjiang Cui [23].

Current trends in the design and methods of PWS formation in cities are considered taking as the example the implementation of pedestrian zones and spaces in cities from Europe, America, Australia, etc. References [24–29], as well as taking into account the works by Carmen Hass-Klau [30], Jeff Speck [31], decisions of The International Transport Forum (OECD) (2011, 2014), corresponding reports of the European Commission responsible for Environment [31] and the Institute for Road Safety Research [32–36] which were dedicated to the development of pedestrian and bicycle traffic.

The analysis of new alternative individual types of transport was carried out on the basis of information provided by manufacturers on their websites [37–45].

The obtained world practical experience in the implementation of pedestrian zones is undoubtedly valuable for other countries in order to prevent mistakes in practice, but it should be adapted to the conditions of Ukrainian cities, taking into account regional and local peculiarities and the state of existing pedestrian areas. In addition, the existing theoretical research does not fully consider the formation of pedestrian space network of the city as a single, integrated design object taking into account the development of alternative types of individual transport.

The purpose of the article is to determine the principles of the formation of the pedestrian and walking spaces network in the city in the conditions of the development of new alternative types of individual transport. Within the specified purpose the following tasks are considered: the analysis of new alternative types of individual transport and possibilities of their combination with pedestrian traffic; the determination of organization principles of PWS network in the city.

The scope of the research is determined by the urban level of the network organization of PWS in the city.

The research methodology. The research is based on the main regulations of the systematic approach in urban planning, the general scientific research methods are also used: comparative analysis, systematization, abstraction and information synthesis. The algorithm of the research methodology includes several stages:

- The analysis of the possibilities of alternative types of individual transport, systematization of individual vehicles regarding potential danger in case of collision with a person;
- The study of the possibilities of connecting different types of vehicles with pedestrian traffic;
- The determination of the principles and methods of reorganization of PWS network in the city.

Methods of the historical, comparative, statistical analysis, the analysis of literature sources, as well as the analysis of the experience of innovative global strategies concerning implementation of pedestrian zones in cities in order to identify current trends, ways and methods of improving existing pedestrian systems were applied in the article.

In order to rank vehicles by danger to pedestrians, the method similar to the one in the automobile industry was used. The contact physics between bodies reflected in the appearance and action of the body momentum (p) was taken into account. Body momentum index along with other factors determine the consequences of a collision between individual road users, revealing the potential danger of vehicles to others. The value of the body momentum is determined by:

$$\mathbf{p} = \mathbf{mv}$$

where: m—*mass*, v—*velocity*.

For greater accuracy of the results the contact time between bodies at the time of the collision is the same for all types of vehicles. In most cases a collision of a running person with a standing person does not lead to fatal consequences. Therefore, in the research all the impulses of the vehicles are compared with body momentum of a person who weighs 80 kg and runs at a speed of 15 km/h (equal to 336 kg × m/s). For comparison, the body momentum of a city car is 15030 kg × m/s (at a speed of 60 km/h) and 7515 kg × m/s at a limited speed of 30 km/h, which is accepted for pedestrian zones in Europe.

2 Outlining of the Main Material

The analysis of the widespread and perspective types of modern individual means of movement (Personal transporter or self-moving transport) according to the following criteria: driving force, mass (kg), maximum speed (km/h), overall width on front (cm) was carried out. The body momentums of all analyzed vehicles were determined (in Table 1).

In view of the fact that a large number of models of certain types of vehicles are presented on the market, the average indicators of models designed for operation in urban conditions were takenfor estimation. The parameters of the front projection of the vehicle, which are important for assessing its compliance with the parameters of street profiles are also shown in the table. From the above mentioned samples it is obvious that the developers follow a single approach in the design of vehicle dimensions and do not go beyond 80 cm on front, which corresponds to the lane of a person's movement.

The growth of the vehicle mass significantly increases its momentum that leads to the risk of a serious injury in case of a collision. Almost all the latest vehicles are electric, so they use different types of batteries. The considered vehicle samples showed a steady tendency to the increase of their mass and, accordingly, the increase of their body momentum. In turn, it makes them more dangerous compared to a traditional bicycle. For some types of electric vehicles (for example, Segway) even a small passport speed (20 km/h) does not compensate for the high rate of body momentum (700 kg × m/s), which is a consequence of its high weight (55 kg).

The conducted ranking of individual means of transport by the value of body momentum is shown in Fig. 1 and it indicates the potential danger in case of a collision with a person.

According to the value of the body momentum there are 3 gradations of vehicles: from 367 to 400 kg × m/s; from 400 to 1900 kg × m/s and from 1900 to 4500 kg × m/s and more. Their comparison with the body momentum of the car at different speeds shows that the second category of vehicles is quite dangerous for pedestrians. In addition, it is dangerous, if it is combined with traffic. This category of individual

Table 1 Comparative analysis of individual vehicles

	Technical characteristics of individual means of transport				
General view Personal transporter	Driving force	Mass (Kg)	Max speed (km/h)	Front width (cm)	Body momentum (kg × m/s)
1	2	3	4	5	6
1. Electric rollers					
	Electrical	3,3	16	–	367
2. Gyro rollers					
	Electrical	3,5	16	–	367
3. Veloriksha					
	Muscle power	30	15	108	462
4. Bike					
	Muscle power	15	20	64	532
5. GyroSkooter					
	Electrical	16	20	70	538
6. GyroSkooter with a pen					
	Electrical	14	20	70	538

(continued)

Table 1 (continued)

	Technical characteristics of individual means of transport				
7. Segway					
	Electrical	55	20	70	700
8. Electric skate					
	Electrical	9,5	39	30	967
9. Electric bike					
	Electrical	25	35	56	1019
10. Electric cycle					
	Electrical	70	25	80	1035
11. Unicycle					
	Electrical	29	80	20	1667
12. Segway mini					
	Electrical	40	50	60	1668
13. Electric scooter 1					
	Electrical	305	60	50	1845

(continued)

Table 1 (continued)

	Technical characteristics of individual means of transport				
14. Electric scooter 2					
	Electrical	56	80	70	3019
15. S-pod					
	Electrical	330	38	80	4346

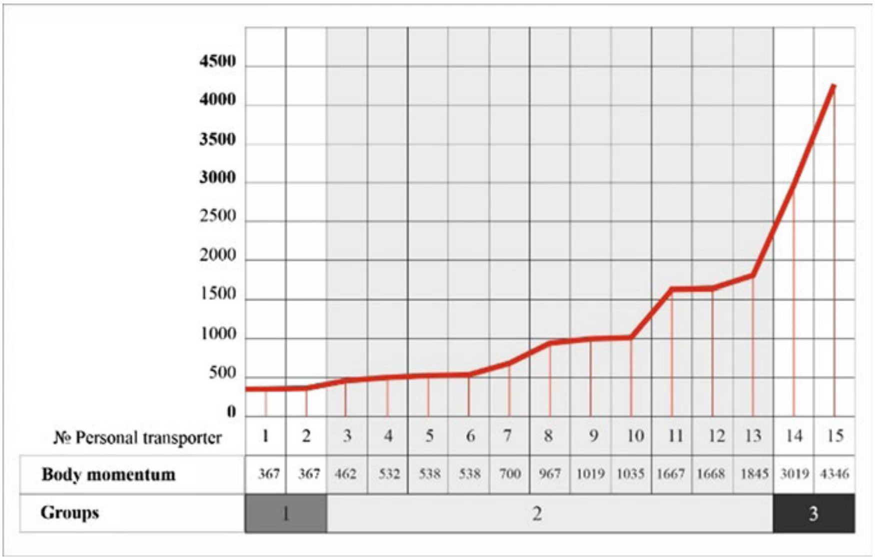

Fig. 1 Ranking of individual means of transport by body momentum indicator

vehicles is quite significant in number and variety of types and requires the formation of its own network.

Taking into account the indicators of body momentum, overall width, the possibility of combining with pedestrian traffic and with each other, it is suggested to distinguish 3 groups of individual transport (Fig. 1).

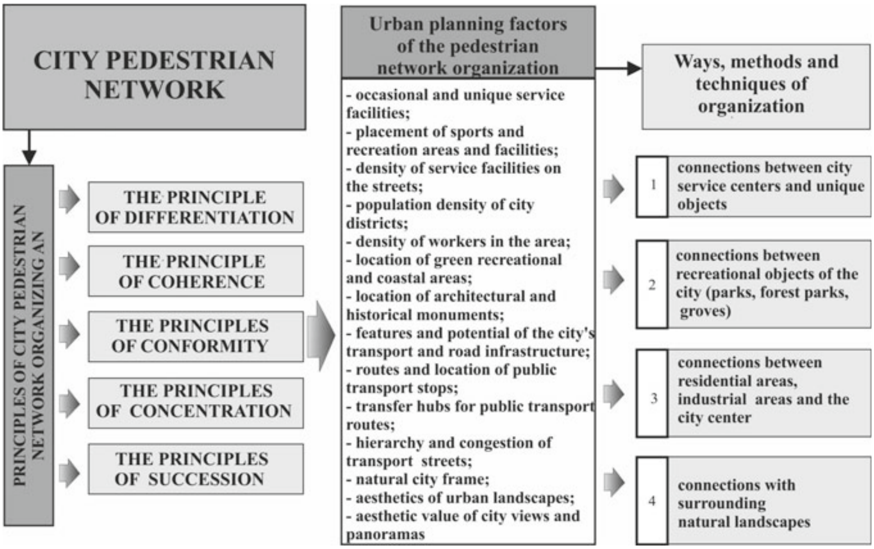

Fig. 2 Model of the organization of the city pedestrian network

(1) A group of combination with pedestrian traffic (electric rollers, gyro-rollers);
(2) A group of alternative traffic (bicycle, gyro-scooter, gyro-scooter with a handle, segway, electric skate, electric bicycle, electric cycle, unicycle, mini segway);
(3) A group of combination with automobile traffic (electric scooter, S-pod).

Within the concept of pedestrian traffic priority, the principles of a pedestrian network formation in the city considering the development of alternative individual means of movement are formulated in the research (Fig. 2): *the principle of differentiation, the principle of coherence of road infrastructure networks, the principles of conformity, concentration and succession.*

The main principle of network formation is *the principle of differentiation*, which determines the need for *spatial separation of pedestrian traffic from other participants in road transport infrastructure*. At the level of the city and urban district, the principle is implemented in *the differentiation of road infrastructure networks and the separation of the pedestrian network from the network of alternative traffic.* Thus, in the road transport network the formation of several independent networks are suggested:

- Pedestrian traffic network (pedestrians and group (1) combination with the pedestrian traffic);
- Network of alternative individual vehicles (group (2) of individual alternative vehicles);
- Car traffic network (cars and group (3) of combination with car traffic);
- Public land transport network;
- Underground network or other underpass public transport network, if available.

The principle requires to start the organization of the entire road transport infrastructure from the formation of pedestrian traffic network and the creation of comfortable and safe conditions for pedestrians. At the level of spaces, the principle is achieved: by spatial separation of pedestrian traffic; spatial distribution of traffic participants within PWS system; differentiation of pedestrian spaces into functional zones taking into account a set of social roles and places of human behaviour; functional specialization of separate pedestrian zones and streets of the city while designing (pedestrian and walking, trade and pedestrian, shopping zones, recreational, tourist and pedestrian, exposition, combined pedestrian spaces, etc.).

The road network, which once displaced pedestrians from the city streets, nowadays corresponds to the planning system of the city. *Based on the world experience, several possible ways of the pedestrian network interaction with other networks are determined (Table 2): reexpansion of pedestrian traffic on the city transport network, creation of an independent pedestrian network, combination of pedestrian routes with other road infrastructure networks, combined method of pedestrian network formation.*

However, any strategy requires the interaction of all defined networks of road and transport infrastructure in the city in order to give the resident the right to choose an acceptable type of traffic depending on the target location in the urban environment

Table 2 Ways of the pedestrian network interaction with other networks

Ways of the pedestrian network interaction with other networks	
Reexpansion of pedestrian traffic on the city transport network	Pedestrian traffic returns to the city streets, which are closed to vehicular traffic. Streets and squares are vacated for walking, recreation, communication, shopping and transit. The pedestrian network corresponds to the existing planning system of the city
Creation of an independent pedestrian network	A pedestrian network independent from other types of traffic and the city's existing planning system is created
Combination of networks	Networks are combined and function within the existing system of roads and streets in the city (**in case of spatially separated pedestrian lanes**). There are different variations of the network combination depending on the urban context (pedestrian-tram streets, bicycle-pedestrian streets, etc.)
Combined method of pedestrian network formation	It combines methods and means of previous ways in different parts of the city depending on the existing situation, the specific of the city and characteristics of urban areas. The combined strategy is the most flexible. It is more prospective to adaptation of the existing road transport infrastructure in the city to the needs of pedestrians

and in accordance with physical capabilities. It is realized in the principle of consistency. *The principle of coherence of road infrastructure networks* is implemented at the city level by the following methods and techniques: combination of pedestrian routes with stops and public transport routes; connection of pedestrian lanes with car storage places; coordination of the city pedestrian network with other networks; adaptation of existing transport streets to the needs of walking; construction of new public transport routes to connect with new pedestrian streets; organization of a joint interchange network from different types of transport routes; formation of mixed traffic streets in the conditions of the urban environment reconstruction (pedestrian-tram streets, bicycle-pedestrian streets, etc.); connection of local and district pedestrian networks with citywide routes of all types of transport.

The next principle of citywide network formation is *the principle of conformity*, which shows the dependence of the organization of pedestrian space network in the city on the subsystem of cultural and household services in the city, the functional zoning of urban areas; correspondence of density and size of pedestrian spaces to the size of the city, its separate inhabited areas and population density of separate areas in the city; and also conformity of the applied strategies and methods of improvement of PWS network to functional specialization of a space, route type, relief features, consumer requirements of space, etc.

The principle of *concentration* is determined by the concentration of new leisure, food, entertainment, recreation and other types of public services on the walking spaces in the city. The aim is to create not only specialized pedestrian routes, but also multifunctional pedestrian spaces and zones. Thus, a variety of leisure activities can be provided and at the same time the conditions for increasing the visit density in the pedestrian areas and intensifying territory use are created.

The principle of *succession* determines the maximum and effective use of historical and cultural heritage potential in the formation of PWS network in the city. The principle is aimed at preserving valuable historical, cultural and architectural monuments. It provides their inclusion in the structure of existing and new pedestrian links. It creates opportunities for sightseeing, "consolidation" and inclusion of perception points of valuable panoramas and city landscapes with cultural heritage sites in PWS system. The implementation of the principle will ensure the preservation of Genius loci places, the originality of routes and local identity.

3 Discussion Points

Insufficient study of issues related to the movement of individual vehicles and the danger they make to each other and pedestrians leads to conflicting decisions in the regulation of their movement. In different countries, even in various states (USA) and lands (Germany) there can be a permission or prohibition of the movement of such vehicles on the pedestrian network. For example, in France, Hungary and the Czech Republic Segway is equated to pedestrians with the appropriate permission to drive on pavement and pedestrian lanes. In Sweden, Luxembourg and the Saarland in

Germany it is equated to bicycles and is allowed to go on bicycle lanes. In different countries opposite solutions are also observed for cycling.

In the research we took into consideration the maximum pedestrian safety in case of the mass use of individual vehicles and proved the need for complete separation of the pedestrian and walking network in the city from other networks and the allocation of a separate network of alternative vehicles. The problem of alternative type interaction of individual transports and their danger to each other requires further research.

The novelty of the research includes:

- Ranking of individual vehicles regarding potential danger in case of a collision with a person and determining the possibilities of their combination with pedestrian traffic;
- Improvement of the formation strategy of PWS network in the city by definition of principles and the corresponding methods of the citywide pedestrian network formation in the conditions of the development of alternative types of individual transport.

The practical significance of the obtained results is in the possibility of applying determined principles, techniques and methods to improve pedestrian network of cities confirmed by the approbation of the research conducted as an example in Poltava (Fig. 3). A combined method of interaction of the pedestrian traffic network with other networks is used. The wide streets of the new city districts allowed to place alternative individual vehicles network in parallel within the existing streets by restructuring the spaces (Fig. 4). In the historic city center develops a pedestrian zone with the main pedestrian street - Sobornosti Street (reception of redistribution of existing transport streets and squares in favor of pedestrians). The total length of the pedestrian part of the street will increase from 350 to 1600 m. The city's cultural and consumer services are concentrated on Sobornosti Street: theater, cinemas, philharmonic society, museums, shopping centers and shops, restaurants and cafes, as well as public gardensand architectural monuments (Fig. 5). It i proposed to form another shopping pedestrian street perpendicular to the existing transport streets. It will pass through the central city market and will connect public transport stops and regional bus station. Additionally, it is proposed to form recreational and tourist cycling routes along the river and lakes, which combine urban recreational areas and country forest parks, outstanding architectural and historical sights of the city (Poltava Battlefield, Hrestovozdvizhenskij Monastery, Sklifosofsky estate and others).

4 Conclusions

With the emergence and development of new alternative types of transport and in competition for traffic space pedestrians remain the most vulnerable on existing streets and city roads. To develop city planning directions and to solve the problems of safe pedestrian network formation, we determined the level of danger that

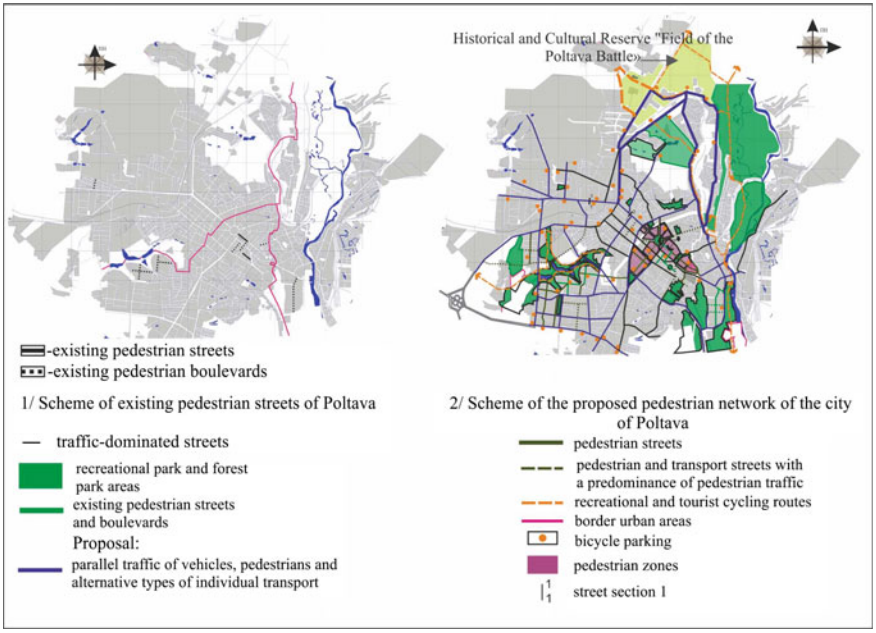

Fig. 3 Schemes of the existing (1) and proposed pedestrian network (2) of the city of Poltava. Drawings by H. Osychenko

might be caused to pedestrians from new types of individual vehicles in case of a collision(in terms of momentum).It allowed to conduct the ranking of individual vehicles according to the degree of danger and divide them into 3 groups: a group of combination with pedestrian traffic, a group of alternative traffic (requires a separate network), a group of combination with car traffic. The concept of pedestrian traffic priority in cities at the present stage was updated. The main principle of designing a citywide pedestrian network–principle of differentiation, which includes the spatial separation of pedestrian traffic from other participants of the road transport infrastructure was defined. The city planning principles of the pedestrian-walking space organization in the city network were suggested: *the principle of differentiation, the principle of coherence of all networks of road transport infrastructure, the principles of conformity, concentration and succession.* The application of the regulations and results of the research will contribute to the development of pedestrian spaces in cities, pedestrian safety and the formation of a comfortable urban environment.

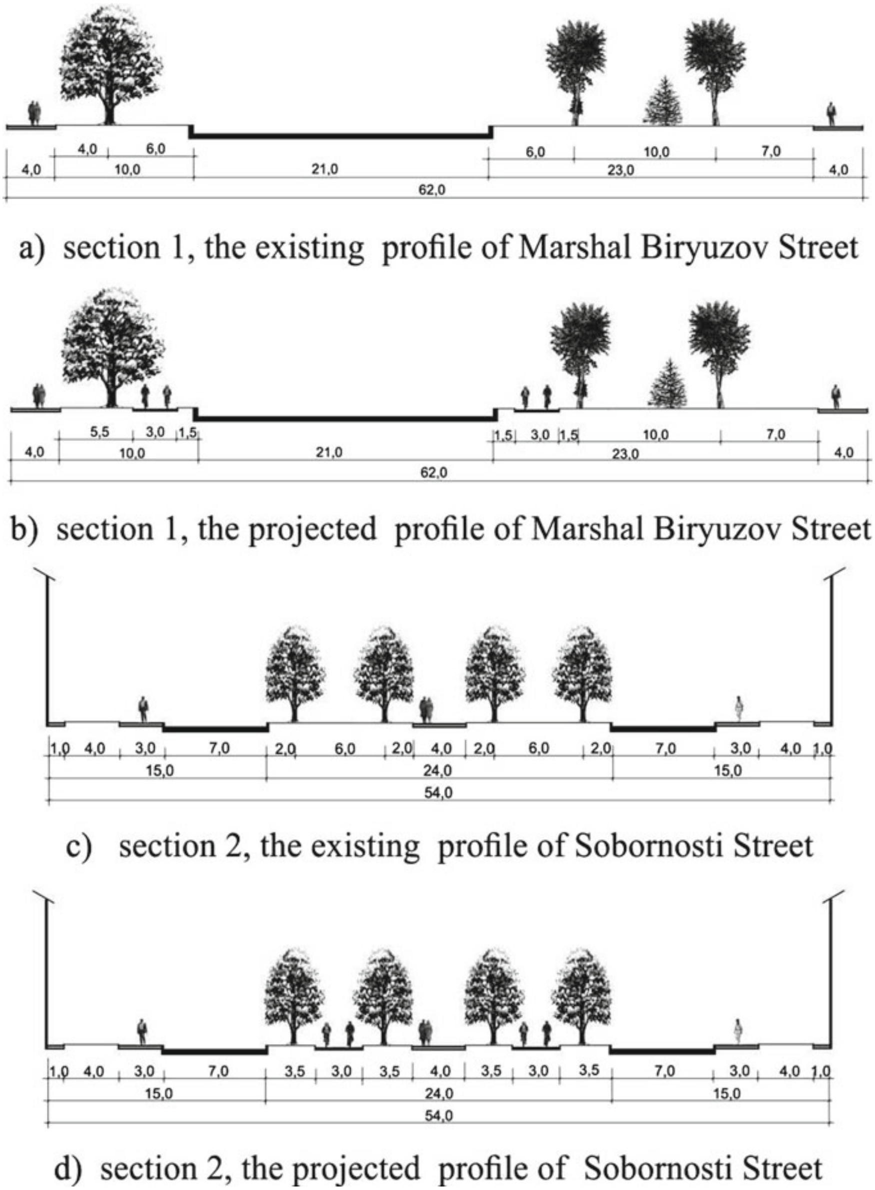

Fig. 4 Restructuring the spaces of existing streets: **a, b**–The existing and projected profile of Marshal Biryuzov Street (street Sect. 1 of Scheme 2); **c, d**–The existing and projected profile of Sobornosti street (street Sect. 2). Drawing by V. Toporkov

a) b)

Fig. 5 **a** Aleksandrovskaya street (now Sobornosti street). Photo of 1910; **b** Sobornosti street–center city pedestrian zone (№ 3 of Scheme 2). Photo January 2020 by H. Osychenko

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Innovative Program of Quality Assessment of Cities for the Compliance with «Smart City» Category

Petro Sankov, Yuriy Zakharov, Nataliia Tkach, Dmytro Chashyn, and Oleg Yurin

Abstract The problem of maintaining and improving the quality and safety of human living conditions is now attracting the attention of researchers from all over the world. The investigation is concerned with the integral value of quality factors planning control of the territory, which are obtained with the help of the methods of mathematical statistics while processing the results of questionnaire survey of specialists of planning control field and ecological safety. The subject of the research is 13 cities of the world, which strategically have to move to the level of Smart City development by the specified time. The scientific novelty of the obtained results is the assessment of the territories of cities around the world, striving to move to the category of "Smart City", for the compliance with indicators and factors of the proposed classes of well-being with the highest indicators of quality and safety. This system is supplemented by the area of well-being 80-00 "Territory of economic activity of a human". These 4 classes of well-being have 31 factors or indicators, according to which qualimetric tables were compiled and integrated quality coefficients were determined. The practical significance of the obtained results of the work is to study and regulate the factors that affect the quality and safety of living conditions in modern cities, in their transition to the category of "Smart City". The compiled qualimetric tables can be used as a tool to optimize the main quality indicator–a considered integrated quality factor for any city in the practice of urban planning and environmental safety.

Keywords «Smart City» · Qualimetric tables · Quality · Life safety · Area of well-being

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_41

1 Introduction

1.1 Relevance of Research

Mankind has approached the invisible boundary that separates the past relation to the biosphere from the new. The eternal ways of society development, based on the standards of thinking about its conquest developed over the centuries, have come to the deadlock. Mankind can no longer develop without a general world strategy. The theory of general relations in the surrounding world has become widespread among scientists [1, 2]. It is established that due to the vital activity of the natural community of fauna and flora, called biota, the environment remains unchanged, because in nature all wastes of higher species of organisms consume other species that are lower in the "consumption chain" [3]. It is impossible to increase the share of consumption of some species at the expense of others with impunity, without violating the stability of the environment. Mankind cannot infinitely influence the natural environment. If the biota does not cope with such an impact, the degradation processes become irreversible, which leads to the death of civilization. That is why the private tasks of nature protection in urban planning are growing into global ones. When developing concepts of regional development, it is necessary to focus efforts on methodologies that allow regulating the natural and artificial systems [4]. It should be considered that in the zone of urban influence of large settlements there are areas of deformation of natural systems due to anthropogenic impact. The task of urban planning specialists is the appropriate management of resettlement systems. This is necessary primarily because society cannot but develop. And secondly, the biosphere must be preserved for this development. And all this is not possible without modern methods and programs aimed at the proper development of cities and towns with a rational specialization of consumption of natural resources. We see the basis of this proper development of cities and settlements in the concept of creating a "Smart City" [5].

1.2 Formulation of the Problem

In connection with the reinforcement of anthropogenic impact on the environment it becomes necessary to develop and adopt the methods that allow estimating ecological state of natural-anthropogenic complex. That is why the development of different monitoring approaches in the system of ecological and planning control in environmental quality management today is the most relevant.

The investigation is concerned with the integral value of quality factors planning control of the territory, which are obtained with the help of the methods of mathematical statistics while processing the results of questionnaire survey of specialists of planning control field and ecological safety. The subject of the research is 13 cities of the world, which strategically have to move to the level of Smart City development by the specified time.

2 Purpose

The goal of the study: the development of innovative methods for assessing the quality and safety of life of territories and objects of planning control, as the main factor in achieving the status of "Smart City" 13 identified cities of the world [6].

This assessment lies in identifying social, natural, technology-related and anthropogenic, environmental hazards and determining the extent and intensity of their manifestation in a particular area with the help of innovative methods developed by the authors. For this purpose the state of social development of the territory, anthropogenic and technology-related loading is considered and analyzed, and the integrated estimation on 4 classes of quality and 31 indicators (factors) in these classes is carried out. Practical recommendations for increasing the consolidated integrated quality factor (Kz) have been developed [7].

3 Methodology

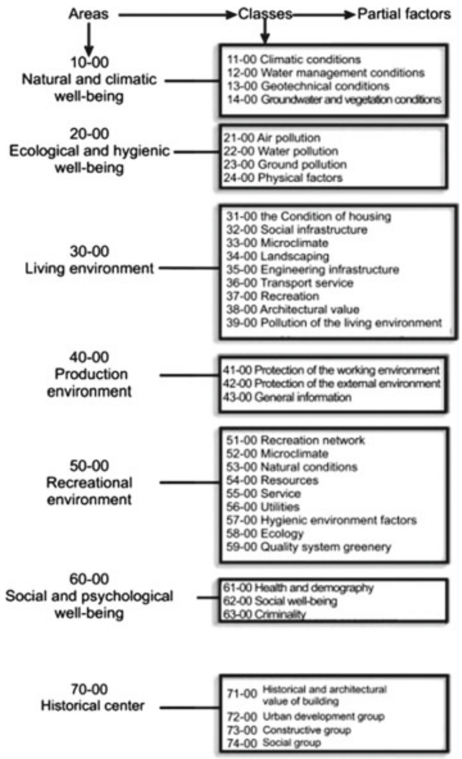
As we defined in the previous article «Modern Smart City Concept Considering Population Safety Issues» the theoretical and methodological basis of the study is the dialectical method of cognition, a systematic approach to the study of economic phenomena and processes, scientific works of domestic and foreign scientists on the problems of urban development. In the course of the work the following basic methods and means of approach were used: abstract science (theoretical generalizations and formulation of conclusions), analysis of electronic resources, bibliographic search, and systematization of the obtained results. The theoretical and empirical basis of the research is the scientific works of domestic, foreign scientists and personal scientific achievements of the authors of real work on the problems of development and improvement of the urban structure, materials of scientific-practical conferences, reference and information publications [8]. The methods of mathematical statistics were additionally used to calculate the significance of factors in the class and the consolidated integrated quality factor (Kc) in each class of factors and in general for the whole area of well-being 80-00 "Territory of human economic activity".

3.1 Theoretical Research on Supplementing the General System of Quality and Safety of Life of the Population (QSLP) with a New Area of Well-Being 80-00

The PGASA has been conducting research for many years related to the methodology of rapid assessments according to the general system of QSLP [5, 6, 9–11]. The general system of QSLP earlier consisted of 7 areas of well-being (Fig. 1).

The scientific novelty of the obtained results is as follows:

Fig. 1 The general system of QSLP from 7 areas of well-being before its supplement



– the general system of QSLP is supplemented by the area of well-being 80-00 and the offered factors which are presented in classes of well-being (81-00) "Social development", (82-00) "Natural indicators", (83-00) "Anthropogenic indicators" and (84-00) "Technology-related indicators" (Fig. 2);
– the assessment of the cities of the world aspiring to transition to the category of "Smart city" on conformity of indicators and factors of the offered classes of well-being to the highest indicators of QSLP system.

Fig. 2 Well-being area 80-00, which complements the overall system of QSLP

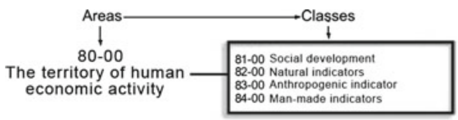


Table 1 Limits of assessing the importance of environmental hazards

Security area category	Points	The value of the factor,% of the standard (or the optimal recommended value)	
		Ascertaining (existing)	Stimulating (advanced)
Fully operational (FO)	4	More than 90%	More than 100%
Operational (O)	3	70–90%	90–100%
Partially operational (PO)	2	50–70%	70–90%
Not applicable (NA)	1	Less than 50%	Less than 70%

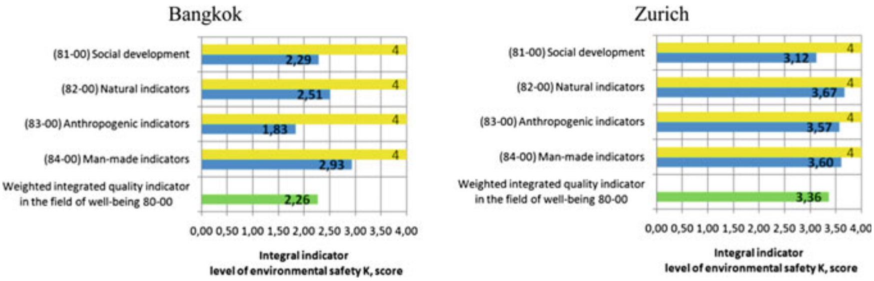


Fig. 3 Example of weighted integrated quality factor for the whole well-being area 80-00 for the cities of Bangkok and Zurich

3.2 Algorithm for Determining the Main Quality Indicators for a New Area of Well-Being 80-00

In total, the proposed 4 classes of well-being identified 31 factors, or indicators, which were the compilation of qualimetric tables (Table 1) and identified integrated quality factors (K). Initially, this integral quality factor was determined for a particular well-being class. Then it was determined for each city. Figure 3 shows an example of a weighted integrated quality factor for the whole welfare area of 80-00 for the cities of Singapore and Zurich, as the lowest and highest indicator of the whole group of cities (13 cities) that were studied.

3.3 Algorithm for Determining the Main Quality Indicators for a New Area of Well-Being 80-00

During the development of this method materials of some foreign and domestic authors studying the urban properties of modern Smart Cities were used [12–14]. We used the current normative documents of Ukraine as the main governing documents in this paper [15–17]. Theoretical research on complex ecological assessment of the territory, which consists in identifying natural and anthropogenic factors of ecological danger and determining the scale and intensity of their manifestation in a particular area using our innovative methodology, was based on the use of partial pairwise comparison and expert assessment [5].

The sequence of actions to determine the numerical value of the environmental safety indicator consists of the following stages:

(1) selection and determination of the number of factors for this class;
(2) numerical score of factors;
(3) ranking of factors within the group;
(4) determination of an integrated indicator of environmental safety for each class of quality of life in the region 80-00.

Thus, the method is based on research to determine the weight and quantify each risk factor and their groups. In such a way, at the first stage, factors are selected depending on the object of study (assessment) and compiled into certain groups of risk factors that have a decisive influence on the category of "Environmental safety of the city." At the second stage the scoring of factors which basis is served by both quantitative and qualitative indicators characterizing the chosen factors is carried out. Scoring of factors is to compare the obtained values of risk factors with the normative (optimal) values. For this purpose, a four-point evaluation system and possible limits for estimating the value of the risk factor are proposed, which are given in Table 1. This process is described in detail in the paper [5, 6, 9].

At the fourth stage, according to the formula below, the integrated indicator of the level of environmental safety K is determined, the score for each class of factors

$$K = \frac{2 \times \sum_{i=1}^{n} \delta_i \times \omega_i}{n \times (n-1)}$$

wher δi–score of the i-th factor; ωi–weight value of the i-th factor; n–number of factors in the group (category).

4 The Main Results

4.1 Compilation of Qualimetric Tables for Factor Assessment

On the basis of parameters of estimation of factors of any class qualimetric (estimation) tables are developed. Table 2 shows an example of a qualimetric table of class 84-00 "Technology-related indicators".

Based on the actual results of quantitative assessment of the above factors on the example of 13 cities in the world, potential Smart City, calculated integrated quality indicators for all classes.

Table 2 Example of qualimetric table by factor "Man-caused load"

Factor	Indicator	Score			
		FO, 4 points	O, 3 points	PO, 2 points	NA, 1 point
Man-caused load	%	<30%	30–39,9%	40–50%	>50%

4.2 Determination of Weighted Integrated Quality Indicator

After obtaining the integrated quality indicators for each class by the method described above, the weighted integrated quality indicator was calculated for all 13 cities of the world offered for comparison. Figure 4 presents weighted integrated quality indicators for all cities.

5 Conclusions

The general system of QSLP is supplemented by the area of well-being 80-00 and the offered factors which are presented in classes of well-being (81-00) "Social development", (82-00) "Natural indicators", (83-00) "Anthropogenic indicators" and (84-00) "Technology-related indicators" (Fig. 2).

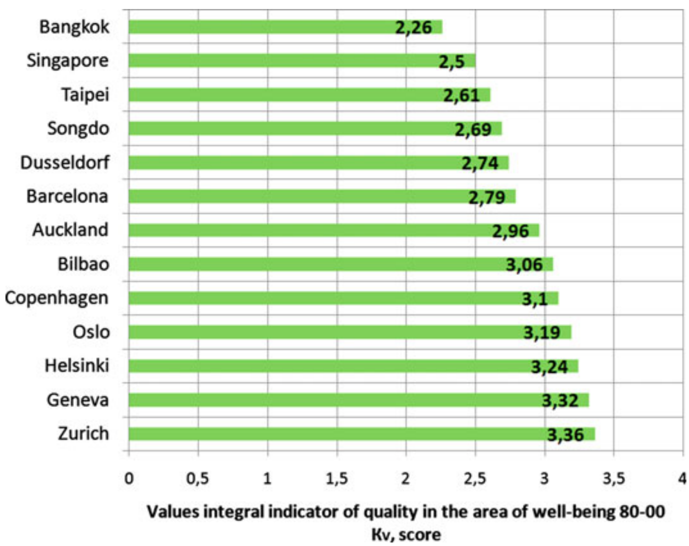


Fig. 4 An example of a weighted integrated quality factor for the entire welfare area of 80-00 of all cities

The assessment of the cities of the world aspiring to transition to the category of “Smart city” on conformity of indicators and factors of the offered classes of well-being to the highest indicators of QSLP system.

The methodology of express train-estimation of QSLP on the proposed factors, which are presented in the classes of well-being (81-00), (82-00), (83-00) and (84-00) can be successfully applied in three directions:

- to select the priority measures to improve the quality of life of the population in urban areas (the first direction);
- to assess the existing situation in the city, district, quarter and other facilities in order to manage the quality of the urban environment and QSLP (the second direction);
- to evaluate the options of management urban projects in order to choose the best (the third direction).

As a result of the study we have found that: the best weighted integral quality factor is in Zurich $K_V = 3{,}36$, and the worst is in Bangkok $K_V = 2{,}26$.

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Design of Agricultural Buildings in the Conditions of Agroecological Farming

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Abstract The system of design of agricultural buildings was considered, which involves the research of the territory and the location of agricultural buildings. The design of modern livestock cooperative buildings for the production of ecological livestock products requires the location of construction sites near the land where agro-ecological farming is carried out. It was determined that quality control over the production of organic products is possible in medium and small enterprises (including farms). Factors contributing to the production of ecological products were listed, namely the construction of industrial buildings and structures with functional zoning and compactness of placement, high-tech equipment with quality control and safety systems, prevention of pollutants and sources, systematic introduction of complex technical, technological, organizational, economic, managerial, legal and other measures in order to produce the required volumes of products of the established quality with minimal cost of material resources and minimal negative impact on the environment. It was proved that the location of industrial buildings and structures should be on environmentally friendly lands. A methodological approach was proposed for the organization of land protection in the context of reducing the degradation processes of agricultural land was proposed that is based on increasing the natural fertility of soils. A structural and logical model of land protection organization was developed to reduce the degradation processes of agricultural land that is based on increasing the natural fertility of soils. The land plot for the placement of agricultural buildings and structures must meet hygienic, animal health, engineering, construction and economic requirements.

Keywords Agricultural buildings · Agricultural enterprises · Agroecology · Soil degradation · Organization of soil protection · Organic farming · Natural fertility

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_42

1 Introduction

With the deteriorating environmental situation in the world, humanity is concerned about improving life and, first of all, the consumption of environmentally friendly products. In Ukraine, the state agricultural policy is focused on maximizing the economic efficiency of the industry. The priorities are concentrated around large and very large agricultural and agro-industrial enterprises, which have significant competitive advantages due to the concentration of production, increasing profitability due to products with high value added, high productivity, etc. Qualitative control over the production of ecological products is possible at medium and small enterprises (including farms), which are physically located at the location of production facilities, directly and daily related to the problems and concerns of rural areas and communities, including local employment, environment preservation and rural society. The development of environmentally friendly production is facilitated by various factors: construction of industrial buildings and structures in compliance with functional zoning and compact placement, high-tech equipment with quality control and production safety [1], prevention of pollutants and sources, systematic introduction of complex technical, technological, organizational, economic, managerial, legal and other measures to produce the required volumes of products of the established quality with minimal cost of material resources and minimal negative impact on the environment [2]. But no less important is the factor of location of industrial buildings and structures, including livestock, on ecologically clean lands, because the land is the main means of "natural" production.

The main purpose of the article is to form a system of measures for land protection, reduction of degradation processes of agricultural land that is based on increasing natural soil fertility through the introduction of organic farming.

2 Page Layout

Agricultural enterprises are located in the production zones of rural settlements in accordance with the approved project of the district planning, master plan, the project of planning and development of production zones of rural settlements.

Land reform in Ukraine is aimed at denationalizing agricultural land, dividing collective farms, and providing land plots for running personal peasant and farm enterprises. As a result, a significant amount of degraded and unproductive lands was attracted to use. Agricultural land, which is located outside the settlements, is fragmented into more than 10 million plots, and a crop rotation system was instituted on the farms. The irrational addition of natural fertility to artificial ones led to a decrease in the quality indicators of the state of agricultural land, especially the fertile soil layer.

In the territory of Polesie, Steppe and Forest-Steppe of Ukraine, degradation processes cover from 10 to 50% of agricultural land.

Valuable arable land involved in intensive use suffers the most. The arable land of Ukraine is 54%, agricultural land–77%, and typical chernozems–91.8%. Soil fatigue increases, which sometimes turns into soil toxicosis, soil density increases (for the last 30 years–from 1 to 1.6 g/cm3), humus mineralization takes place, soil acidity increases. For example, over the last century Poltava chernozems have lost almost half of their humus: from 7–10% to 2.5–5% [3]. In conditions of unstable moisture, non-observance of crop rotation reduces in dry years the reserves of productive moisture in the 0–100 cm layer to 20–25 mm, approaching the dead stock threshold. Sunflower, soybeans and sugar beets reduce moisture reserves 2.5–3 times compared to wheat. At the same time, the restoration of productive moisture reserves after sowing sunflower comes only 5–6 years. Most of the regions of Ukraine are monocultural oriented and increase the area of cultivated soils and open and subsoil crops.

While maintaining the rate of decrease in the humus content of 0.1% over 10–15 years, the humus content in half of the arable land in Ukraine by 2050 can reach the threshold of 2%, which is a critical value for natural fertility. This characteristic requires the conservation of arable land in natural forage lands for 5–15 years, as well as high costs for biological reclamation to renew the natural fertility of soils.

The basis for sustainable and efficient agricultural production is the soil resources rational use. The agricultural sector of the economy uses 71% of the total area of Ukraine, including swing–more than 32,400,000 ha. On the basis of the peculiarities of the soil cover and the administrative-territorial division, the territories of Polissya, Forest-steppe and Steppe were distinguished [4].

The Polissya zone includes Volyn, Rivne, Zhytomyr, Chernihov, Lviv, Ivano-Frankivsk, Transcarpathian regions.

In the forest-steppe zone–Kyiv, Cherkassy, Vinnytsya, Chernivtsi, Poltava, Sumy, Kharkiv, Khmelnytskyi, Ternopil regions.

In the Steppe zone–Odessa, Kherson, Mykolayiv, Zaporiozhya, Donetsk, Dnipropetrovsk, Kirovohrad, Luhansk regions, the Autonomous Republic of Crimea. The variety of climatic, geographical, lithogranulometric and other factors led to the formation of heterogeneous soil cover. Sod-podzolic soils of light granulometric composition are dominant for the Polissya zone. They are characterized by insignificant accumulation of humus, weak saturation of bases and acid reaction of soil solution.

Soddy-calcareous soils occur in low low-drained areas and are characterized by increased accumulation of humus in the upper horizon–2.0–5.0% depending on the particle size distribution, and signs of gleying in the profile due to stagnant groundwater. Sod-carbonate soils are characterized by a profile developed up to 50–60 cm, mainly by the neutral reaction of the soil environment–pH-hydrogen. = 6.7–7.5, significant humus accumulation–2.2–3.7% depending on the content of physical clay.

According to the results of agrochemical certification, the area of soils with high and very high humus content is 22.7% of the surveyed (Fig. 1). Most of them are concentrated in the steppe zone, where the usual chernozems are dominated by medium and low humus. The area of soils, which are characterized by medium and high humus content, is 13.5 million hectares or 60.9% of the surveyed. Of these, 51.8% are concentrated in the steppe, 33.8%–in the forest-steppe, 14.4%–in Polissya.

The redistribution between soil and climatic zones of soils with low and very low humus content is the opposite compared to groups with higher security. Of the 3.6 million ha of these soils, 50% are concentrated in the Polissya zone, where light low-humus soils predominate (sod-podzolic and sod), 33%–in the Forest-Steppe and 17%–in the Steppe [5, 6].

The distribution of agricultural land in Ukraine by humus content, % of the surveyed, is shown in Fig. 1.

In case if intensive agriculture is continued and there are no measures to replenish humus stocks, its content and, consequently, soil fertility decreases and soil depletion occurs.

The characteristics of soil groups in Ukraine by humus content are given in Table 1.

The structure of soil groups of Ukraine in terms of humus content is shown in the Fig. 2

A sharp decrease in the content of humus in soils is observed with the use of high doses of mineral fertilizers, especially nitrogen, when microorganisms are activated, which include soil organic matter in metabolic processes, consuming humus that has accumulated for thousands of years.

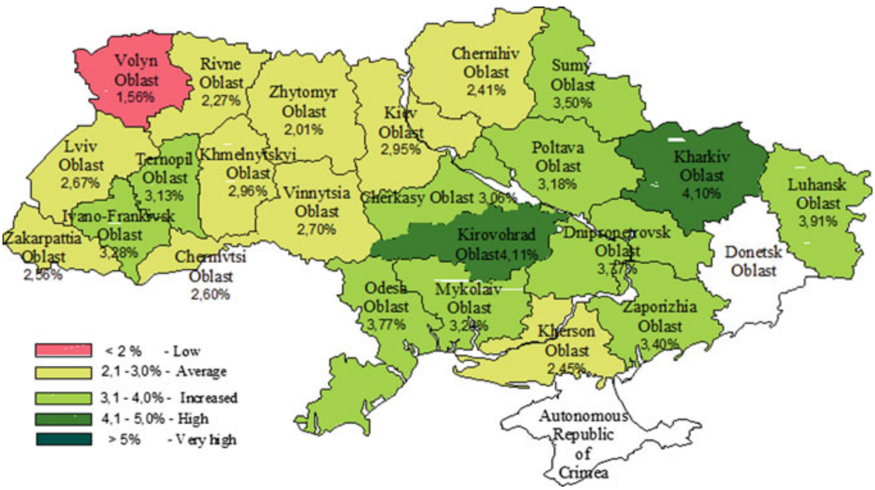

Fig. 1 Distribution of Ukraine by humus content, % of the surveyed one

Table 1 Soil groups of Ukraine by humus content

Groups	Humus content	Structure %	Structure %
Very low	<1,1	1,1	16,4
Low	1,2–2	15,3	
Average	2,1–3	26,1	60,9
Increased	3,1–4	34,8	
High	4,1–5	19,7	22,7
Very high	>5	3,0	

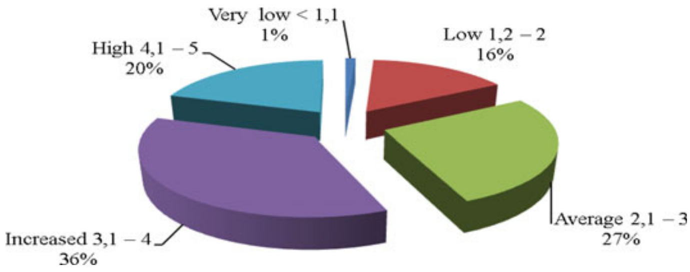

Fig. 2 Structure of soil groups of Ukraine by humus content, %

Soil erosion is a major factor in the degradation of agricultural land. Over the last decade, soil erosion has reached alarming proportions. The reasons for this are long-term ecologically unreasonable intensive exploitation of land resources, excessive plowing of the soil cover, imbalance of the circulation of chemical elements in agroecosystems.

In the territory of Poltava region there is also a spread of degradation processes of agricultural land. In recent years, the process of deconservation, 68,000 ha of arable land removed from active cultivation in the 1990s, has been intensive, and the process of plowing natural forage lands is underway, which significantly worsens the environment. The structure of the Poltava region lands is presented in the Table 2 and the Fig. 3.

Agricultural land is 2168.2 thousand hectares, or 75% in the Poltava region. A significant part is arable land–1770.5 thousand hectares (82%), Table 3.

The structure of the agricultural grounds in the Poltava region is shown in Fig. 4.

The division of agricultural land led to the formation of lease relations, where consumer behavior prevails, both landlords and tenants. Both the first and the second, acting exclusively on their own private interests, destroy natural fertility, receiving the maximum material economic benefit, ignoring the interests of society, the requirements of environmental safety, soil protection and sustainable development.

Profit orientation has led to humus mineralization over the past 20 years by almost 0.2–0.5%. As a result, a large number of chemicals have accumulated in the soils,

Table 2 Explication of lands on the territory of Poltava region

Name	Area, thousand hectures	Structure %
Agricultural land	2168,2	75,42
Forests	283,8	9,87
Built-up land	118,1	4,11
Open wetlands	85,4	2,97
Ravines	12,8	0,45
Other lands	58,3	2,03
Open water	148,4	5,16
Total	2875	100

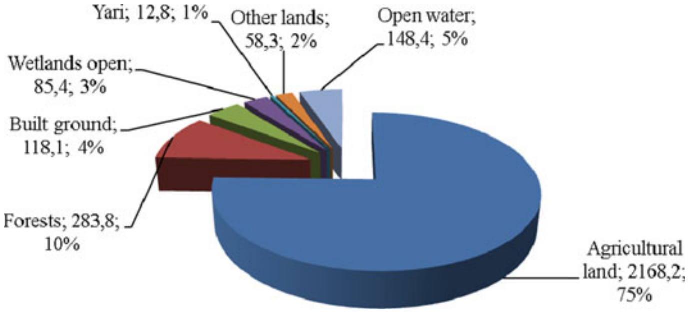

Fig. 3 Land structure in the Poltava region

Table 3 Explication of agricultural land on the territory of the Poltava region

Name	Area, thousand hectares	Structure %
Arable	1770,5	81,66
Hayfields and pastures	363,8	16,78
Perennial plantings	29,0	1,34
Fallows	4,9	0,22
Total	2168,2	100

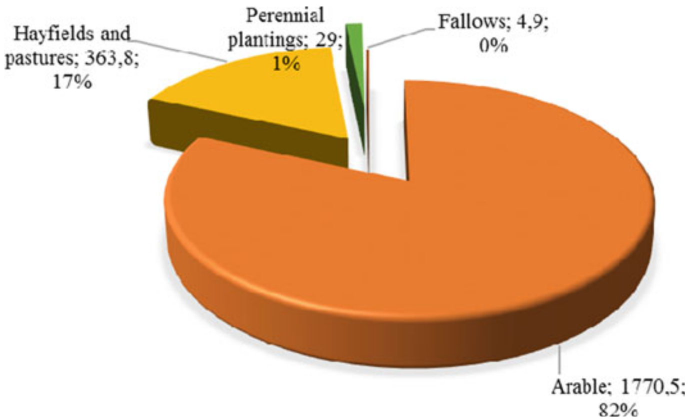

Fig. 4 The structure of agricultural land in the Poltava region

which negatively affect the quality of the soil. Agricultural land with acidic soils accounts for 45% (787.867 thousand hectares), and the subjects of water and wind erosion–43% (Table 4 and Fig. 5).

There is a need to form a system of measures for land protection in the context of reducing the degradation processes of agricultural land that is based on preserving the natural fertility of land.

Table 4 The area of land subject to degradation processes on the territory of the Poltava region

Name	Area, thousand hectares	Structure %
Agricultural land susceptible to water and wind erosion	749,2	42,93
Agricultural land with acidic soils	787,867	45,15
Agricultural land with saline soils	207,935	11,92
	1745,002	100

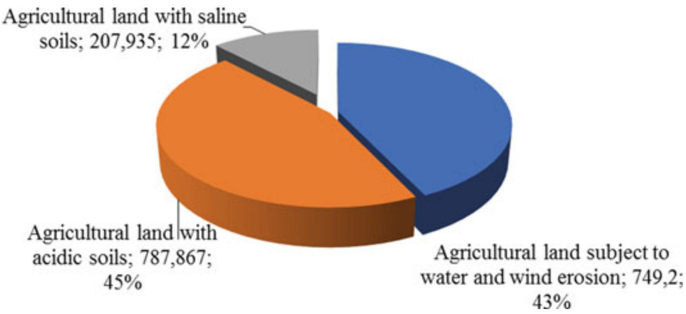

Fig. 5 The structure of agricultural land by the prevalence of degradation processes in the territory of the Poltava region

The basis of such a system is to ensure the restoration of the natural characteristics of soils by increasing natural fertility, namely, optimizing crop rotations, using organic farming, developing objects of the natural reserve fund and objects to maintain the stability of natural and anthropogenic natural ecosystems, including national natural and regional landscape parks.

Organic farming is creating a need to return agricultural production to organic farming systems. Such farming aims to eliminate the use of artificial chemicals in the production process. At the same time, organic farming ensures soil health.

For the first time the concept of “organic agriculture” (organic agriculture) was used by the founder of modern scientific organic agriculture W. Northborn in 1940 in the work “Look to the Land” [7, 8].

In 1991, the European Council of Ministers adopted Agricultural Regulation (EEC) No. 2092/91 on organic farming and the corresponding labeling of agricultural products and food products [9]. The introduction of these rules was part of the reform of the EU’s Common Agricultural Policy and represents the completion of a previous process in which organic agriculture was officially recognized. In June 2007, the EU adopted a regulation on the production and labeling of organic products. In which emphasis is placed on the protection of the environment, biodiversity and high standards of animal welfare: organic production must respect natural systems and cycles to make the most of biological and conservation farming methods without the use of genetically modified organisms (GMOs) [10].

The leading countries of the world have adapted their national laws to international requirements and certified part of agricultural land as organic. There are four countries in Europe where more than 10% of agricultural land is under organic farming: Liechtenstein (29.8%), Austria (15.9%), Switzerland (11.1%) and Sweden (10.8%) [eleven]. In the United States, a unified network of certification centers (Certified Organic) and certification of domestic and foreign certification agents have been created, which must check organic farming facilities. An important component of the activities of such centers is to conduct educational, explanatory work, popularize organic farming, publish brochures and magazines.

In Ukraine, as well as in the leading countries of the world, a certain experience has been accumulated in the introduction of organic farming. It ranks eleventh in Europe in terms of organic land area–381,000 ha. It is 1% of the country's agricultural land. More than 294 organic agricultural enterprises are registered. 90% of Ukrainian organic agricultural products are exported to the Netherlands, Germany, Great Britain [11]. The dominant export crops are corn and wheat. The most organic region is Odessa, where the area of certified organic land is 102,000 ha. Most agricultural enterprises have small areas of organic land. Arnika is in first place with 158,000 ha of organic land.

The Poltava region is one of the five best regions of Ukraine, which are engaged in organic farming and the production of organic food. Thanks to the action of the Program, the areas of certified land for organic farming are growing annually in order to preserve their quality. There are 30.7 thousand hectares of such areas in the region, which is 2.3% of the total agricultural land in the region. Now 28 enterprises have certificates for organic production and processing [12, 13].

The research and production enterprise "Agroecology" in the Poltava region, which ranks third in terms of organic land area–7500 ha, has a positive experience of ecological farming. For more than 40 years the company has been engaged in organic farming, abandoning the use of any chemicals in agricultural production. On the lands of the private enterprise "Agroecology" it took almost 25 years to obtain really healthy soil, which indicates the full-fledged conduct of organic production. During this time, more than 9 thousand hectares of arable land have been improved.

The farm has mastered modern methods of intelligent farming, which ensured not only radical improvement of the soil, but also restored the humus content for 40 years by 0.53–1.0% in the soils used by the enterprise, and the total mass in a meter layer of living organisms and nutrients the remains reaches 40 tons per 1 ha [3].

The economic incentive for organic farming is the market prices for organic agricultural products, which are 2–3 times higher than the average prices for food in Ukraine, that is, the formation of a monopoly ecological rent and its consumption by an agricultural producer is taking place.

But, the key aspect of organic farming is the preservation and improvement of soil fertility [14, 15].

The measures to ensure the achievement of the goal include:

- optimization of the ratio of crops within each farm;
- effective use of local organic fertilizers (manure, peat, compost, sapropel, organic waste of agricultural products processing);
- widespread use of crops of perennial grasses and an increase in the areas of green manure crops;
- chemical reclamation based on the use of local deposits of limestone, chalk, marls;
- the use of local raw materials to improve soil fertility (phosphorites, zeolites, glauconites, phosphate slag, defecate);
- a decrease in the cultivated areas for sunflower, which leads to a deterioration in the phytosanitary state and dehydration of the soil, due to the expansion of areas for soybeans, rapeseed, mustard, oil flax;
- introduction of minimum tillage, introduction of modern wide-cut deep loosening units;
- application of contour-reclamation organization of the territory, prevents soil destruction;
- restoration and support of field protection zones, as the most important element of the agricultural landscape and securing the border of fields.

In grain-steam-tilled crop rotations, the need for organic fertilizers to achieve a deficit-free humus balance on chernozems is typically 10 t/ha of sivosminnoi area [5].

A 10% reduction in the area of row crops in crop rotations and the replacement of black fallow with an occupied one, reduces the need for organic fertilizers for a deficit-free humus balance by 40% and by 60% for the introduction of 20% of the area occupied by perennial grasses. Embedding of crop by-products in the soil reduces the additional need for organic fertilizers in the first case by 30–37%, and in the second–by 65–90%. In crop rotations with perennial grasses and the incorporation of by-products, an expanded reproduction of humus is achieved even in the absence of the use of organic fertilizers.

The measures that enables to increase the flow of organic matter into the soil, in addition to the use of manure, include the incorporation of crop residues and, above all, grain straw. With a gross grain harvest of 40 million tons, the country produces 40–45 million tons of straw annually, up to 40% of which should be used as organic fertilizers. Considering the area of only winter crops (about 7 million hectares), the incorporation of crop residues allows saving more than 100 thousand tons of nitrogen, 70 thousand tons of phosphorus and 250 thousand tons of potassium annually.

Scientifically based use of straw as an organic fertilizer has a positive effect on the humus state of soils. In terms of the humus equivalent, 37 cwt of straw corresponds to 100 cwt of bedding manure, or 270 cwt of green fertilizer. It is calculated that from 50 cwt/ha of dry matter of straw 5 cwt/ha of organic matter enters the soil, with crop residues–10 cwt/ha, with roots by weight of 25 cwt / ha–4 cwt/ha.

Sideration should also be considered as a multifunctional agronomic measure of agriculture, which has a positive effect on the soil, productivity and quality of crops.

Sideration should include a set of highly productive green manure crops for independent, under-sowing and re-sowing, their seed production system, technologies and technical methods of growing and using as fertilizer. For the effective use of by-products and green manure as organic fertilizers, it is necessary to improve the production, technological and methodological support of this event.

A decrease in the mineralization of organic matter and an increase in the specific gravity of humification processes up to 50% can be achieved in the case of a deep priming of organic materials in the arable layer. Shallow tillage by the type of disking accelerates the mineralization and the use of the latter by field crops. The most expedient, in order to stabilize the humus state, is a rational combination of minimal tillage with periodically deep plowing.

In some regions of Ukraine, environmental concepts are being implemented, among which the main ones are the conservation of biodiversity, nature conservation, the development of the eco-network and the provision of environmentally sustainable development of regions, but the current environmental legislation does not allow to radically correct the existing situation [4].

In Ukraine, a system of objects of the natural reserve fund and objects of maintaining the stability of natural and anthropogenic natural ecosystems, including national natural and regional landscape parks, is being formed, but it completely bypasses agroecological issues and the protection and preservation of soils.

According to the concept of optimization of the nature reserve and regional econetwork of the Poltava region in the Shishatsky district at the initial stage of work on the design of the forest-steppe chernozemny national landscape park, which should become a unique object of this type, intended for the conservation, protection and rational use of biodiversity and natural resources in combined with the acquisition of "Agroecology" (an associate member of the National Academy of Agrarian Sciences of Ukraine), it forms an integral agricultural landscape complex of a unique territory.

On the territory of the girder system among the villages of Manachinovka, Pokrovskoe and Klimovo, Shishatsky district of Poltava region, on an area of 216.8 ha within the boundaries of land use of the private enterprise «Agroecology», work on the creation of an agro-landscape park, which is considered as a key object and the core of the projected national landscape park «Lisostepovyi chornozemnyi», has been begun [16].

Thus, on the basis of the formation of a system of measures for land protection, a structural-logical model for organizing land protection has been developed to reduce the degradation processes of agricultural land that is based on increasing the natural fertility of soils.

The creation of national and agro-landscape parks aims to optimize the landscape complex, rationally and efficiently use land resources according to the approaches of organic farming by creating a system of pumped storage facilities, a system of protective plantations, obtaining ecologically clean raw materials of wild and cultivated plants, and providing environmental education [17]. In perspective, the "Lisostepovyi chornozemnyi" park and the agro-landscape park should become the basic ecological and educational center of the international level. The functioning of the center is facilitated by the existing one in the village. Pokrovskoe Ecological Center "Agroecology", providing practical training for students and schoolchildren, scientific research, scientific and practical events (conferences, seminars, round tables), the development of ecological tourism in the region [18, 19].

To maintain the stability of natural and anthropogenic ecosystems, it is necessary to optimize the nature reserve and regional ecological network as a basis for the development of agro-landscape parks [20, 21].

3 Conclusion

According to the research results, a system of land protection measures has been formed in the context of reducing the degradation processes of agricultural land that is based on ensuring the natural fertility of lands.

The basis of such a system are measures to restore the natural characteristics of soils by increasing their natural fertility, namely, optimization of crop rotations, use of organic farming, development of nature reserves and objects to maintain the stability of natural and anthropogenic ecosystems, including number of national natural and regional landscape parks. Maintaining the content of quality humus in soils is the most important task of agriculture, it is the basis of sustainable farming, the main factor of soil fertility, and for Ukraine, in the current geopolitical realities, the main relevance of national food security.

To ensure simple reproduction of soil fertility, it is necessary to review existing crop rotations in order to reduce the proportion of row crops and bring them in line with the recommendations for the optimal ratio of crops in crop rotations of different soil and climatic zones of Ukraine. To prevent the current negative trend of reducing the content of humus in the soil, it should be considered the crops of continuous sowing to have the lowest value of the organic matter mineralization factor. Saturation of crop rotations with row crops (sugar beets, corn) with a simultaneous decrease in the area under legumes, on the contrary, enhances the humus mineralization processes.

Necessary introduction into the production of soil-protective crop rotations with the optimal ratio of crops, as well as the expansion of areas under perennial grasses, especially legumes, growing intermediate crops and greens, replacing pure vapors with busy, significantly revives the soil environment.

Reproduction of natural soil fertility should be based on the use of organic farming as one of the main means of soil protection, providing agricultural land quality composition.

Thus, the implementation of the land protection measures proposed system in the context of reducing the degradation of agricultural land that is based on natural land fertility enables the strategic development of processes to restore the natural characteristics of agricultural land.

The rational design of agricultural buildings should consider the general provisions of agricultural production, the placement of agricultural land in agroecological farming, accurate calculations of the natural and economic characteristics of particular economy and the prospects for its development.

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Landscaping and Greening of the Residential Buildings Courtyards of the 50s–Early 80s of the XX Century in Ukraine: Current Situations and Renewal Perspectives

Liudmyla Shevchenko, Olga Mykhaylyshyn, Natalia Novoselchuk, Olena Troshkina, and Mohammad Arif Kamal

Abstract The residential buildings courtyards of the 50s–early 80s of the previous century is the object of this scientific paper. Residential environment of this kind is predominant in the central historical districts of the majority Ukrainian cities, including Poltava, Rivne, and Kyiv. The main aim of this paper is to analyze the residential courtyards of the outlined period, to find out its current stands and to provide perspectives of their improving. The complex methodology became the basis for this study. The results of the analysis of the current state of residential yards during the study period became the starting point in the process of their modernization on the way to the humanization of the modern architectural environment. Ways to update residential yards as part of the living environment are a scientific novelty of this study. They show that reconstruction and modernization achieve positive social and economic results (both for buildings and courtyard space).

Keywords Residential building · Courtyard · Landscaping · Greening · Perspectives

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_43

1 Introduction

The topic is related to the intensive search for measures to improve the environment. Last but not least, this applies to urban space, landscaping of its territory, including residential one. The beginning of this period coincided with the solution of the post-war housing crisis in the cities of the Soviet Union. Mass construction of typical and fast-moving buildings was one way to overcome housing shortage. At the same time, a number of "concomitant" problems were solved. Among them are rapid recovery and development of industry, creation of new urban infrastructure, energy efficiency, durability, consumer quality, and comfort of life. Such housing met the social standards in force at that time and was quite comfortable, despite the simplicity of the appearance of buildings and their functional organization [1]. Residents of residential buildings had adjacent territories and courtyards at their disposal. These yards formed a unique microclimate with its atmosphere of Soviet life in the mid-50s–early 80s of the twentieth century.

1.1 Direction of Scientific Research

Housing in this period has been the subject of authors' research and coverage of results in previous publications for many years. This concerns its consideration in terms of the possibility of modernization as a way to humanize the modern architectural environment [2], giving new life to old residential buildings [3]. They are promising at this stage in the cities of our country. This publication is dedicated to residential yards as an integral part of housing in the mid-50s–early 80s of the twentieth century. It is important to find out their level of development and compliance with modern requirements of the time.

This study is conducted in the context of research work of the Department of Building Architecture and Urban Planning (National University "Yuri Kondratyuk Poltava Polytechnic", Poltava) on "Humanization of human life as part of European integration of Ukraine" (state registration number 01117U003244), Department of Architecture and Environmental Design (National University of Water Management and Nature Resources Use) on "Contemporary issues of architectural history, theory and practice of the North-Eastern region of Ukraine" (state registration number 01117U007677) and the Department of Fundamentals of Architecture, Design and Urban Planning (National Aviation University, Kyiv) on the topic "Synthesis of visual arts in the architectural environment" (state registration number 108/10.01.08).

1.2 Source Base of Research and Its Methodology

The complex technique became the basis for this study. It is based on a number of methods aimed at clarifying the current state of residential yards of this period in the structure of cities and considering possible perspectives for their renovation. Analysis and systematization of materials of previous researchers showed that most of them relate directly to residential buildings, their structural systems, architectural solutions. But the yards in the formed residential groups from such houses are not represented in typical projects.

Previous works of scientists are of importance. A number of them are dedicated to various aspects of the reconstruction of residential areas of the study period. The author's vision of solving these issues is covered in the works of Dyomin [4], Gabrel [5], Schreiber [6], Bulgakov [7], Kartashova [8], Dyachenko et al. [9], Dubel [10], Novoselchuk [11] and others. Scholars widely present the spatial, economic, social, structural, technical and artistic, and aesthetic aspects of housing of various standard series. But not enough attention is paid to residential courtyards in these works. Consideration and systematization of these materials in accordance with the specific period under study–the mid-50s–early 80s of the twentieth century–became possible due to the architectural and typological method. These issues are closely linked to the country's urban, social and housing policies. The method of analytical analysis of such processes, their impact on the formation of housing groups and their internal environment showed the relationship between the study period and the present. This allowed the authors to find answers to the question: do the courtyards of housing in the 1950s and 1980s meet the modern requirements and needs of citizens? Is there a potential for updating them now?

Information on landscaping and improvement of cities and its separate territories, text descriptions of courtyards are found from the researched materials. Among these materials are the works of Gorokhov [12], Lunts [13], Bakutis [1] and others. They are devoted to urban green building in general and landscaping of residential quarters and quarters in particular. Also important are the plans of residential areas, quarters with groups of houses and photos of the then state of the courtyards as research objects. Identification and substantiation of features of landscape-planning and compositional decisions of courtyards at comparison of the investigated and modern periods became possible thanks to a method of the comparative analysis. Analogous objects and unrealized projects in the post-Soviet states are the basis for these results. Here we should note the state legislative normative building base of both periods, which substantiated the design decisions and their implementation.

The scientific achievements of scientists on the improvement of settlements, including residential courtyards are worth noting. The research of Bocharova [14], Khromov [15], Shakhova and Schmidt [16], Lille [17] and others is devoted to this issue. The authors also benefited from the materials of scientists related to the artistic and aesthetic issues of the urban environment in general and its residential areas in particular. Among them are the works of Sychova and Titova [18], Simonds [19], and other authors. The use of the method of visual field examination allowed the authors to verify the reliability of the research results, the correctness of the applied empirical and theoretical methods. In general, the idea of this study was primarily crystallized from a significant layer of visual material collected by the authors in the form of photographs of fragments of residential courtyards, which were inherited from 1950–1980 in Poltava, Kyiv and Rivne (Ukraine).

2 Urban Policy of the State on the Formation of the Living Environment in the Study Period

The object of this research is the courtyards of residential groups of 1950–1980. In the most cities of Ukraine, such a living environment is a significant part of the development of their central historical parts. At one time, specialists developed a method of landscaping and "design of engineering improvement of residential areas, micro districts and quarters" [1], and other components of the urban structure of Soviet cities. This was also prescribed by the "Rules and Norms of Urban Planning and Development" approved in 1958, the "Building Norms and Rules" and the directives for the construction of Soviet society. According to these rules, "it is necessary that micro districts and quarters are convenient for the population, provide the necessary green areas and devices for physical education, children's games and recreation, farmyards, as well as have adequate engineering equipment and landscaping. When landscaping the internal quarters should use simple economic forms, it is recommended to widely use lawns as a cover, avoiding unnecessary asphalt pavements in the courtyards" [20]. Guided by these rules, a system of landscaping of the city was created. It included general, limited and special purpose facilities. The theory and practice of Soviet urban planning showed that such a system determined the planning structure of the city and, at the same time, was determined by its division into planning elements (including micro districts, quarters, and separate residential groups). There was an active search for rational planning solutions in micro districts and quarters with residential development (see Fig. 1).

Later, freer planning decisions began to be introduced to improve sanitation. By the way, once, the famous expert J. Symonds considered it a mistake of urban planners "to force our cities into grids of quarters and districts with constant size, with constant functional use of the site" [19] and continuing–"in a residential area such use is not allowed!" [19]. He offered his own vision of the compositional placement of residential buildings on the site and emphasized the reasonable "narrowness" of the space, the diversity of its compositional solutions and human scale.

In our country, the spatial organization of groups of buildings (including residential) at that time largely depended on the limitations of the construction industry and methods of installation of buildings on construction sites. As a result–sometimes residential courtyards reached significant sizes. They were often monotonous. Attempts to avoid isolation and monotony, the transition to more "free schemes" in some cases led to chaos [21]. But the attempt to preserve and emphasize the features of the landscape opened up the possibility of creating expressive compositional solutions. They

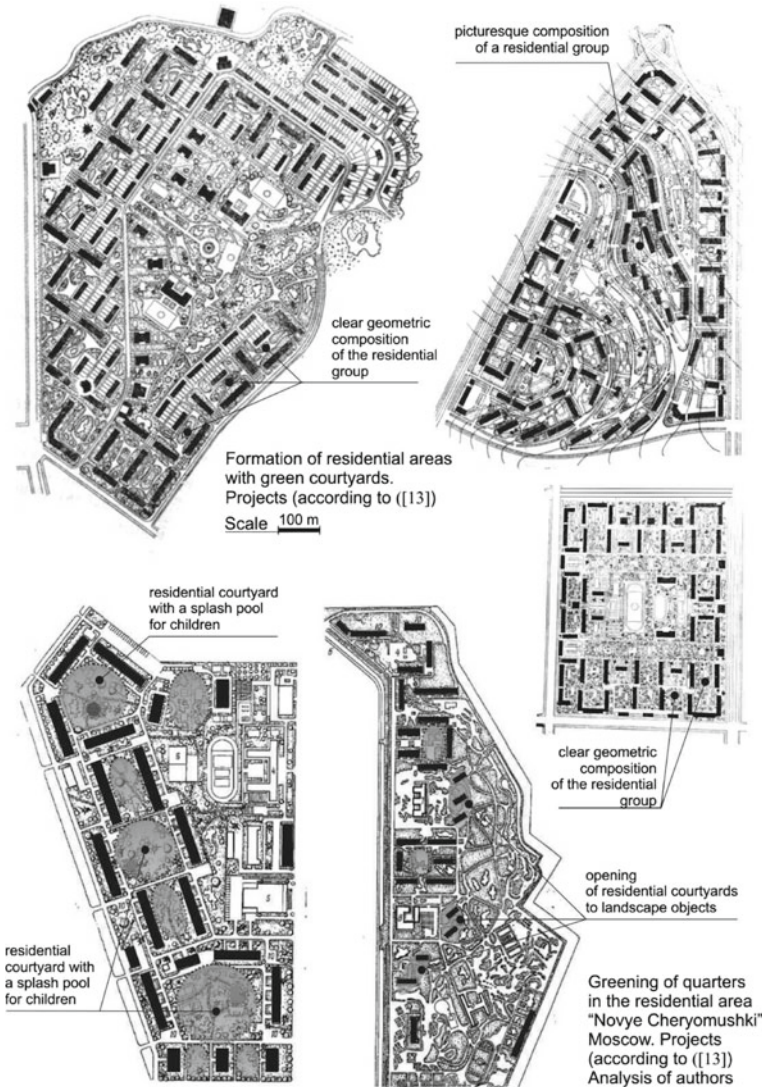


Fig. 1 Search for rational planning decisions of micro districts and quarters with residential development. *Source* photo–by authors, schemes–by Lunts [13]

were based on the interaction of the same type of houses, grouped in picturesque groups, and the natural environment, represented by the volume of vegetation and the planes of reservoirs (see Fig. 2). Therefore, researchers of this period are convinced that the value of housing in the 1950–1980s lies in the planning structure of micro districts with a system of paths, green areas, playgrounds for children, swimming pools, cozy green spaces with developed social infrastructure.

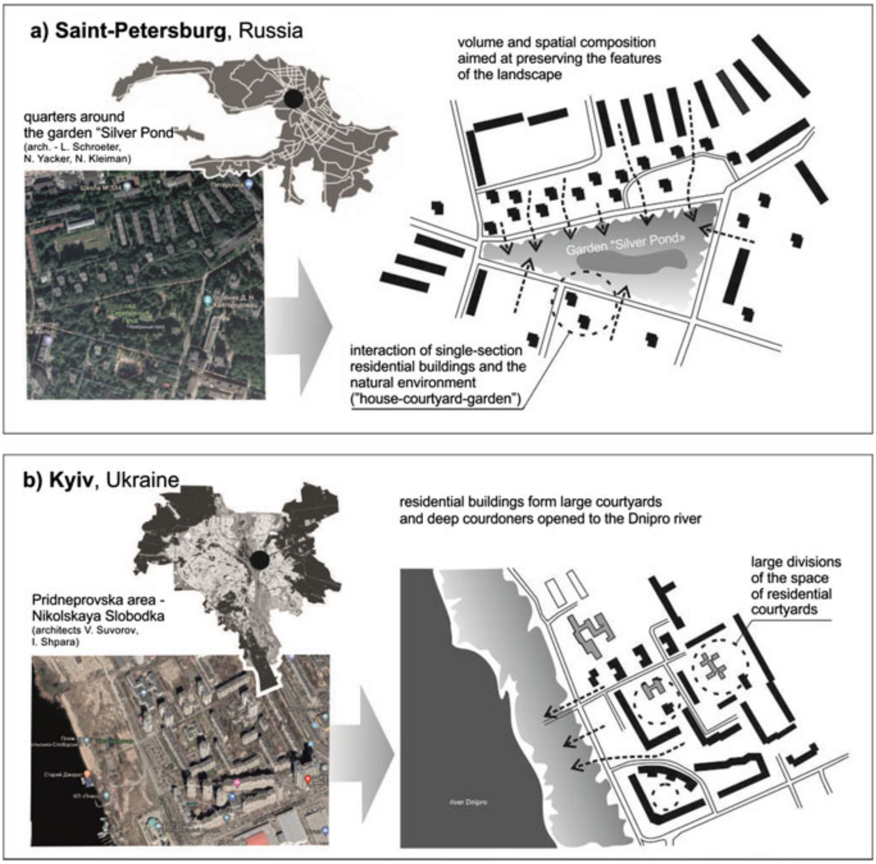


Fig. 2 Implemented compositional solutions aimed at the interaction of groups of residential buildings and the natural environment (vegetation, water reservoir). *Source* schemes–by authors

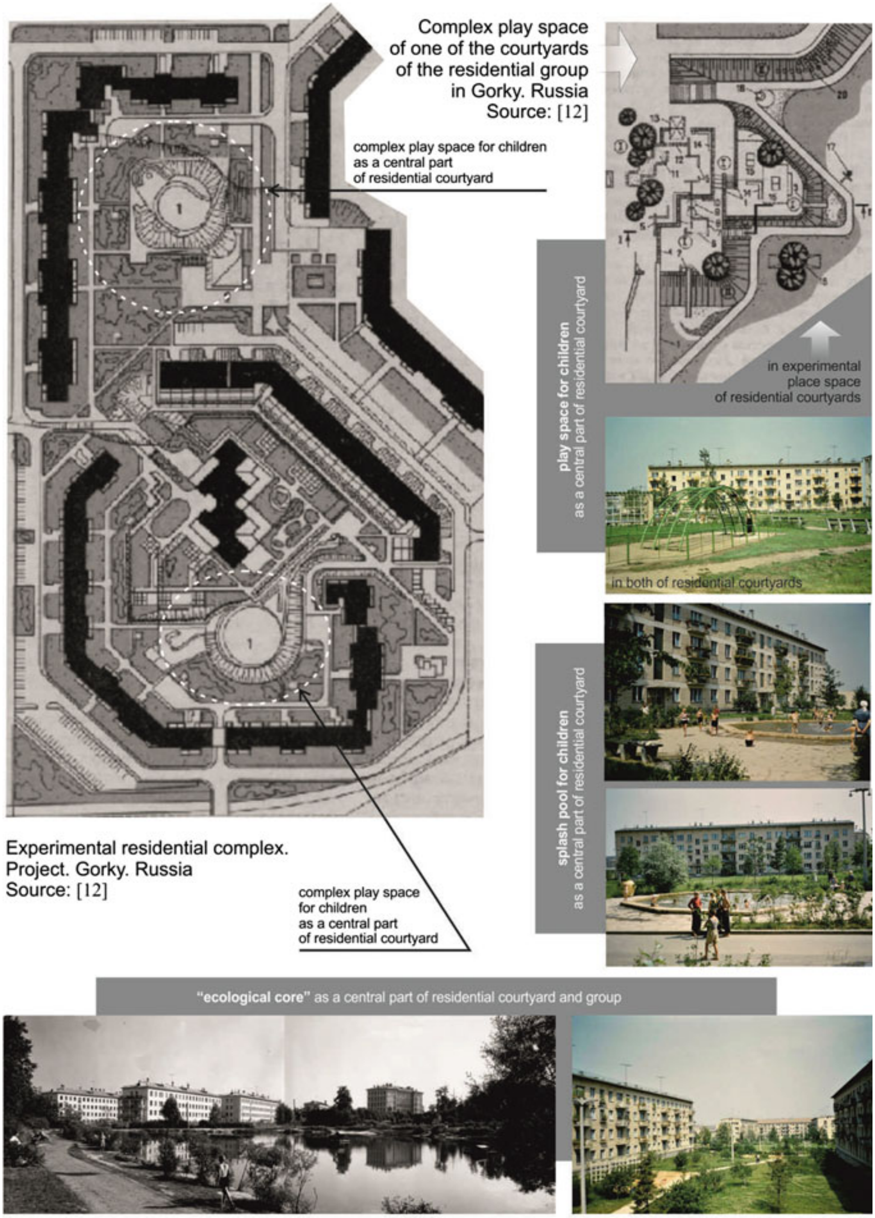
3 Landscaping of Residential Buildings' Courtyards in the 50s–Early 80s of the Twentieth Century

The residential courtyard in the studied period was the main space of the then neighborhood [12]. It was then, and is now a continuation of the housing, but in the fresh air. This is a kind of primary connection of residents with nature. The main function of residential courtyards was seen in recreation and rehabilitation. One of the main tasks was to provide the most favorable functional zoning of the yard with areas for quiet rest (near houses), active rest with sports grounds and splashing pools, for rest of children of different ages. At the same time, the yards provided optimal sanitary and hygienic conditions (in the adjacent areas), partial shade in the heat and isolation from farm areas.

Two main methods were used for landscaping residential yards. The first was to create a small micro-garden near each house. The second was based on the amalgamation of building plots in a group of residential buildings into one large green area. According to scientists and practitioners, the second method was more common in the practice of forming courtyards [13]. This approach made it possible to create pleasant microclimatic conditions for different categories of residents of the residential group by arranging playgrounds with different types of recreation. In addition, such large areas created more acceptable conditions for plant development and care. The analysis of design decisions showed that in the most cases they tried to create a so-called "ecological core" of the yard (see Fig. 3). Its size depended on the size of the courtyard. Therefore, the compositional and spatial organization of the nucleus was represented by a landscape group of trees and shrubs, as well as a small grove of Aboriginal trees, or a green lawn. It was important to preserve the existing vegetation, micro relief, and soil.

For the first time in the Soviet Union, complex landscaping with perennials was used on the territory of residential courtyards. This minimized the effects of noise and wind. Alleys were provided here. They were well landscaped (1, 5–2 rows of trees) and had dense insulation from transport (trees with bushes). Quiet walks, jogging, skiing and cycling are the main purpose of such alleys in the courtyards. Active sports movement and healthy recreation fully corresponded to the Soviet country proclaiming itself a healthy society. Alleys played the role of communication green corridors in the general structure of the micro districts. They connected adjacent residential courtyards and led them to the nearest parks and promenades. Such technical structures as transformer substations, boiler houses, garbage collectors and parking lots were supposed to be moved outside the central green space. According to the norms in force at that time [20], garages, utility blocks and boiler houses were not part of the residential area of the district [20]. It was recommended to combine communal premises into economic complexes with the arrangement of separate economic yards. Open parking lots for private cars were provided in areas isolated from residential buildings, recreation areas for their residents and playgrounds for children.

It should be noted that landscaping had to be coordinated with the general architectural and spatial composition of the quarter and its functional purpose (artistic, aesthetic and utilitarian–shading of playgrounds, recreation areas, insulation from driveways and playgrounds). The landscaping guidelines emphasized careful preservation and use of all existing vegetations (including each individual tree); wide use of grass cover for landscaping of residential courtyards; application of landscaping techniques with maximum approximation to the natural conditions of the area; use of flowering shrubs, fruit trees, vertical landscaping and hedges [20].



Moscow. Fili-Mazilovo. 1963. Photo from the archive of the Institute of Modernism. Source: https://archi.ru/russia/64030/estetika-sovetskoi-zhiloi-arkhitektury

Fragments of residential courtyards. Source: https://back-in-ussr.com/2018/10/te-samye-novenkie-hruschevki.html

Fig. 3 Formation of the compositional center of the yard of the residential group of the 50s–early 80s of the twentieth century

4 Landscaping of Residential Yards of the 50s–Early 80s of the Twentieth Century. Current State

According to the above-mentioned norms, the external improvement was carried out in "simple economic forms" [20] with wide use of landscaping and maximum reduction of the area of asphalt pavement in residential courtyards. The amount of landscaping per unit area and the proportion of lawns and paths determined the general nature of landscaping. According to the proposals of the project organizations at that time, 250–450 trees and 2000–3000 bushes were provided per 1 hectare of territory. Lawns were to occupy 70–79% of the territory, and paths–10% [13]. The paths provided a convenient connection of entrances to residential buildings with all other buildings and areas of the residential group. Therefore, their construction was given a significant place in the overall complex of works on landscaping of green courtyards. The choice of the type of coating of both tracks and sites was especially important, based on aesthetic and economic requirements, their purpose and operation. The color and nature of the pavement had to be harmoniously combined with the natural environment.

The possibility of industrial production of payments and the provision of surface water runoff were significant factors influencing the choice of their type in the study period. The authors make an analysis of the types of pavements used in paths and areas in residential courtyards in the mid-50s–early 80s of the twentieth century. At the initial stage, two main types of tracks were used–asphalt and gravel (see Fig. 4). But in subsequent years, the first were not recommended for use due to the negative effects on microclimatic conditions in the courtyards and insufficient decorative characteristics. The second–crushed stone–was not effective enough due to occurrence of dust in hot weather and dirt–in the rain. As a result, prefabricated payments made of artificial elements with their characteristics have become widely used. The main characteristics of this coating included: the possibility of industrial rapid production; mass production; variety in shape, color, texture, and thickness. These became the motivator of their widespread use in housing development.

Studies have shown that concrete tiles made of sandy or silicate fine-grained concrete had the best results in terms of physical, mechanical and economic indicators [13]. Unlike ordinary concrete, the filling elements of large fractions are not part of sand concrete. And silicate concrete was made by acting on the limestone-sand mixture with high pressure steam. Ground sand was added to this artificial stone material, resulting in high-strength slabs called "silica". In the factory, concrete slabs were made using methods of pressing, vibrating, vibro-rolling and vibro-ironing. In this way, the most commonly used tiles were obtained in sizes 30 × 30, 40 × 40, 50 × 50 75 × 75 cm. They were made with a thickness of 3.5–7 cm. They were of different geometric shapes–square, quadrangular, hexagonal and round. Tiles were laid on sand, gravel and gravel substrates (see Fig. 5). In 1972, the state standard for concrete paving slabs was approved (GOST 17,608–72). The standard sizes of square, rectangular and hexagonal plates which were widely used in practice of improvement of inhabited territories by this standard were established.

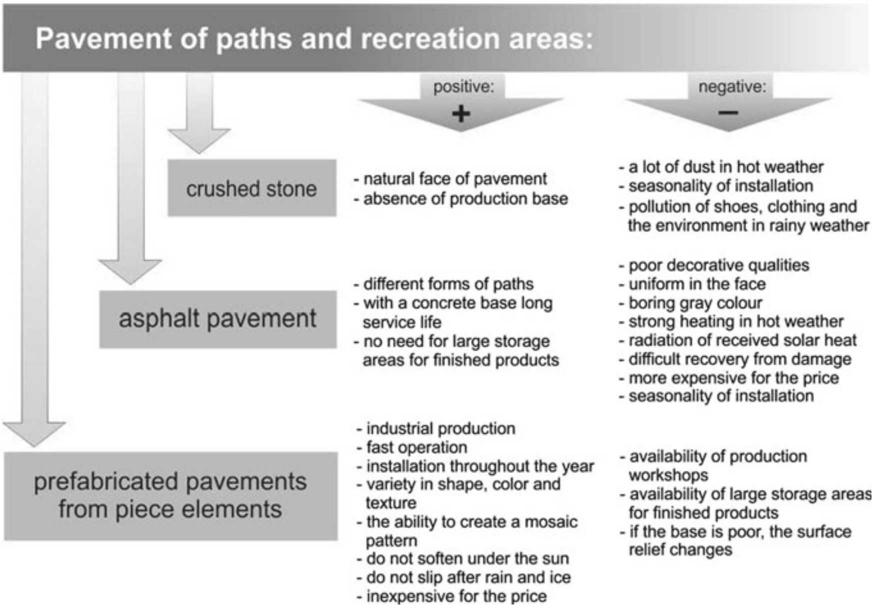


Fig. 4 Characteristics of the main types of pavement paths and areas in residential courtyards in the mid 50s–early 80s of the twentieth century. *Source* by authors

To obtain a solid coating, the tiles were laid tightly, without gaps. Such landscaping was usually created in the most visited areas of the courtyard–near the entrances to residential buildings. The lawn was included in the construction of the pavement to combine the paths with the surrounding landscaping and create the aesthetic integrity of the courtyard. To do this, the coating tiles were laid with an interval of 20–30 mm. Grass was sown in these seams (see Fig. 5b). This made it possible to organize the natural flow of water through such grass seams and even reduce the cost of such a coating by 10%. With the help of colored cements and dyes, concrete tiles were given different colors–from gray to terracotta and burgundy shades. This palette helped to create a pleasant aesthetic environment. The combination of different types of paving in accordance with the load of the plots has become an important technique in the improvement of residential areas. For example, tiles–at the entrance to the house, asphalt–on the main roads, and gravel paths, which are scattered among the lawns (see Fig. 6). Thus, the hierarchy among materials, functions and qualities of a covering was observed. In addition, it made it possible to more tolerantly combine the natural and urban environment, constantly changing their ratio.

Small architectural forms should be included in the details of landscaping of residential courtyards of the studied period. Gazebos, outdoor furniture, fencing elements, and sculptures are among the most used at that time. The practice of using industrial elements to create small architectural forms in the living environment was the most widespread in the activities of architects. Among them are precast concrete elements, plastic, organic glass, etc. Creation of small forms of individual

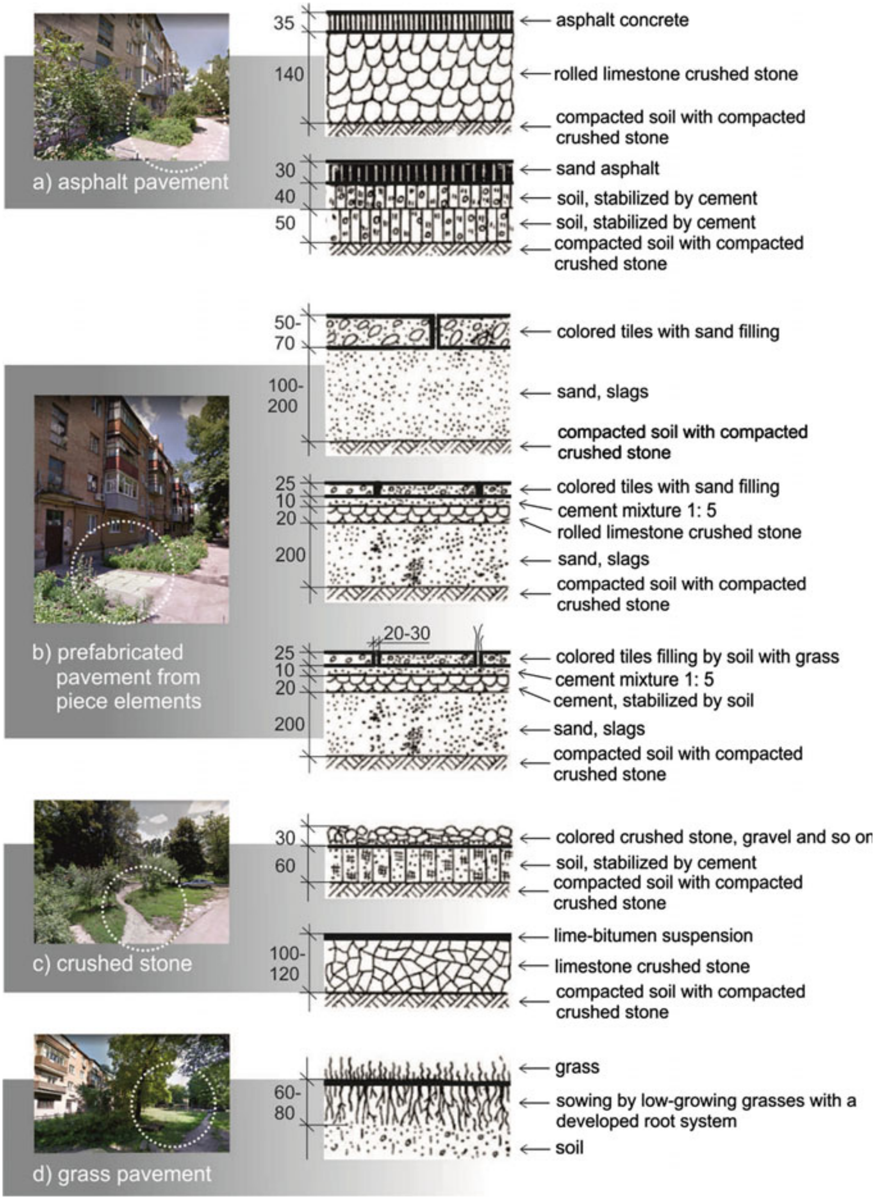


Fig. 5 Constructive schemes of the most used types of paving of paths and areas in residential courtyards of the mid 50s–early 80s of the XX century. *Source* photo–by authors, schemes–by Lunts [13]

Fig. 6 Analysis of the elements of the payment of one of the yards of residential buildings of 1950–1980 Poltava (Ukraine). *Source* photoby authors

production from natural materials (wood, stone) has not become widely used. The industrial direction of production of landscaping elements for residential courtyards made it possible to introduce standardization and typification of small forms, which was fully consistent with the rate of Soviet urban planning. Not only individual products (benches, tables, fencing elements, etc.) were unified, but also individual components. This was valuable at the time, as it made it possible in the current standardization and unification to create from such elements various forms and their combinations in the composition and "fit" into a specific living environment [18].

Preservation of the principle of standardization in industrial production made it possible to create the maximum number of types of finished products from the minimum number of components. In this way, not only individual small forms were obtained, but also sets for the arrangement of various sections of residential courtyards. A list of mandatory small forms of architecture for housing has been introduced, depending on the purpose of the site. According to Balyan [22], Dyomin et al. [23], Orlenko et al. [24], playgrounds for children should have a sandbox, canopies, water play devices, swings, gymnastic equipment, lanterns, benches and urns. Sports and playgrounds should be equipped with simulators, racks, tennis tables, campaign stands, benches, and lanterns. Sports facilities must include equipment for hockey, tennis, basketball, volleyball, and benches. Household areas were provided with garbage collectors, equipment for drying laundry and things [22].

The focus on the industrial way of creating small forms and the rapid pace of housing construction contributed to the development and emergence of catalogs of typical elements of the external improvement of micro districts for use in residential areas of cities. The catalogs contained ready-made products that could be selected for a specific residential group. At the same time, such unification of elements led to the identity of the territories of different residential groups. Is it possible to say that the typical designs of the houses themselves, the planning decisions of the residential groups, their equipment with small forms and equipment in general in most cases led to similarities and vagueness? This situation has persisted to this day in our cities.

The authors analyzed the elements of landscaping in residential areas of Poltava (see Fig. 7), which were formed during the study period. Problematic issues related to the compliance of the courtyards with the current regulations and the level of comfort were identified through the analysis of the territory and a sociological survey of the residents of these residential courtyards. Among the most relevant are:

– presence of narrow and through passages;
– lack of turning and exit platforms;

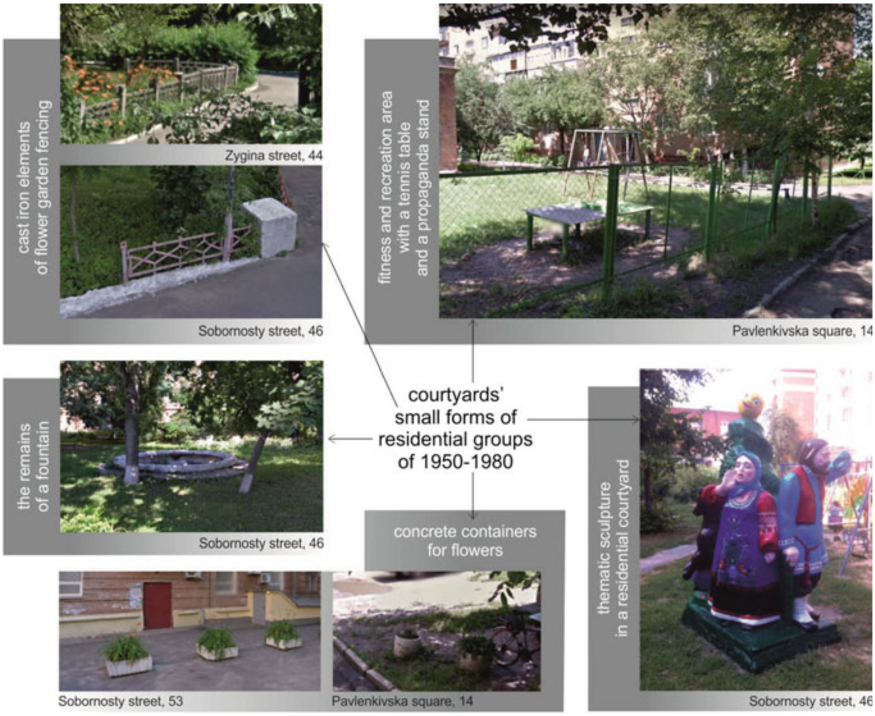


Fig. 7 Small forms in the improvement of housing groups mid. 50s–early 80s of the XX century, preserved in the courtyards of Poltava (Ukraine). *Source* photoby authors

– lack of temporary parking for cars (as a result–cars are "parked" everywhere, including on playgrounds);
– outdated improvement of residential yards;
– various functional areas lack clear visual boundaries, which leads to a lack of comfort, security and privacy;
– lack of modern elements of equipment–games, sports, etc.

The study also revealed the positive features of the spaces of these residential courtyards, which are the comfortable density of buildings and the coziness of the green yards. The analysis of residential courtyards of the studied period of some cities of Ukraine showed that today their space is not equivalent and different parts of its territory are "updated" in different ways and to different degrees. In a number of objects, the elements of improvement were eventually replaced by the new residents of the houses, or the city administration. But these are all local point steps. First of all, this applies to the areas closest to the house. Flower beds and car parks are huddled to the windows of the ground floors of houses. This indicates a desire to separate inside the courtyard, to create their own microspace. Signs of the development of living space are household items–linen on a rope, a chair in front of the entrance, thrown toys in the sandbox, and so on. However, now such courtyards increasingly remain undeveloped objectively and are not marked as a private space that is different from the neighboring one. Because household activities have gradually moved into housing.

5 Promising Approaches to Improving the Landscaping of Residential Yards in the Mid-50s–Early 80s of the Twentieth Century

Courtyard is an elementary part of urban space, assigned to a particular house or group of houses. Clearly fixed, closed space of the city yard is always commensurated with the person. This is an intermediate space during a person's transition from the door of his apartment to the vast space of the city. At the same time, the city yard is a protected space, the boundary of the division of the territory into "own" and "foreign". Housing itself (house, apartment) is the starting point "as much as possible", and the city as such–"as alien as possible." From the point of view of the residents, the yard is thought of as a private territory, where everyone knows each other well, who owns the territory of the yard for many years of living in this residential area.

Based on the results of the study and the method of experimental design, the authors of the article had the opportunity to make proposals for the modernization of the residential courtyard in the mid 50s–early 80s of the twentieth century in the city of Poltava (Ukraine). The quarter is limited by Sobornosti St., Nechuya Levytskoho St., Zyhina St., and Klubny Lane. The project provides for the partial preservation of existing transport links and new passages with turning and exit platforms (since before the reconstruction all the passages of the quarter were through). The authors have arranged places for temporary parking of cars and proposed underground parking for cars of residents of the residential group. Due to this, to free space in the courtyard under the old garages and natural parking spaces. Some changes in the pedestrian organization of the living space have been proposed in accordance with the new intra-quarter connections and playgrounds. Pedestrian connections run along the sidewalks, which are arranged along the perimeter of the quarter. Alleys and a network of paved paths have been arranged for transit connections through the block between residential courtyards. It is proposed to update the elements of their coverage. A comfortable and durable coating of colored tiles with sand filling or soil with grass on the sidewalks and at the entrances to the houses is offered. Colored crushed stone, gravel, and so on are provided in the landscaped areas of the yard.

The area of the residential courtyard is about 0.04 hectares. The vacated areas contributed to the placement of convenient playgrounds, comfortable areas for quiet recreation of the adult population and small sports areas (see Fig. 8). It is proposed to supplement the whole area with a quality lawn, flower beds in the form of front gardens, small groups of shrubs and trees. Greenery allows you to isolate different functional areas, protect the entire area from noise and gassiness of nearby streets, to create shade for a comfortable stay. Ground floor apartments are proposed to be converted for people with disabilities. They provide access to their own adjacent territory in the form of green terraces. Update of elements of improvement and subject filling of various functional platforms is offered. The basis of the elements are simple objects made of natural and comfortable artificial materials (wood, metal, rubber), which allow both children and adults to transform the space. These changes are possible during themed games, trainings, etc. Together with active physical activity, these sites will provide an opportunity to develop creative abilities, imagination, the ability to possess the necessary tools.

6 Conclusions

Today there are many challenges in the improving and landscaping of urban areas, and in terms of creating public spaces that are needed by local residents, not officials. The residential courtyard is the smallest urban public space in this system, a kind of microworld of a big city. Accordingly, it should be treated taking into account the wishes and needs of local residents and involving them in cooperation with architects and landscape designers.

The problems, highlighted in the article, are relevant for residential buildings of the study period and other post-Soviet countries. World practical experience of their solution, and modern trends in this area have made it possible to clarify the methods of modernization of courtyard spaces. They lead to their transformation into a modern comfortable living environment, including:

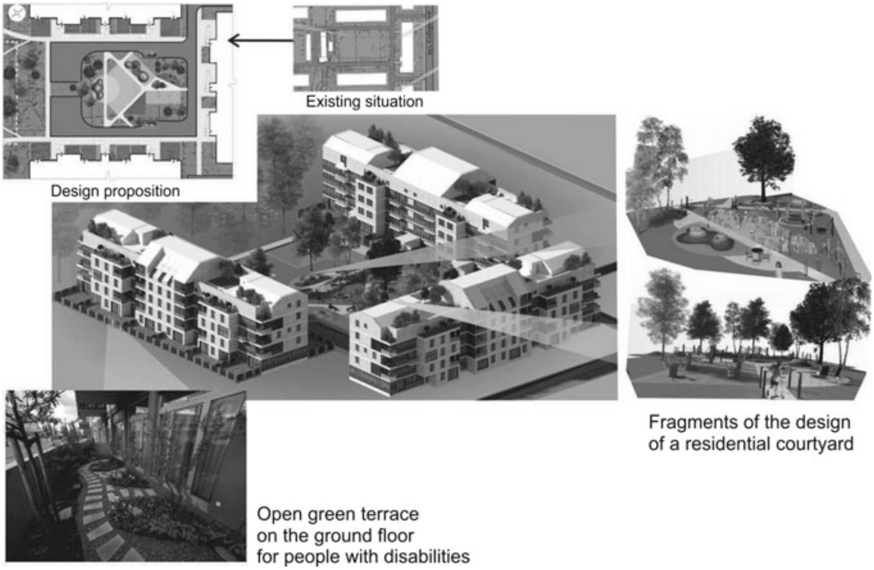


Fig. 8 Modernization of a residential courtyard built in the mid-50s–early 80s of the twentieth century in the city of Poltava (Ukraine). *Source* by authors

- liberation of the territory of the courtyard from the places of permanent storage of vehicles of residents;
- use of the underground space of the courtyard for parking within the limits allowed by the current building regulations;
- transformation of existing playgrounds into complex sports and play areas of active movement for children and adults, modernization of their equipment in the direction of physical and creative development;
- reconstruction of the existing landscaping with additional planting of bushes and trees for isolation of functional zones and formation of small landscape groups;
- reconstruction of front gardens and flower plantations with the possibility of involving residents of housing groups in their further care and maintenance;
- reforming pedestrian and transport links in accordance with current building codes and the convenience of residents of the residential courtyard;
- modernization of elements of improvement of pedestrian communications in the courtyard by replacement of coverings according to construction base and functional loading;
- modernization of small architectural forms by replacing them with modular equipment and elements of the subject content of the residential courtyard, which will avoid monotony and contribute to the creation of a unique living environment.

The implementation of these measures will lead to the renewal of the living environment, its improvement, elements of the subject content and landscaping. This is a way to a positive transformation in accordance with current building codes and the wishes of residents of residential groups. These steps provide an opportunity to preserve the unique cozy atmosphere inherent in the studied residential courtyards of the mid 50s–early 80s of the twentieth century. In addition, the renewal of the living environment shows that its reconstruction and modernization achieve positive social and economic results (both buildings and courtyard area). The proposals, developed by the authors for one of the residential districts of the central part of Poltava (Ukraine), are relevant for both citizens and representatives of the authorities. Their practical significance lies in the possibility of introducing real positive changes in the living environment, physical and moral condition of his courtyard.

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Formation of United Territorial Communities Based on the Principle of Urban Agglomerations

Halyna Tatarchenko, Nataliia Biloshytska, Mykola Biloshytskyi, Maryna Shparber, and Serhii Bida

Abstract The paper analyses factors, properties, and criteria contributing to the formation and development of the territorial community based on the principles of urban agglomerations in modern conditions on the example of cities in Luhansk oblast. In the modern world, it is no longer a question of competition between countries but actually between cities–agglomerations or metropolitan cities. In fact, they have been in Ukraine, e.g., large cities of Kyiv, Kharkiv, Lviv. Currently, Ukraine has introduced three levels of the administrative-territorial system, which distinguish the following units: community, district, region. As a part of the decentralization reform in Ukraine, 490 old districts have already been liquidated and 136 new ones have been formed. There have been created 1470 united territorial communities, which should become the basis of local self-government. A criterion analysis of the territory with adjacent settlements has been conducted from the point of view of unification into a territorial community. Priority measures for the development and improvement of the united territorial community as an urban agglomeration have been proposed. Based on the criterion analysis of 'Severodonetsk-Lysychansk-Rubizhne' territory with adjacent settlements, we can consider the united territorial community as an urban agglomeration, and develop it as a complex system that includes not only cities and settlements around them, but also all production facilities, resettlement of inhabitants, interaction of nature and urban population as a single entity. For such agglomerations, emphasis should be placed on spatial development, in particular on traditional distribution factors, such as transport, material, labour costs.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_44

Keywords Agglomeration · United territorial community · Criterion analysis of the territory · Boundaries of spatial influence areas

1 Introduction

At the present stage of development of society, the most common form of settlement is an urban agglomeration. It is a compact cluster of rapidly developing localities consisting of dozens and sometimes more urban and rural settlements, closely related to each other. Settlements in the agglomeration are grouped around one or more core cities and are united by various and intensive connections.

Territorial communities are a basic administrative unit in Ukraine that are formed based on the criteria of population and compactness. The territory of a territorial community is an inseparable unity within which the territorial community exercises its powers to resolve issues of local character according to the Constitution and laws of Ukraine, both directly and through local governments.

Urban agglomerations aim to restrain the excessive concentration of population and industry in the core city, to form a common labour market, to transfer some functions from the core city to the periphery of the agglomeration, to form a service economy in the suburbs. That is, a single spatial and economic territory is formed connecting the core city of the agglomeration (there may be two or three) and their satellites.

The priority of united territorial communities (UTC) is the consolidation of districts. For that purpose, they used several criteria including the population of at least 150 thousand people and the distance to the district centre not exceeding 60 kms.

2 Analysis of Recent Research and Publications

The emergence of agglomerations is a qualitatively new stage in the city evolution with the transformation of settlements into a system with 'blurred' borders. Agglomeration is a component of higher-ranking regional resettlement systems [1]. The territory of the agglomeration must be organized and structured as elements of regional urban planning systems. According to [2–6], 'the agglomeration does not have an appropriate management mechanism or a developed single regulatory document, so it accumulates individual decisions, sometimes effective only from the point of view of a ministry or agency'.

In the modern world, it is no longer a question of competition between countries, but actually between cities–agglomerations or metropolitan cities. In fact, they have been in Ukraine, e.g., large cities of Kyiv, Kharkiv, Lviv. Currently, three levels of the administrative and territorial system have been introduced within the framework, according to which the following units have been distinguished: community, district, region. As a part of the decentralization reform in Ukraine, 490 old districts have already been liquidated and 136 new ones have been formed. There have been created 1470 united territorial communities, which should become the basis of local self-government [7].

In the understanding of 'urban agglomerations', the following main approaches have been formed [8]:

– economic, i.e., agglomeration as an organization of economic space through the production ties of various industrial enterprises and resource-financial interdependence of territories;
– geographical, i.e., agglomeration as a set of settlements with various connections;
– social, i.e., agglomeration as an organization of people's activities, the connection of different communities by economic and household ties;
– management, i.e., agglomeration as a form of management of settlements based on a voluntary solution of common problems;
– environmental, i.e., a way to optimize the system of settlements based on the natural and environmental framework;
– urban, i.e., a group form of resettlement of inhabitants, which requires a combination of economic, geographical, social, managerial, and environmental approaches in equal measure.

The main factors that determine the formation and development of urban agglomerations are [4, 9]:

1. Territorial factor, i.e., expansion of the territory of settlements due to the development of the core city into the adjacent suburban areas;
2. Legal factor, i.e., the availability of a legal framework for the creation and functioning of the urban agglomeration;
3. Infrastructure factor, i.e. the presence of a sufficient number of objects of social, cultural, public services and housing utilities; availability of transport infrastructure for communication between settlements and development of territories;
4. Human factor, i.e., the concentration of a larger population in the core city of the agglomeration, pendulum migration within a given urban agglomeration.

Based on the main factors that contribute to the formation and development of urban agglomerations, we can identify their properties and criteria.

The main properties of the urban agglomeration include:

– compactness of the territorially close settlements;
– presence of transport corridors ensuring the interaction of transport;
– accessibility, which allows expanding the boundaries of the agglomeration due to the developed system of transport corridors;
– concentration of population, production activities, and services;
– heterogeneity of the territory by functions and their density (complex functional and spatial structure);

- close administrative and political, organizational and business, labour, economic, cultural, and recreational ties;
- complementarity of activities and territorial units in the urban agglomeration;
- integrity of markets of labour, real estate, and land;
- dynamism of development (rates of development of urban agglomerations are higher than rates of development of cities as a whole).

Considering various aspects of the genesis of urban agglomerations, we can single out the main criteria that identify the area as an agglomeration.

The research objective is to analyse factors, properties, and criteria that contribute to the formation and development of the united territorial community based on the principles of urban agglomerations in modern conditions on the example of cities in Luhansk oblast.

3 The Main Research Results

One of the points of growth or formation of the agglomeration in Ukraine is 'Severodonetsk-Lysychansk-Rubizhne' triangle. The idea of uniting those cities into a single system was put forward in the late 50's. Those cities were united not only by the territorial proximity of 10–15 km, but also by a powerful industrial chemical complex, so the name was supposed to be Mendeleevsk or Lysychansk-Rubizhne agglomeration. Severodonetsk received the status of a city only in 1958. It developed rapidly, primarily due to the development of 'Azot' chemical plant, and since 1962 has become a city of regional importance. Interestingly, at that time, Severodonetsk had 24 construction departments and trusts, 11 research institutes and design bureaus. The city was ahead of the neighbouring Lysychansk and Rubizhne in terms of population, and essentially became the core city of 'Severodonetsk-Lysychansk-Rubizhne' agglomeration with adjacent settlements.

Unfortunately, the deep economic downturn in the country has significantly reduced the industrial potential of the region, having affected its demographic, social, environmental, and spatial development. Since 2014, the city of Severodonetsk has served as an oblast centre, and it is important to determine its role in the development of this area.

Based on the main criteria for establishing the external boundaries of the spatial influence areas of the centres of agglomerations [10–15], let us analyse the state of the territory now.

1. Functional criteria are the most important from the point of view of establishing the external boundaries of areas. In fact, strong economic and social ties were formed during the emergence and growth of that system of settlements.
   Many problems are still similar for the whole territory, e.g., electricity and water supply, disposal of household and industrial waste, etc. The level is average.
2. Demographic criterion is one of the most positive for this area.

Intensive construction has attracted an influx of huge amounts of human resources, and the proximity, accessibility, and organization of transportation still allows intensive migration throughout the territory. The level is good.

3. Economic criterion. Most likely, we have to talk about it more in terms of the potential for the revival of economic entities. Unfortunately, many ties have been broken, and most of these entities are forced to work not at full capacity or stand still for a long time. For example, in Severodonetsk these are PJSC 'Severodonetsk Azot Association', OJSC 'Skloplastyk', Severodonetsk Chemical and Metallurgical Plant 'SHMZ', 'Ukrhimenergo', 'Severodonetsk ORGCHEM'. In Lysychansk these are PJSC 'Lysychanskvuhillia', Lysychansk Oil Refinery, Lysychansk Glass Factory 'Proletary', Lysychansk Glass Factory 'Mekhsklo', Lysychansk Soda Plant 'Lyssoda', Lysychansk Plant of Rubber and Technical Products, Lysychansk Liquefied Gases Plant. In Rubizhne these are 'Pivdennyi', LLC 'Research and Production Enterprise 'Zarya', PJSC 'Rubezhnoe Cardboard and Packaging Mill', LLC 'Rubizhansky Krasitel', LLC 'Plant of Reinforced Concrete Products'. The level is potentially high.
4. Urban criterion for this area is characterized by the flow of people from rural areas to cities as elsewhere in the world, but construction is virtually suspended due to the lack of funding and a significant increase in the secondary real estate market due to the events of 2014 and the overall decline of population. In particular, one of the predominant factors that do not contribute to construction is the lack of enterprises for the manufacturing of building materials and products in the region. This leads to higher prices of new houses. Now there are large areas in possession of the private sector. In cities, buildings are formed largely by 4–5-storey, and by 9-storey houses in some neighbourhoods. Construction is virtually non-existent. The level is low.
5. Technical criteria are also a weak link in many cities and towns, but in general, we can talk about a satisfactory state of technical infrastructure. In particular, after a long period of mismanagement in the region, many city councils have begun to work with grant programmes taking into account public opinion aimed at the reconstruction and development of utility services. The level is average.
6. Social criteria are associated primarily with the standard of living, education, occupational structure of the population. This level can be characterized as very good and promising. The average salary is currently UAH 11,446 in Ukraine, and UAH 9,399 in Luhansk oblast determining its average place in terms of living standards among other regions. Despite the difficult moments of life, the region maintains its 5 higher education institutions, 9 colleges, 3 higher vocational schools, 16 vocational lyceums, 279 general secondary education institutions, 268 preschool education institutions, 11 boarding schools, and 23 out-of-school education institutions. The region has a high intellectual potential, a developed network of socio-cultural and sports facilities. The level is very good.
7. Criteria of spatial connectivity characterizing the functional connections of the centre with the surrounding settlements were also well-formed in the last century that is a positive factor for rapid transportation. A network of roads of regional

P-66 and territorial significance T-13-02 and T-13-06 passes through the territory of the city agglomeration. The level is good.

8. The criterion of management is oddly enough the most difficult criterion for any territory according to the present-day reality. The level is the hope for political will for the formation of the agglomeration, and a strategic decision for the development of its spatial, innovative, economic, and social centre.

According to the Resolution of the Verkhovna Rada of Ukraine №3650 dated July 17, 2020 'On the formation and liquidation of districts' in Luhansk oblast eight new districts were formed: Alchevsk, Dovzhansk, Luhansk, Rovenki, Svatovo, Severodonetsk, Starobilsk, and Shchastia [14]. All settlements of the agglomeration will now be located in one district of Severodonetsk (administrative centre is Severodonetsk), except for the village of Novoakhtyrka (which belonged to Novoaidar district, currently it belongs to Shchastia district). As Severodonetsk district includes six city territorial communities (Severodonetsk, Lysychansk, Rubizhne, Hirske, Kreminna, and Popasna) with their united settlements, it will be reasonable to include them in the agglomeration. The population of the district is 491.5 thousand people (including 101.7 IDPs). The area of Severodonetsk district is 2793 km^2 (Fig. 1).

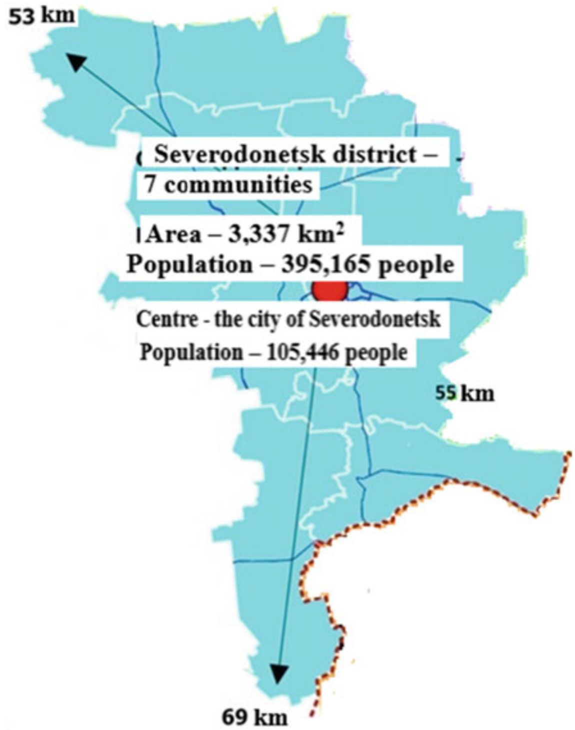

Fig. 1 Severodonetsk district

The criterion of the population is not fundamental in the creation of united territorial communities. Like urban agglomeration, they provide socio-economic ties of settlements. That is, from the moment of forming a united territorial community (UTC), and before providing its proper functioning, it is necessary to establish links inside the agglomeration, which are formed by.

- establishment of joint partnerships and mechanisms of economic, urban-planning, and other development that contributes to the formation of a single integrated agglomeration space. Discussion of problems and creation of coordination activity;
- development of legal mechanisms for regulating economic and urban-planning activities. Creating a system of the urban-planning documents as a basis for the development of the planning structure and other subsystems;
- prime establishment of territories of common interests tied by the balanced development of social, environmental, transport, information, and other infrastructure;
- creation of mechanisms that allow efficient use of natural, labour, financial, and other resources;
- intensive development of transport and communication infrastructures,
- creation of joint logistics centres,
- availability of fast public transport connecting the cores of the agglomeration, and the cores with satellite cities;
- implementation of projects aimed at expanding the problematic issues in the resource provision of the agglomeration: construction materials (especially relevant for Luhansk oblast, where there are no manufacturers of construction materials and products), electricity, water supply, etc.

Thus, in the organization of territorial communities, it is worth using a significant contribution into the research of the formation and development of urban agglomerations of such national and foreign scientists as G. Lappo, F. Listengurt, Y. Pivovarov, A. Stepanenko, Y. Bilokon, D. Bogorad, M. Diomin, V. Semenov, G. Filvarov, G. Clark, E. Pertsyk, M. Gabrel and others.

In addition, an ‘Open Land’ portal can also contribute to UTC. Its data from the geoportal will help solve the problem of unregistered lands that are used, but taxes on them are not paid. All state registers will be able to exchange data, track the value of purchase/sale agreements etc. It will be possible to obtain information on the concentration of land in the hands of a single person. The key areas include support for urban UTCs under the municipal energy management implementation project; creation and improvement of organizational structures and processes; introduction of strategic energy planning in the most active cities; promotion of urban investment measures to improve energy efficiency; communication and awareness raising.

4 Conclusions

Thus, based on the criterion analysis of 'Severodonetsk-Lysychansk-Rubizhne' territory with adjacent settlements, we can consider the territorial community as an urban agglomeration, and develop it as a complex system that includes not only cities and settlements around them, but all industries, resettlement of inhabitants, the interaction of nature and the urban population as a whole. Priority measures are proposed for the development and improvement of the united territorial community. For such agglomerations, emphasis should be placed on the aspect of spatial development, in particular on traditional distribution factors, such as transport, material, labour costs. Special attention should be paid to infrastructure and environmental components.

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Research on the Opportunities to Reduce the Operational Cost of the Thermal Power Facilities

Halyna Tatarchenko, Pavlo Uvarov, Zakhar Tatarchenko, and Nataliia Biloshytska

Abstract The problems of efficiency and reliability of the heat power engineering equipment, the productivity of using make-up water and systems for supplying and dosing chemicals are analyzed. One of the ways to improve the technological process of preparation makeup feed-water has been developed, by simultaneous dosing of several reagents to reduce the aggressive effect of water on the inner surfaces of the equipment of heat power facilities, to ensure an anti-limescale and anti-bacterial regime, which significantly reduces operating costs. The Chemical Injection Package with the reagents for various purposes is proposed fitting together with the existing water treatment scheme. As a result, this will lead to a decrease in the corrosion intensity; the internal deposits formation prevention and the destruction of the bacteria that cause ulcerative sub-sludge corrosion of pipelines and equipment. For the thermal power facilities equipment reliability and efficiency, as well as for ensuring its optimal water-chemical regime, a scheme for corrective treatment of the make-up water for heating networks was developed and implemented. It is proposed to use chemical reagents to achieve the formation of thin protective films on the surface of metals, which will prevent the aggressive effects of water. To reduce operating costs when servicing thermal power facilities and operational reliability due to the provision of an optimal water-chemical regime, a scheme for corrective treatment of the make-up energy water used in the heating networks was developed and implemented.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_45

Keywords Dosing method · Feed-water makeup · Corrosion · Limescale · Chemicals

1 Introduction

Thermal power generation is considered to be the most water-intensive industry. Furthermore, special requirements are imposed on the quality of the water that is used in heating and hot water supply systems (HSS). There is no doubt that water treatment for the HSS is a mandatory action for the normal their thermal equipment operation. The working surfaces of the boilers are prone to the formation of scale and lime deposits. If the treated water does not meet the quality requirements, the heating efficiency will decrease. Therefore, the efficiency of the entire heating complex will drop. Competent water treatment for the boiler plant is a guarantee of the trouble-free operation of heating equipment, which provides consumers with heat on time and in the required volume.

The efficiency and reliability of the thermal power facilities equipment largely depends on the regulatory water-chemical regime provision. In particular, the water used must ensure the uninterrupted operation of the thermal complex without the formation of the corrosion damage, sludge and limescale deposits on the working units and parts surfaces. Similarly, the steam level should be maintained at the planned level.

The existing methods of preventing limescale deposits are often ineffective (the use of inorganic polyphosphates for recirculating cooling systems) or costly (water softening for heating systems and low-pressure steam boilers). In addition, for the efficient use of the feed-water make-up with chemicals there is a problem with their supply and dosing systems. Therefore, the need to increase the efficiency of the thermal power facilities heat supply systems and high requirements for the environmental protection force to revise the existing technological schemes of the main and auxiliary equipment in order to improve them.

2 The Objective of the Work

The objective of the work is to improve the technological process for the make-up feed-water, by simultaneous dosing of several chemicals. This will effectively reduce the aggressive effect of the water on the inner surfaces of the heat power facilities equipment and ensure a scale-free and antibacterial regime, which will lead to a significant reduction in operating costs during its maintenance.

3 Literature Review

In obedience to current regulations in Ukraine, the water-chemical regime should ensure the operation of the equipment without damaging its elements and reducing efficiency caused by corrosion of internal surfaces, as well as without the formation of scale and sludge. To assess the quality of natural waters and waters at various stages of their purification, the following main indicators are used: hardness, alkalinity, iron and chloride content, pH. Methods for monitoring these indicators coincide with the normative references to the State Standards of Ukraine 7525:2014.

For the power engineering facilities water supply, mainly natural waters are used, both as surface as ground, located near the object of consumption. The first are rivers and lakes. To the second are soil or artesian wells, main water supply [1]. Each of the listed sources has its own specific set. In order to determine and concretize these parameters, sampling and laboratory analysis of impurities and contaminants of the water planned for use are carried out. An important condition is the availability of appropriate accreditation in the laboratory. The information obtained is necessarily taken into account when forming the structure of the water treatment scheme.

All impurities that pollute water are divided into three types depending on their particle size. The particulate pollutants impurities have a particle size of more than 10^{-4} mm. These are particles of sand, clay, plant debris and others. The ingress of the particulate pollutants impurities into the boiler leads to foaming of the water in the drum, scale deposits formed on the wall tubes, the lower collectors of the boiler circulation circuits are clogged. Therefore, particulate pollutants impurities are certainly removed from the water at the water treatment plant by filtration and settling. Coloid-dispersed impurities have a 10^{-4}–10^{-6} mm particle size. These are impurities of organic origin–decomposition products of organic substances, humic substances or mineral origin–silicic acids, compounds. If they get into the boiler, the water in the drum foams strongly and it may get into the superheater, and scale will also form on the heating surfaces. Coloid-dispersed impurities are removed from the water at the water treatment plant by coagulation. Molecular dispersed impurities have a particle size of less than 10^{-6} mm. These are water-soluble gases (O_2, CO_2, N_2, H_2S), as well as cations and anions of salts, acids, alkalis (Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-, $SO_4{}^{2-}$, HCO_3, “OH” and other). These impurities are removed by deaeration, precipitation, cationization and anionization [2].

During the operation of the heat supply and hot water supply (HWS) systems, circulating cooling systems, distillation desalination plants and evaporators, low-pressure steam boilers when heating water, the water can become saturated with salts, primarily calcium carbonate, which leads to the formation of scale on heat exchange surfaces. With a high corrosiveness of the water, the accumulation of iron compounds in water determines the formation of the iron oxide deposits on the heat exchange surfaces. The presence of the limescale and deposits leads to a deterioration in the heat transfer, a decrease in the equipment efficiency, in some cases to burnout of the boiler pipes and economic losses [3–5].

4 Research Results

Options of the schemes using traditional technologies and modern water purification schemes have been investigated, using the LLC Kramatorskteploenergo thermal power facilities as an example (Fig. 1). The water of the Severskyy Donets-Donbass canal is used as the source water, and the water of the Kazennyy Torets river is used as a reserve source. The source water in the required amount is supplied to the pre-treatment plant, where by liming (or soda-liming) with coagulation, the river water is pretreated and its quality is improved–hardness, salt content, suspended solids and other indicators are reduced in accordance with the plant equipment operation regime map.

Further, the treated water (decarbonized and clarified) is fed to a chemical water treatment plant operating according to the two-stage Na-cationization scheme. Typical direct-flow filters are used as the softening stage I at the plant, sometimes the newer technologies are used–counter-flow filters. For the stage II, the typical direct-flow ion exchanger filters are used.

The softened water after stage I is used to feed the heating network and is fed to the stage II filters to prepare the highly softened (chemically purified) water to supply the low-pressure boilers and evaporators. The desalted on the evaporator water (distillate) is fed to the OH-H ionization unit for deep desalination and, further, to the deaeration unit of the high-pressure boilers. Evaporation and desalination plants are used to replenish steam and condensate losses by the boiler-turbine shop equipment

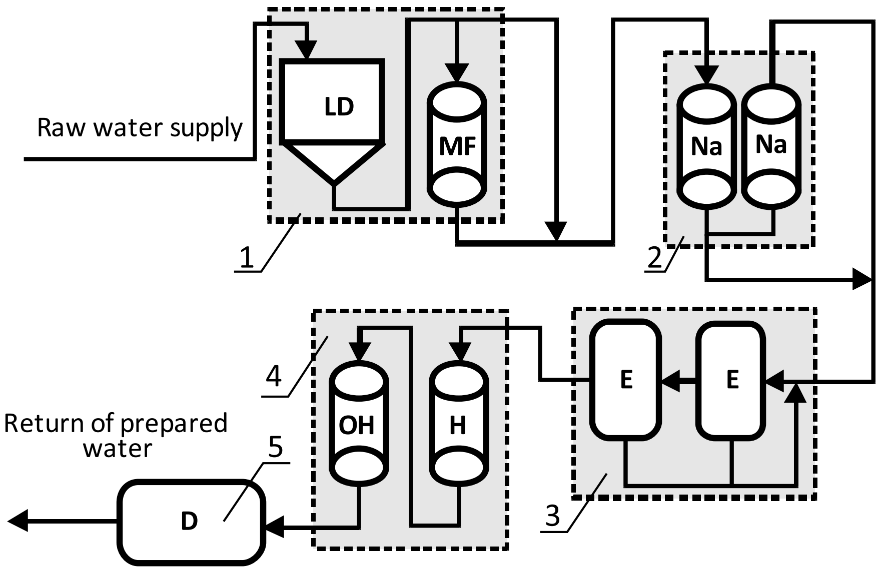

Fig. 1 General scheme of water treatment: 1–preliminary clarifying (LD–lighting device; MF–mechanical filter); 2–Na-cationization; 3–evaporator; 4–OH-H- ionization; 5–deaeration plant

Fig. 2 Oxygen corrosion of metal

at the thermal power facilities. From the deaeration unit, the feed water is pumped to the boilers to produce high pressure steam.

One of the conditions for ensuring the optimal water-chemical regime is the use of a rational scheme for the corrective treatment of the coolant and makeup water for heating networks. Water purification with the ion exchange by means of sodium cationization leads to the metal corrosion rate increase by 20–30% (Fig. 2).

According to the studies carried out, in the overwhelming majority of cases, it is advisable to inject chemicals to the feedwater, makeup water and boiler water, which either inhibit the metal corrosion process, or promote equal corrosion instead of very dangerous local or ulcerative one. At the same time, using chemicals, it is possible to achieve the creation of the thin protective films on the surface of the metal, which will prevent the aggressive action of water.

The anti-scale water treatment prevents formation of the mineral deposits on the heat transfer surfaces with a high scale-forming ability of water, ensuring the equipment operation without damage due to limescale and sludge deposits during complete or partial shutdown of installations, which reduce the hardness and (or) alkalinity of the water.

The use of corrosion inhibitors helps to prevent the accumulation of iron compounds in water and the formation of iron oxide deposits, as well as reduce the damage to equipment and pipelines with the internal corrosion [1, 5–7].

At the same time, there is a problem of the bacteria presence that cause pitting sub-sludge corrosion of the pipelines and equipment, therefore antibacterial measures are also needed. Based on the need for a complex process of the make-up water preparation, the problem of injecting and dosing the chemicals arises in order to achieve the maximum reduction of the aggressive effect of the water on the metal surfaces of the equipment of the thermal power facilities and to ensure a scale-free and antibacterial mode of operation [6–11].

5 Results and Discussion

The careful dosing of the chemicals to reduce the water corrosiveness and to prevent the formation of the limescale must be carried out before the feed-water, boiler-water and delivery water enters the heating generators.

Before using the chemicals, a specialized organization must inspect the thermal power equipment and the water used, and select the types of chemicals with the accurate doses, based on the results of the successive performed chemical studies.

The specialized organization should carry out a complete range of work on the selection and application of reagents, carry out studies of the water used, refine the operational characteristics of thermal power plants, start and adjust the chemical injection package. It chooses the type of chemicals and fixes their dose based on the results of successive chemical tests with different dosing. Reagent doses are not allowed to be selected according to analogies and graphs, nor is the dose chosen according to the quantity of water composition (for example, in terms of rigidity and alkalinity).

For the thermal power facilities equipment reliability and efficiency, as well as for ensuring its optimal water-chemical regime, a scheme for corrective treatment of the make-up water for heating networks was developed and implemented.

To reduce operating costs when servicing thermal power facilities and operational reliability due to the provision of an optimal water-chemical regime, a scheme for corrective treatment of the make-up energy water used in the heating networks was developed and implemented (Fig. 3).

With the drumpump H2 the chemicals are pumped from the mobile container E2 into the surge tank E1. With the dosing pumps H1/3-H1/6 out of the container E1 the reagent is added to the respective chemicals injection package and further to the feed-water of the boilers.

For automatic operation of the dosing pumps the corresponding control signals are sent from the existing make-up water flow measurement units.

The presence of nitrates and nitrites in the heat circuit of the thermal network, whether drinking or technical or river water, can cause biological corrosion. Intermittent (1–2 times per year) microbicide treatment of netted water is recommended for prevention. For this a chemical reagent with a bactericidal treatment developed by Water-Treatment Technologies Research And Design Institute, Ltd, can be recommended. It has a pungent peculiar "medical" smell, and is stored in highly diluted aqueous solutions. In addition, the treatment of the heating network with a bactericidal treatment is a self-sustaining measure, since it allows identifying the coolant leakage spot, reduce the amount of make-up water and form a plan for repair and restoration work of the heating network equipment and the thermal power facilities.

The periodic delivery of the microbicide treatment means into the network water is carried out from the container by dosing pumps, that is, according to the design scheme. To ensure the functionality and control of the injection package equipment, the necessary control and measuring devices and automatic equipment are

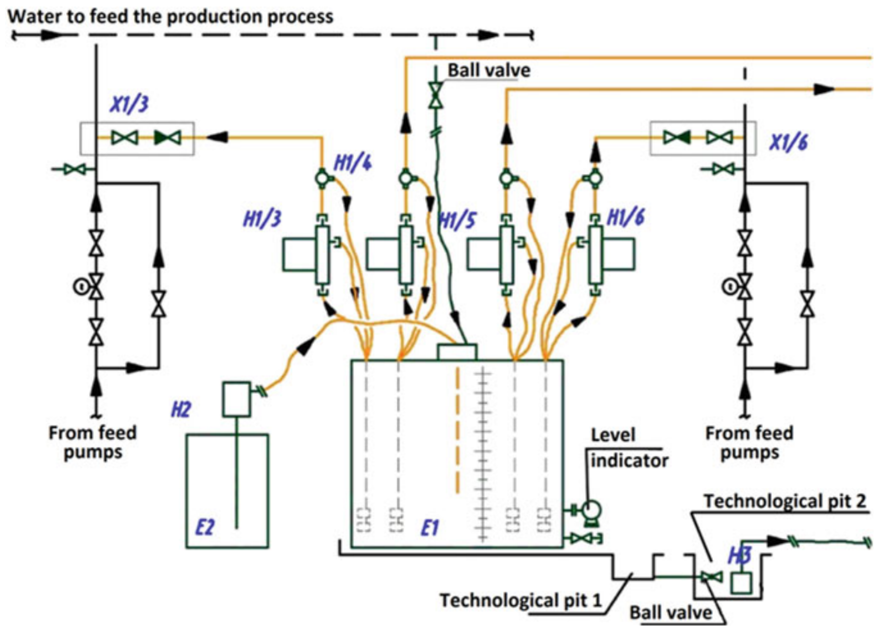

Fig. 3 Corrective treatment of the make-up energy water scheme

provided, and sampler points to conduct the analytical control during the starting-up and adjustment works and installed equipment operation.

The installed equipment is controlled from the existing automated workstation (AWS) and locally. For the design of the installation, the use of modern equipment and fittings is provided. All technological equipment is selected during the operation of the unit, both in normal mode and in emergency situations (availability of working and backup equipment).

Installation performance provides processing 70–250 m^3/h of the feed-water for heating networks in normal operation mode and 400 m^3/h when filling the system and emergency situations. The use of two chemical reagents for different purposes for one injection package, its connection to the existing preparation scheme allows not to carry out thermal deaeration, to reduce current and capital costs.

6 Conclusion

The problems of efficiency and reliability of the heat power engineering equipment, the productivity of using make-up water and systems for supplying and dosing chemicals are analyzed.

On the basis of the carried out studies, an additional chemical injection package for accurate dosing of the necessary chemicals for a specific purpose was proposed.

It was included in the scheme of the existing water treatment plant contributing to the improvement of the feed-water quality. Due to this, the aggressiveness of the energy environment decreases, the intensity of corrosion decreases, the formation of the internal scale deposits is eliminated, and bacteria that cause pitting corrosion of heat exchange equipment are destroyed. As a result, the service life between technological maintenance and repair of the heat exchange equipment increases, which leads to a decrease in operating costs for a cogeneration plant maintenance and, in the end, to a decrease in the cost of the final product.

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The Model of a Technical System Operation at a Certain Time Interval

Valery Usenko, Tetiana Zinenko, Sahib Farzaliyev, Iryna Usenko, and Olga Kodak

Abstract In the theoretical study, attention is drawn to the fact that a significant increase in the level of reliability of technical systems cannot be obtained by separate isolated measures. Solving problems combined into a system increases the efficiency of resolving individual problems. Also, this integration makes it possible to obtain qualitatively new theoretical and practical results. In the publication, mathematical modeling of the reliability of technical systems is considered as an approximation of the characteristics of their reliability by the known theoretical divisions. The article highlights some approaches to identifying the main patterns of failure of structurally complex technical systems. A geometric model of the probability of failure-free operation of a technical system for a certain period of time is proposed. The publication compares the time of the probability of failure-free functioning of technical systems with various forms of their structures. Examples of analytical description of the probability of failure-free functioning and graphical representation of some redundant structures are given. A comparative analysis of the probability of failure-free functioning of the structures of a number of technical systems among themselves and the reliability of the elements that make up the structure is carried out. The significant influence of the form of structures of technical systems on the time of their trouble-free operation is clearly shown. As a result, the possibility of predicting the period of operation of structurally complex technical systems to their failure is shown. The proposed model makes it possible to predict the reliability of the functioning of technical systems, depending on the duration of the cycle of solving functional problems.

Keywords Technical system · Structural reliability · System uptime · System structure · System operation time

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_46

1 Problems of Structural Reliability of Technical Systems

The need to combine various scientific directions in the problem of technical systems reliability in fact that this problem is complex. Theoretical studies show [1–3] that it is impossible to achieve an increase in the level of reliability of a technical system by separate isolated measures. The solution of problems combined into a system not only increases the efficiency of each of them, but also makes it possible to obtain qualitatively new results [1].

The quality properties of the components of technical systems are constantly improving. However, the problem of the reliability of technical systems continues to be one of the main ones. This is due to the fact that the development of science and technology is characterized by an ever increasing use of various technical systems in all spheres of industry and management. The functions that modern technical systems perform are quite complex, and the tasks assigned to them are extremely responsible. Therefore, in modern conditions, the old standards of reliability require revision.

Mathematical models of the reliability of technical systems are considered as an approximation of the characteristics of their reliability by the known theoretical distributions [2]. Determining the analytical expression for the distribution function of random variables (for example, operating time and resource) allows to determine the necessary reliability indicators. This is, in particular, the likelihood of failure-free operation.

The choice of the failure model, that is, the determination of the analytical expression of the distribution function, is usually carried out on the analysis basis of:

- statistical data of full operating time (resource or persistence)
- degradation processes that determine failure, or limiting state.

The first approach to identifying patterns of failure occurrence is to use some distributions of random variables, which are known as probabilistic failure models [1, 2]. Failures are then treated as abstract random events.

The second approach to establishing the patterns of occurrence of failures is carried out on the basis of the analysis of the statistical patterns of the processes flow that lead to failures [1]. This approach defines failure models that are built solely to describe the phenomenon being studied. In this case, the distribution parameters have a specific physical interpretation.

2 Generalized Expression of System Reliability in Time

The construction of a mathematical model of reliability provides determin of an analytical expression for the probability of failure-free operation of the system. There are dependencies between the various processes that form the failure of the technical system and the types of distribtion functions of the full operation of the elements of the technical system.

One of the main criteria for the reliability of non-renewable technical systems is the probability of failure-free operation of the system for a certain period of time t [1, 2]:

$$R(t) = e^{s},\ s = -\int_{0}^{t} \lambda(t)dt, \tag{1}$$

where t is the operating time of the technical system, λ is the rate of system failures at time t.

The concept of "system element" is relative and depends on two factors: the nature of the object as a whole, as well as on the objectives of the study. An element of the system is an independent and clearly distinguished (constructively, schematically or functionally) part of it, further detailing of which is not advisable within the framework of the analysis. A simple system, the division of which into elements does not make sense in the framework of this study, can be considered as an element.

Failure of an element is a random event that occurs under the influence of many random factors. Quantitative indicators of random events are built on the basis of a probabilistic measure, which makes sense when there is a sufficiently large set of investigated events. In practice, the quantitative characteristics of the reliability of elements are determined statistically on the basis of testing under certain conditions a sufficiently large batch of elements of the same type [1].

A complete characteristic of any random variable is its distribution law. This is the relationship between the possible values of a random variable and the corresponding probabilities.

The exponential distribution law is used in the analysis of structurally complex technical systems that have gone through a period of running-in and sudden failures. Also due to defects in technology, and in the theory of queuing. Operating time between successive failures in a steady-state mode of structurally complex technical systems functioning is subject this law [1, 2, 5, 9–11].

3 The Probability of Failure-Free Operation of a System with a Certain Structure

3.1 Functions of the Probability of Failure-Free Functioning of the Systems

The probability of failure-free operation of a technical system is determined by the probability of failure-free operation of its elements and their connectivity, depends on the form of the structure of the technical system.

If the elements have the same behavior of the probabilities of failure-free operation of the elements, which is described by one of the known distributions, then we use the definition of the function of the failure-free operation of the system. The probability of a sum of an arbitrary number of adjacent events is reflected by the well-known formula [1, 6–8]:

$$R\left(\sum_{i=1}^{n}(A_i)\right) = \sum_{i=1}^{n} R(A_i) - \sum_{i,j}^{n} R(A_i A_j) + \sum_{i,j}^{n} R(A_i A_j A_k) + \cdots\cdots + (-1)^{n-1} R(A_1 A_2 A_3 \ldots A_n), \quad (2)$$

where A_i, A_j, A_k,... A_n,—adjacent events of system performance; n is the number of system health events; R is the probability of the sum of an arbitrary number of events.

Accordingly, we obtain the equation of failure-free operation of the technical system for a given distribution of system elements over a period of time t.

$$R(t) = R(r_1(t), \ldots, r_i(t), \ldots, r_m(t)), \quad (3)$$

where t is the operating time of the technical system, p is the probability of no-failure operation of the element during the time t, m is the number of elements of the technical system.

The principle of equal-strength design, which is considered in publication [4], provides for a uniform distribution of reliability between various elements of the system, and, consequently, a uniform distribution of the probability of failure-free operation of these elements planning. When elements are of the same type, there is a high probability that they have the same distribution. Then Eq. (3) will look like:

$$R(t) = R(r_i(t)), \quad (4)$$

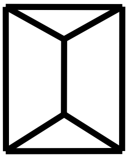
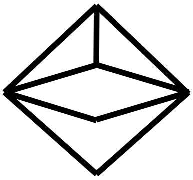
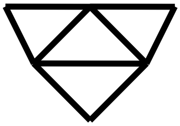
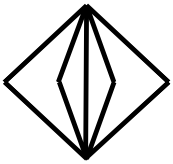
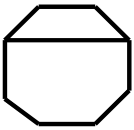
where $R(t)$ is the value of the probability of failure-free functioning of the system for a certain period of time t; $r_i(t)$ is the value of the probability of failure-free operation of the system elements for a certain period of time t, $i = 1, \ldots p$; p is the number of edges in the structure. The probability of failure-free operation of a technical system during time t will be obtained according to the distribution of random variables established by the law [1].

Let's look at an example. According to Eqs. (2), and (4) find the probability functions of no-failure operation for a number of redundant structures of a technical system and enter them in Table 1.

3.2 Reliability Analysis of Structure Variants

The structures of the technical system from numbers 1–4, which are given in Table 1. have the same numerical characteristics. The number of edges in them is $p = 9$, the number of nodes is $v = 6$, the number of closed cycles is $k = 4$. However,

Table 1 Functions of failure-free functioning for some structures with equal values probability of failure-free functioning probability of elements

Numbers	System structure form	Equation for failure-free functioning of a technical system
1		$R_1(t) = 26r^9(t) - 132r^8(t) + 255r^7(t) - 223r^6(t) + 75r^5(t)$
2		$R_2(t) = 22r^9(t) - 111r^8(t) + 214r^7(t) - 188r^6(t) + 64r^5(t)$
3		$R_3(t) = 16r^9(t) - 84r^8(t) + 168r^7(t) - 153r^6(t) + 54r^5(t)$
4		$R_4(t) = 16r^9(t) - 79r^8(t) + 152r^7(t) - 136r^6(t) + 48r^5(t)$
5		$R_5(t) = 15r^9(t) - 37r^8(t) + 23r^7(t)$

these structures have different geometric shapes. Therefore and accordingly, different probability of failure-free operation. These structures have a reserve, because they have a number of redundant bundles between nodes.

Figure 1 shows a graphical interpretation of the probability of failure-free operation of technical systems with appropriate structures. This is a comparative graph of the structural reliability functions of the five technical mentioned technical systems.

For comparative analysis in Table 1, number 5 also shows the structure of a technical system with other numerical characteristics and a different configuration: the number of edges $p = 9$, the number of nodes $v = 8$, the number of rings $k = 2$ The probability of failure-free operation of these structures for a certain period of time t is shown in Fig. 1.

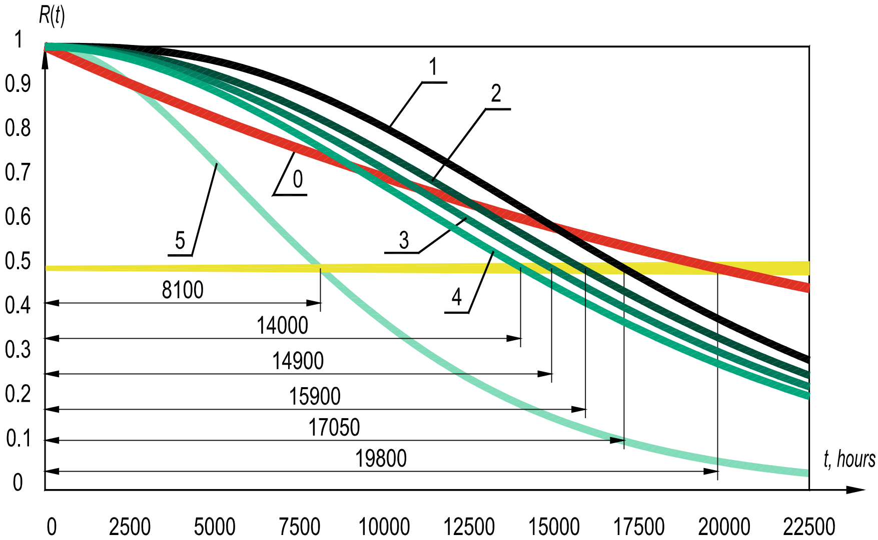


Fig. 1 Graphical probability interpretation of failure-free functioning of a technical system with various forms of structure during the time interval *t*

The graphs of the functions show different behavior of the probability of failure-free functioning of systems with different structures and their elements during the time interval *t*. The rate of decrease in the value of the probability of failure-free functioning of systems in this time interval depends on the shape of the structure and the parameters of the distribution law. The probability of failure-free operation of the elements of a technical system is described by known distributions. In this case, the law of distribution of a random variable is accepted exponentially [1]. However, there is a possibility of using other laws of distribution of a random variable.

$$r(t) = e^{-\lambda t} \tag{5}$$

where $r(t)$ is the probability of failure-free operation of an element of the technical system, t is the operating time of the element, λ is the failure rate of system elements over the time interval t, $\lambda = 0.000035\ \text{h}^{-1}$ for this case.

In Fig. 1, the graph of the probability function of the failure-free operation of the elements of the technical system is indicated by the number 0. It has a red color. From the very beginning of operation, a gradual and smooth change in their reliability is observed. The loss of half of the reliability life for the elements will occur after 19,800 h of operation. This is a longer period than the period of a similar event for all considered systems.

The graphs of the functions of the probability of failure-free operation of a technical system in the form of a structure with Table 1 are designated by the corresponding numbers 1, 2, 3, 4, 5 and color from blue to black.

Among structures 1–4 (see Table 1), combining elements into structure # 1 is the most efficient. This is explained by the fact that at each moment of time and with the same values of reliability $r(t)$ of elements, this form of the structure of the technical system has the highest probability of failure-free operation. In this case, all the numerical characteristics of structures 1–4 have equal values. Thus, it is possible to assess the influence of the form of the structure of a technical system on the reliability of the structure. Hence, it becomes possible to determine the form of the structure of a technical system that has maximum reliability for a number of variants.

Of these structurally redundant configurations 1–4, configuration 4 has the lowest reliability with the same numerical characteristics. Obviously, it has more consistent connections that reduce the level of system reliability. Redundant structure 5, which has the same number of edges $p = 9$, more nodes $v = 8$, but less number of closed paths $k = 2$, has the lowest probability of no-failure operation among all those presented in Table 1.

The probable operation time of the technical system with the structure form # 1 is the longest, as can be seen from Fig. 1, and for configuration 5 it is the smallest. The level of reliability of this technical system with a value of 0.591 will be equal to the level of reliability of its elements in about 15,000 h. For systems with other structure forms from a given series, similar events are likely to occur earlier and with higher reliability levels: 0.644, 0.684, 0.727, 0.919, respectively, for structure forms 2–5. It depends on the number of redundant connections in the redundant structures. Dimensional lines show the moments of time of loss of half of the reliability resource of a technical system with various forms of structure.

4 Conclusion

The publication proposes a model of the probability of failure-free operation of a technical system for a certain period of time t. The model is based on the form of the structure and the distribution law of the operating time of its elements to failure. A restriction is introduced that the elements of a technical system must have equal or close probabilities of failure-free functioning. In case of variant design or reconstruction of structurally complex, including redundant systems, this model will be useful for making optimal decisions.

The form of the structure of the technical system and the many connections directly affect the duration of its trouble-free functioning. The number of closed loops in the structure and their shape also affects.

The proposed model makes it possible to predict the reliability of the functioning of technical systems, depending on the duration of the cycle of solving functional problems.

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Artificial Lighting Environment of the City

Aleksandr Vasilenko, Amil Tanirverdiiev, Andrii Koniuk, and Oksana Vorobiova

Abstract In the theory of urban planning and architecture, the problem of forming artificial light environment of the city is in the foreground. Spectacular lighting for landmarks in many cities around the world, once dominated by lighting engineers with architects being just officials, coordinating proposed solutions, has always attracted public interest to new improvement opportunities and new environmental standards shaped by lighting. These opportunities are steadily increasing due to progress in the field of lighting technology and rising living standards. Artificial lighting that exists today in any city is an indispensable element of its life support. The problem of artificial lighting is solved in the process of designing the city and most of the objects in it, together and along with the traditional tasks of creating urban planning, architectural and design forms. With such a formulation of the matter, philosophy is enriched and the field of professional activity expands: architecture should be created not only for life in it and perception of it during the day (this is one visual state of the surrounding world), but also at night, and at the same time should look not like a simple repetition of daylight (which appears to be impossible in the exterior), but have their own peculiar imagery-emotional qualities. This should be considered a second visual state and architectural image of the urban environment.

Keywords Urban environment · Architectural form · Lighting sources · Artificial environment · Visual comfort · Artificial lighting

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_47

1 Introduction

Topicality of the problem. The need to address the issues of forming a visually complete lighting image in the evening and at night is associated with the following circumstances: the aesthetic qualities of architecture are evaluated by visual impressions, and they are possible only in case of lighting; the visual perception of the architectural form depends on its features and on the amount of light and the quality of its illumination; in recent years, in the regional cities of Ukraine, in the capital city of Kyiv, in many district cities of the state and certainly all over the world, there continues positive and favourable transformations of the urban environment lighting; high quality of lighting ensures the reduction of the number of road and traffic accidents; decreases the income from evening tourism; develops the lighting industry; saves time on transport; provides for visual comfort; high quality videos with spectacular views of the illuminated objects.

The relevance of the topic lies in the fact that this study considers the following aspects—the formation of the city's artificial light environment; the solution of architectural problems in the field of architectural lighting in design.

2 Formulation of the Problem

The history of the urban artificial lighting has been developing for quite a few centuries. Two stages can be distinguished in it—a long era of pre-electric lighting and electric lighting, which is reflected in the works of L. S. Kalff, P. Papagalov, L. Monzer, D. Neumann, D. Phillips. Relatively recently, the advent of electric lighting at the end of the nineteenth century changed the evening look of settlements. In addition to its original purpose—to illuminate the spaces of streets and squares for the safety of movement and protection of possessions, new functions have appeared—artistic lighting of the facades of representative objects and illuminated advertising.

The streets of the cities of Ancient Sumer, Egypt, Assyria and Babylon were lit with torches or small lamps—clay bowls with oil and a wick. More regulated, with the help of torches or bonfires on resinous wood, they illuminated places of worship (temples, statues of gods), administrative centers and strategic objects—city gates, towers, bridges (Fig. 1).

The main advantage of gas lamps was that they were an order of magnitude brighter than their oil predecessors. As a result a street or a square lit by gas, a residential building or a theater could be seen not only during the day, but also at night. Gas lamps were adopted by manufactories and factories: thanks to gas, night shifts and continuous production became possible. In general, urban nightlife under gaslight became more intense and vibrant. Very quickly, gas lamps became the most popular version of a street lamp, their presence in the city testified to its development and modernity. Sixteen years after the experiment, 40,000 lanterns illuminated Pall Mall London.

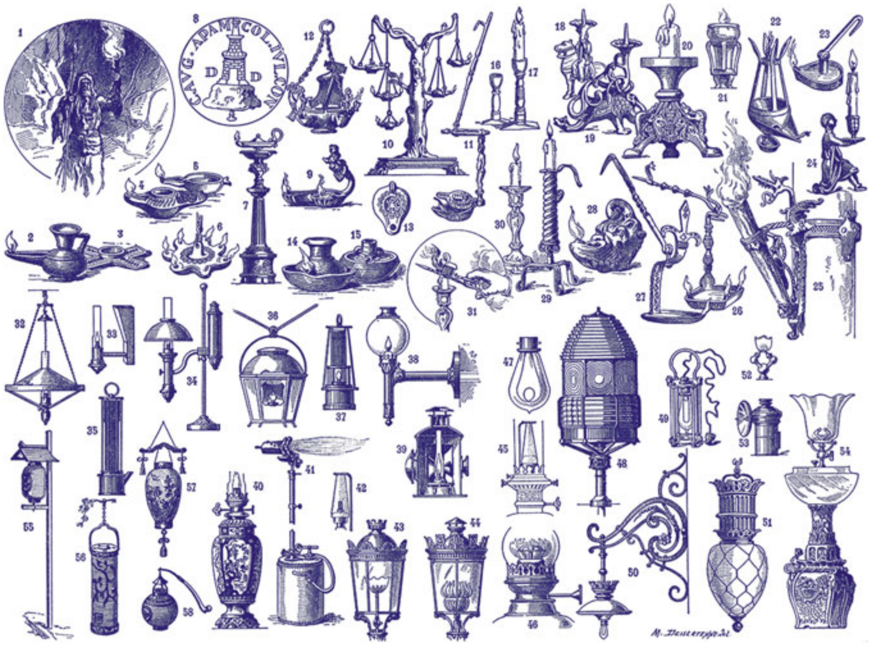

Fig. 1 Ancient world: 1. Primitive society. 2–3. Ancient Egypt. 4–5. Assyria 6–13. Ancient Rome. 14–15. Carthage. 16–17. Merovingian period. Middle Ages and Modern Times: 19–20. eleventh century. 21. twelfth century. 22. thirteenth century 23–24. fourteenth century. 25–27. fifteenth century. 28. sixteenth century. 29. seventeenth century. 30–31. eighteenth century. Modern period: 32. Argand lamp. 33–34. Modernized Argand lamp (by Antoine-Arnaud Quincke). 35. Stephenson Georgie Lamp. 36. Street light. 37. Davy lamp. 38. Kerosene lamp. 39. Train lamps. 40. Carcel lamp. 41. Gas-burner. 42. Auer gas lamp with incandescent grid. 43. Street gas lighting. 44 Outdoor gas lighting (of high intensity). 45. Auer lamp (gasoline). 46. Gasoline lamp 47. Incandescent lamp. 48. Lighthouse. 49. Portable lamp. 50. Incandescent lamp for street lighting. 51. Electric arc lamp. 52. Carbide lamp (with burner). 53. Carbide lamp (for bicycles). 54. Carbide lamp. Japan: 55. Street light. 56. Lamp for transport (rickshaw). 57. Burial lamp. 58. Portable flashlight [13]

Certain aspects of urban lighting are dwelt on in the published works of architects, art critics, artists, designers (Le Corbusier, D. Poiti, J. Lurçat, M. Ragon, R. Venturi, L. Larson, J. F. Caminada, I. *Araújo*, D. Je. Arkin, N. V. Obolensky, S. Gaponov, K. Mende, V. Jankowski, D. Neumann, K. Gardner). From the standpoint of lighting science and practice, the issues of urban lighting are reflected in the works by N. V. Gorbachev, V. M. Tsarkov, O. B. Vasilenko, N. V. Volotsky, V. V. Meshkov, M. A. Ostrovsky, M. S. Dadiomov, A.B. Matvjejev, G. V. Kamenskaya, V. K. Petrov, V. M. Pyatigorsky and others.

In recent decades, well-known architects from a number of Western countries (N. Foster, R. Rogers, J. Nouvel, B. Chumi, C. de Portzamparc, F. Gehry, T. Ito, R. Meyer, T. Ando) create original lighting images of their buildings in collaboration with the specialists of a new emerging profession—lighting designers (lighting artists, concepteur lumiere). The interests of lighting designers have already gone beyond the traditional facades of individual objects into urban space. The term “light architecture” (Parchitecture lumiere) was supplemented by “light urbanism” (Furbanisme lumiere). Conceptual light-composition works of various scales are carried out—from the whole city to a separate ensemble, designed for a different perspective in terms of implementation time [1]. Lighting designers R. Narboni, L. Claire, A. Hiyo, P. Bidault, J. Kersalé, J. Bern in France; R. de Alessi, D. D. Mooney, D. Lay, S. Graf, K. Roder, T. Ruzika in the USA; I. Motoko, K. Tahara, X. Fujita in Japan; C. Wilkins, P. Fordham, D. Speirs, K. and D. Engle in England and others.

The issue was also considered in the works written in the “electric” era, even in recent decades, on urban planning and the aesthetics of the city, composition theory, the basics of architectural shaping and the artistic language of architecture (L. N. Avdotjin, M. G. Barkhin, A. V. Bunin, A. P. Vergunov, V. L. Glazychev, A. E. Gutnov, A. V. Ikonnikov, L. Sh. Sirillova, Ya. V. Kositsky, A. Kuchmar, I. G. Lezhava, K. Lynch, I. M. Smolyar, Z. N. Yargina), on the formation of the urban environment and its aesthetic assessment (A. Yu. Becker, E. L. Belyaeva, K. Day, I. I. Serdyuk, S. A. Khasieva, V. T. Shimko, A. S. Shchenkov).

3 Results

The modernization of lighting facilities, which took place in stages within the century, was caused mainly by technical and economic reasons and each time led to an obvious result: the city became brighter and more comfortable, its night color changed and became more complicated—from monochrome warm-white light with incandescent lamps in the first half of the twentieth century to special lighting in its various zones with several types of discharge lamps in the second half of the century. The scale of illuminated ensembles was enlarged and differentiated, as the range of lighting installations expanded from low-power lamps of the beginning of the century to a wide modern palette of devices of different power, flooding micro- and mesospaces, areas of the territory and surfaces of objects with light [2]. In 1765, more than 5,500 cd lanterns were replaced in Paris with more efficient oil reflectors. In this variation, the light from the oil lamp was reflected from a shiny reflector plate set at a certain angle. The scattering area increased and the light became softer. Gradually, oil lanterns were introduced to other European cities. The central London street of Pall Mall was lit by gas lamps created by the inventor William Murdoch. His version gained popularity (Fig. 2.). A patent for a gas lantern was registered in 1799.

Chestnut Alley in the regional center of Poltava appeared in 1913. The area of the alley is 4 hectares, its length is 1 km. Properly illuminated Chestnut Alley is a botanical monument of nature (Fig. 3).

A more fundamental reason for the dependence of urban lighting on the arsenal of lighting technology is the theoretical insecurity and the practical lack of demand for this problem within the architectural community. This is reflected, firstly, in the

Fig. 2 A lamplighter lights a gas lamp. Berlin, mid nineteenth century [13]

Fig. 3 Artificial lighting Chestnut Alley. Poltava [14]

current terminology: architectural lighting is called "light design", "additional decoration of urban planning ensembles" (Z. N. Yargina), "artistic illumination", "illumination" etc., which illustrates the third-rate nature of the issue, street lighting being considered utilitarian and technical problem, not worthy the attention of architects.

The purpose of the study is to develop a concept for the formation of an artificial light environment of the city. *Research objectives:* (1) to analyze the lighting of the urban environment, taking into account modern architectural requirements. (2) to determine the specifics of professional work on lighting in the field of architectural and design planning.

The object of the study is the urban environment and its elements at night.

The subject of the research is the artificial lighting of the urban architectural environment and its interaction with urban planning forms.

In the modern era, the possibilities of electric lighting systems that can detect out of the dark, optically transform architectural forms in a wide range, provide quick and diverse modifications of the visually perceived environment, make artificial light an important urban planning factor and architectural material. Its full use today is associated with the creation in the dark time of the day, according to the laws of expediency and beauty, of a special type of organization of the architectural environment, which has visual and environmental comfort with a pronounced visual and figurative specificity. In contrast to daytime, all the parameters of this environment perceived by sight are designed and controlled by a person. The "super task" of the creative activity of an architect, designer in the formation of an artificial light environment is the creation of light ensembles and illuminated objects with figurative expressiveness.

At night, not the entire territory, space and objects of the city are illuminated, as during the day, but only their functionally used or compositionally necessary fragments [9, 10]. At the same time, they are illuminated in different ways and receive a different scale-figurative interpretation in all categories of the architectural form.

The light environment of communication is the most important in terms of meaning and composition illuminated pedestrian areas of the city in the structure of its public centers and enterprises of various hierarchical ranks. By the nature of the behavior of the people who visit them with certain practical goals, they occupy a key position between the linear, dynamic light environment of movement and rest. This is an environment characterized by internal dynamism and significance, having relative discreteness and developed connections with the environment, and in which the aesthetics of the elements that form it and the content of visual information are important [7]. The light environment of movement—illuminated pedestrian paths, a part of the system of urban communications that play a major role in the perception of the city in space and time. Usually they coexist in parallel with transport light spaces, so their visual definition is of great importance for the ordinary environment of a person in a city who needs normal visibility at certain distances in the direction of travel and a general orientation in space, which ensures safety.

To analyze the content of the term "artificial light environment of the city" and related design tasks, the authors identify four main components in the conditional scheme of their interaction: architectural and urban planning, functional, lighting engineering and visual. The first two represent the constant urban basis of the environment, the other two are changing factors that introduce specifics that distinguish the artificial light environment from the daytime one: these are artificial lighting systems that are modified in time much faster than the constant basis of the environment, and possess, in addition, characteristic kinetics, spectrum and light distribution in space; and this is the presence of a person, without which the concept of "light environment" and its certain visual assessments under conditions of unstable night, twilight or daytime adaptation lose their meaning (Table 1).

The central aesthetic problem of forming the city's light environment concept is the interaction of artificial light with the architectural form in its four main types or categories (space, volume, plastic, color), as a result of which space, color, plastic, form are formed with new, other than day, visual qualities (Table 2).

The possibilities of visual transformation of each type of architectural form with the help of lighting is very broad. It is the perception at its three coordinates that changes most at night. A person who is within the limited size of the light space, visually does not accept the parameters of dark environment. Such a circumstance is an important technique of organizing the movement in the evening city [5]. Under the terms of visual adaptation it is a full contrast to daylight conditions when the beautiful and the ugly, the far and the near, the main and the secondary, the large and the small, the coloured and the achromatic are represented equally, and a person feels an absolute egocentric in a visible space which has a structurally uniform light field with a constant direction of light from above.

The visual component represents the importance of the human factor in the concept of the urban environment. Practically, it is the key one in this scheme, since it unites the other three ones and connects them with a person who appears as a variable object of the environment, participating in the formation of its appearance, and at the same time as a subject evaluating its qualities through visual perception. Its specificity is determined by other, more complex than during the day, conditions of the eye: a decrease in all visual functions in an unstable, and therefore relatively uncomfortable and non-ecological mode of night-twilight-day vision, with high brightness and color contrasts and, in many cases, the blinding effect of visible light sources and the luminous elements [3].

As such an illumination quality criterion as the distribution of light emitted and reflected in the space, i.e. the structure of the light field created in a specific urban ensemble, within which a person moves and which is characterized by uneven distribution of light directivity, luminance contrast, the dimensions of illuminated spaces and surfaces. They define the scale of the created light spaces, which has received in some papers the name of lighting scale. At daytime, in architecture, the light space scale is estimated with a scale to a person, as well as with the dimensional quantities and ratios of illuminated elements and the surrounding darkness within the visual field [8] (Fig. 4).

Given the variability of the observation conditions of a person moving in an urban surrounding, the most appropriate criteria for a large-scale assessment appear to be the extent of light space with the given photometric parameters and angular dimensions of the lighted and luminous objects in view of the height of their location above the horizon.

Practical verification of the results made it possible to offer a theoretical model of the light environment in the residential areas of the city and supply the principles

Table 1 The main components of the formation of the artificial light environment of the city

The light environment of the city													
Functional lighting	Architectural lighting	Light information	Road traffic	Pedestrian traffic	Communication	Rest	Night vision	Twilight vision	Day vision	Space	Volume	Plastic	Colour
Selective artificial lighting			Basic structural elements				Unstable adaptation mode			Categories of architectural form			
Lighting efficiency							Assessment of the light environment						
Visual behavior. Lighting form formation							Visual behavior. Lighting form formation						
Managed environmental elements													

Table 2 Scheme of interaction of artificial light with architectural form

Main categories of form in architecture								
Space								
Pedestrian and transport								
Rest	Communication	Movement	Parking	Road junctions	Roadway			
Colour								
Landscape and man-made objects								
Buildings	Structures	Monuments	Small forms	Earth	Sky	Water	Nature	Earth
Plastic								
Elements of the landscape and objects								
Sky	Water	Nature	Buildings	Structures	Small forms			
Form								
Man-made objects and landscape								
Nature	Buildings	Structures	Small forms	Monuments				
Artificial light source								

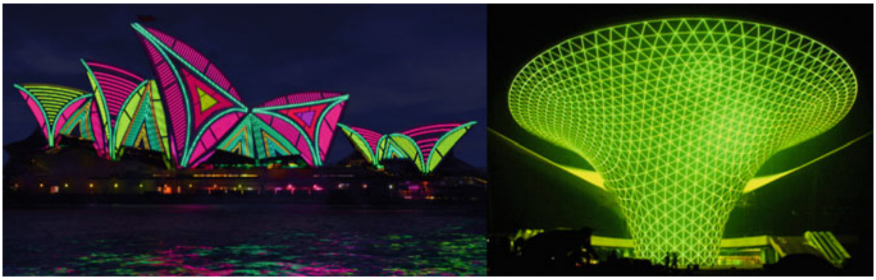

Fig. 4 Lighting environment (coloured cityscape) [15]

of its construction. They can serve as a methodological basis for solving scientific and design problems and should provide a systematic approach and freedom of creative solutions in any urban planning situation [6]. The construction of a conceptual model involves the use of the following principles:—light-colour differentiation of the urban area into the main structural elements;—light hierarchical differentiation of each of the structural elements;—large-scale light module of structural elements, taking into account their type and category;—formation of a system of light ensembles and dominants using structural elements of different hierarchical levels;—complex development of light-colour and material-spatial parameters of the architectural environment.

Visual differences in the levels of illumination of different types of spaces are enhanced by the colour ones. Different colour of adaptive lighting of spaces is the main distinguishing feature of light-colour zoning. Given the peculiarities of the current situation and psychophysiological preferences for the colour of radiation, the authors provides for the following distribution of it by types of spaces: transport zones are optically formed by the yellow light of sodium lamps; in public pedestrian light spaces, white light with good colour rendering is preferable, giving them a certain splendor and “sunshine” and enabling without noticeable distortion to show the colour of people’s faces and clothes and the colour scheme of the ensemble; recreational light spaces are created primarily with cold white, “plein air” light, in harmony with the green surroundings; light space of movement can be formed mainly by sources of warm white light, consonant with the dark shades of the figures of pedestrians.

A large-scale lighting module of urban spaces is carried out on the basis of their structural and hierarchical differentiation by functional and architectural lighting systems, taking into account their type and category.

The light ensemble implies the presence of a dominant, to which its other elements are subordinate. The category, scale and significance of this dominant are determined by its dimensions, historical and architectural or artistic and cultural value and the conditions of its vision in the light panoramas of the city and its ensembles. The possibilities of creating light dominants have a fundamental and advantageous difference compared to daytime [11].

The above principles are more effectively solved in a complex development of light-colour and material-spatial parameters of the architectural environment, which predetermines their organic relationship. The process of creating a light environment presupposes not only the identification of the existing features of the urban structure, but also the active interaction of its material and light components. It makes no sense to illuminate an ugly architecture or an undeveloped landscape, it is necessary to bring them into the proper condition according to the scenario, which among other things includes an expressive light and color solution [12] and others [16, 17].

The complex creation of the environment in the future implies the development of not only material-spatial and light-colour, but also some other parameters (sound, temperature-humidity, aerodynamic, smell etc.), functioning according to specified programs or automatically responding to changes in external conditions and synthetically influencing on the human senses. This will enhance the overall emotional effect with a relatively low intensity of each of the parameters taken separately.

4 Conclusions

The concept of forming the artificial light environment of the city is a theoretical and methodological basis of a modern and effective solution of functional and artistic lighting as a part of the integrated improvement of urban areas and ensembles of any purpose and scale, at any stage of design. Its essence lies in a fundamentally new attitude towards the evening environment and the architecture of the city as their second visual “incarnation”, the second figurative state, comparable in significance and alternative in impression to the daytime one. It will provide a favorable psychological climate in urban spaces and will make the evening environment more humane and comfortable. These qualities are achieved in the process of creative activity, considered as a new direction in the profession of an architect or a designer, which is based on the use of theoretical means and methods of organizing the urban planning form and the specific expressive potential of man-made and controlled artificial light with constantly growing technical capabilities.

The problem of designing artificial city lighting is considered as an undeveloped, important and creatively promising section of professional work on the formation of a new figurative world of architecture and the creation of a comfortable light environment. A theoretical basis for the integrated design planning of the artificial light environment of the city in the form of a concept has been provided. To implement the concept, a methodological base has been developed in the form of interrelated principles for the organization of urban lighting at different stages of the implementation of urban planning and architectural projects, which can be called the methodological principles of light urbanism. The technique provides for a comprehensive solution of compositional problems based on a systematic approach through the use of light in an urban environment.

This study is of a special nature, because it is not tied to any urban planning system and allows for the possibility of flexible modification in a specific urban situation, providing the necessary creative freedom to the authors of lighting projects. A new area of professional activity has been defined, where the architect must be a competent creator while making lighting solutions in architectural projects.

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Synergetic Approach to the Dynamics of Balanced Development of the "Noosphere—Technosphere—Road Environment" System

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Abstract The article explores a synergistic approach to the dynamics of balanced development of the "Noosphere—Technosphere—Road Environment" system. A generalized model that allows identifying universal patterns of self-organization and evolution of complex systems, taking into account the laws of self-organization of a system of any nature, the interaction of system components, for example, a person, a vehicle and road environment) is considered. It is possible to calculate the quantitative and qualitative characteristics of the "Noosphere—Technosphere—Road Environment" system, crisis processes in the natural, technogenic and social spheres with the help of this model. The analysis of the functioning of the technogenic system consistently realizing a fixed goal is carried out. At the same time, the characteristics of vehicles, the composition of traffic flows, and the psychological characteristics of drivers change during the service life of highways. The roads themselves are reconstructed, change their quality. Therefore, we propose to model not the functioning of this system, but its evolution. When the number of elements and connections between them changes the maximum entropy of the system changes as well. At the same time, the system seeks to achieve a new level of adequacy with the environment. Similar models can be obtained for each component of the system.

Keywords Synergetics · Noosphere · Technosphere · Road environment · System · Degree of compliance with goals · Satisfaction of needs · Entropy

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_48

1 Introduction

Today, every person and humanity as a whole experience a certain shock from the change of eras, try to sum up some results of the previous stage of life and imagine the main directions, ways and trends of future development.

At present, more than 2000 works in Ukraine, Great Britain, USA, Spain, and Japan have been carried out on the blow-up regimes theory. This theory is considered now as an integral part of the theory of self-organization or synergetics—an interdisciplinary approach to the dynamics of balanced development of the system "Noosphere—Technosphere—Road Environment". Synergetics studies the basic laws of self-organization of complex systems of any nature, or the interaction of system components [1]. Synergetic models describe complex behaviour in general and the mechanisms of self-organization of any complex systems. It allows identifying universal patterns of self-organization and evolution of complex systems, natural, technical and social.

We regard sustainable balanced development as a mode of stabilization of the main material characteristics of the world system.

2 Defining the Problem

The essence of the problem that humanity is facing at the present stage of its evolution is precisely that people do not have time to adapt their culture in accordance with the changes that they make into this world by themselves. The solution to these problems depends primarily on the person, his or her anima [2].

Human existence and well-being can depend on our ability to bring the principles of long-term and sustainable balanced development to the level of global ethics [3–14].

On the basis of synergetic knowledge, conclusions about approaches to managing the balanced development of such a complex and nonlinear system as "Noosphere—Technosphere—Road Environment" can be drawn.

The noosphere is the sphere of interaction between society and nature, where reasonable human activity becomes a determining factor in development.

The technosphere is understood as a sphere that contains artificial technical structures that are manufactured and used by humans. A part of the biosphere has been radically transformed by humans through the indirect influence of technical means on technical and technogenic objects (buildings, roads, vehicles, mechanisms, etc.) in order to meet the socio-economic needs of mankind best.

3 Research Results

The road environment is a set of factors that characterize (taking into account the season, time of day, atmospheric phenomena, road illumination) visibility in the direction of travel, the condition of the road surface (cleanliness, equality, roughness, adhesion), as well as its width, the value of slopes by descents and ascents, turns and curves, the presence of sidewalks or shoulders, traffic control devices and their condition.

In accordance with the principle of "necessary organization", the adequacy between the components of the system "Noosphere—Technosphere—Road Environment" (NTRE) and the environment is established when the following condition is met:

$$Q_i = Q_{cp.i}, \tag{1}$$

where Q_i is absolute organization of system component *i*;

$Q_{cp.i}$ is absolute organization of the environment of the component *i*.

Taking into account (1) the equation of static equilibrium of the component *i*:

$$Q_{cp.i} - Q_i = 0, \tag{2}$$

When the static equilibrium is disturbed, the absolute organization of the component *i* of the system changes by the value of dQ_i over the elementary time interval dt. Therefore, the conditions of dynamic equilibrium of the component *i* can be represented as:

$$\frac{dQ_i}{dt} = \Delta Q_{cp.i} - \Delta Q_i, \tag{3}$$

Assuming that each component of the system can be in only two states (actual and specified), then:

$$Q = 1 + P_i \log P_i + (1 - P_i)\log(1 - P_i), \tag{4}$$

where P_i is the probability of transition of the component *i* of the NTRE system from the actual to a specified state.

Considering (4):

$$dQ_i = C_i dP_s, \tag{5}$$

where C_i is the organizational capacity of the component *i*.

Then the equation of dynamic equilibrium has the form:

$$C_i \frac{dP_i}{dt} = \Delta Q_{cp.i} - \Delta Q_i, \tag{6}$$

Since each component of the system seeks to balance with the environment, the absolute organization of this environment acts as a kind of norm to which the component seeks.

The norm of the absolute organization of the "Noosphere—Technosphere—Road Environment" system component can be defined as the weighted average of the individual norms of the components:

$$Q_{\text{н}i} = \frac{\sum_{j=1}^{m} \gamma_j^{(i)} Q_{\text{н}j}^{(i)}}{\sum_{j=1}^{m} \gamma_j^{(i)}}, \tag{7}$$

where $Q_{\text{н}i}$ is the norm of absolute organization of the component i of the system;

$Q_{\text{н}j}^{(i)}$ is the norm of the absolute organization of the environment component j for the component i of the system;
$\gamma_j^{(i)}$ is the rigidity of the norm $Q_{\text{н}j}^{(i)}$.

Hereinafter, the norm is understood as the optimal absolute organization to the greatest degree of compliance with the goals and objectives of the functioning of the "Noosphere—Technosphere—Road Environment" system.

Taking into account (7), we get:

$$\begin{aligned} Q_{\text{нн}} &= (\gamma_T Q_{HT} + \gamma_Д Q_{\text{ндс}} + \gamma_c Q_{\text{нс}})/(\gamma_T + \gamma_{\text{дс}} + \gamma_c), \\ Q_{HT} &= (\gamma_{\text{н}} Q_{\text{нн}} + \gamma_{\text{дс}} Q_{\text{ндс}} + \gamma_c Q_{\text{нс}})/(\gamma_{\text{н}} + \gamma_{\text{дс}} + \gamma_c), \\ Q_{\text{ндс}} &= (\gamma_{\text{н}} Q_{\text{нн}} + \gamma_T Q_{\text{н}T} + \gamma_c Q_{\text{нс}})/(\gamma_{\text{н}} + \gamma_T + \gamma_c), \end{aligned} \tag{8}$$

where $Q_{\text{нн}}$, $Q_{\text{н}T}$, $Q_{\text{ндс}}$, $Q_{\text{нс}}$ are individual norms of absolute organization of system components;

$\gamma_{\text{н}} \cdot \gamma_T$, $\gamma_{\text{дс}}$, γ_c are rigidity of individual norms.

Let us introduce the designations:

$$\begin{aligned} k_T^{(1)} &= \frac{\gamma_T}{\gamma_{\text{дс}} + \gamma_T + \gamma_C};\; k_c^{(1)} = \frac{\gamma_c}{\gamma_{\text{дс}} + \gamma_T + \gamma_C};\; k_{\text{дс}}^{(1)} = \frac{\gamma_{\text{дс}}}{\gamma_{\text{дс}} + \gamma_T + \gamma_C} \\ k_{\text{н}}^{(2)} &= \frac{\gamma_{\text{н}}}{\gamma_{\text{н}} + \gamma_T + \gamma_c};\; k_{\text{дс}}^{(2)} = \frac{\gamma_{\text{дс}}}{\gamma_{\text{н}} + \gamma_{\text{дс}} + \gamma_c};\; k_c^{(2)} = \frac{\gamma_c}{\gamma_{\text{н}} + \gamma_{\text{дс}} + \gamma_c}; \\ k_{\text{н}}^{(3)} &= \frac{\gamma_{\text{н}}}{\gamma_H + \gamma_T + \gamma_C};\; k_T^{(3)} = \frac{\gamma_T}{\gamma_{ДС} + \gamma_T + \gamma_C};\; k_c^{(3)} = \frac{\gamma_c}{\gamma_{\text{н}} + \gamma_{\text{дс}} + \gamma_c}. \end{aligned} \tag{9}$$

where k_H, k_T, k_C are the weight coefficients of noosphere, technosphere and environment.

We get:

$$\begin{aligned} Q_{нн} &= k_T{}^{(1)} Q_{нT} + k_{\partial c}{}^{(1)} Q_{н\partial c} + k_c{}^{(1)} Q_{нc}\,, \\ Q_{нT} &= k_н{}^{(1)} Q_{нн} + k_{\partial c}{}^{(1)} Q_{н\partial c} + k_c{}^{(1)} Q_{нc}\,, \\ Q_{н\partial c} &= k_н{}^{(1)} Q_{нл} + k_T{}^{(1)} Q_{нT} + k_c{}^{(1)} Q_{нc}\,, \end{aligned} \tag{10}$$

where $k_T^{(1)} + k_{\partial c}^{(1)} + k_c^{(1)} = 1$; $k_н^{(2)} + k_{\partial c}^{(2)} + k_c^{(2)} = 1$; $k_н^{(3)} + k_T^{(3)} + k_c^{(3)} = 1$..

Taking into account the above-stated, after the expansion into Maclaurin series of increments of absolute organization, the equations of dynamic equilibrium of the components of the NTRE system are represented in the form:

$$\begin{aligned} C_н \frac{d\Delta P_н}{dt} - \left(\left(\frac{\partial Q_{cp.н}}{\partial P_T}\Delta P_T + \frac{\partial Q_{cp.н}}{\partial P_{\partial c}}\right) - \frac{\partial Q_н}{\partial P_н}\Delta P_н\right) &= \frac{\partial Q_{cp.н}}{\partial P_c}\Delta P_c\,, \\ C_T \frac{d\Delta P_T}{dt} - \left(\left(\frac{\partial Q_{cp.T}}{\partial P_н}\Delta P_н + \frac{\partial Q_{cp.T}}{\partial P_{\partial c}}\right)\Delta P_{\partial c} - \frac{\partial Q_T}{\partial P_T}\Delta P_T\right) &= \frac{\partial Q_{cp.T}}{\partial P_c}\Delta P_c\,, \\ C_{\partial c} \frac{d\Delta P_{\partial c}}{dt} - \left(\left(\frac{\partial Q_{cp.\partial c}}{\partial P_н}\Delta P_н + \frac{\partial Q_{cp.\partial c}}{\partial P_T}\right) - \frac{\partial Q_{\partial c}}{\partial P_{\partial c}}\Delta P_{\partial c}\right) &= \frac{\partial Q_{cp.\partial c}}{\partial P_c}\Delta P_c\,, \end{aligned} \tag{11}$$

where $C_н$, C_T, $C_{\partial c}$ are the organizational capacity of noosphere, technosphere, road environment;

$Q_н$, Q_T, $Q_{\partial c}$ are the absolute organizations of the noosphere, technosphere, road environment;

$Q_{cp.н}$, $Q_{cp.T}$, $Q_{cp.\partial c}$ are the absolute organizations of the external environment for the noosphere, technosphere, road environment;

$\Delta P_н$, ΔP_T, $\Delta P_{\partial c}$, ΔP_c are the increase in the function of the transition of the noosphere, technosphere and environment from the actual to the specified state (the state of norm).

$$\Delta P_н = P_н - P_{н0}\,;\ \Delta P_T = P_T - P_{T0}\,;\ \Delta P_{\partial c} = P_{\partial c} - P_{\partial c0}\,;$$

$P_{н0}, P_{T0}, P_{\partial c0}$ are the initial probabilities of transition of the noosphere, technosphere to the state of the norm.

The partial derivatives in Eq. (11) are:

$$
\begin{aligned}
\frac{\partial Q_{ср.н}}{\partial P_T} &= k_T^{(1)}\left[\log P_T - \log(1-P_T)\right],\\
\frac{\partial Q_{ср.н}}{\partial P_{дс}} &= k_{дс}^{(1)}\left[\log P_{дс} - \log(1-P_{дс})\right],\\
\frac{\partial Q_{ср.н}}{\partial P_c} &= k_c^{(1)}\left[\log P_c - \log(1-P_c)\right],\\
\frac{\partial Q_{ср.T}}{\partial P_н} &= k_н^{(2)}\left[\log P_н - \log(1-P_н)\right],\\
\frac{\partial Q_{ср.T}}{\partial P_{дс}} &= k_{дс}^{(2)}\left[\log P_{дс} - \log(1-P_{дс})\right],\\
\frac{\partial Q_{ср.T}}{\partial P_c} &= k_c^{(2)}\left[\log P_c - \log(1-P_c)\right],\\
\frac{\partial Q_{ср.дс}}{\partial P_н} &= k_н^{(3)}\left[\log P_н - \log(1-P_н)\right],\\
\frac{\partial Q_{ср.дс}}{\partial P_T} &= k_T^{(3)}\left[\log P_T - \log(1-P_T)\right],\\
\frac{\partial Q_{ср.дс}}{\partial P_c} &= k_c^{(3)}\left[\log P_c - \log(1-P_c)\right],\\
\frac{\partial Q_н}{\partial P_н} &= C_н = \left[\log P_н - \log(1-P_н)\right],\\
\frac{\partial Q_T}{\partial P_T} &= C_T = \left[\log P_T - \log(1-P_T)\right],\\
\frac{\partial Q_{дс}}{\partial P_{дс}} &= C_{дс} = \left[\log P_{дс} - \log(1-P_{дс})\right],
\end{aligned}
\tag{12}
$$

Let us introduce the designations:

$$\begin{gathered}
b_{н} = k_{c}^{(1)}\left[\log P_{c} - \log(1-P_{c})\right]/\left[\log P_{н} - \log(1-P_{н})\right] = const, \\
b_{T} = k_{c}^{(2)}\left[\log P_{c} - \log(1-P_{c})\right]/\left[\log P_{T} - \log(1-P_{T})\right] = const, \\
b_{\partial c} = k_{c}^{(3)}\left[\log P_{c} - \log(1-P_{c})\right]/\left[\log P_{\partial c} - \log(1-P_{\partial c})\right] = const, \\
\left[\log P_{\partial c} - \log(1-P_{\partial c})\right]/\left[\log P_{н} - \log(1-P_{н})\right] = \left[\log P_{\partial c} - \log(1-P_{\partial c})\right]/ \\
\left[\log P_{T} - \log(1-P_{T})\right] = 1, \\
\left[\log P_{н} - \log(1-P_{н})\right]/\left[\log P_{\partial c} - \log(1-P_{\partial c})\right] = \left[\log P_{T} - \log(1-P_{T})\right]/ \\
\left[\log P_{\partial c} - \log(1-P_{\partial c})\right] = 1, \\
\left[\log P_{н} - \log(1-P_{н})\right]/\left[\log P_{T} - \log(1-P_{T})\right] = \left[\log P_{T} - \log(1-P_{T})\right]/ \\
\left[\log P_{н} - \log(1-P_{н})\right] = 1.
\end{gathered} \tag{13}$$

Taking into account (12) and (13), Eq. (11) is transformed into the following form:

$$\begin{cases}
\dfrac{\partial \Delta P_{н}}{\partial t} - \left[(k_{T}^{(1)}\Delta P_{T} + k_{\partial c}^{(1)}\Delta P_{\partial c}) - \Delta P_{н}\right] = b_{н}\Delta P_{c} \\
\dfrac{\partial \Delta P_{T}}{\partial t} - \left[(k_{н}^{(2)}\Delta P_{н} + k_{\partial c}^{(2)}\Delta P_{\partial c}) - \Delta P_{T}\right] = b_{T}\Delta P_{c} \\
\dfrac{\partial \Delta P_{\partial c}}{\partial t} - \left[(k_{н}^{(3)}\Delta P_{н} + k_{T}^{(3)}\Delta P_{T}) - \Delta P_{\partial c}\right] = b_{\partial c}\Delta P_{c}
\end{cases} \tag{14}$$

Since social, economic, political, environmental changes take place in the environment over time, it can be considered that $\Delta P_c \neq const$.

At the initial moment of time t_0, the values of the probabilities $P_{н} = P_{н0}$, $P_T = P_{T0}$, $P_{\partial c} = P_{\partial c0}$ of the transition of the noosphere, technosphere to the state of norm are given. Moreover, it is considered that $P_{н} = P_T = P_{\partial c} = 0$ for this moment of time.

For numerical integration of the system of differential Eqs. (14) we present it in the form of Cauchy:

$$\Delta\overline{P} = A\Delta\overline{P} + B\Delta P_c, \tag{15}$$

where $\Delta\overline{P}(3 \times 1) = [\Delta P_{н}, \Delta P_T, \Delta P_{\partial c}]^T$ is the vector of unknowns;

ΔP_c is the input action that can be set: tabular, analytically, random (at choice);

$A(3 \times 3)$, $B(3 \times 1)$ are the system matrices that have the form:

$$A = \begin{vmatrix} \Delta P_{н} & -\kappa_{T}^{(1)} & -\kappa_{\partial c}^{(1)} \\ -\kappa_{н}^{(2)} & \Delta P_{T} & -\kappa_{\partial c}^{(2)} \\ -\kappa_{н}^{(3)} & -\kappa_{T}^{(3)} & \Delta P_{\partial c} \end{vmatrix}; \quad B = \begin{vmatrix} b_1 \\ b_2 \\ b_3 \end{vmatrix} \tag{16}$$

The parameters $k_{н}^{(1)}, k_{дс}^{(1)}, k_{c}^{(1)}$, $k_{н}^{(2)}, k_{дс}^{(2)}, k_{c}^{(2)}$, $k_{н}^{(3)}, k_{T}^{(3)}, k_{c}^{(3)}$ of the system are determined from the system of nonlinear equations:

Let us note that the number of equations in the system is one less than the number of unknowns. Therefore, one of the unknowns, for example $\gamma_{н}$, will be considered a free term with the value of $\gamma_{н} = a$.

Let us introduce a vector of unknown variables:

$$\overline{X} = \begin{bmatrix} x_1 = k_{T}^{(1)}, x_2 = k_{дс}^{(1)}, x_3 = k_{c}^{(1)}, x_4 = k_{н}^{(2)}, x_5 = k_{дс}^{(2)}, x_6 = k_{c}^{(2)}, \\ x_7 = k_{н}^{(3)}, x_8 = k_{T}^{(3)}, x_9 = k_{c}^{(3)}, x_{10} = \gamma_T, x_{11} = \gamma_{дс}, x_{12} = \gamma_c. \end{bmatrix}$$

and the vector $\overline{Y}$ of the left parts of the equations. After that, the system can be represented as follows:

$$A = \begin{vmatrix} \Delta P_{н} & -x_1 & -x_2 \\ -x_4 & \Delta P_T & -x_5 \\ -x_7 & -x_8 & \Delta P_{дс} \end{vmatrix}; \quad B = \begin{vmatrix} b_{н} \\ b_T \\ b_{дс} \end{vmatrix}$$

After determining the vector $\overline{X}$ of parameters of the system, we proceed to its solution (numerical integration).

$$\Delta P_c = A \sin wt \tag{17}$$

where *A, w are* amplitude and frequency of harmonic oscillations, respectively, set by the user.

The model of NTRE system development taking into account the variability of components in the open state.

In the open state of the NTRE system, the satisfaction of human needs ($П2^{-}$) in the activity of interaction with the environment takes place. The activity of interaction is provided by increasing the number of states of the system. The latter are implemented by increasing the number of elements entering the system from the environment.

When the number of elements and the connections between them changes the maximum entropy of the system changes as well. At the same time, the system seeks to achieve a new level of adequacy with the environment.

The process of establishing adequacy is dynamic and for each moment of time is represented in the form:

$$\begin{aligned} H_m^s(t) &\approx H_m^e(t); \\ H^s(t) &\approx H^e(t), \end{aligned} \tag{18}$$

where H_m^s, H_m^e are maximum entropies of the system and the environment, respectively;

H^s, H^e are the current entropies of the system and the environment, respectively;

s, *e* are the indices of belonging to the system and environment;

t is time.

In accordance with the principle of the optimal speed of satisfying needs in an equilibrium state, the speeds of satisfying needs remain constant and equal to the optimal speed, that is:

$$\frac{dH_m^s}{dt} = a = const,$$
$$\frac{dH^s}{dt} = b = const. \tag{19}$$

If at $t = 0$, $H_m^s = 0$, $H_{mo}^s = 0$, $H^s = 0$, then:

$$H_m^s = H_{mo}^s + at; \tag{20}$$

or

$$H_m^s = H_{mo}^s + \frac{a}{b}H. \tag{21}$$

Taking into account the law of organization storage, we can write

$$Q^s(t) = H_m^s(t) - H^s(t). \tag{22}$$

or

$$Q^s(t) = H_{mo}^s(t) - (b - a)t. \tag{23}$$

where Q^s is the absolute organization of the system.

Differentiating $Q^s(t)$ by time we get:

$$\frac{dQ_s}{dt} = a - b. \tag{24}$$

The last equation allows establishing the conditions for increasing the level of organization of the NTRE system in the open state:

$$\frac{dQ_s}{dt} > 0, \text{ if } a > b. \tag{25}$$

The inflow of energy and information from the external environment can be spasmodic. In this case, changes in the maximum entropy of the system will have a weakly oscillatory character with damping and tendency of the process over time to a certain adaptation value. Transient data of a process of this type are described with solving a second-order inhomogeneous differential equation with complex-connected roots of the characteristic equation:

$$\frac{d^2 H_m}{dt^2} + p_1 \frac{dH_m}{dt} + q_1 H_m = R_1, \tag{26}$$

The solution to this equation for nonzero initial conditions can be represented as:

$$H_m = e^{-at}\left[\frac{H'_{m0} + \alpha(H_{m0} - H_{my})}{\beta}\sin\beta t + (H_{m0} - H_{my})\cos\beta t\right] + \ H_{my}, \tag{27}$$

where H_{m0}, H'_{m0} is the maximum entropy and its derivative at t = 0;
α is decrement of oscillations damping,

$$\alpha = \frac{p_1}{2};$$

β is circular frequency,

$$\beta = \frac{2\pi}{T} = \sqrt{q_1 - \frac{p_1^2}{4}};$$

T—is the period of oscillations;

H_{my} is the value of the maximum established entropy (the limit of the adaptive capabilities of the system);

At zero initial conditions ($t = 0$) $H_{m0} = H'_{m0} = 0$:

$$H_m = H_{my} \cdot \left[1 - e^{-at}\frac{\alpha}{\beta}\sin\beta t + \cos\beta t\right] \tag{28}$$

A similar pattern of changes in the current entropy of the system:

$$H^s(t) = e^{-at}\left[\frac{H'_0 + \alpha(H_0 - H_y)}{\beta}\sin\beta t + (H_0 - H_y)\cos\beta t\right] + H_y, \tag{29}$$

where H_y is the value of the established current entropy;

H_0, H'_0 are the initial value of the current entropy and its derivative.

Figure 1 shows a typical adaptation scheme. The oscillatory nature of the curve allows us to speak about the predominance of certain mechanisms in time and divide the entire dynamics of adaptation into stages. At the first stage, from the beginning

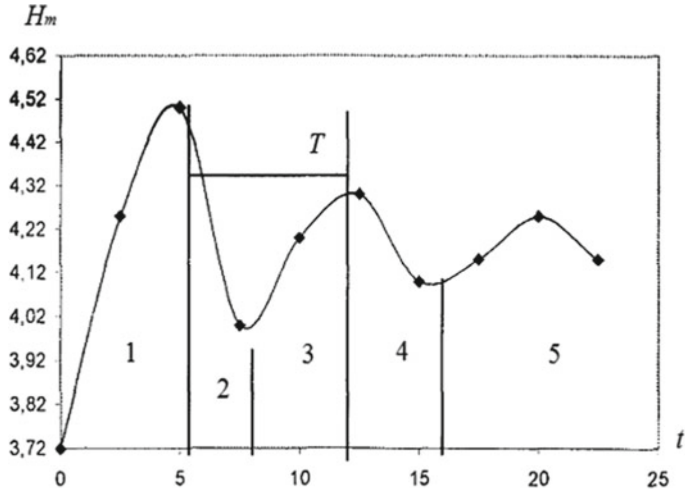

Fig. 1 Adaptation curve

of adaptation to the first maximum value of the maximum entropy, the mobilization of structural and functional reserves predominates. At the second stage, from the first maximum to the first minimum, the accumulation of damaged structures predominates. The third stage, from the first minimum to the second maximum, is characterized by the processes of restoration of functions of the first transformed structures. The fourth stage, to the establishment of equilibrium, is characterized by structural and functional balance of processes. The fifth stage is characterized by balance and value H_{my}.

Mathematical model of the NTRE system development taking into account component variability.

The probabilities of transitions from an actual to a specified state can be used as the weighting factors of these states. Therefore, in the closed state of the NTRE system, its characteristics can be provided on the basis of the following model:

$$X(t) = X_0 q(t) + X_3 p(t), \tag{30}$$

where $X(t)$ is the current quantitative characteristic of the system component;

X_0 is the quantitative characteristic of the component at $t = 0$;

X_3 is the specified characteristic of the component;

$q(t)$ is the probability that a component of the system has not entered a specified state;

$p(t)$ is the probability of transition of the component to a specified state.

In the open state, it can be assumed that the increase in the quantitative characteristic of the system state is determined by the difference between the maximum uncertainty of the state of the system and its current absolute organization. This is followed by an empirical formula:

$$\Delta X^s(t) = \beta_i \left[H_m^i(t) - Q^s(t) \right] = \beta_i H^s(t), \tag{31}$$

where $\Delta X^s(t)$ is the increase in the quantitative characteristic of the system state;

H_m^s, H^s are maximum and current entropy of the system;

Q^s is absolute organization of the system;

β is the coefficient of proportionality and dimensionality.

Thus, the model for predicting the characteristics of the state of an open system can be represented in the form:

$$X^s(t) = X_0^s + \beta_i H^s(t), \tag{32}$$

where X_0^s is the quantitative characteristics of the system at $t = 0$.

4 Conclusions

The resulting model is universal; the quantitative and qualitative characteristics of the "Noosphere—Technosphere—Road Environment" system, crisis processes in the natural, technogenic and social spheres can be calculated with its help.

Similar models can be obtained for each component of the system.

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Building Economics, Implementation of European Standards and Principles of Energy Efficiency

English Multicomponent Construction Economics Terms as a Means of Professional Texts Cohesiveness

Anna Ageicheva, Alla Bolotnikova, Yuliia Hunchenko, and Oleksandra Aheicheva

Abstract The given research refers to multicomponent construction economic terms as a means of cohesiveness of scientific and popular texts on construction economics. Professional texts coherence and cohesion is provided with a number of factors among which compound multicomponent construction economic terms have an important place. These terminological units are predominantly made up due to word combinations terminologization, forming in turn compound multicomponent terms. Like any professional lexis, multicomponent construction economic terms possess a special place among lexical means of cohesion connection in professional texts, being an important tool of actualization of identity, opposition, implication, particular and common, class and variety etc. Thus, one of the term's most important features is its ability to be the key cohesion component of professional texts. Term's cohesion function provides discursive cohesiveness of professional construction economic text organization. Discursive connectedness of cohesive lexis consists in its ability to connect terms into nominative construction.

Keywords Construction economics · Terminology · Multicomponent compound terms · Coherence · Cohesion

1 Introduction

Business development involves innovation technologies implementation, which is completely inevitable in construction sphere. This particular field of any country's activity is of vital importance and thus requires combined efforts and research results of various contiguous spheres. Construction economics as a science studies the

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_49

laws of construction development, factors that determine labor efficiency and use of production means in this branch of economics, as well as forms and methods of economic work in construction production.

Construction economics also explores specific forms and manifestations of economic laws in construction industry, examines the ways of construction industry development, and links with other sectors of economics. It also studies methods and means of improving its efficiency. At the same time, it is intended to solve specific economic problems that arise in the processes of development of construction production management organizational forms development of capital investments, use of available resources, etc.

Construction economics objectives include development of economic bases of construction design, construction typing, industrialization, economic conditions and urban development by means of improving social and economic benefits necessity of estimated cost reduction. It develops a system of methods for planning capital investments and construction production, examines its efficiency factors, criteria, conditions for increasing labor productivity, increasing capital efficiency, improving use of material and other resources, accelerating development of existing and new production facilities, achievement of technical and economic project indicators, etc. As a science, construction economics develops in close collaboration with economic theory and with many specialized disciplines (finance and credit, accounting statistics and business analysis, etc.), as well as with sciences that study production and technical basis of construction.

Thus, economic construction terminology is an example of several scientific fields integration and interrelation, made up of construction and economic terms aggregate, correlated with these sciences notions systems, regulated and controlled. Specificity of economic construction terminology causes linguists' interest, at the same time intensifying research in scientific and technical translation sphere.

Construction terminology occupies a special place among other terminologies due to specificity of the human activity sphere it supplies. In the context of construction terminology the domain specific terminologies are marked out, among them terminologies of building machinery, construction materials, mathematics, physics, chemistry, electrical engineering, town-planning, ecology etc. Diversified study in the field of modern English construction terminology and special aspects of its translation contributes to identification of its formation regularity, functioning, systematization, and helps to predict the main tendencies of its further development [1].

Professional texts are objects of numerous research, which is due to the fact that terms functioning can be best traced and revealed in the texts. Our research refers to scientific-popular texts, which while containing latest research on the topic still do not require the audience to possess deep scientific knowledge, and thus are aimed at the wide readers' audience.

Scientific-popular texts have already been an object of linguistic research [1–3]. Still, multicomponent compound terms functioning in such texts as well as their cohesion functions have not been yet investigated.

All the above mentioned make conditions for determining the aim of the current research, which is to trace the ways of English economic construction multicomponent terms building and determining their role in professional texts cohesion. It should also be noted here that diversified study in the field of modern English construction economic terminology contributes to identification of its formation regularity, functioning, systematization, and helps to predict the main tendencies of its further development. This is what determines the field of our research.

2 Results

Current research is conducted at the material of English multicomponent compound nouns—construction economic terms with consideration to both their terminological and world-building aspects. Since compounding is considered to be one of the main areas in English lexis development, its study appears as an important aspect in word-building investigation process.

English construction economic terminology is characterized by its diversified structure, which generally includes such terminologies as construction marketing, finance, insurance, accounting, design and others. Modern English construction economic terminology is an example a few scientific fields terminologies integration, like industry economics, labor economics, economic geography,, statistics, finance, accounting etc.

In order to reveal the topic under discussion, the functional approach of studying word-formation is applied, which enables enlarging knowledge base about derivatives as the main unit of word-formation, its semantics creation as well as context surrounding it. The main means of replenishing the lexical structure of the language, along with affixation, conversion, abbreviation and borrowing, is word formation. According to the latest research on the modern English word formation, there is a tendency to further increase the share of compound words, which constitute a largest group of lexical neologisms. The object of this study is multicomponent compound nouns—construction economic terms of modern English economic terminology. The aim of the study is to investigate the peculiarities of their formation and identify structural and semantic characteristics, which in turn will reveal the semantics of constructing economic terms.

The object of the study is 350 compound English construction economic terms, the study of which was performed using the following methods: descriptive method, word-formation analysis related to the structure and semantics of terms, method of word-formation modeling structure of compound nouns—constructing economic terms and quantitative analysis.

In the modern English construction economic terminological system there is a tendency to multicomponent formations creation. The basis for their formation can be syntactic units, which are phrases and sentences. As a result of merging syntactic constructions into a single unit, so-called compound words of syntactic type are formed [4]. The number of compound terms of syntactic type is growing, which confirms the opinion of scientists about the growing tendency to multicomponent combinations formation. A significant part of such formations arises on the basis of phrasal definitions, which are visualized as adjectives [5].

The main difference between compound words of syntactic type from ordinary composites is that they are formed not by combining syntactically independent words, but are formed on the basis of ready-made phrases by integrating syntactically dependent components [3, 6]. An important role in the formation of multicomponent units is played by analogy, when new units are formed rather by the example of a specific lexical unit by filling it with new material [4, 7–22].

Example: *To shore up the euro, Germany foresees* ***give-and-take*** *in which core countries pay to save the periphery in exchange for a more federal Europe. To the Dutch, that looks like* ***take-and-take****.*

There's a ***once-an-owner-always-an-owner*** *philosophy that means* ***homeowners*** *don't adapt their future intentions even after facing foreclosure, seeing the value of their home plummet, or finding themselves owing more than their home is worth.*

The purpose of compound nouns—construction economic terms of syntactic type formation on the basis of ready-made combinations by integrating components that are syntactically dependent on each other, is semantic or syntactic convenience. Thus, there exist a number of ways the compound nouns of such type can be formed. The authors suggest showing some of the formation formulas and examples in the Table 1 (see below).

Complex nouns—economic terms of syntactic type are characterized by such a connection between their elements, which is inherent in the syntactic units (phrases and sentences) from which they originate. Thus, the list of examples can be further continued. The meanings of such words are usually non-idiomatic, and can be derived from the values of the elements that form it, i.e. the meaning of complex terms of the syntactic type is the addition of the meanings of its formation elements. In compound terms of syntactic type, the means of external syntax are preserved, especially prepositions and conjunctions (*cash//-and//-carry, roll//-on//-roll//-off*).

The area of terms functioning is in particular a scientific-popular text. Its characteristic features include: (1) information saturation, which causes greater than in other types of text interdependence of all its elements; (2) implementation of such categories as informativeness, coherence, integrity and ability to articulate [23]. The key to the correct understanding of texts of this type is their organization in accordance with certain requirements, namely the structuring of information presented in popular science text, which contributes to a better understanding of it.

One of the most important features of a term, and in particular a compound construction economic term includes its ability to be a key cohesive component in the professional communication texts. Cohesion, which is a text category enabling information transfer through the system of interrelated and integrated elements in the complex of their structural, semantic, cognitive and functional characteristics, is one of the most important features of scientific text [3]. Coherence and cohesion are the two concepts, which are closely connected and even sometimes regarded as synonymous. Still, coherence is a cognitive phenomenon. Its recofnition involves text

Table 1 Compound nouns—construction economic terms formation formulas and examples

No.	Formation formula	Compound term example	Compound term example in the text
1	noun + preposition + noun	*grant//-in//-aid* *stock//-in//-trade* *value//-at//-risk* *boom//-and//-bust* *stock//-in//-trade*	*Finally, in finance, let's ban the risk-management method called "**value-at-risk**" currently used by banks* *After the **boom-and-bust** 1980s, the government should have rid banks of bad loans, deregulated industry, made tax policies more pro-business, raised productivity, and encouraged entrepreneurship*
2	verb + preposition + verb/noun	*give//-and//-take* *mark//-to//-market* *cash//-and//-carry*	*In 2007 Walmart and Bharti established Bharti Walmart Private for wholesale **cash-and-carry** and supply-chain management*
3	verb + preposition + pronoun + verb	*pay//-as//-you//-earn* *roll//-on//-roll//-off*	*France's looming pension problem will be most acute over the next 20 years, as the baby-boomers born in the 1950 and 1960s retire, as a government-commissioned report into pensions published on June 14th pointed out; this will throw the **pay-as-you-earn** pension scheme off balance, as the ratio of those of working age to those over 60 shrinks from 2.6 to 1.5*
4	numeral + noun + noun	*one-stop-shop*	*On the other side is almost everyone else, insisting on the virtues of **one-stop-shop** universal banking which has served Germany well for decades*

(continued)

Table 1 (continued)

No.	Formation formula	Compound term example	Compound term example in the text
5	verb + numeral/noun + verb + numeral/noun + adverb	*Buy-one-get-one-free*	*These gimmicks often take the form of **buy-one-get-one-free** (or BOGOF) offers*
6	adverb + noun + adverb + noun	*Once-an-owner-always-an-owner*	*There's a **once-an-owner-always-an-owner** philosophy that means homeowners don't adapt their future intentions even after facing foreclosure, seeing the value of their home plummet, or finding themselves owing more than their home is worth*
7	adverb + noun + noun	*Purchasing-power-parity*	*Western Europe's per-person GDP is 72% of America's, on a **purchasing-power-parity** basis*

and refers to logical flow of interrealted topics in a text, thus establishing a mental textual world. Cohesion can be regarded as an explicit indicator of relations between topics in the text. It refers to text-internal relationship of linguistic elements linked by lexical and grammatical devices across sentenses boundaries.

Terminology plays the role of a systemic factor in the text, so it serves its cohesion [24]. The cohesive function of the term according ensures discursive integrity of construction economic text the structural and semantic organization. Discursive significance of cohesive vocabulary in the text lies in the ability of a term to combine into a nominative construction not only terminological units, but also commonly used words. Specificity of English scientific construction economical text, much alike to scientific economical text, consists mainly in comparatively small amount of key concepts being used in it, which are in close connection with each other. Terms in such a text, together with terminological meaning can supply the elements of the common language meaning, while the non-terminological lexis can supply scientific information [1, 2].

In the sphere of popular science economic text, terminological vocabulary widely demonstrates its systemic qualities. According to the results of our research, compound nouns—construction economic terms mostly provide actualization through the function of text compression. The main structural and semantic feature of the composite term is the combination of a few full-fledged creative bases. The semantic meaning of such a term is always bigger than the sum of meanings of its forming elements, and therefore a compound term, a multicomponent compound term in particular, has a higher informativeness than a simple term, which enables it performing the function of text compression. That is the reason why multicomponent compound nouns—construction economic terms are often used in the titles of articles of popular science texts.

3 Conclusions

The research conducted enabled tracing the ways of English economic construction multicomponent terminology formation and their role in professional texts cohesion.

The authors revealed characteristic terminological features of such a specific branch of science, which is construction economics, in particular, multicomponent compound nouns. The authors have investigated the formulas, according to which these terminological units are built, as well as traced their functioning in the professional texts. Terms occupy a special place among lexical means of the professional text cohesion coherence, being an important instrument of maintenance of identity, opposition, involvement, a part and a whole, a class and plurality etc. Terms in the text serve as a system factor, i.e. serve cohesion.

It was also revealed that multicomponent compound nouns—economic terms have a stable tendency to formation, which is explained by the syntactic and semantic convenience of their formation and use. The growing number of terminological composites of the syntactic type creates a basis for their further study. Diversified study in the field of modern English construction economic terminology contributes to identification of its formation regularity, functioning, systematization, and helps to predict the main tendencies of its development.

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Building Information Modeling—As a Way of Increasing Competitiveness of Construction Companies in Azerbaijan

Konul Aghayeva and Svitlana Sivitska

Abstract In modern conditions, innovation is the most important tool for improving the quality and competitiveness of construction companies. The transition of the civil construction industry to a higher level of competitiveness in many countries of the world is associated with the creation of full-fledged building information modelling (BIM). The goals of building information modelling (BIM) and the related methods and technologies are overcoming the insufficiency and budget and time consuming by replacing old non-digital practices with the integrated management of design, construction, operation, and maintenance information throughout the lifecycle of a project. The object of research in this article is directly BIM as a technological innovation, its advantages and limitations in Azerbaijan.

Keywords BIM modeling · Competition · Competitive position · Construction industry · Technology · Innovation

1 Introduction

Construction is an independent branch of the national economy, aim of which commissioning of new facilities, as well as reconstruction, expansion, modernization and technical re-equipment of existing production and non-production ones. The main role of the construction industry is to provide conditions for the progressive development of economy of the country. The purpose of the activity of any society is the production of goods (material and non-material) to meet the needs of people. Satisfaction of these needs is impossible without the participation of the construction industry, designed to create and modernize production and non-production fixed

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_50

assets. All mentioned explain reasons why increasing competitiveness of construction companies is very important for economy and society in general. BIM (Building Information Modeling) is one of such kind solutions.

It is necessary to mention that construction industry in Azerbaijan is one of the medium-tech sectors of the economy. Consequently, innovation in this filed remains aloof and receives less attention in comparing with high-tech industries. Considering the high proportion of construction production in the country's economy, the transition of the construction industry to high-tech production will ensure the development of Azerbaijan economy as many others spheres of the economy that interact with the construction industry.

2 Main Part

2.1 Purpose of the Article

The purpose of the article is to substantiate the effectiveness of the application of BIM technologies in the construction sector of Azerbaijan. As well factors positively influencing the introduction of information modeling in construction and problems hindering its development were main directions of analysis of article. In the near future, the mandatory application of the Information Model is expected in all budget projects with state funding in Azerbaijan. Currently, specialists from the State Committee for Urban Planning and Architecture of Azerbaijan Republic are working on this process and such kinds of investigation provide good sources for making decisions in this field.

2.2 Research Methodology

The solution to the tasks set in the study was carried out using a systematic approach (when studying the BIM technology in the construction process), an abstract-logical approach examination (in the analysis of terminology) and forecasting method (in the making forecasts for the impact of BIM technology on the competitiveness of construction companies).

2.3 Results

Despite some difficulties in applying BIM technologies in the construction sector of Azerbaijan, this process is inevitable. For a more systematic and fundamental application of this new technology, the process must be started in parallel with the inclusion of this discipline in the curricula of specialized educational institutions. This will provide in the long term training specialists in this industry.

Due to special attention paid by the President of the Republic of Azerbaijan Ilham Aliyev to the development of the construction sector, radical reforms have been carried out in this area recently, significant progress has been achieved in the planned and systematic organization of architectural activities and urban planning processes in the country and in the applying of leading world standards and modern technologies to the construction. Over the past few years, the State Committee for Urban Planning and Architecture of Azerbaijan Republic has digitized design and permitting procedures in construction, developed and put into operation an "Single Window" electronic system covering all country.

The digital transformation taking place on a global scale presupposes an inevitable change in the model of creation and development of modern cities in Azerbaijan. The need of our time is to satisfy the growing demand for the level and quality of life, types of activities and services, as well as the competitiveness of the field. New approaches to creating an urban environment based on modern high technologies that are an integral part of the state urban planning policy.

A number of Azerbaijani companies have already achieved significant success in the development and application of new technologies in design. For example, Azfen company has implemented an important project that won international recognition on the basis of Tekla Trimble technology. Meanwhile SOCAR Foster-Wheeler Engineering company which works on the reconstruction of the Heydar Aliyev Baku Oil Refinery carried out work in accordance with the highest global standards [1, 2].

Thus BIM (Building Information Modeling or Building Information Model) is a quantitative representation of the physical and functional characteristics of an object that includes more than just the scope of building. BIM takes into account many factors and information about an object, its individual elements (even manufacturer's parts), geography, design and other data, including its impact on the environment and vice versa. All these data, along with the technical and economic indicators and other characteristics of the object, form an information model in which a change in one parameter leads to an automatic recalculation of all others [3].

The building information model is quantitative information that has high levels of coherence and interconnection, amenable to calculations and analysis, having a geometric reference, suitable for computer use, allowing the necessary updates.

The BIM principles, formulated by Robert Aish in 1986:

- 3D modeling;
- Automatic receipt of drawings;
- Intelligent parameterization of objects;
- Sets of design data corresponding to the objects;
- Distribution of the construction process by time stages [4].

Of course, nowadays scope of BIM is more wider. Besides of the full use of the capabilities of computer technology, special programs and telecommunications BIM provides that all projects are carried out in innovative software environments that support parametric modeling (for example, Autodesk Revit) and collaboration between different specialists (for example, BIM 360). Such systems not only make it possible to quickly organize the work of large teams of specialists on one project, but also to identify collisions and errors before starting of construction, and to eliminate them in a timely manner. The presence of a digital model makes it possible to determine the need for building materials with the utmost accuracy, as well as to work out different options for solutions and finishes, which allows to accurately control the cost of construction. The construction process itself becomes transparent and predictable: on the basis of a BIM model, it is possible to make a complete construction schedule, send the necessary equipment at exactly the right time, understand which contractor is doing what work, and clearly control the volume and quality of completed projects. Moreover, the same model covers the operation and demolition phase and is the basis for a full-fledged smart homes. In this way, BIM manages the entire life cycle of a building till demolition.

The importance of applying BIM technology in Azerbaijan construction is huge: the decreasing time of project, the increasing of operational efficiency of the finished building, reducing number of reworkings and errors, fewer gaps in the information flow.

The main tasks that organizations are implementing BIM technologies try to solve are:

- increasing the efficiency of using software;
- work with a single database of the object;
- obtaining a visual model;
- objective information about the object;
- increasing the level of coordination of participants in the project and construction process;
- improving the quality of the issued project documentation;
- improving the quality of construction;
- increasing competitiveness between companies and in the world market.

Also, one of the most important tasks solved when implementing information modeling of buildings in the design and construction is to reduce the cost of construction in order to save public and private funds. This is due to the fact that BIM allows at the early stages to calculate the cost, timing of work, the exact amount of required materials and construction equipment, calculate the risks, and so on.

When applying BIM technology, a collective approach to work is very important. Consequently, only with streamlined collaboration and data management processes it is possible to take full advantages of the BIM—first of all, have a chance to receive any information in the model at any time.

The subsequent ease of use of project depends on how correctly and in detail each specialist enters information about any part of the project. A single information model project can be created and worked on by several hundred people representing many disciplines. Each of them daily generates new information, for the management of which it is necessary to build an effective system. While there is no system, data is lost, which leads to violations of the construction and design timelines. Due to errors of internal interaction with a lag from the planned schedule, up to 90% of projects are released, up to 28 h a week, intellectual labor specialists spend on searching for information and correspondence with each other.

This technology is new in the field of construction, and therefore there are a lot of contradictions associated with its implementation and application. Based on this, the main task of modern construction is to understand the importance of BIM and to solve problems associated with the development of information modeling.

Now there are many worldwide examples of the use of BIM modeling with the analysis of the obtained results. For example, Tom Hughes, a BIM consultant at the Mott MacDonald consulting company, cited the following data: the use of BIM in the design of Casement Park stadium in Belfast, UK reduced the cost of engineering work by 52%, as a result, the cost of the stadium per spectator place decreased by 38%. The company also created the "Steps" technology for modeling human flows and applied it in tandem with BIM to optimize pedestrian and transport traffic at the facility [3]. In Azerbaijan the Olympic stadium in Baku is a prime example of the benefits of BIM, showcasing the speed and design quality at every level of its development. The new 68,000-seat, retractable roof stadium was designed to meet the highest international standards for stadiums set by the UEFA. What is more, the truly global team has just 18 months to design and build the venue.

As we can see modeling information in construction projects allows to create a 3D model of the whole system, which helps the designer and contractor to get a more complete picture of the final result than traditional two-dimensional drawings, which in turn prevents time loss and improves quality.

It should be noted the main advantages of BIM in Azerbaijan construction industry:

- specialists in different fields work with the same design data;
- gaps and errors in the collected information are reduced;
- developing of detailed and informational model, which contains all the calculations of the object being built;
- modeling, management and control occur throughout the entire life cycle of the facility;
- the ability to conduct an experimental survey of the model under certain conditions;
- the time and cost of the project of a building or structure are largely reduced.

All of these advantages increase the competitiveness of the construction industry on a global scale.

Nevertheless, despite all of the above, information modeling, and specifically BIM technologies, in addition to all the advantages, has certain limitations. Experts identify the following implementation difficulties:

- retraining from CAD-design to BIM software product;
- the interaction of departments when working in BIM technologies takes a long time to adapt;
- high price of relevant software products;

- limited number of BIM managers who are ready to train all staff and organize the transition to BIM technologies;
- resistance by staff to new technology;
- lack of BIM experts and structured training and certification programs [5].

The small interest of enterprises is based on the fact that at this stage many companies are not ready for the transition due to a complete change in the structure, personnel, introduction of new technologies of the construction process, since all this requires a large initial investment of funds. Everyone believes that it is better to invest in something that is time-tested, and the new can only bring down the construction process of the organization.

2.4 Scientific Novelty

BIM technology is a new, not yet widely used method of digital management of the construction process, not only at the production stage, but also at the operation and demolition stages. In the near future, the use of this technology will be mandatory for some types of the construction sector invested by the state funds. Therefore, scientific research in this direction will have a certain impact on the making of effective decisions in this matter.

2.5 Practical Importance

However, the research in the field of applying BIM in construction organizations in the majority of cases are descriptive in nature; some issues of BIM technology are light poorly or are not considered at all. The lack of science-based approach that takes into account the specific features of building sector of Azerbaijan is one of the reasons for this kind of research.

The guidance notes for practical application of theoretical bases of BIM technology, preparing specialists in this field and ways of applying it in building companies also need improvement. It is necessary to change mindset of people working in this field and shift production and operation toward more efficient and more "green" technology. With this aim the results of the study can be used in the organizing of construction sector by making BIM technology mandatory.

3 Conclusion

Thus, despite some difficulties explained in the paper, the result of the work is the main advantage of implementing BIM modeling. Construction objects built using BIM are characterized by high building quality, architecture, elaborated infrastructure, convenience and safety. Also, this model allows to reduce the time and costs of projects, avoid possible errors during construction, rationally distribute human and material resources. BIM is base and transitional stage for green construction.

Green BIM is the applying of BIM technology in environmentally friendly construction by the analysis of climatic conditions, modeling of engineering systems, assessment of the life cycle of a building and its optimal functioning from an economic and environmental point of view. So, in particular, Green BIM helps to determine the optimal orientation of a building object in relation to the cardinal points, analyzes the illumination, the possibility of using solar panels and wind turbines, the level of water consumption, the creation and control of engineering systems that can provide maximum comfort. Green BIM allows to design the most ideal project, which provides reducing costs and time for implementation. Undoubtedly, all these processes are not possible without fundamental preparing of specialists in this field. From this point of view, the role of educational institutions that train specialists in this field will increase in Azerbaijan.

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Research Evaluation of the Effectiveness of Capital Investments in the Construction and Reconstruction of Highways

Ruhangiz Aliyeva and Volodymyr Ilchenko

Abstract The article discusses the current problems of the road industry, ways to solve them and directions of efficiency. The essence of the effectiveness of capital investments in road construction is revealed. It is noted that in modern conditions the effectiveness of capital investments in road construction has a high socio-economic significance. It was revealed that there are five potential effects from the development of road construction. The essence and features of each effect are revealed. A more detailed analysis of the effectiveness of the development of road construction abroad and the role of government programs for the effectiveness of capital investments. The socio-economic effect of the development of the road network, which has a two-sided character, is considered. It has been established that the transport effect characterizes direct benefits for road users.

Keywords Capital investments · Effect · Efficiency · Road construction · Highways · Infrastructure · Finance

1 Introduction

In modern conditions, reducing the time and transport costs in road transport, improving the quality of transport services significantly depends on the level of development of roads in the country. At present, the need for effective development of road construction is determined by the influence of the following main factors: the continued rapid growth in the number of vehicles in the fleet, which requires a revision of the requirements for the main consumer properties of roads; significant

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_51

cost of basic road building materials and modern high-performance equipment, which requires the improvement of pricing mechanisms in the road industry; the spread of new (including foreign) technologies in the construction and operation of roads, which entails an increase in the requirements for the quality of road works, taking into account the characteristics of the republic; the use of economically viable technologies and local materials, the preparation of updated standards for the design, construction and operation of such roads; priority consideration of the requirements for ensuring road safety and environmental standards in road construction.

The economic efficiency of capital investments and modern technologies in the road industry is of high socio-economic importance. The use of new technologies, equipment and materials contributes to a significant improvement in the consumer properties of roads, which include: continuity, safety, speed and ease of movement; traffic capacity and level of traffic congestion; the ability to pass vehicles with specified dimensions, axle loads and carrying capacity; environmental Safety; the cost of building and operating highways.

The main limiting factor in ensuring high consumer properties of roads is the direct impact of these factors on the cost of construction, reconstruction and repair of roads. Road construction creates an effect not only in related areas, but also stimulates the development of many sectors of the economy due to the qualitative improvement of road infrastructure.

2 Defining the Problem

The main purpose of the article is to develop economically sound scientific and methodological approaches and practical proposals for determining the effectiveness of capital investments in road construction.

The methodological basis of the study was the works of domestic and foreign scientists-economists on various aspects of assessing the effectiveness of capital investments and the introduction of advanced technologies in road construction, materials from specialized journals, data from periodicals.

The article used general scientific research methods: comparative and factor analysis, a systematic approach.

Many scientists have contributed to improving the efficiency of capital investments in road construction [1–10]. However, the results of these scientific analyzes show that these recommendations are not enough to improve the efficiency of capital investments in road construction. Therefore, it is necessary to consider in detail the causes of premature pavement, identify factors and develop evidence-based recommendations for the effectiveness of capital investments in road construction.

3 Research Results

As a result of the study, it was found that the process of development and improvement of the construction of roads in the country is considered in two aspects: one reflects the technology of road construction, the other reflects capital investments.

As can be seen from Fig. 1 for a detailed analysis of premature damage to the road, it is necessary to initially monitor the road surface. Timely monitoring can give a full assessment of the condition of the road surface and allow you to take measures for its further restoration.

At present, the problems of finding more advanced and cost-effective road construction technologies are still not solved in our country, as well as, of course, which is no less important, the repair and restoration of the pavement of all types of roads. The point is that the road construction and repair technologies that are used today, in our opinion, simply do not provide the required service life of roads and cause the appearance of cracks and defects in the pavement already in the very first year of active operation. As a result, repeated capital investments for the repair of the pavement [12].

It should be noted that the shifts in the development of roads in the country are determined by the size of capital investments. The term “capital investments” in the economic literature is considered adequate to the term “investment”. Both terms are of a financial nature and all quantities here are inevitably expressed in terms of money.

In modern conditions, increasing the efficiency of capital investments in the construction and reconstruction of roads is perceived as a very wide range of improvements in road conditions. The studies conducted by the author show that measures to improve the efficiency of capital investments in the construction and reconstruction of roads should help increase the speed of traffic flows and road capacity, and improve road ecology.

A qualitative change in the technical condition of the existing road network and its further development cannot be carried out without a significant increase in the volume of capital investments in the road industry, therefore, it is necessary to look for additional sources, as well as effectively use the existing financial base, which will further create a mechanism for effective mixed financing of the road industry.

It should be noted that capital investments are long-term investments that can be directed to the construction, reconstruction and modernization of roads.

Economic science interprets the efficiency of capital investments as the ratio of the result (commissioning of road construction facilities) to costs. Costs and results are calculated taking into account the time factor [13].

The efficiency of construction, reconstruction and modernization of roads is characterized by a system of indicators that reflect the final results of road construction, as well as the ratio of results and costs due to their design, reconstruction, repair, operation, maintenance, including roadside infrastructure, taking into account the latest achievements of science and technology.

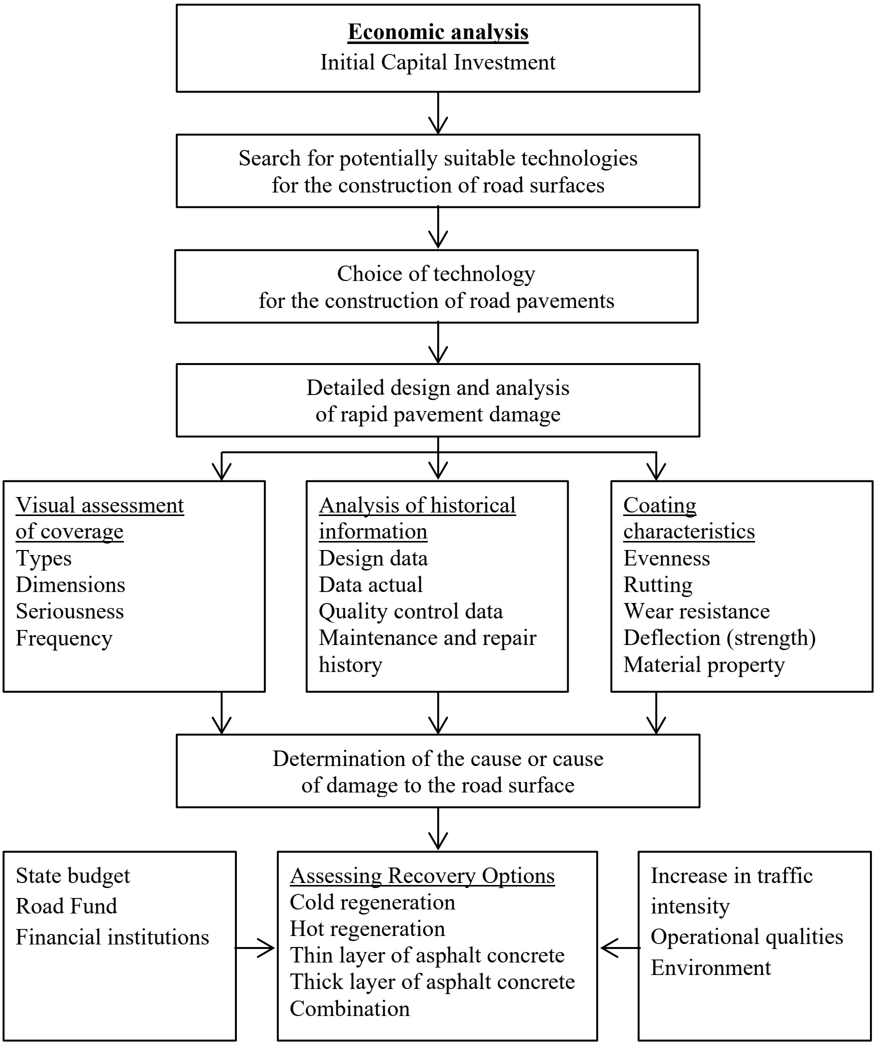

Fig. 1 The relationship between the goals of development and modernization of roads in the Republic of Azerbaijan (compiled by the author based on the source [11])

Studies have shown that there are currently five potential effects from the development of road construction: socio-economic effect; budget effect; the effect of the introduction of new technological equipment; the effect of changing the principles and approaches in the organization and management of road production; effect of capital investment.

The socio-economic effect takes into account the costs and effects not only in the road industry and road transport, but also outside the transport sectors of the economy, including in the social sphere [11].

When planning in the road industry, the determination of the effectiveness of capital investments is aimed at choosing and economic justification of the most effective areas of capital investments. In this case, the best option for the development of the road network is selected with the solution of socio-economic problems in a certain planning period and in the future, the order and timing of the construction and reconstruction of individual sections of the road network are established.

The introduction of new technological equipment at road construction enterprises, first of all, is carried out with the aim of reducing the time of construction, reconstruction, repair; cost savings on raw materials and road materials; increasing the productivity of workers.

To increase the effects of development and improvement of road construction, it is necessary to introduce modern principles and approaches in the organization and management of road construction production. This requires the use of fast-response production methods.

Therefore, for a more detailed analysis of the effectiveness of the development of road construction, it is necessary to distinguish between methods for evaluating indicators:

- socio-economic efficiency, taking into account the final results of the construction and reconstruction of roads in the economy as a whole, i.e., the integral effect for manufacturers, consumers and investors;
- technological efficiency, taking into account the consequences of the introduction of new equipment and innovations in the field of road construction;
- budget efficiency;
- financial efficiency and efficiency of capital investments, taking into account the final results of improving the condition of roads for each of the participants in the construction and reconstruction process;

1. *Indicators of socio-economic efficiency from the construction and reconstruction of roads include* [14]:

   - the integral volume of value added, including depreciation due to the construction and reconstruction of roads, as well as its growth compared to the previous year, in monetary units;
   - the total amount of income (profit), as well as its increase in comparison with the previous year, in monetary units;
   - total return on capital, calculated on the basis of annual income, and its growth compared to the previous year, %;
   - economic effect obtained in the field of road construction, calculated on the basis of net production, including depreciation, and its growth, in monetary units;
   - economic effect obtained in the field of road construction, calculated on the basis of net profit and depreciation, in monetary units;
   - the payback period of capital investments directed to the field of road construction and its change in comparison with the previous year, years;

– the total amount of taxes received by the budget due to the improvement of road construction and its increase in comparison with the previous year, in monetary units.

2. *Performance indicators due to the introduction of new technological equipment and the use of innovations* [14]:

   – the cost of net products obtained through the modernization of equipment and its increase in comparison with the old one, in monetary units;
   – income (profit) due to the modernization of technological equipment and its growth in comparison with the old one, in monetary units;
   – savings from reducing the cost of production, obtained through the modernization of equipment, in monetary units;
   – potential profit from the modernization of equipment, in monetary units.

3. *Indicators of budgetary efficiency of road construction development include*:

   – integrated budgetary effect for the entire period of road construction, in monetary units;
   – integral reduced (discounted or accrued) budgetary effect for the entire period of road construction, in monetary units;
   – the degree of financial participation of the state in the financing of road construction, %.

4. *Financial performance indicators from road construction include*:

   – net income from the development and reconstruction of roads and its growth compared to the previous year, in monetary units;
   – net profit due to the development and reconstruction of automobile roads and its growth in comparison with the previous year, in monetary units;
   – profitability of production, calculated on the basis of net income from the development of road construction and its growth in comparison with the previous year, %;
   – profitability of production, calculated on the basis of net profit from the development of road construction and its growth in comparison with the previous year, %;
   – the total amount of profit received through the development of road construction and its growth compared to the previous year, in monetary units.

5. *Indicators of efficiency of capital investments* [15]:

   – the volume of capital investments obtained through the development of road construction and its growth in comparison with the previous year, in monetary units;
   – the economic effect of capital investments calculated on the basis of annual costs and losses received through the development of road construction and its growth compared to the previous year, in monetary units;

- the economic effect of capital investments calculated on the basis of net profit and net income received through the development of road construction and its growth compared to the previous year, in monetary units;
- the payback period for capital investments based on the net income received from the development of road construction and its change compared to the previous year, years;
- profitability of capital investments, calculated on the basis of net income from the development of road construction and its growth in comparison with the previous year, %.

However, the widespread use of such methods significantly complicates a comprehensive assessment of the feasibility of capital investments in the road industry in the conditions of market relations.

As you know, the insufficient level of development of the road network leads to significant losses in the economy. In economically developed countries, investments in road infrastructure are used as one of the fundamental tools for accelerating industrial growth, developing markets, domestic and foreign trade, creating new jobs, and improving the investment and business climate. For example, for the countries of Europe, investments in the development of road construction have become such a "motor" of structural transformations in the economy. The result was not only an "automobile boom", which stimulated the rise of many industries, but also a transition to a qualitatively new model of socio-economic development, one of the main distinguishing features of which is the high mobility of the population and market entities.

In most highly developed countries (USA, Germany, Japan, etc.), the tasks of forming a backbone network of roads were solved on the basis of long-term state programs that set indicators for the development of the road network and the corresponding volumes of financial support.

Studies have shown that over the past 100 years, the Interstate Highway System Program has had the greatest impact on the US economy and American lifestyle. The US government considered the implementation of this program a priority task of state policy. The construction of the expressway system has increased US business activity, increased labor efficiency and investment, created new jobs and reduced accident rates.

The United States has the most powerful road system in the world, which is the main tool for ensuring the reliable functioning of the country's economy, especially in the competition with Europe and Japan. The main efforts in the development of US highways are aimed at adapting the American road system to the promising requirements of the new century [15].

The priority measures of the EU countries in the field of road policy include the formation of a trans-European road infrastructure and the integration of the "newcomers" of the European Union into the common road network. To this end, significant amounts of public funding by the EU countries (including the Pooling Fund and loans from the European Investment Bank) are provided for priority projects for the development of the Trans-European Road Network, necessary to increase road capacity.

The road network is developing rapidly in China, India, and Brazil. Simultaneously with the construction of high-speed roads in these countries, the construction of adjacent local roads is under construction, which ensures a high load on the network and reduces the payback period of investments invested in it.

In the United States, federal highways are funded by the Federal Highway Trust Fund, which is made up of revenue from road tax, excise taxes on fuels, lubricants and tires, a tax on trucks and trailers, and fines for traffic violations. Large projects may have targeted funding from the federal budget. State roads are maintained by local highway funds, which, in addition to excise taxes on fuel, receive taxes on car rentals or mobile homes.

In the UK, the Highway Agency maintains most of the roads. Its budget is formed from revenues from the tax for the use of roads and the excise tax on fuels and lubricants. In June 2005, the government proposed to replace them with a single mileage tax by 2015–2020. The satellite system will track the movement of all vehicles in the country, and then their owners will be billed for miles driven differentially in the countryside and in the city during rush hour.

In Japan, federal highways are funded by the Highway Bureau of the Ministry of Land, Infrastructure and Transportation through taxes on fuel and vehicle tonnage. Local highways are managed by local road funds, which are formed from the same taxes, as well as fees for the purchase of a car (3–5% of the cost) and taxes on road use.

In world practice, there is a so-called multiplier effect from investing in the road industry. If we take investments in the road industry as 100%, then these funds are distributed in a certain way: funds for paying for the work of road organizations − 26%; funds to pay for the products of construction industry organizations (including industries for the extraction and processing of non-metallic materials) 54%; funds to pay for road engineering products 20%.

According to studies, the funds intended to pay for the work of road organizations include: income tax 3%; payments to off-budget funds -6%; financing of road works −73%; VAT −18%.

An analysis of the presented data shows that only 26% of investments in the road sector are actually used to pay for the work of road organizations, and 27% of them are returned to the budget in the form of taxes and payments to off-budget funds.

These data confirm the fact that investments in the road sector lead to an increase in investments in related sectors of the economy (construction materials enterprises, road engineering), tax revenues to the budget and extrabudgetary funds, and contributes to the growth of GDP in the country as a whole [14].

Therefore, ensuring capital investments in roads is one of the most important tasks of the state, the successful solution of which determines the success of the development of the economy of the regions and the country as a whole.

The development and functioning of the road industry and road transport, and with the establishment of optimal proportions between them, is solved on the basis of two tasks. Solving the tasks of the first group increases the economic effect of the consumption of road industry products by transport. Solving the problems of the second group reduces the cost of producing these products.

The first group includes: ensuring the most efficient ways of using capital investments in road facilities; ensuring compliance between the measure of road consumption by road transport and the measure of their reproduction; organization of traffic on the roads, providing the greatest economic effect from their use; proper road maintenance; rational distribution of traffic by mode of transport.

The second group includes: the production of road works, taking into account the costs of road organizations and transport losses in the areas of work on operated roads; increasing the efficiency of using the production resources of road enterprises in order to reduce the cost of construction work; improvement of financial performance of road enterprises [7].

In Fig. 2, the author presents the socio-economic effect of the development of the road network, which has a two-sided character.

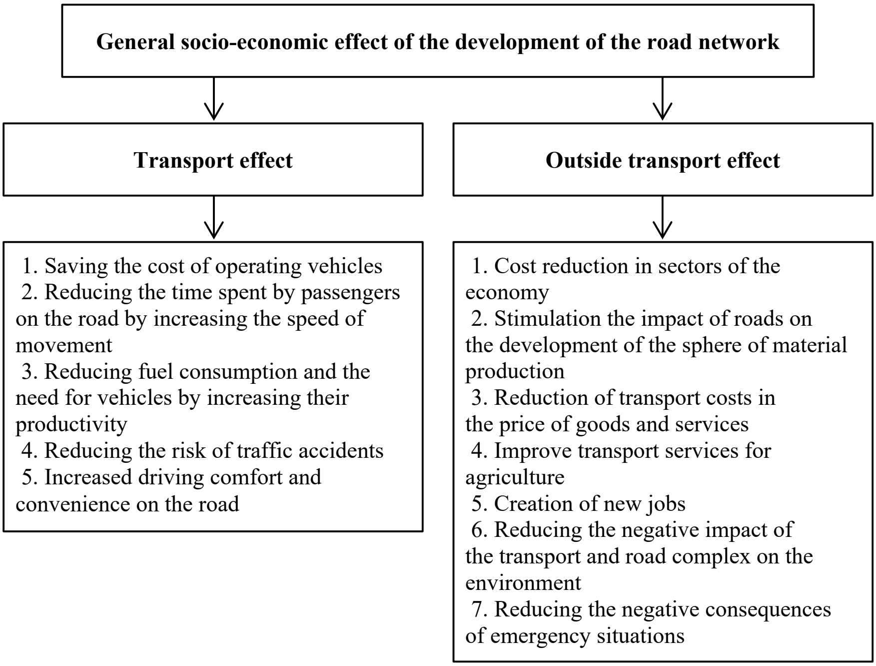

Fig. 2 Types of socio-economic effect of the road industry (compiled by the author based on the source [12])

The data of Fig. 2 reflect that the transport effect characterizes the direct benefits for road users. In value terms, it is determined on the basis of changes in the cost of transportation, economic losses from traffic accidents, the valuation of time, saving resources by accelerating the turnover of vehicles.

Outside, the transport effect reflects the impact of the development of the road network on the socio-economic development of the republic and the environmental situation. Its main indicator is the growth of gross domestic product in the republic as a whole.

Externally, the transport effect is determined by the influence of the existing road network on the costs of road transport and on the demand for road transport. Also taken into account are the effects associated with an increase in the speed of vehicles, an increase in the reliability of communication along the road network. Reducing the cost of road transport creates an opportunity to reduce tariffs for the transportation of goods and passengers. This, in turn, affects the cost of goods, works and services and leads to a reduction in production costs, thereby increasing the added value created in the sectors of the economy. In addition, it contributes to lower producer prices, which leads to an increase in demand.

As can be seen from Fig. 3, solving the problems of improving the condition of roads creates effective conditions for the favorable activity of economic sectors, which in turn effectively replenishes the budget of the republic [11].

Thus, due to multiplier effects, roads reduce the intermediate consumption of other industries using road services and increase GDP. Consequently, the problem rests on the necessary level of financing of roads in the country, at which the maximum GDP growth will be achieved.

4 Conclusions

As a result of the study, the most significant factors affecting the efficiency of capital investments in the construction of roads were identified and classified. The dependence of the influence of these factors on the efficiency of capital investments has been established. A model of economic efficiency of road construction has been developed that meets modern requirements of world standards and its role in replenishing the country's budget.

The study showed that due to multiplier effects, roads reduce the intermediate consumption of other industries using road services and increase GDP. Consequently, the problem rests on the required level of capital investment in the construction and reconstruction of the country's highways, at which the maximum GDP growth will be achieved.

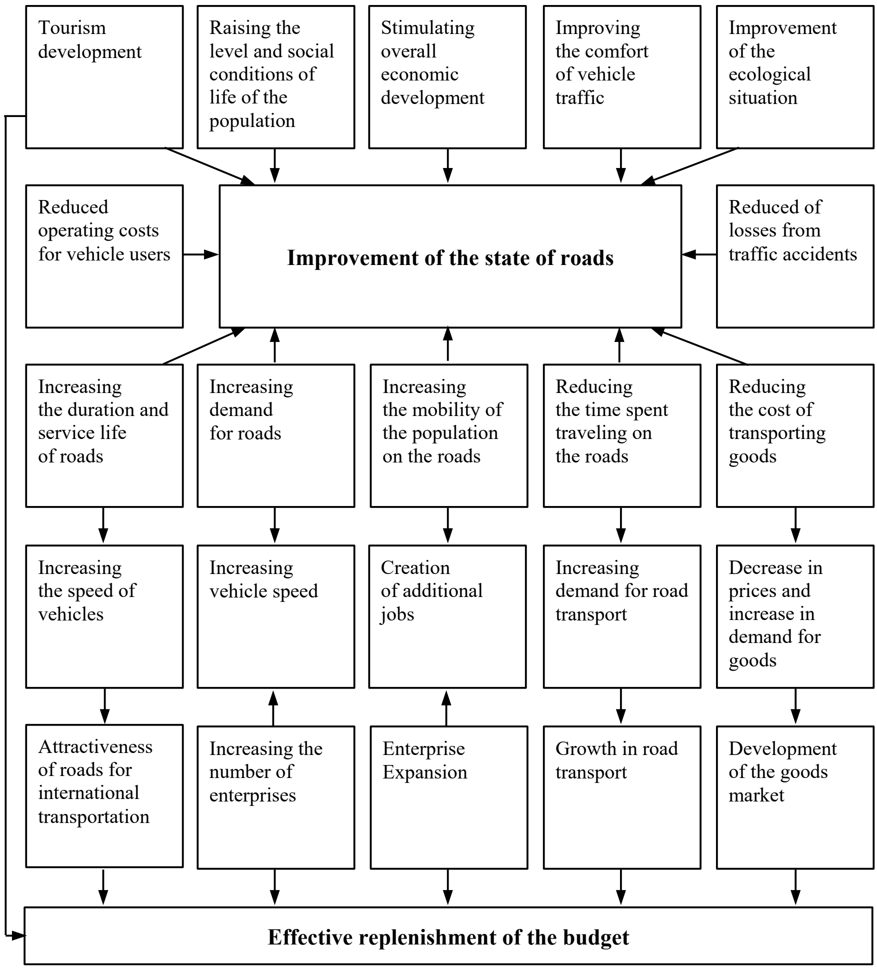

Fig. 3 Multifactorial model of economic efficiency of construction and reconstruction of highways (Fig. 3 is by the author)

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Analysis of Informal Employment AS a Basis for Implementation of European Union Standards in Ukraine

Alla Bielova, Nataliia Zhuravska, Svetlana Koval, Alona Kochedykova, and Pavlo Stefanovych

Abstract Achieving full and productive employment in an ideal society is recognized as an independent European value and involves reducing the impact on the labor market of such phenomena as the shadow economy, undeclared work, informal employment and more. These phenomena not only limit the state's ability to pursue modern social policies in the fields of education, health care, skills development, employment, social protection, pensions, they contribute to the creation and existence of unfair competition against those businesses that are fully ensure the fulfillment of obligations regarding the payment of taxes, labor protection and social security of employees. Therefore, the International Labor Organization and the world community draw attention to the problems of the informal economy and undeclared work, which today are one of the most powerful obstacles for countries to ensure decent work and higher growth rates. Thus, the problem of informal employment is one of the obstacles for Ukraine in ensuring decent work of citizens, improving the quality of life and growth in the global labor market. The coronavirus pandemic crisis (COVID-19) has once again increased the vulnerability of the informal and informal livelihoods and is a reminder of the crucial need to make the transition from informal to formal employment a priority national policy.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_52

Keywords Employment · Labor market · Population · Informal economy · Informal employment

1 Introduction

1.1 Analysis of Information Sources

The problems of informal employment are covered, in particular, by the following authors: Bondarchuk on informal employment in rural areas and regulatory levers for its formalization [1]; Vedernikov, who focuses on ways to overcome the problem of the informal sector in the structure of the national labor market [2]; Gnybidenko and Rusnak, who study the prospects of optimizing informal employment among the rural population [3]; Zima focuses on the structural features of employment in the informal sector of the Ukrainian economy [4]; Kashuba discusses employment trends in the informal sector of the Ukrainian economy [5]; national consultant Tsymbal on undeclared work in Ukraine, forms of its manifestation, scale and ways to overcome [6]. However, in the scientific discussion on common terminology for describing forms of employment that does not meet the requirements of the law, the final agreement has not yet been reached.

In Ukraine, two concepts are officially used to describe various forms of employment that do not meet the requirements of the law. The concept of the shadow economy, which is based on the recommendations of the SNA-2008 national accounts system, is used by the Ministry of Economic Development of Ukraine. The concept of the informal economy, based on the recommendations of the 15th International Conference of Labor Statistics (ICPS) on informal employment (until 2013) and the recommendations of the 17th ICPS (since 2014) on informal employment—is used for regular and representative surveys of economic activity of the population State Statistics Service of Ukraine (Gosstat). Within the framework of these surveys, the State Statistics Service of Ukraine provides reliable information on forms of informal employment in Ukraine in terms of gender, age, region, type of economic activity, employment status, level of education and professional qualification groups.

The purpose of the article is to analyze the main features of the current state of informal employment in Ukraine on the basis of official sources of information of the State Statistics Service for 2016–2020 and provide relevant conclusions.

2 Presenting Main Material

In 2002, the ICPS proposed moving from the concept of informal employment to the concept of informal employment. To determine it, criteria were proposed that assess the nature of jobs. Based on these criteria, the whole sphere of employment is divided into formal employment and informal employment. Formal employment within this concept means that the legal requirements for registration of the enterprise and for full registration of the employee's employment (employment agreement, entry in the employment record book, reflection in the company's documentation of the regime and volume of work), and the company pays all necessary contributions to social funds, taxes, compliance with occupational safety and health requirements, social guarantees of employment, etc. [6, 7].

Informal employment, according to the "Guide to the statistical definition of informal employment" covers the following categories [6, 8]:

- self-employed workers engaged in the production of goods exclusively for their own end use by their household;
- self-employed persons, acting alone or in a group at their own discretion in the informal sector;
- employers who work in their own enterprises of the informal sector;
- unpaid family workers, regardless of whether they work in formal or informal sector enterprises;
- members of informal cooperatives of producers;
- Unformed employees—persons working in informal jobs, regardless of whether they are employed in formal or informal sector enterprises or as household workers.

Since 2014, the State Statistics Service of Ukraine has made changes to the methodology of informal employment research, which meet the requirements of the 17th ICC of the International Labor Organization (ILO) on the transition to the measurement of informal employment based on jobs. In this regard, informal employment is considered to be a set of officially undeclared jobs used in formal and informal sector enterprises, as well as in households. Persons working in such jobs are defined as the informally employed population [6].

The main sign of informal jobs is the lack of labor registration relations in state bodies or non-compliance with other requirements of the state for registration employment contracts. Because the laws of different countries have different requirements for the registration of labor relations, the lack of registration of employees may be due to two different reasons [1–5]:

(1) if certain labor relations, in accordance with current legislation, are not fully or partially covered by national labor law, income tax rules, social protection, etc.;
(2) if the employment relationship is fully covered by labor law, but the requirements of these laws are in practice completely or partially ignored.

According to the analytical report "Labor Rights of Migrant Workers from the Eastern Partnership Countries—Ukraine, Belarus, Georgia, Working in the Informal Sector in the European Union", the ILO's Classification of Informal Employment is based on the distribution of production units by type of job and employment status. The classification of workers into formal or informal employment is in accordance with the nature of the employment relationship in which they participate, ie depending on the characteristics of jobs within production units, and not on the basis of the production units themselves. Therefore, an employee is considered to be employed informally if the formal norms and rules governing the use and remuneration of labor imposed by the state are not observed [9].

In this case, all informally employed can be divided into the following three groups:

(1) informal employees of formal enterprises (indicator 1);
(2) informal employees of informal enterprises and households (indicator 2);
(3) informal self-employed workers (indicator 3).

After combining the terms informal employment and informal sector, the sphere of informal employment can be represented as two sectors [6, 10]:

(1) informal employment in the formal sector, where there are undocumented jobs in enterprises registered in accordance with state requirements;
(2) employment in the informal sector, where there are enterprises and individuals who are not registered in accordance with the requirements of the legislation.

That is, informal employment in the formal sector is the use of hired labor without registration of labor relations in the enterprises of the formal sector of the economy [7, 11–17]. In this case, the employment relationship is established on the basis of an oral agreement, without signing any formal employment agreements or contracts. Such workers are not covered by labor law, they are not subject to income tax and social insurance requirements.

Employment in the informal sector is an economic activity of unregistered enterprises, individuals without registration, declaration to state bodies in accordance with the requirements of national legislation.

Thus, three indicators will be used in the future—informal employment in general, which combines both of these forms, and each of them separately.

Given that in 2016 there was a decline not only in the overall rate of informal employment, but also most of its components, as well as against the background of reducing the shadow economy in Ukraine as a whole, there is reason to believe that 2016 was a year of reversal deformalization of employment. The total level of informal employment in 2016 was 24.3% of the total employed population. This is less than in 2014 (25.1%) and in 2015 (26.2%). Among men, the level of informal employment was much higher than among women for three years. The level of informal employment in rural areas was significantly higher than in urban areas. At the same time, during 2015–2016, the level of informal employment in urban settlements decreased from 18.7 to 16.9%, while in rural areas—from 42.6% in 2015 to 40.6% in 2016. It should be noted that if in urban areas the reduction of informal employment was observed only in 2016, in rural areas it has been reduced for three years with increasing rates [6, 10].

These characteristics mostly prevailed in 2020. Thus, in 2020, the number of informally employed population aged 15–70 compared to 2019 decreased by 6.4% and amounted to 3.2 million people, or 20.3% of the employed population of the corresponding age, and the total the level of informal employment was 20.5% (Table 1) [18].

Table 1 Employment of the population aged 15 and over in the informal sector by sex and type of locality in 2020*(%)

Employment groups	Level of informal employment	Share of informal employment in the formal sector	Share of employment in the informal sector relative to total employment
Women	17.1	6.9	10.9
Men	23.6	10.5	14.6
Urban area	13.2	8.6	5.0
Countryside	36.5	9.2	30.1
In general	20.5	8.8	12.8

**Source developed by the author on the basis of data* [18]

Also, as we can see, there is a significant predominance of informal employment among men compared to informal employment of women and in rural areas compared to urban.

Since 2016, informal employment has been predominant in the self-employment sector, where the share of the population working in informal jobs was 74.3% and 15.1% of such employees. At the same time, during 2016, there were changes in the structure of the employed population in the status of employment among the formally and informally employed population. Thus, in 2016, compared to 2015, there was an increase in the share of employees among the officially employed population (84.9% vs. 82.7%) and a corresponding decrease in non-employees (25.7% vs. 26.8%).

In 2016, two thirds (66.2%) of the informally employed population were those who had vocational and complete general secondary education, and the officially employed population was dominated by persons with higher education (including full, basic and incomplete higher education). 61.2%).

According to Table 2 in 2020, almost two thirds of the informally employed population aged 15–70 had vocational and general secondary education (66.3%). The lowest share among the informally employed were persons with basic higher education, which is a very positive indicator for assessing the employment of graduates of higher education institutions (1.4%) [18].

In 2020, compared to 2016, the trend that the level of employment in the informal sector is the highest in agriculture and construction continued and even intensified. Both in 2016 and in 2020, agriculture, forestry and fisheries were the main activities of the informally employed population (40.8%; 44.1%, respectively). Other common types of economic activity of the population of this category were wholesale and retail trade (20.9%; 16.1%) and construction (15.5%; 17.2%)—Fig. 1 [18].

In 2016, the share of the informally employed population among workers in the simplest professions was significantly higher than among the officially employed population (49.0% vs. 9.2%). A similar situation was observed in 2020, when the informally employed population mostly worked in the simplest professions (50.1%), and the least—technical staff (1.1%)—Table 3 [18].

Table 2 Informal employment of the population aged 15–70 by level of education in 2020*

Educational level	Number of informally employed population aged 15–70, persons	The structure of the informally employed population aged 15–70 years, %
Higher Education	435.2	13.5
basic higher education	45.2	1.4
incomplete higher education	454.0	14.0
vocational and technical education	1 103.8	34.1
complete secondary education	1 043.1	32.2
basic education, primary education general secondary or have no education	156.5	4.8
Total	3 237.8	100.0

**Source developed by the author on the basis of data* [18]

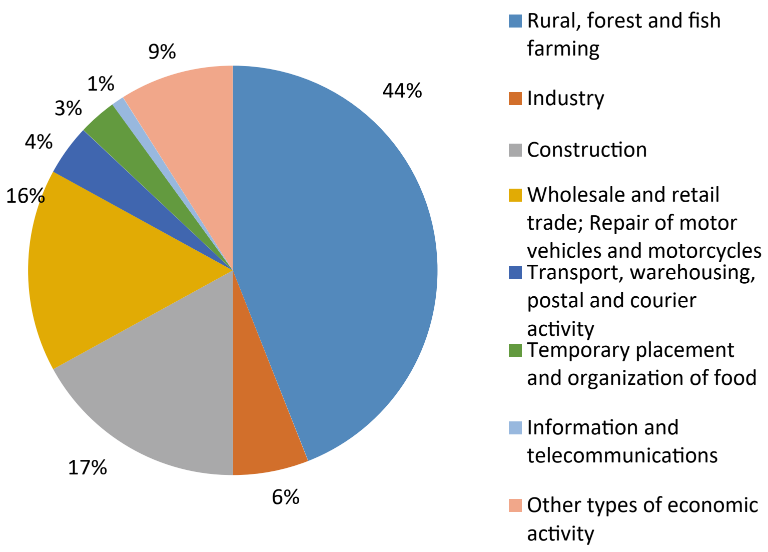

Fig. 1 Distribution of informal employment of the population aged 15–70 by type of economic activity in 2020

3 Conclusions

In order to be used for public policy purposes, the analysis of informal employment in Ukraine allows us to assess in detail the two main forms of undeclared work:

(1) informal employment in the formal sector;
(2) employment in the informal sector.

Table 3 Informal employment of the population aged 15–70 by occupational groups in 2020*

Professional groups according to the Classifier of Professions	The number of informally employed population aged 15–70 years, persons	The structure of the informally employed population aged 15–70 years, %
legislators, senior civil servants, executives, managers (managers)	43.8	1.4
professionals	93.8	2.9
specialists	95.0	2.9
technical staff	35.9	1.1
trade and service workers	480.7	14.8
skilled workers in agriculture and forestry, fish farming and fishing	109.3	3.4
skilled workers with tools	552.7	17.1
workers for maintenance, operation and control of technological equipment, assembly of equipment and machinery	202.9	6.3
the simplest professions	1 623.7	50.1
Total	3 237.8	100.0

**Source developed by the author on the basis of data* [18]

An analysis of official statistics showed that the informally employed are mostly people with a low level of education and those engaged in manual or unskilled labor.

Taking into account the experience of the European Union (EU), public measures to reduce the informal sector are based on four main principles:

(1) preventive measures aimed at simplifying the procedures for declaring activities, as well as reducing costs and restrictions that hinder the creation and development of business, especially small businesses;
(2) sanctions related to the supervisory function in relation to those entities that receive income from covert or shady activities, in particular, by improving coordination between the relevant state bodies;
(3) cooperation between EU Member States to combat informal employment in the framework of transnational economic activity [19–25];
(4) measures aimed at raising public awareness of the negative consequences of informal employment on social insurance, as well as social solidarity and justice.

Therefore, the national state policy in the field of informal or informal employment should combine at least preventive measures and sanctions in order to balance and achieve a balance of all necessary decisions and make great efforts to achieve full and productive employment in Ukraine to bring this policy closer to the best European solutions.

Thus, the policy in the field of informal or informal employment should contain four main categories:

(1) tax and other direct or indirect financial measures;
(2) labor legislation in the field of employment;
(3) regulation of entrepreneurial activity;
(4) administrative measures.

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Analysis of Ways of Increasing the Competitiveness of Monolithic Reinforced Concrete Construction Products of High-Rise Buildings

Sahib Farzaliyev and Valery Usenko

Abstract The growing demand for the construction of high-rise monolithic reinforced concrete buildings has made it relevant to study its competitiveness. The search for methods to improve the competitiveness of construction products is based on the analysis of both economic and technical problems. The most important technical indicator of competitiveness is the quality of construction products. If we consistently consider these indicators of the competitiveness of construction products, we will determine the impact on them of organizational and technological solutions of construction processes used in the construction of monolithic reinforced concrete buildings. The main principle of improving the quality of construction products is the effective managing of all factors that affect the construction process in the production process. The article analyzes the issues that determine the degree of influence of organizational and technological factors on the quality of the construction product in the construction of monolithic reinforced concrete buildings.

Keywords High-rise monolithic reinforced concrete · Organizational and technological factors · Increasing competitiveness · Construction product

1 Introduction

The growing demand for high-rise monolithic reinforced concrete buildings makes it necessary to solve a number of organizational and technological issues that serve to increase its competitiveness. The most important technical indicator of competitiveness is considered to be the improvement of the quality of construction products. The analysis carried out during the construction of high-rise buildings in large cities

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_53

of the republic shows that the quality of the construction products produced is unsatisfactory. This foundation is characterized by various defects and defects associated with the implementation of monolithic reinforced concrete works, and a significant number of violations [1–5].

To increase the competitiveness of the construction of high-rise monolithic reinforced concrete buildings, the result depends on the determination of factors affecting its quality indicators and their evaluation. Determination and evaluation of the quality of construction products requires consideration of the problem of its organizational and technological solution. It serves to increase the competitiveness of a construction company, improve the quality of construction products and address issues such as reducing labor costs for it and reducing cost of production.

2 Main Part

2.1 Purpose of the Article

The main goal set in the article is to determine the degree of factors affecting the quality and competitiveness of the construction product in the construction of high-rise monolithic reinforced concrete buildings. In our study, an appropriate structural scheme is proposed to determine the factors affecting the competitiveness of the construction of monolithic reinforced concrete buildings. The result of the analysis shows that these factors can be grouped into a technical, organizational, technological, economic form and characterized as indicators of assessing the quality of construction products and construction production.

2.2 Research Methodology

The methodological basis of the study is a systematic approach aimed at studying the works by domestic and foreign scientists dealing with problems aimed at increasing the competitiveness of the construction of high-rise monolithic reinforced concrete buildings and its solution.

During the research, methodological guidelines of leading scientific institutions dealing with the problem of improving the quality and competitiveness of monolithic reinforced concrete buildings, as well as actual materials of a number of contractor construction organizations performing large volumes of monolithic reinforced concrete works were used.

As a research methodology, methods of individual, complex, integral, differential assessment of quality, probability theory and mathematical statistics, data analysis and modeling were used.

2.3 Results

Currently, in the construction complex of large cities of the republic, there are a number of contractors are specializing in the construction of high-rise monolithic reinforced concrete residential buildings. It should be noted that, despite the growing demand for the use of monolithic reinforced concrete in construction production, there is high competition between the enterprises performing these works [6].

The object of management in the practical activities of construction subjects is the competitiveness of the construction product.

Let us consider the problem of managing the competitiveness of products of enterprises that are engaged in the construction of high-rise monolithic reinforced concrete buildings. To clarify the essence of the concept, it is necessary to determine its relationship with other economic concepts and categories.

As a rule, the competitiveness of an enterprise or its products is understood as the ability to meet the requirements of the current market that exists for the period under review.

All construction products that can be produced by the company are analyzed according to individual and complex indicators of the competitiveness of these products.

In the economic literature, it is proposed to consider the following individual indicators that characterize the competitiveness of construction products (Fig. 1).

Thus, the search for ways to increase the competitiveness of construction products is based on the analysis of both economic and technical problems, and as a result, the parameters that ensure the competitiveness of the product at the lowest cost for the manufacturer are identified.

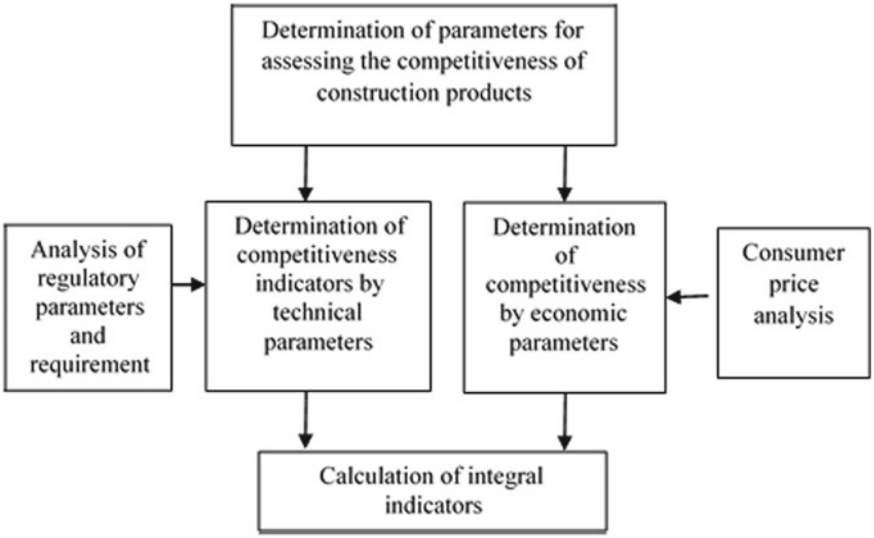

Fig. 1 Scheme for assessing the competitiveness of construction products

The most important technical indicator of competitiveness is the quality of construction products.

Let us consider these indicators of the competitiveness of construction products and determine the impact on them organizational and technological solutions of construction processes used in the construction of monolithic reinforced concrete buildings.

The quality of construction products is understood as a set of useful properties of the finished object, ensuring the satisfaction of specific individual and social needs [7].

The main principle of improving the quality of construction products is the effective management of all factors of production that affect the construction process. The purpose of our research is to determine the degree of influence of organizational and technological factors on the quality of the construction product in the construction of monolithic reinforced concrete buildings.

These factors are determined by quantitative indicators, some of which are constant (unmanageable), and others are optional (manageable).

Constant (unmanageable) factors that affect the quality of organizational and technological solutions are regulated by regulatory documents and the design assignment, and it is impossible to influence on them at the considered (production) management level.

At this level, the influence on optional (manageable) factors is possible.

Various indicators are used to determine and evaluate the quality of construction products. The following indicators are more widely used:

- common (characterizes the property of building products);
- complex (reflects several properties of building products);
- integral (fixes the ratio of the total useful effect from the operation of the product to the total cost of its creation);
- differential (the prices of relative indicators are calculated).

Based on the specific situation, the most appropriate quality indicator is selected, according to which the decision on evaluation is made.

Based on the specific situation, the most appropriate quality indicator is selected based on the decision to assess the situation. This indicator is called a deterministic indicator.

A decisive indicator of the quality of products for the construction of monolithic reinforced concrete buildings is a comprehensive indicator of the final product. The integrated method of assessing the quality of construction products is used when it is possible and appropriate to characterize its level using a functional indicator, which is given by the number Wp and is called a generalized complex [8]. In general, this indicator is as follows:

$$W_p = f(P_j \ldots, P_i \ldots, P_n),$$

where Pi is a single indicator of product quality number i;

n—the number of product quality indicators taken into account.

As a rule, individual indicators are measured in points, and their prices are determined relative to each other.

The generalized complex KK indicator, consisting of a number of interrelated individual indicators of product quality, is defined as follows:

$$K_k = \sum_{i=1}^{n} K_i M_i,$$

where;

Ki—quantitative assessment of the i-th characteristic of the coating quality;

Mi–$\sum$Mi = 1 dimensionless weight coefficient of the i-th attribute;

п—the number of characteristics taken into account when evaluating the quality of the coating.

At this time, the requirements for a number of work operations and technological processes, such as the installation and acceptance of formwork, dismantling of formwork from monolithic structures, cleaning and lubrication of formwork surfaces, etc. are determined specifically for each individual object, depending on its design features, construction conditions, characteristics of the materials used, molding systems, machines and mechanisms [9].

The analysis of the current state of construction complexes, which is currently being carried out in the major cities of the republic, shows that, in general, the quality of the construction products produced cannot be considered as satisfied.

Over the past decades, there have been several serious accidents associated with the collapse of structures made from monolithic reinforced concrete. Every year, the State Agency of the Ministry of Emergency Situations for the Supervision of Safety in Construction identifies various defects and shortcomings associated with the implementation of monolithic reinforced concrete works, and a significant number of violations are recorded.

As a result of studies conducted in high-rise monolithic reinforced concrete buildings in Baku and Sumgayit, a number of technical defects in monolithic reinforced concrete structures and their causes were identified. They mostly consist of:

- Deviation from the geometric dimensions of monolithic reinforced concrete structures-36%
- Failure to achieve the design performance indicator of concrete in monolithic reinforced concrete structures-23%
- Deviation of the geometric dimensions of monolithic reinforced concrete enclosing structures from the design indicators, unacceptable deflections, cracks, loss of load-bearing capacity -17%
- Violation of the protective layer of concrete-24%

As can be seen from the above data, the main reasons for the occurrence of violations and shortcomings, which are reflected in monolithic reinforced concrete structures, are factors of an organizational and technological nature.

Thus, an important part of the quality management system is the assessment of the impact of factors that affect the organizational and technological solution of construction processes used in the construction of monolithic reinforced concrete buildings.

In most cases, the price is determined based on the amount of the planned profit at the cost of production. Thus, the cost of production is the main way of forming the price. Accordingly, improving the competitiveness of construction products in terms of economic indicators depends primarily on reducing the cost of construction and installation work.

Correct and complete accounting of all factors affecting the cost of construction and installation works allows you to identify and realize reserves for its reduction. The result of the analysis shows that it is more appropriate to group these factors into technical, organizational, technological, and economic forms. All these factors are due to the peculiarities of construction products and construction production.

Technical factors are related to the quality and characteristics of materials, parts, structures, construction machines and mechanisms used on the basis of the technical base of construction production. Organizational and technological factors are related to the organization of labor, production, and management. The economic factors should include the forms of economic incentives for labor and cost of production (wage systems, participation of employees in making a profit, the dependence of wages and remuneration on the final results of the organization's activities)..

In accordance with the task set in our study, it is necessary to determine the degree of influence of organizational and technological factors.

The whole range of issues should be taken into account at the stage of development of PPW and PTO, when organizational and technological factors are solved during the construction of each object.

An important issue is the choice of criteria for evaluating organizational and technological decisions of construction processes adopted during the construction of the object. The discrepancy between the criteria and the results of solving local issues to each other significantly reduces the effectiveness of the applied organizational solutions, does not allow an objective assessment of the level of organization of construction production. There are different approaches to solving this issue.

Evaluation of organizational and technological solutions can be carried out on the basis of single and complex indicators of the organization of construction production.

Complex indicators that characterize the quality of organizational and technological solutions are:

- duration of construction and installation works or construction of the object;
- unit cost and labor intensity of production of a unit of production;
- level of mechanization, specialization and configuration;
- application of in-line production methods;

– the coefficient of performance of construction machines of the norms of using the strength and durability of the structure;
– material capacity;
– an indicator of the specific time consumption per unit of production.

Complex factors are obtained by combining individual factors. At the same time, particular factors have a system of relative evaluation.

Construction and design organizations that develop and approve PTO and PPW, as a rule, evaluate various options for organizational and technological solutions based on factors of reducing the cost and time of work. To determine the factors that affect the competitiveness of the construction of monolithic reinforced concrete buildings, the following design scheme is proposed (Fig. 2).

Thus, the evaluation of organizational and technological solutions of construction processes used in the construction of monolithic reinforced concrete buildings is important both in the management of the quality of construction products, and in the development of measures to increase competitiveness and reduce the cost of construction and installation work.

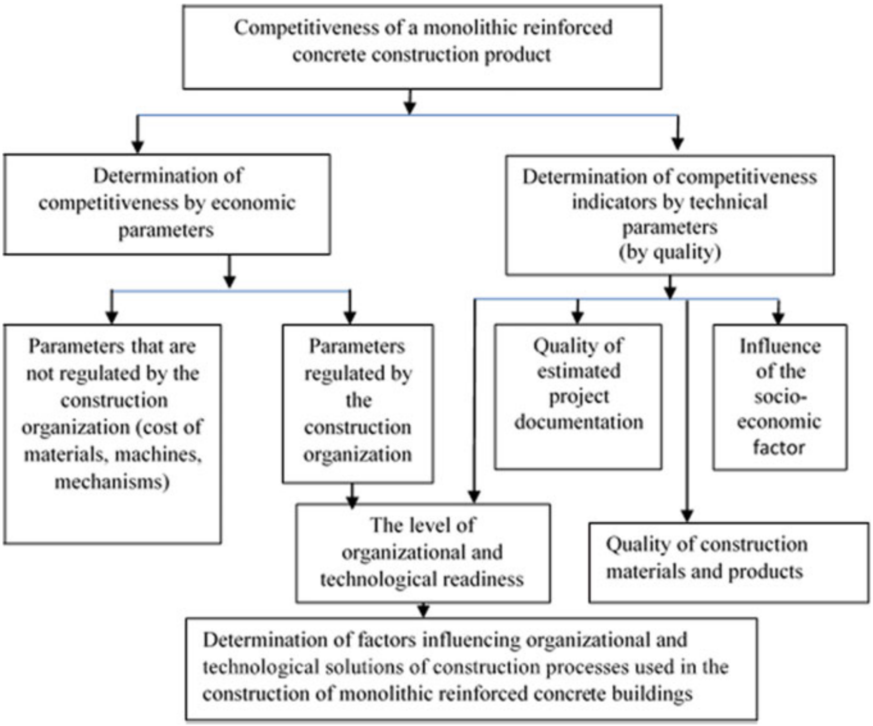

Fig. 2 Block diagram for determining the factors that affect the competitiveness of the construction of monolithic reinforced concrete buildings

2.4 Scientific Novelty

For the first time in our republic, the factors affecting the competitiveness of the construction of high-rise monolithic reinforced concrete buildings have been analyzed. It is established that an important factor affecting the competitiveness of a construction product is its quality indicators and its organizational and technological solutions. Reasonable recommendations are given for a comprehensive assessment of the quality of construction products and quality management.

Thus, the factors influencing organizational and technological solutions for increasing the competitiveness of the construction of high-rise monolithic reinforced concrete buildings and improving their quality management system have been identified. The solution of organizational and technological factors in the construction of each high-rise monolithic reinforced concrete building should be solved at the stage of development of the production project of works and the construction organization project.

2.5 Practical Importance

The results of the study can be successfully used in increasing the competitiveness of contractors engaged in the construction of high-rise monolithic reinforced concrete buildings, in improving the quality of the construction product, in effective management and the development of promising concepts. It is also necessary to ensure the creation of a cheap construction product in the construction market.

3 Conclusions

The ways of increasing the competitiveness of construction products in the construction of monolithic reinforced concrete buildings are analyzed. It is established that the issue of assessing organizational and technological solutions and the quality of construction processes used in the construction of high-rise monolithic reinforced concrete buildings is relevant, and additional research is needed to solve it.

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Definition of Concept "City": Multidisciplinary Approach

Yuliia Fedorenko and Yuliia Kolos

Abstract The present article deals with the problem of diversity of definitions, interpretations and approaches to the notion of the term "city" in urban planning, economics, sociology, linguistics, philosophy, etc. The concept "city" is clarified for a holistic consideration of the term in related sciences, as the "city" is inherently multifaceted. Comparative analysis of definitions and classifications of the concept "city" as a multifaceted phenomenon that gives prospects for the development of the city and urban planning in general is given. The classification of Ukrainian cities and features of different approaches to the definition applied in urbanistics are investigated in the scientific paper. The most common criteria of "city" definition such as administrative/legal aspects; economic links; customary/historical background are given. The existence of an "urban center" as a spatial concept based on a matrix of high population density cells and the stages of affiliation of a settlement to a city that takes place in several stages are determined.

Keywords City · Population center · Urban village · Urban planning · City center · Urban center

1 Introduction

The fact that the city today is one of the most interesting objects for researchers, gives rise to many different approaches, methods, and techniques of analysis of relevant urban life aspects. The significance and versatility of the city makes it the subject of scientific research in various fields of science. Thus, the problem of diversity of definitions, interpretations and approaches to the notion of the term "city" in urban planning, sociology, linguistics, etc. where there is a number of theoretical definitions

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_54

within several paradigms, appears. It is necessary to find out and interpret this problem for the clarifying of the concept "city", as well as for a holistic consideration of the term in related sciences.

In 1945 Chauncy Harris and Edward Ullman published their classic study "The nature of cities" which stands out as a multidisciplinary project. Harris and Ullman were geographers who chose to publish their article in a leading sociological journal. The article contains a composite diagram showing concentric, sector and multiple nuclei models of cities. Of these three basic models of the internal structure of cities, one was from sociology, another was from land economics, and they added their own geographical proposal. And this multidisciplinarity is very proper: cities are inherently multifaceted [1, 2].

The city is the main structural element of administrative-territorial division system at national and global levels. Political, economic, social, and construction processes that reflect human life are accumulated in the city. It is the driving force of economic development of regions in particular and of a country as a whole. Insufficient attention, paid to city development and satisfaction of its needs, results in a significant reduction and slowdown of regional, national and global development.

In modern dynamic and contradictory conditions of development, there is a need to clarify the essence of the concept "city" and to carry out a comparative analysis of definitions and classifications of the concept "city" as a multifaceted phenomenon that gives prospects for the development of the city and urban planning in general.

Despite the importance of cities for economic, social, cultural development of a region and a country as a whole, there is no single approach to the definition of "city" in scientific literature.

Indisputable proof of the urgency of this problem is the significant number of scientific works of Ukrainian and foreign scientists in various scientific fields: urban planning, socio-political and economic sciences. Among foreign scientists, a significant contribution to the study of this issue was made by J. R. Boudeville, A. Lösch, F. Perroux, J. Friedmann. The study of the "city" as enterprises location organization is contained in the works of German regional scholars of the late 19-th century: J. Thünen, A. Weber, W. Christaller. Generalization and classification of etymological and socio-logical contexts of the concept "city" are presented in the works of V. Vagin, S. Pirogov, E. Trubina, V. Gorodyanenko and others. L. Repina considers the city as a separate expression of civilization system. Sociocultural approach in the definition of the city is developed in the concepts of urban lifestyle as a defining sociocultural characteristic, studied in the works of L. Wirth, I. Turov, L. Kogan. Fundamental contribution to the definition of "city" concept was made by M. Weber, L. Mumford, R. Park, E. Burgess, R. Monier, W. Sombart, F. Tönnies, L. Wirth. The works of Ukrainian scientists V. Buriak, V. Babayeva, T. Balyk, O. Boyko, V. Vakulenko, N. Hrynchuk, Y. Dekhtyarenko, O. Dmytruk, O. Karlova, N. Lysyak are devoted to the study of these issues. Thorough research in the field of "city as a system of government" was carried out by scientists: V. Averyanova, V. Bakumenko, V. Mamonova, S. Sakhanenko, V. Tertychka, Y. Sharov and others. Systematic approach to the interpretation of the concept "city" was considered by: S. Bohachov, A. Ositnyanko, T. Balyk, O. Karlova, S. Sakhanenko, Z. Siroich, V. Babayev, O. Dmytruk and others.

The aim of our research is to analyze the definitions of the concept “city” in Ukrainian and worldwide scientific literature, to investigate the classification of Ukrainian cities, and to define the features of different approaches to the definition applied to urbanistics.

In this research, a complex of theoretical methods was used: analysis, synthesis, systematic approach, the method of historical parallels, linguistics, social and philosophical vision of the task.

2 Results

Despite the importance of cities for economic, social, cultural development of the region and the country as a whole, in the scientific literature there is no single approach to the definition of the term “city”.

Multiple definitions of the city have been adopted at varying contexts, which made data comparability even more difficult. When the number of cities was compared based on national definitions across countries it was found out that it is distorted by difference in methodology [3].

The Law of Ukraine on “The Principles of Administrative and Territorial Organization of Ukraine” defines the concept of “population center”, namely: a compact place of residence of people, formed as a result of historical traditions, economic and other activities, has a stable population, proper name, separate territory and is registered in the manner, prescribed by the law. According to urban and socio-economic characteristics, population centers are divided into cities, urban villages and villages. In the same Law, the term “city” is defined as a population center with mostly compact building scheme, on the territory of which industrial and processing enterprises, utilities, housing, a network of socio-cultural institutions are located, and which has developed social, communal and transport infrastructure. In contrast to this concept, there are two more: “urban village” and “village”. Urban village is a territory with mainly manor buildings, stable population; the formation and development of urban village are associated with enterprises for the production and processing of agricultural, forestry, fishery products, railway junctions, hydraulic and other structures and facilities, located on its territory; urban village has social and communal infrastructure. Village is a population center with homestead buildings, formed in the conditions of predominant employment of its inhabitants in agriculture, forestry or fishing, folk crafts, primary processing of agricultural, forestry or fish products, the availability of the inhabitants of individual farms, homesteads territory. The Law also states that cities belong to urban population centers, but urban villages and villages belong to rural population centers [4].

There is no common definition of urban vs. rural population, neither on city vs. urban area. The most common criteria of “city” definition include one or more of the following:

- administrative/legal aspects (population, physical boundary, functional, "continuously built-up" areas);
- economic links between the main city and neighbouring areas;
- customary (historical, e.g. through a charter) [5, 6].

Etymological contexts of the concept of "city" are the subject of specialized dictionaries analysis. In English, there are several terms that denote the phenomenon of the city, depending on the quantitative specifics of the city in question. Thus, the term "city" (Latin *civitatem*—"city") is used to denote a populous large business centers, megacities with large populations, accelerated pace of life and concentration of significant material, technical and cultural resources [7]. Instead, the term "town" (Old English *tun*—"garden, field, home-farm") [8] is used to denote small suburbs of agricultural direction, as well as dormitory towns, satellite towns/cities with a relatively small population.

Online etymology dictionary gives the following definition of the term "city": c. 1200, it took its origin from Old French cite that is defined as "town, city" (10c., Modern French cité). It was originated from earlier citet, from Latin term civitatem (which was taken from nominative civitas; in Late Latin it was called as citatem). It originally meant citizenship or rights of a citizen or just membership in the community. Later it denoted community of citizens or state or commonwealth (it was used, for example of the Gaulish tribes), from the word civis "townsman," from PIE root *kei- (1) that means "to lie". It also was the forming words for such words as "bed, couch," and with another meaning of "beloved, dear". Nowadays it is defined as "a large and very important town," but in origin, in early Middle English period a walled town or a capital or cathedral town was named in such way. The distinction from town was made in early 14 c. In OED it was determined as "Not an original designation, but firstly as a grandiose title, which was used instead of the OE. word burh" [7].

Comparing Latin and English terms it was clarified that the sense was transferred from particular inhabitants to particular place. The Latin word for "city" was originated as urbs, while resident was called civis. Civitas seems to have been replaced by urbs as Rome (the ultimate word is urbs) lost its prestige. At the same time the loss of Latin letter-v- is regular in French in some cases. Another sound changes from the Latin word yielded appeared in Italian as citta, Catalan as ciutat, in Spanish language as ciudad, Portuguese as cidade [7].

Another glossary defines the term "city" as follows: a city is a specific territory (or place) where a great number of people spend their lives. The term "city" is also used to refer to all of the people who inhabit this place or to something that is related to specific territory. The term "city" has specific meanings and it depends on the country. City is a limited area where a great number of people gather for living and/or working. Cities are much larger than other territories referred to as towns. They are also known for having homes or particular apartments and they are placed more closely together than in other territories. Different countries have certain definitions of the territory, that they qualifies as a city. In general, this term is often used for describing some specific place where a lot of people live. The first registerd word of city come from around 1175. It originally comes from the Latin word cīvitās, that means “citizenship” or “state,”. It also originated from the word cīvis that means “citizen” [9].

The "Etymological Dictionary of Ukrainian language" emphasizes the origin of term *місто* (“city”) from the concepts of “market place”, “market”, which later formed the concept of “large population center” [10, p. 484]. That is, the market origin of cities in the historical process of social development and the scale of the population center are emphasized. “Etymological dictionary of Russian language” through the concept of *град* (“fortified town”) connects the origin of the Russian term *город* (“city”) with “fence”, “hedge”, “fortress” [11, p. 206]. The concept of *град* reveals the history of the origin of ancient Slavic cities from fenced fortified population centers, which with further development acquired socio-cultural content and turned into large cities.

The most common definition of the city is given by V.P. Maksakovsky, according to which the “city” is a population center classified in compliance with the law and has, as a rule, a significant (compared to rural settlements) service, science and culture [12, p. 94].

The philosophical approach to the interpretation of the concept “city” was proposed by J. Beaujeu-Garnier and E. Howard. Scholars view the city as the result of the efforts of natural environment and human, and as a symbol of society, science, art, culture, religion, without attaching much importance to other aspects of city life and functions. It is interesting to understand the concept “city” as a group of people united and charged with a common “energy”, which is separated from the countryside. According to L. D. Stamp, a city is a group of residents, registered as a unit and managed by the mayor. According to D. Dickinson, the city is a centered settlement, most of workers in which are not engaged in agricultural activities [13, 14].

According to for M. Antsiferov, the defining characteristic in the concept “city” is the presence of a social group of a complex nature; J. Vermenych considers the city as a type of coexistence of people, the center of civilization; N. Hrynchuk and V. Yaroshchuk—as places of application of human labor, and T. Melikhov—as a set of anthropogenic landscapes. According to G. Lappo, a settlement becomes a city after reaching a certain level of complexity of its functional structure. The city is characterized by multifunctionality, which determines its integration qualities, the ability to generate new, social attractiveness. O. G. Topchiev interprets the concept of “city” as a spatial social formation, which is the center of mass settlement of people and the concentration of their socially useful activities in any form other than obtaining primary agricultural products as a single occupation. It is organized into a permanent economic and construction complex, designed to serve the lives and activities of the population.

In addition to the general geographical category, the concept of “city” is considered as an economic category. The city is a territorial form of concentration of different spheres (tangible and intangible), industries and activities, and hence—the main productive force and lifestyle. A city is a type of settlement that has historically been formed as a result of the coexistence of people whose goal was to perform work not related to agriculture. The city is a social territorial community, which is characterized by a high concentration of population in a relatively small space, occupied mainly in the field of non-agriculture [15].

In different historical times, different phenomena with different characteristics and content were called "city." M. Weber in his research systematized scientific views on the understanding of the concept "city" and singled out the economic and sociological approach [16, p. 335–336]. From an economic point of view, the city is a settlement, where there is a market; where the term "market" means the presence of regular trade within the settlement as a significant component of income and satisfaction of the population needs. From sociological point of view, the city is a settlement, i.e. living close to each other in houses, that make up such a wide territory, that the mutual personal acquaintance of residents with each other, which distinguishes the neighborly connection, is absent. M. Weber considered the city as a complex set of phenomena, a specific historical formation, formed at the intersection of complex socio-political and military processes. It has a complex social structure (it is inhabited by both consumers and producers), distinct commercial and industrial nature. Residents of cities are personally unfamiliar with each other, engaged mainly in non-agricultural labor, mostly involved in various industries and trade. Therefore in the cities management functions are concentrated [16, p. 309].

According to G. N. Ozereva and V. V. Pokshishevsky, city is a large settlement performing industrial, organizational and economic, managerial, cultural, transport and other (but non-agricultural) functions. Therefore, most of the population is not employed in agriculture [15].

Another quite common definition was proposed by F. Ratzel: a city is a long-term concentration of people and their homes, which occupy a large area and are located in the center of large communications [17].

Sociologist E. Burgess stated that city is a system of concentric zones, located one inside the other with the most important business area in the city [14, 21, p. 19–20].

Urbanist S. Price [18] in his study for visual representation proposed to assign images of different egg dishes to the city models. In particular, "Arche-Citta", an archaic city, is a hard-boiled egg, where the yolk is the center, the egg-white is the urban periphery, the shell is the city walls; "Cine-Citta", is a city, represented by scrambled eggs, where the yolk is still the center, and the egg-white is an urban agglomeration, but the city walls, the shell, has disappeared. Finally, "Tele-Citta", the city of telecommunications is an omelet, in which the yolk is a subcenters of the city region polycentric system. These theoretical developments were officially introduced into urban planning terminology by the International Congress on Urban and Regional Planning (ISoCaRP) in 2001 [14, 19–23].

The Organization for Economic Co-operation and Development (OECD), has developed its own method of defining cities, suitable for the Western European space. This definition is based on the existence of an "urban center" as a spatial concept based on a matrix of high population density cells. Determining the affiliation of a settlement to a city takes place in several stages. On the first there are cells with a population density of more than 1,500 inhabitants per square kilometer. At the next stage, the adjacent cells are grouped by density, and only clusters with a minimum number of 50,000 inhabitants are determined by the “city center”. In the third stage, all municipalities with at least half the population within the “city center” are selected as candidates to become part of the city. The fourth stage is applied exclusively to the analysis of European cities. The city is determined based on the presence of a connection with the political level, the residence of at least half of the population in the “city center”, and the residence of at least 3/4 of the population of the “city center” in the city [3, p. 2]. This approach focuses entirely on the specifics of territorial and spatial localization of people, providing an opportunity to formally determine the affiliation of most European settlements to cities or rural areas.

3 Conclusions

The diversity of views on the essence of the concept “city” depends on the approach used and the field of study (demographic, social, economic, geographical, functional, urbanistic etc.). Thus, in urban planning, the city is characterized as an environment that includes a system of social institutions that ensure the viability of the urban population, as man-made specific conditions necessary for diverse activities. City is a sociocultural, structural, philosophical phenomenon of urbanization integrating economical potential of modern society. OECD-European Commission has developed methodology of unified and harmonized city definition which allows to conduct cross-country analysis of European cities.

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Information and Analytical Support of Business Security in the Context of Economy Digitalization

Nataliia Fursova, Anna Komelina, Maryna Korsunska, and Viktoriia Myronenko

Abstract The article highlights modern approaches to the notion of digitalization. Also, the need to study the impact of digitalization on the transformation of the business environment and business security was substantiated. Economic Digital-transformations of the country contribute to the formation of the enterprises business model, as well as affect its infrastructure. The modern features of Digital-technologies introduction into the activity of the enterprises which occur under the influence of three main drivers such as: change of inquiries of users, development of innovative technologies, strengthening of a competition are investigated. The requirements for the formation of information and analytical support security system during the Digital transformation of the economy is substantiated. The information and analytical system of business security should provide protection against threats, risks and dangers associated with competition and changing market requirements, taking into account the adaptation of doing business online. An analysis of the availability and reliability of information sources, the availability of software for various calculations, determination of final results and their analytical processing, changes in strategic business positions (online business positioning; IT tools for sales promotion, etc.) were carried out.

Keywords Digitalization · Security · Business · Information and analytical support · Information technology

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_55

1 Introduction

Digitalization as a complex process of economic transformation requires a thorough study in terms of business security. Enterprises are actively implementing digital technologies in the changing environment and in order to survive in fierce competition conditions. This requires the identification of new features for the information and analytical support formation of business security.

Digital business transformation covers the entire range of enterprise functions from procurement automation to marketing and sales. It affects both the change of the operating model and the actual infrastructure of the enterprise, which in turn is based on digital technologies and is under the influence of three main drivers: changing user requests, technology development, increasing competition.

The following problems of business security are key in the context of the economy digitalization—the low integration level of digital technologies into Ukrainian business, partial and irregular use however, the experience of most countries of the world proves that the driver of economic development in the XXI century is the digital economy. Countries that are actively developing the digital economy show the highest rates of economic growth. According to the forecasts of the Ukrainian Government, digitalization will significantly increase labor productivity in the country, as well as become a powerful accelerator that can "warm up" the Ukrainian economy in the shortest possible time and as a result ensure its real growth by 10–12% annually.

2 Purpose of the Article

The purpose of the article—to substantiate the system of requirements for the formation of information and analytical business security in order to ensure its economic security in terms of the economy digitalization.

3 Literature Review

Digital technologies are developing extremely fast, significantly changing the nature of doing business, labor relations between employer and employee, as well as society as a whole. Research in the field of digitalization processes in economic systems of different levels is considered in the works of the following scientists: De Clerc [1], Koptielov [2], Onore [3], Luttseva [4], Scuotto et al. [5], Ochs and Riemann [6]. A significant contribution to the development of the modern theory of digitalization was made by such domestic scientists as I.V. Dulska [7], Hurenko and Hashutina [8], Koliadenko [9], Korenivska [10], Kryvoruchko and Kraus [11], Liashenko and Vyshnevskyi [12], Meshko [13], Sokolova [14] and others. The first scientists who studied the formation peculiarities of the digital economy in society were D. Tapscott,

P. Samuelson, B. Nalebuff. For instance, D. Tapscott uses the concept of "epoch of network intelligence", the essence of which lies "not only in network technologies … but in the interaction of people using network technologies" as "an object that combines intelligence, knowledge and creativity to create social capital and prosperity" [15]. T. Ochs, U. Riemann define digitalization as the integration of digital technologies into everyday life through the digital transfer of everything that can be digitalized [6]. While W. Squatto, F. Serravalle, A. Murray and M. Viassone consider the concept of "digitalization" as a process of implementing digital technologies in order to benefit from the usage of new advanced technologies that process a giant digital flow of information within a dynamic digital network [5]. According to Kh. O. Lutseva, digitalization is a qualitatively new state of the modern economy, where information technologies are the material engine of all processes occurring in it [4].

In most foreign sources during the interpretation of the "digitalization" concept, emphasis is placed on technologies and interaction methods of economic elements [16]. For example, the consulting company Gartner provides the following definition: "Digitalization is the usage of digital technologies in order to change the business model and provide new income sources, as well as opportunities to create improved products; it is a process of transformation into a digital business system" [17]. The organization of economic cooperation and development defines this concept as follows: "digitalization" is the process of using data and digital technologies, as well as the relationship that creates new or changes existing activities, while digital transformation carries out economic and social impact [18]. The Oxford Learner's Dictionaries defines: "Digitalization is the process of digitizing information for easy reading and processing on a computer" [19]. T. Honore believes that digitalization is necessary in order to use software and information technology to optimize the business, which in turn will help make it simpler, more economical and better in the context of providing services to customers and meeting their needs. Moreover, digitization aims to automate all workflows [3]. J.P. Clerk understands digitalization as a process of transformation into a digital format, which can then be used to achieve various goals in the computer system. Digitalization can be considered as the usage of digital technologies and data for obtaining profit [1]. The works of Koliadenko [9], Meshko [13] should be noted among domestic authors who consider digitalization as a process of bringing a variety of information into electronic form.; Dubyna and Kozliachenko [16] propose to consider digitalization as a stage of economic development characterized by a significant diffusion level of information technologies, information resources and social processes, resulting in the digitization of data of different origins, which in its turn expands the possibilities of their usage in all spheres of human activity; S.I. Tull understands the concept of digitalization as a process of large-scale changes in relations between different participants (government, business and society represented by its individuals), occurring in all stages of social activity under the integration influence of digital technologies, digital data and the Internet [20].

According to the Development concept of digital economy and society in Ukraine for 2018–2020 digitalization—is a filling of the physical world with electronic-digital devices, means, systems and also establishment of electronic-communication exchange between them that actually enables integral interaction of virtual and physical, creates cyberphysical space [21].

Accelerating the Digital-transformation of the world economy and Ukraine increases the importance of the economic security problem in the business sphere. This requires the most efficient usage of business resources in order to prevent threats and create conditions for the stable functioning of its main elements during the process of nationalization [22, 23]. The issue of forming the appropriate information and analytical support [24, 25] of the digitalization processes of the business environment, as well as the conditions of business development becomes acutely important.

The results of a study by the World Economic Forum regarding the development of the information society and its impact on the countries competitiveness around the world made it possible to determine the Network Readiness Index—a comprehensive indicator that examines the acceleration of digital transformation in the global economy after COVID in 2020. According to data obtained in 2020, Ukraine ranked 64th in the network readiness index among 134 countries [26] (see Fig. 1). The rating goal for 2018–2020 [26], in accordance with the Concept of Development of the Digital Economy and Society in Ukraine, was to reach 30th place in 2020. The index includes 62 indicators, which in turn are divided into 4 groups of components: technology, people, management, influence.

The "Technology" Group provides an opportunity to assess the level of technology required for the country's participation in the global economy, as technology is the basis of the network economy. It identifies indicators of access, content, future technologies. According to the meanings of indicators "Technology", Ukraine ranks 62nd

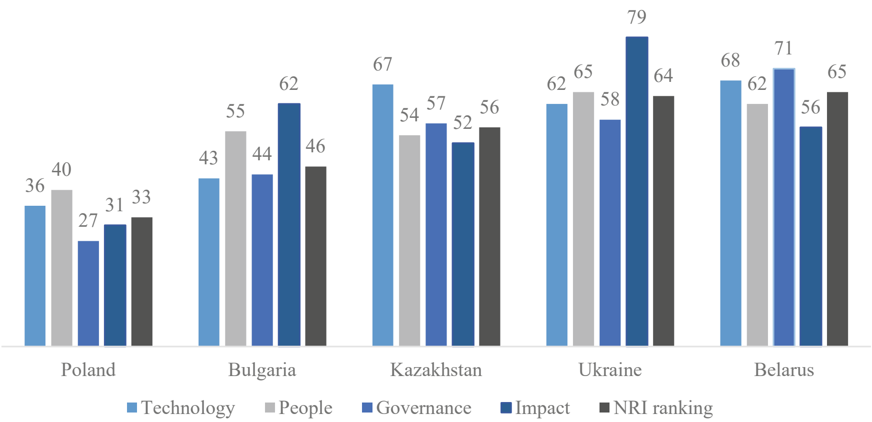

Fig. 1 Network readiness index and its components in selected countries for 2020

(Poland—36, Bulgaria—43, Kazakhstan—67, Belarus—68). In terms of access indicators that demonstrate the level of information and communication technologies in countries, including the indicator of communication infrastructure and accessibility, Ukraine has a low position in terms of high cost for phones—113 rating position (Poland 42 p, Kazakhstan 45 p, Belarus 62 p).) and 4G mobile network coverage—129 ranking position (Poland 1 p, Bulgaria 16 p). In terms of content indicators that reflect the type of digital technologies produced in countries, Ukraine has the lowest point in the development of mobile applications—61 rating position (Bulgaria—28, Poland—40). Using indicators of future technologies, the preparation degree of countries for the future network economy and new technological trends, such as artificial intelligence and the Internet of things, is studied, among these indicators Ukraine ranks 61st in terms of investment into new technologies (Bulgaria—50) [26].

The indicators group "People" divides the usage of information and communication technologies by people into three levels: individuals, business and government. The availability and level of technology in a country only matters when the population and organizations have access, resources and knowledge to use it productively. According to the "People" indicators group, Ukraine ranks 65th (Poland—40, Bulgaria—55, Kazakhstan—54, Belarus—62). Among the indicators groups that determine the usage level of technologies by individuals and the way they use such technologies and skills to participate in the network economy, Ukraine ranks lowest in terms of active mobile broadband subscription—102 position (Poland 3 p., Bulgaria 27 p., Belarus 51 p., Kazakhstan 63 p.). Among the subgroup of business indicators that characterize how enterprises use information and communication technologies and participate in the network economy, Ukraine ranks 71st in terms of business usage of digital tools (Poland—36, Bulgaria—40). Among the subgroup of government indicators that determine what to invest in Ukraine, the lowest rating indicators are government spending on R&D and higher education—80 rating position (Poland 57 p., Bulgaria 75 p.) and public online services—71 rating position for Ukraine (Kazakhstan 11 p., Poland 22 p., Bulgaria 46 p., Belarus 64 p.) [26].

The Governance indicator group demonstrates how favorable the national environment is for a country's participation in the network economy, includes subgroups of trust, regulation and inclusiveness. According to the group of Governance indicators, Ukraine ranks 58th (Poland—27, Bulgaria—44, Kazakhstan—57, Belarus—71). The analysis of these indicators subgroups shows that the lowest for Ukraine is the rate of digital payments usage in the field of agriculture, Ukraine occupies 93 ranking position (Poland 57th position, Bulgaria 75th position) [26]. The Impact indicator group assesses the economic, social and human impact of participation in the network economy. This group of indicators forms the basis of the digital potential in each society. According to the results of the rating assessment by the group of indicators "Impact", Ukraine ranks 79th (Poland—31, Bulgaria—62, Kazakhstan—52, Belarus—56). Among these subgroups, the lowest indicator in Ukraine is the social impact of participation in the network economy on quality of life: happiness and freedom to make life choices. Ukraine ranks 109th and 105th on these indicators (Poland 40 and 39 position, Kazakhstan 36 and 54 position, Bulgaria 89 and 65 position). It is also worth mentioning the indicator that determines the impact of information and communication technologies on the environment, namely the indicators: availability and purity of energy (Ukraine ranks only 128 position) [26].

The World Economic Forum announced that a sufficient level of information environment in the country creates favorable conditions for economic and social processes, ensures security and development at all levels. Thus, the network development of the state—is the technological basis of spatial development, providing an opportunity to form a digital environment of society and doing business in new conditions.

Nowadays, there is a range of software solutions that allows businesses to move into the direction of digitalization, such as: CRM (Customer Relationship Management systems); SCM (Supply Chain Management); Product Lifecycle Management—PLM (Product Lifecycle Management); Supplier Relationship Management (SRM) systems; intelligent systems of strategic management support—BI (Business Intelligence). Among a number of software solutions, the most effective solutions are enterprise resource planning systems ERP (Enterprise Resources Planning), which are focused on optimizing resource management.

According to Oracle research, ERP systems are software that organizations use to manage business activities (accounting, procurement, project management, risk management and compliance, supply chain operations). The complete ERP package includes performance management, as well as software that helps plan, budget, forecast and to make reports about the financial results of the organization [27].

Every year, ERP systems expand their functionality, become more flexible to business needs and, what is more, are a security tool that contains complete information about activities and resources. Today, the usage of ERP systems enables businesses to be protected from threats, risks and dangers associated with competition and changing market demands, taking into account the adaptation of doing business online.

All ERP-systems have similar structures in which there are platforms with a core and implemented basic functions (user directories, clients, products and other additional software tools that can be configured); databases with management, complexes for storage, interpretation, processing, sending of information; modules that use information from a similar database; products for communication and integration with applications for information exchange.

Comprehensive implementation of business process management solutions together with the CRM system, aimed at developing relationships with the customer base and building a marketing policy is an important step, because it directly affects the economic security of the business and increases the result of management decisions. The most popular option for creating ERP-systems is SaaS (Software-as-a-Service), also possible options in the cloud and locally.

Today, SaaS is the most well-known cloud model according to which programs and services are developed and maintained by the service provider. It hosts programs and services in the cloud, gives the user access through a browser or application on a computer. The service provider is responsible for updates and technical support, the customer has the opportunity to use the service free of charge or in accordance with certain contractual conditions.

When implementing an ERP system, it is necessary to take into account the requirements for scalability, which preserves the efficiency and effectiveness of the system, while the ability of the system to increase its capacity is determined by the capabilities of the hardware; distribution—the system supports distributed data storage; modularity—the system consists of separate modules connected with each other.

ERP-systems must meet all these requirements and provide adaptability, flexibility, interoperability, portability, reliability, stability and convenience of usage for the end user.

In the process of implementing the ERP system, it is important to carry out an assessment of the economic security level for a certain period of activity, such as:

- formation of a single information space in order to objectively assess the level of economic security;
- adjustment of indicators and criteria for assessing the level of economic security;
- control and analysis of economic business development;
- performing calculations of economic security indicators;
- accumulation, processing of statistical and analytical information regarding business security;
- substantiation of performing methods of cluster, factor and other analysis types regarding business development security;
- analysis of trends and regularities in the dynamics of business security.

The ERP system which performs the function of business security management and has a multipurpose purpose must have a convenient web interface. The modern web interface should have a high degree of convenience, usability and support for the usage of modern network technologies.

4 Conclusion

Thus, in terms of ensuring the economic security of business in the context of digitalization, the problem process is the formation of information-analytical and methodological support, which requires the following of such issues: (1) availability of information sources (availability, sufficiency, need for additional expenditures, etc.); (2) availability of software for calculations, determination of final results and their analytical processing; (3) obtaining reliable initial data for analysis; (4) cybersecurity and cybercrime; (5) strategic business positions in the context of the economy digitalization (online business positioning; IT tools for sales promotion, etc.).

The purpose of information-analytical and methodological support of business security is to model its activities, as well as to assess the consequences of management decisions, to avoid failures due to incompetence.

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Regulativity of Scientific and Technical Texts on Architecture and Construction

Svitlana Halaur, Iryna Yakubenko, and Maryna Moskalenko

Abstract The problems of the scientific style and its substyles, in particular their influence on the perception of the recipient have been investigated. The issues of regulativity of scientific and technical texts on architecture and construction have been researched. Scientific styles have been classified by reconciling the unity of the communicative task extra-linguistic motivation and linguistic implementation criteria. The correct perception of scientific and technical texts is ensured by the category of regulation. The influence on the recipient of the texts under consideration has been determined which gives scientific and technical information and provides its content adequate understanding. Obtained data enable to understand scientific and technical texts on architecture and construction more adequate.

Keywords Scientific styles · Substyles · Regulativity · Recipient · Perception · Genres · Scientific and technical texts

1 Introduction

The problems of the scientific style and its substyles, in particular their influence on the perception of the recipient, have not been resolved yet. This task remains a priority, since successful scientific and technical communication is the basis of technological evolution in the world.

Traditionally, it is believed that the scientific style has a main purpose such as systematizing knowledge, understanding the world, reporting on research results, proving theories, justifying hypotheses, classifications, explaining phenomena, presenting material, presenting scientific data to the public. The scientific style is divided into the following substyles: scientific, popular science and scientific and educational. This classification of styles, considered for a long time as operationally

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_56

balanced, today still does not claim to be universal and requires clarification by reconciling the unity of the communicative task extra-linguistic motivation and linguistic implementation criteria. The influence on the recipient of the texts under consideration is determined which gives scientific and technical information and provides its content adequate understanding.

2 Problem Search

Since at the present stage of information exchange, communication is in the foreground and its high manifestation is interaction, it is necessary to differentiate scientific texts considering the subject of science or the branch of knowledge. According to this approach, it is necessary to highlight the natural science, scientific-humanitarian and scientific-technical substyles of the scientific style. Texts about architecture and construction belong to the scientific and technical substyle. They are characterized by informativeness, consistency, accuracy, objectivity, abstractness, clarity, standardized form, modality on the scale of "truth - possibility - fallacy".

The content structure of a scientific and technical text is a detailed presentation of the reality real objects properties and functions. The technical text, as noted by Rashid S. Alikaiev, is built on descriptive microtexts, which are presented one after another in logical sequence [1]. In these microtexts, a large number of concepts, the nomenclature of specific objects, processes, states, symbolic speech are used. In addition to the theory, they are devoted to descriptions of technology, methods, experiments. Succinctness and at the same time high persuasiveness are considered to be the dominant features of scientific and technical texts.

These are, in particular, fragments of scientific and technical texts, such as: *The two-jet air distributor DSPR allows to supply inflow air to the upper area of the room of different purpose with the formation of a swirling and flat laying jet. Due to the presence of moving plates attached to the air distributor diffuser, the aerodynamic parameters of the resulting air flow are improved by reducing the coefficients of attenuation of the velocity and temperature of the air flow* [2]; *The field survey was complemented by data analysis of notes, audio and video records. The data were compiled to form factors. These factors include motivation to construct an earthen house, performance of already existing structures, maintenance requirements, economy, image, influence of government and policies, and education and training* [3] prove a forenamed and show that they are characterized by a formal, almost mathematically rigorous presentation of the material. The person who writes these texts avoids imprecise definitions, unfounded generalizations, sensations. The emphasis is on the logical rather than the emotional side of the information. In the course of the material presentation "collective" approach to the phenomena description is used.

The influence on the recipient of the texts under consideration is determined by pragmatic category of regulation—a special text category with a set of regulatory means (lexico-phraseological, grammatical, graphic) and regulatory methods (specific structuring of regulatory means) [4], which gives scientific and technical information and provides its content adequate understanding. At the same time, scientific and technical information includes the results obtained in the process of scientific research, experimental design, design and technological, production and public activities, recorded in a form that ensures their reproduction, use and distribution [5]. The main features of regulatory means and regulatory methods of scientific and technical texts are the accuracy of such information transmission and its visualization. "The selection of linguistic means, conditioned by the pragmatics of the extralinguistic situation, ensures the correct expression of the meaning of the statement, its understanding, assessment and influence on the recipient and is carried out with the help of general literary linguistic resources" dissemination [6].

The terms—highly specialized and general scientific, abstract vocabulary, internationalism, scientific phraseological units should be considered to be the most representative lexical and phraseological regulatory means of the scientific and technical substyle. As for the terms in scientific and technical texts on architecture and construction, it should be clarified that they go beyond this area. It can be explained by the fact that in our time, construction is a complex and multilateral process that combines technical, economic, legal and social aspects. The main stages of construction are land allocation, development, project coordination, building construction process, commissioning. Experts involved in the design and implementation of construction projects must establish effective planning mechanisms, budgeting, document circulation, timely delivery of building materials, logistics, workplace safety, etc. In addition, it is necessary for them to consider the environmental impact of the work.

Morphological regulatory means are represented by nouns that create high nominativeness), including their plural forms, impersonal, passive forms of the verb, adverbs, grammatical forms of time in the attributive sense, prepositions for the transmission of hyperonymic relations, and the like. Syntactic regulatory means arise primarily as complex sentences with causal relationships, impersonal syntactic constructions, introductory words, quotations. Diagrams, tables, graphs are used as graphic regulatory tools. The pragmatic relationship between the addressee and the addressee of a scientific and technical text requires special ways of structuring regulatory means, among which the compositional organization of the text, repetitions, and graphic highlighting of the text (font, spatial) prevail. The following example clearly demonstrates the above: *The changes in construction engineering revolution have been hugely affected by the ways and standards the constructed facilities have been maintained. Prior to World War-II, maintenance was carried out on 'breakdown basis'. From the 1950 onwards, construction industry demanded better maintenance which led to the development of 'planned preventive maintenance'* [1]. *From 1960, 'reliability centered maintenance' was practiced and from 1980, maintenance has been transited from 'reactive to strategic' approach with effective maintenance programs* [7].

Most scientists argue that the set of regulatory tools should lack those ones that indicate the identity of the author, his or her preferences, emotions (for example, expressive synonyms, suffixes, polysemantic lexemes, verbal tropes, individual neologisms, etc.). Other authors of scientific texts point to the gradual collapse of such a "ascetic tradition", which began, perhaps, with Newton and began at that time the hypocritical modesty of the customs of the English medieval church (Cambridge), still forcing many authors remove from scientific reports everything that, in their opinion, does not directly relate to the obtained results and the used methods [8]. Anyway, some regulatory means still violate the stereotype of emotionless presentation, for example, specific paragraph division, inserted units, linkwords, text-forming constructions "question—answer", rhetorical questions, quotes: *What is creativity? According to a popular reference article, the term "refers to the invention or origination of any new thing (a product, solution, artwork, literary work,* etc.*) that has value. "New" may refer to the individual creator or the society or domain within which novelty occurs. "Valuable", similarly, may be defined in a variety of ways* [9].

For a better understanding with the recipient, naked outline of facts is gradually replaced by a kind of scientific and ironic style, associated with an increase in information, complication of scientific knowledge, etc. [10].

A unit of information resources in the aspect of scientific and technical information is a scientific document. Depending on the purpose of creation, scientific documents are differentiated into subtypes:

(1) providing society with relevant scientific information: scientific monograph, dissertation, dissertation abstract, research report, scientific article, report abstracts, scientific report, invention description, information sheet, information critical review, and the like;
(2) ensuring the process of professional training of future specialists: textbook, study guide, lecture notes, workshop, educational reference book, manual for specialists, etc.;
(3) provision of secondary factual information of science and production: a brochure, an industrial catalog, a standard, a reference book on the branch of knowledge, a specialist's reference book, an encyclopedic dictionary, a terminological dictionary, a determinant of technical objects, and the like;
(4) ensuring the popularization of the scientific, technological, production achievements, their history: a popular science article, a popular science monograph, a popular science review, a popular science essay, a popular science encyclopedia, an informational abstract, an informational abstract review, and the like.

Considering the presented classification, it can be stated that within the framework of the scientific and technical substyle, different genres can be distinguished. Some of them demonstrate the diffuseness of the boundaries of the scientific and other styles. Texts of different genres do not violate the unity of the scientific and technical style. They imitate its general features and characteristics, are guided by lexical, syntactic and compositional stereotyping, however, having different purposes, it is logical that they are characterized by certain differences in the use of regulatory means. It is demonstrated by analyzing some genres of the scientific and technical substyle and the organization of information perception in them.

Scientific and technical developments—samples of the scientific sub-style proper—are aimed at significant improvement of objects that already exist. Scientific and technical developments find linguistic expression in technical documentation, namely: preparation of work instructions, recommendations, etc. on the application of innovations, including the preparation of drawings, specifications, instructions, recommendations used in the transfer of innovations to production. Consequently, scientific and technical developments are intended to transmit (qualitative or quantitative) information. This information should be completely free from preconceived judgments, therefore, it is worth choosing linguistic means that have direct impact on the user, which provide direct access to technical reality, instant transfer of the recipient into it. Preference is given to lexemes with direct meaning that have a direct impact on the user.

The specificity of another genre—the textbook—is the programmatic presentation of the material, aimed at activating the student's thinking, the sequence by the introduction of terminological vocabulary. Scientific and educational genres, for example, a textbook, occupy an intermediate place between the scientific and popular science substyles. They are distinguished from the first by somewhat less rigor of presentation, less thoroughness in the reference to primary sources, more simplified proving system, which is aimed at greater availability of information. From the second—less artistry, more consistency in presentation, severity. Non-linguistic means of presentation also play an important role in the textbook—illustrations, maps, plans, diagrams, pictures, diagrams: *characteristics of concern in the comparison are listed in the first column. The numbers in the second column indicate the relative importance of each characteristic to the owner: 1 denotes lowest priority and 10 highest priorities. These are the weights. In addition, each of the partitions is ranked on an ordinal scale, with 10 as the highest value, in accordance with the degree to which it possesses each characteristic. These rankings are listed as relative values. For construction cost, for instance, the metal partition is assigned a relative value of 10and the glass-metal partition a value of 8, because the metal partition costs a little less than the other one. In contrast, the glass-metal partition is given a relative value of 8 for visibility, because the upper portion is transparent, whereas the metal partition has a value of zero, because it is opaque* [11].

According with the regulatory theory, for example, popular science articles can be considered quite different from the scientific genres. They aim to interest a wide range of people with scientific information, regardless of their level of training. The main function of such an article is to draw attention of a non-specialist to the actual problems of a particular science, therefore, to present the problem in an accessible, interesting form. Among the regulatory means of this genre are epithets, metaphors, paraphrases: *They may all appear similar to the* ***untrained eye****, but bricks have always been an individualized product. Today there are tens of thousands of varieties on the market—and in the hands of avid brick collectors (and brick thieves). In Milwaukee, Wisconsin, many old buildings feature "Cream City" bricks, an unusually light yellow color block thanks to local clay. In the Windy City, where hundreds of old buildings have been demolished, a reuse market for certified "Old Chicago" bricks have formed. Down in St. Louis, historic bricks can be tied back to one of the 50-or-so brick manufacturers that operated there in the mid-nineteenth century. Wherever you live, your city's* ***bricks tell a story*** [12].

There are differences in the use of regulatory tools in scientific and technical style texts in different languages. Thus, the specificity of the English scientific and technical background is to replace subordinate clauses with adjectives in the postposition, in the use of infinitive forms in the function of definition. Characteristic features of the English scientific and technical background are the widespread use of elliptical structures, cases of omission of the article. Constructions with the preposition of and numerous attributive groups are widely used, e.g.: *In this relation formation and practical realization of the mechanism of providing region social and economic security require analyses of social policy effectiveness* [13], *Special training exercises and techniques are suggested to be applied in the teaching process; Professional text enables the most compete disclosing of the term's meaning. For that reason, we have based our research on scientific popular economic texts, which are periodical literature on economic subject, considered to be a secondary sphere of economic terms functioning* [14].

In English scientific and technical texts, there is a frequent use of expressive language means, in particular comparisons and metaphors.

In the scientific and technical substyle of the Ukrainian language, homogeneous members of the sentence, participial and adverbial expressions are actively used: *Під будівельним процесом розуміють сукупність взаємозалежних основних, допоміжних і обслуговуючих технологічних операцій, здійснюваних на будівельному майданчику, внаслідок взаємодії яких створюється будівельна продукція.* Часто використовуються ланцюжки з кількох іменників у родовому відмінку (наприклад, *аналіз шляхів досягнення цілей*) [15–18].

Some regulatory tools are quite applicable in all languages, therefore, they are universal. These are, for example, logical means of communication, nouns, which become the core of the vast majority of phrases. These regulatory tools in all languages are focused on the main functional tasks and meet the dominant requirements for the scientific and technical background.

It should be considered that the perception of scientific and technical texts also depends on the circumstances that are not influenced by correctly selected regulatory means, organized in regulatory ways in accordance with the genre of the text. Users turn to scientific and technical texts when they can be useful to them, so such texts usually do not need an entertaining, attractive language composition.

3 Conclusions

In accordance with the subject of science and branch of knowledge, texts on architecture and construction are classified as scientific and technical. Within the framework of the scientific and technical sub-style, different genres can be distinguished, some of them demonstrate the diffuseness of the boundaries of the scientific and other styles, primarily journalistic. The correct perception of scientific and technical texts is ensured by the category of regulation. Its means are diverse: lexico-phraseological, grammatical, graphic. Some of them are universal, that is, they are used in different languages.

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Digital Technologies and Its Impact on the Quality of Human Resources in Azerbaijan (In the Case of Construction Industry in Line with Education System)

Kanan Hasanov, Konul Agayeva, and Oleksandr Shefer

Abstract This paper presents the main factors influencing quality of human resources. High-tech affects practical aspects of the functioning of society and organization, including the selection process. The company's priority tasks are formation of a professional and competent team, hiring, recruiting, and finding the appropriate personnel. Digital-economy executes entirely new necessities for training and competence. Digital transformation is an indispensable condition for maintaining the competitiveness of construction organizations in the modern conditions of the digital economy. In this article, digital transformation of construction organizations and condition of national education system in terms of digital economy have been evaluated comprehensively.

Keywords Digital economy · Human resources · Labor market · Education system · Construction sector · Digital transformation

1 Introduction

Accelerating technological development processes, along with increasing competition and ever-faster innovation cycles of business models, lead to changes both in the operational activities of organizations and in the needs of product consumers. In these conditions, digital technologies are becoming critical for maintaining the competitiveness of the organization, and many industries (entertainment services, software, mobile applications) have already appreciated the benefits of introducing

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_57

and applying elements of digital innovation, such as big data analytics, technologies of “smart cities”, augmented reality, blockchain, etc. The digital transformation of construction organizations significantly affects every direction of activities, which increases the quality of the provided product and optimizes activities of organizations to create it. In accordance with the prevailing trends in digital development of the economy, development of the concept of digital transformation of organizations becomes important both within the framework of a theoretical study of this process and for the formation of rational business strategies [1]. Digital transformation of organizations is not associated with the introduction of individual innovative tools for production and management, but with the improvement of the entire activities of the organization in accordance with the adopted digital development strategy. Moreover, digital transformation of construction organizations enables not only to create products and provide services using digital technologies, but also provides formation of new business models in this industry.

The process of globalization and digital economy is a recent and significant trend nowadays. Cutting-edge technologies affect almost all practical aspects of social functioning and organization, including the selection process. Forming a competent and professional team, hiring, selecting, recruiting, and finding the appropriate personnel are priority tasks for a company. Digital-economy exposes entirely new demands for the key characteristics of the workforce—training and competence. A successful solution to the issue increases the organization’s human capital, which is a primary factor of a company competitiveness. The financial result and efficiency of this organization depend on the efficiency and qualification of personnel.

As per the strategy [2], the population has to form necessary competencies in innovative activities: readiness and aptitude towards self-learning, continuous education, willingness for innovations, professional mobility, capacity for calculated risk and entrepreneurial spirit, creativity and ability to work on its own as well as teamwork skills, professional command of a foreign language. Support is allowed driven by disengaged financial resources of business projects and modernization of digital economy infrastructure. According to statistics, funding of science by government budget has increased since 2019 by 42% and made up 193.7 million AZN. Total amount of State budget allocations to science in 2020 accounted for −0,40% of GDP. Major increase (3,0 times) was noted for 1998–2019 years. Around 31% of the total amount was spent on fundamental investigations in 2020. 65% accounted for applied investigations, 3% for education, country-wide issues—4%, public health—6%, sphere of national economy—60.0% [3]. For comparison, percentage of education expenditure in GDP was 6.0 and 5.0% on health sector in Turkey in 2020 (The Gross Domestic Product (GDP) in Turkey was worth 715 billion US dollars in 2020) [4]. Despite the importance of developing and implementing a digital strategy for a successful digital transformation of construction organizations, a study by KPMG International, conducted in 2018 in 84 countries with participation of more than 4,000 respondents, showed that only 23% of construction organizations have developed and are implementing a digital strategy [5]. Another 23% of organizations have a digital strategy in certain areas of development, and the remaining 54% currently do not have a clear understanding of digital transformation. Yet even with a digital strategy in place, 42% of construction organizations recognize the process of digital transformation ineffective and only 12% of respondents believe that the strategy is being fully implemented [5].

2 Human Resource Management and Its Digitalization

2.1 Main Challenges in Digitalization of Human Resources

Currently, there are some challenges that do not allow full implementation of the concept of an innovative person and formation of the necessary demand for knowledge in the market. This is mainly due to insufficient number of projects and programs that envisage talent engagement, yet the creation of new high-tech jobs can normalize this situation. There are also some issues associated with the slow growth of small and medium-sized businesses while maintaining the state as the principal employer and a poorly formed venture capital market, which does not allow attraction of necessary investments. It should be expected that the market situation in the next ten years will change based on technological, demographic and political trends, creating new challenges.

Researchers mention that income stratification within and between countries is growing;

- employment in segments of low-skilled workers will be characterized by increased competition for jobs;
- due to ageing of the population, the nature of competition for human resources will be changed by 2025 (generation Z has a set of digital competencies);
- forms of employment in the economy will be completely different (there will be a threat of job loss by those who have low qualifications) [6];
- number of freelancers will be increased due to pandemic effect and recently acquired digital trends (particularly work from home).

Digital economy thus imposes completely new requirements for training and competencies, that is, for the characteristics of labor resources in general and for quality in particular. The volume of digital economy is growing rapidly every year. Global digital projects were launched almost from a scratch and large digital companies were created [7]. Thus, the level of digitalization in the country for the period from 2015 to 2019 grew by almost 10–15% [2].

The barriers to successful digital transformation of organizations can be divided into following groups:

1. Transformational barriers
2. Innovation barriers
3. Management and regulation barriers/bureaucracy.

2.2 Development of Digital Strategy

Implementation of digital strategy directly depends on investments in digital technologies, organizational, personnel, and other activities. Currently, lack of funding is considered as one of the most significant problems in digital transformation of organizations.

British studies have shown [8] that the greatest obstacle to digital transformation of the design process is precisely the high cost of innovative technologies. Among other pronounced problems in the implementation of digital technologies, they highlight lack of support from top management, unwillingness to radically revise all processes in the organization and slow decision-making on digital transformation due to excessive management caution. In terms of another industry, the ICT sector is a pioneer in the application of innovative technologies in Azerbaijan. ASAN services provided by the government represent a one-stop shop for public service delivery, which has been praised by various institutions, such as Asian Development Bank, for reducing bureaucracy, improving time efficiency and transparency in service delivery.

This data suggests that the conditions are favorable for expansion of digital-based activities. It should be emphasized that development of digital technologies on a global scale is accelerating more and more, and modern information solutions raise concerns with regards to complete replacement of human by algorithms and robots. So far, researchers do not have a definite answer to this question. According to various estimates, in the next 15–20 years, about 50% of professions will face the risk of automation, which means that software products will be able to replace a person dealing with routine work. According to forecasts of domestic experts, due to the influence of digital technologies on the labor market by 2030, about 186 new professions will appear and about 57 "traditional" ones will disappear. All this suggests that in today's realities, human labor takes on new, more complex forms.

"Task complication" in occupation allows some free time for more complex tasks, however, there is also a factor of raised standards of employee qualification requirements. Completely new approach for responsibility allocation is emerging. Formerly, an employee was in charge of a specific task, whereas nowadays there is a responsibility of multitasking.

Future occupations will require set of skills and capabilities from their employees:

- IT proficiency (irrespectively of the occupation);
- Ability to work remotely;
- Creative thinking;
- Readiness for periodical requalification (approximately every 10 years);
- Self-learning skills;
- Ability to work with big data;
- Ability to work abroad and frequently travel (due to globalization).

As can be seen from the above, simply educational degree is not enough to succeed, continuous self-improvement is necessary. Training/ education can be realized not only in an Educational Institution, but also in the employing company during the process of a practical experience [2, 9]. According to estimations of foreign scientists, expenses on human resources training in Azerbaijan are 10 times lower than in Europe. It is fair to say that the environment in our country is not very promotive of self-improvement and self-fulfillment, since approximately 80% of country labour force belongs to mid class population, without additional income.

With this consideration, it is important to provide readiness of professional education for digital economy. Major strategies and horizons that need to be highlighted:

- Throughout life education
- Gradual transformation of mass education into individual.

Nevertheless, the process of developing and implementing a digital strategy in construction organizations faces the following obstacles:

1. Continuous improvement of digital technologies discourages some organizations from developing a digital strategy and subsequent digital transformation due to the uncertainty about what changes they need.
2. Training and retraining of personnel for working with digital technologies requires both financial and time costs.
3. Digital transformation is fraught with risks of not receiving the planned benefits, since in the digital economy, organizations act on the principle of "fail fast": a quick "failure"-learning-moving forward.

It can be acknowledged that digital economy transforms university structure and provokes introduction of advanced solutions and approaches in the direction of education and science.

3 Higher Education and New Competences/Skills

3.1 Quality of Education Systems

Formerly, massive debut of online courses was accepted as an unfavorable trend by higher educational institutions. Recently, the integration of these courses into educational processes can be observed.

It must be noted that countries with well-developed market orientation focus on improvement of cognitive skills through the transformation process of educational systems. These countries emphasize on occupational retraining of human resources [10]. With regards to local education system, the task is assigned to leading universities. These institutions have to become a locomotive of high-tech development of the country. In this regard, it is necessary to create a creative environment for increasing the number of talented teachers and researchers, who will become the core of the

Table 1 Quality of national education systems

Countries	Ranking of national higher education systems	Index
US	1	100
UK	6	83.6
Canada	7	83.2
Germany	16	70.5
China	26	56.8
Russia	35	49.1
Turkey	39	46.3

Source: Compiled by the author based on the materials of "Ranking of National Higher Education Systems 2020"

human resources potential in the future. This implies the creation of a talent management system in universities and encouragement in terms of involvement of employees in professional development.

In major reports of Europe, Russia and other developed countries, there is a new motto: "From Personnel to Talents", which is a new formulation of "Target Model of Competence", which includes socio-behavioral, digital and cognitive skills. Without mastering these competencies, it is impossible to achieve efficiency in the twenty-first century and especially in digital-economy. At the same time, professional standards are designed today to combine the requirements of business with the qualifications of graduates. Standardization is seen as a mean to ensure quality and uniformity. In this regard, rules, norms and requirements regarding the quality of human resources should be developed.

The national higher education systems included in international rankings (see Table 1) serve as a measure of the quality of the training competent specialists for the digital economy by the national education system [11–19]. Compared countries have significantly more universities included in the world rankings, than other countries. Therefore, Azerbaijan education system in comparison with the countries stated above in the Table 1, has to spend more efforts and budget to improve the quality of education.

4 Conclusion

Digital transformation of construction organizations implies reorganization of all areas of the organization's activities, and such changes should be based on a digital strategy. Lack of a consistent digital development strategy is the greatest obstacle to the digital transformation of a construction organization.

The following stages are distinguished on the way of forming a successful digital strategy of construction organizations [7]:

1. Initiating the creation of a digital strategy.
2. Implementation of pilot projects to identify the necessary digital transformations in a specific organization.
3. Direct formation of the digital strategy of the organization.
4. Solving problems arising in the organization on the basis of the developed digital strategy.

Currently, the process of creating a national qualifications' system is being observed, which will unify the requirements for employees in various industries. However, in the digital economy, requirements are changing rapidly, and therefore it is very important to track changes and form a flexible mechanism of interaction between educational institutions and the labor market. All this should directly affect the quality of human resources in our country.

The three major changes coming for education as outlined below are based upon exposure to literature, private sector reporting, and practice around the globe. It is important to highlight the governance structures, economic stability, labor relations, and the uptake of technological advances as relevant context for each country and educational institution. Three major shifts in education are identified: (1) changes in the funding of education; (2) changes in the duration of learning; and (3) changes in the way of learning. The following sections will walk through each major shift for the future of education.

The main directions of the development of education, using digital technologies, for the preparation of qualified specialists who meet the requirements of the digital economy include:

- development of digital libraries and digital campuses of universities;
- active development and use of technological resources of the information educational environment;
- increasing the level of digital competencies and skills in the use of information and communication technologies of the teaching staff;
- teaching students to work with big data, to learn skills in engineering and technological entrepreneurship;
- high mobility and changeability of the current situation both in the economy and in the field of higher education necessitates constant adjustment of educational programs, taking into account the ongoing changes;
- development of intellectual educational technologies, scientific and applied research;
- IT startups in the educational sphere, etc.

An important element of the effective implementation of the digital strategy of a construction organization is the presence of a management capable of making a decision on digital transformation and ready to create conditions for the introduction of digital technologies in various areas of the organization's activities. The gradual digital transformation of construction organizations is a response to the changing conditions of construction activities. The basis of the modern digital strategy of construction organizations should be a focus on ways of interaction with customers, introduction of the entire set of digital tools and systems, digital education of personnel and development of methods for managing new business models.

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Construction Industry of Ukraine: Current State and Role in Ensuring Economic Security of the State

Volodymyr Onyshchenko, Olena Koba, Olena Filonich, Yevheniia Кarpenko, and Oksana Furmanchuk

Abstract Activity indicators of construction enterprises of Ukraine for 2010–2021 are analyzed. Development trends in construction industry of Ukraine during this period are identified. Reasons for negative dynamics of indicators are determined. A number of problems that hinder the development of construction industry in Ukraine are defined. Further prospects for development of construction industry are clarified. Peculiarities of economic security system formation of construction industry taking into account the state-regulatory, technological, managerial, financial aspects are considered. A conceptual model of economic security of the construction industry is proposed, which consists of three groups of measures: information-analytical, regulatory, control.

Keywords Construction industry · Economic security · Volume of construction works

1 Introduction

In terms of modern economic conditions, which are characterized by destabilization of economy, low living standards and political and financial crisis, construction remains a priority of the national economy development strategy of the countries worldwide. Effective activity of the construction industry promotes development of construction materials and equipment, mechanical engineering, metallurgy, petro chemistry, woodworking, transport and energy, which has a positive impact on the economy, solves social problems and strengthens economic security. In this regard, it is extremely important to ensure stable development of construction and determine its impact on the level of economic security. This determines relevance of the research topic.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_58

Construction industry combines activities of general construction, specialized, design and survey, scientific and research organizations, enterprises of the construction industry, and enterprises for the production of building materials, structures, parts and transport enterprises.

Construction is a process of buildings and structures construction by creating new as well as expanding, reconstructing, technical re-equipment of existing enterprises and other facilities of industrial and non-industrial sphere, and in accordance with the International Convention on Safety and Health at Work includes:

(1) construction works, which include earthworks and constructions, structural changes, restoration works, capital and current repairs and demolition of all types of houses or buildings;
(2) civil engineering, including earthworks and constructions, structural changes, capital and current repairs and demolition, for example, airports, docks, harbors, inland waterways, dams, protective structures on the rivers, seas, landslides, roads, railways, bridges, tunnels, viaducts and facilities related to the provision of services such as communications, drainage, sewerage, water and energy supply;
(3) installation and dismantling of buildings and structures from elements of factory production, as well as the production of prefabricated elements on the construction site [1].

In scientific literature, the «construction» concept is identified with the concept of «construction industry». Construction industry in modern conditions functions as a set of territorial technological clusters [2].

Its characteristic features are as follows: duration of the enterprises production cycle; real estate of created products; influence of climatic, weather and geological conditions; high dependence on financial, logistical and organizational support; high material consumption of production; the need for a significant number of employees; participation of a large number of auxiliary and contracting organizations in the construction of facilities; the need to move in the production of material, technical and human resources; regulations and legal regulation; mandatory permits; standardization and rationing of construction quality; high cost of products, which requires appropriate financial support and investment resources; the need for complex production cooperative relations between economic entities to ensure the construction process [3–5].

2 Trends in the Development of Construction Industry in Ukraine in 2010–2021

The development of this industry in Ukraine has gained some stability in recent decades, as evidenced by growth of construction output during 2010–2021 (Fig. 1). At the same time, the structure of manufactured construction products by type changed insignificantly (Fig. 2).

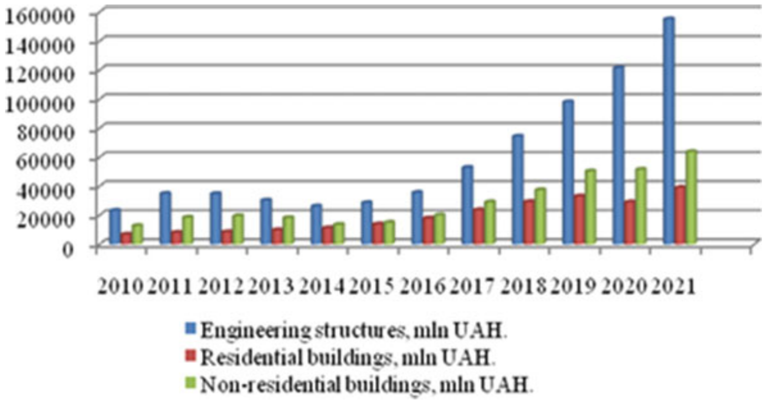

Fig. 1 Dynamics of construction output by its types in Ukraine in 2010–2021. *Source* Built by the authors according to the State Statistics Service of Ukraine [6]

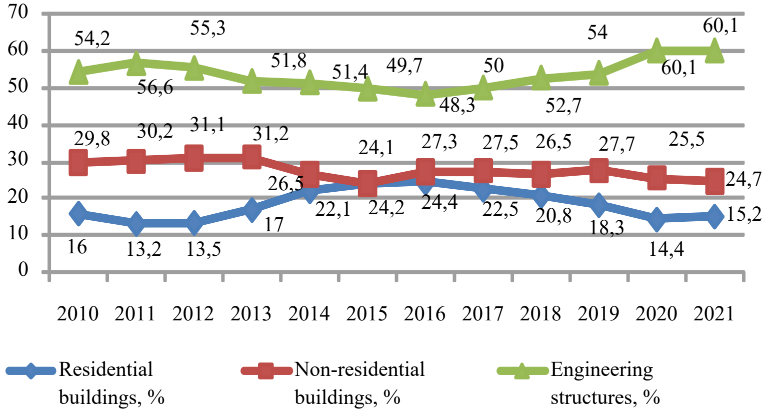

Fig. 2 The structure of construction output by its types in Ukraine in 2010–2021. *Source* Built by the authors according to the State Statistics Service of Ukraine [6]

Construction industry contribution to the country's gross domestic product (GDP) in absolute terms increased in 2010–2021. In percentage terms, this figure decreased in 2010–2015 due to the effects of the financial crisis. Its level began to recover in 2016, but the greatest value of the pre-crisis period until 2021 was not achieved (Table 1). The adoption of a number of legislative changes in 2017 to deregulate construction contributed to the improvement of the situation. It should be noted that the share of GDP in the construction industry in Ukraine is much lower than in European countries. The reasons for this situation lie, above all, in the corruption of the industry. According to the results of 2021, the index of construction products in relation to 2020 amounted to 106.8% (Fig. 3) [6].

Table 1 The share of construction in Ukraine's GDP in 2010–2021

Year	Total GDP, UAH million	GDP of construction, UAH million	Share of construction GDP in total GDP,%
2010	1,079,346	35,366	3.3
2011	1,299,991	39,575	3
2012	1,404,669	39,049	2.8
2013	1,465,198	36,902	2.5
2014	1,586,915	36,876	2.3
2015	1,988,544	38,928	2
2016	2,385,367	47,457	2
2017	2,983,882	64,431	2.2
2018	3,560,596	81,259	2.3
2019	3,978,400	107,430	2.7
2020	4,222,026	119,441	2.8
2021	5,459,574	151,826	2.8

Source Calculated by the authors according to the State Statistics Service of Ukraine [6]

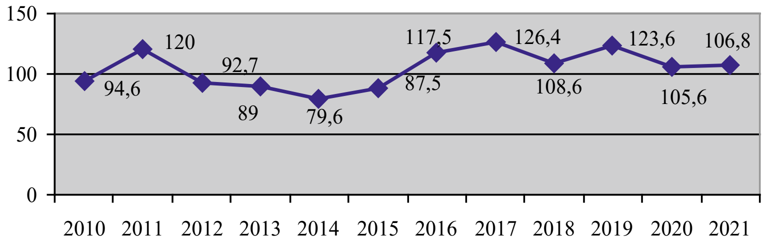

Fig. 3 Indices of construction products in Ukraine in 2010–2021, % to the previous year. *Source* Built by the authors according to the State Statistics Service of Ukraine [6]

The development of construction industry in 2020–2021 was significantly influenced by implementation of "Large Construction" projects, which began in March 2020. Thus, in 2021, production volumes increased by 28% compared to 2020, and for certain types of construction products—by more than 34% (Table 2).

However, compared to previous years, the share of new construction decreased significantly (by 44.6% compared to 2019), while the volume of repair work (by 19.3% compared to 2019) and reconstruction and technical re-equipment increased (25.3%) (Fig. 4). In January 2022, the share of new construction and reconstruction and technical re-equipment increased to 49.2 and 27.1% of the total construction output, the share of repairs (capital and current) decreased to 23,7%.

The leaders of the construction industry in terms of production in 2021 were Kyiv, Odesa, Dnipro, Kharkiv, Lviv, Kyiv, Vinnytsia, Donetsk, Khmelnytskyi, Poltava oblasts (Table 3). According to the results of January 2022, the leading positions

Table 2 Dynamics of production volumes in Ukraine in 2020–2021

The volume of construction products by type	2020, UAH million	2021, UAH million	Absolute deviation, UAH million	Growth rate, %
Construction, total	202080.8	258073.6	55992.8	127.7
Including: engineering structures	121455.2	155179.3	33724.1	127.8
Buildings, total	80625.6	102894.3	22268.7	127.6
Of them: residential	29083.6	39147.9	10064.3	134.6
Non-residential	51.542	63746.4	12204.4	123.7

Source Calculated by the authors according to the State Statistics Service of Ukraine [6]

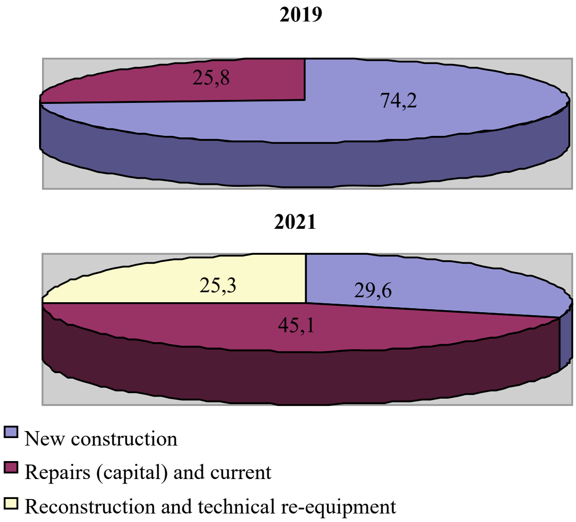

Fig. 4 Distribution of construction output in Ukraine by nature of construction in 2019 and 2021, %. *Source* Built by the authors according to the State Statistics Service of Ukraine [6]

were maintained in Kyiv—UAH 2,162.6 million, Kharkiv oblast—UAH 1,228.7 million, Dnipropetrovsk oblast—UAH 1,046.8 million, Lviv oblast—UAH 923.06 million. UAH, Kyiv oblast—UAH 519.6 million.

The change in the number of operating entities in the construction industry is negative (Table 4). Thus, in 2010 this figure was 75,221 thousand units, or 3.4% of the total number of business entities. In 2011, due to the financial crisis, it decreased to 59,197 units. This indicator has been recovering since 2016 and in 2020 it amounted to 56,926 units, or 2.9% of the total number of businesses. A similar trend was observed in the number of employees employed in construction entities (Table 5).

Performance efficiency of the construction industry depends on its investment [7]. Capital investment into construction has grown for the period of 2010–2021 (Fig. 5). However, it reduced in 1.6 times in 2020 because of lockdown caused by COVID-19 pandemic compared to 2019.

Table 3 Volume of construction work performed by type of construction products by region in 2021, UAH million

Oblast of Ukraine	Construction works conducted, total	Of them on the construction site			
		Buildings	Including		Engineering structures
			Residential	Non-residential	
Ukraine	258,073.6	102,894.3	39,147.9	63,746.4	155,179.3
Vinnytsia	15,919.6	2201.7	605.3	1596.4	13,717.9
Volyn	3273.5	1737.1	695	1042.1	1536.4
Dnipropetrovsk	21,325.5	8704.6	1335.2	7369.4	12,620.9
Donetsk	11,586.2	2153.8	154.4	1999.4	9432.4
Zhytomyr	2649.4	1470.1	373.3	1096.8	1179.3
Zakarpattia	1751.9	809.7	114.9	694.8	942.2
Zaporizhzhia	3802	1998.8	235.3	1763.5	1803.2
Ivano-Frankivsk	5063.3	2257.1	868.6	1388.5	2806.2
Kyiv	16,896.9	6471.2	1579.2	4892	10,425.7
Kirovohrad	1269.1	871.6	103.4	768.2	397.5
Luhansk	785.1	385.4	102.1	283.3	399.7
Lviv	18,608.3	8906.7	4051.6	4855.1	9701.6
Mykolayiv	4612.1	1545.2	255.6	1289.6	3066.9
Odesa	35,693.3	5736.1	3281.5	2454.6	29,957.2
Poltava	9425.4	3318	630.4	2687.6	6107.4
Rivne	4516.3	2560.8	381	2179.8	1955.5
Sumy	2055.5	1455	398.5	1056.5	600.5
Ternopil	4156.2	2646	1826.9	819.1	1510.2
Kharkiv	20,215.3	8576.1	4224.9	4351.2	11,639.2
Kherson	1465.1	703.5	132	571.5	761.6
Khmelnytskyi	9442	2236.5	745.2	1491.3	7205.5
Cherkasy	3675.5	1101.1	432.2	668.9	2574.4
Chernivtsi	1648.4	1159.7	474.7	685	488.7
Chernihiv	2953.1	1291.2	475.5	815.7	1661.9
Kyiv city	55,284.6	32,597.3	15,671.2	16,926.1	22,687.3

Source Summarized by the authors according to the State Statistics Service of Ukraine [6]

Index of capital investment into construction by the same period of the previous year (Fig. 6) grew to 64.4% in 2021, while it dropped by 49.5% in 2020 as a result of the investment pause for most enterprises of the real sector [8].

Table 4 Number of business entities in Ukraine in 2010–2020

Year	Number of operating entities in total, units	Number of operating entities in construction	
		Units	% of the total
2010	2,184,105	75,221	3.4
2011	1,701,797	59,197	3.5
2012	1,600,304	50,830	3.2
2013	1,722,251	52,983	3.1
2014	1,932,325	52,189	2.7
2015	1,974,439	55,128	2.8
2016	1,865,631	50,208	2.7
2017	1,805,144	50,261	2.8
2018	1,839,672	52,531	2.9
2019	1,941,701	56,855	2.9
2020	1,973,652	56,926	2.9

Source Developed by the author according to the State Statistics Service of Ukraine [6]

Table 5 Number of employees in the construction industry in 2010–2020

Year	Number of employees employed by business entities in total, persons	Number of employees employed by construction entities	
		Persons	% of the total
2010	11,000,590	523,979	4.8
2011	10,393,516	467,487	4.5
2012	10,198,733	439,838	4.3
2013	9,965,118	399,581	4
2014	9,008,315	318,477	3.5
2015	8,331,952	282,458	3.4
2016	8,244,013	283,976	3.4
2017	8,271,365	293,639	3.6
2018	8,661,298	312,251	3.6
2019	9,145,513	344,484	3.8
2020	9,057,014	329,095	3.6

Source Developed by the author according to the State Statistics Service of Ukraine [6]

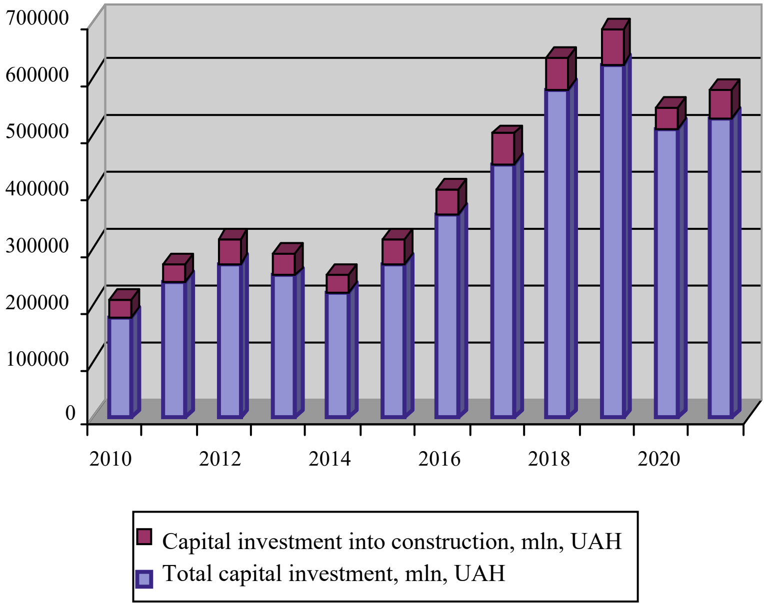

Fig. 5 Dynamics of capital investment into construction in Ukraine in 2010–2021. *Source* Developed by the authors based on the data provided by the State Statistics Service of Ukraine [6]

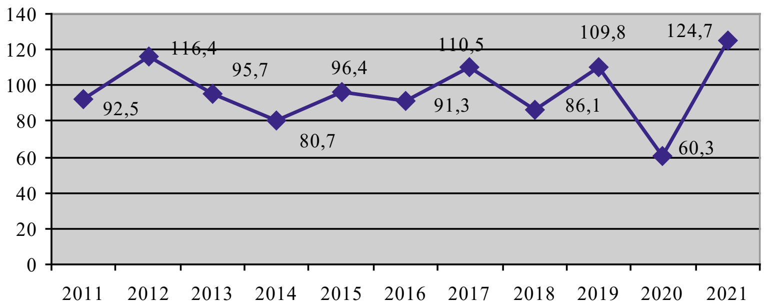

Fig. 6 Indices of construction products in Ukraine in 2010–2021, in % in contrast to the previous year. *Source* Developed by the authors based on the data provided by the State Statistics Service of Ukraine [6]

3 Development of the Construction Industry in Ukraine as the Guarantee of Stability of the State Economic Security

Analysis of the indicators of the development of the construction industry in Ukraine in 2010–2021 [8–11] reveals their instability and existing problems, which include:

- corruption. According to the analytical report, it is one of the biggest problems for both foreign and domestic construction business. High level of bribery and abuse causes the breakdown of the system of society values, total distrust of state authorities and results in negative economic effects that increase inequality and slow down the population's income growth [12, 13];
- underinvestment into construction industry. Almost absent foreign investment into the construction industry of Ukraine during the period of 2010–2021 caused by political and economic situation as well as COVID-19 pandemic [14];
- weaknesses of regulatory and information databases. Current approaches to their formation do not provide investors and contractors with clearly stated and defined criteria, which could be used for quick, efficient and cost-effective conduct of procurements for the construction of industrial estates, housing and social and cultural facilities. That is why the leading factor defining a winner of the tender is the lowest construction cost that is not always a justified one especially in case of the presence and taking into account the rest of the factors that make up the advantages of other tender offers;
- lack of financial resources caused by the growth of interest rates and deterioration of lending conditions;
- weakness of the system of organization and technology of construction operation, slow introduction of new efficient developments;
- sustainable growth of the product prime cost which increases business unprofitability and decrease in its cost-effectiveness [15];
- weakness of the pricing system [16]. Corruption in the construction industry resulted in the formation of uneconomic prices for the construction products combined with the lack of regulations and methods to direct it;
- lack of skilled and qualified employees partially caused by the low level of construction education, insufficient interaction of science and practice, low level of modern developments and research, loss of professional builders due to their migration abroad [17, 18];
- high wear level of the fixed assets.

This is proved by Ukrainian indicators in Doing Business rating (Table 6) published by the World Bank by 2021. According to them, liquidation, connection to electricity systems, quality control and assurance, registration and investment in the construction industry remain the most challenging aspects [19].

Not only current issues will have intensified but also the new ones will have appeared since the beginning of the Russian Federation aggression on the territory of sovereign Ukraine.

Table 6 Ukraine's position in Doing Business rating in 2015–2020

Indicator	Ukraine's position in doing business rating					
	2015	2016	2017	2018	2019	2020
Convenience of doing business	61	83	80	76	71	64
Business registration	20	30	20	52	56	61
Building permit approval	128	140	140	35	30	20
Connection to electricity system	61	137	130	128	135	128
Property registration	37	61	63	64	63	61
Getting loans	45	19	20	29	32	37
Investors' protection	65	88	70	81	72	45
Taxation	74	107	84	73	54	65
International trade	63	109	115	119	78	74
Contract enforcement	146	98	81	82	57	63
Liquidation of an enterprise	142	141	150	149	145	146

Source Developed by the author based on the data [19]

Firstly, they will include sufficient material losses caused by the destruction of infrastructure, transport routes, damaged equipment, unfinished construction projects and building sites, etc.

Secondly, they will be connected with the worsening of the enterprise personnel potential in the construction industry due to employees' deaths and partial staff outsourcing to Europe as a result of migration.

Thirdly, because of the active hostilities in the leading construction regions (Kharkiv and Kyiv ones), partial area occupation, staff mobilization, most construction companies will not be able to restore their activity. While those, which will manage to do it, will not be able to work at their full capacity (the forecast capacity will make about 50% of pre-war output).

However, the demand growth for new housing development is being currently fixed in the western regions of the country. The rise of such requests is expected to be at the level of 30–50% compared to 2021. The introduction of mortgage programs being developed by the banking system should promote this trend. In addition, the transfer of small and medium businesses to the west of Ukraine should increase the demand for areas and premises. In such a way, we may forecast the growth of construction activity in Western Ukraine in 2022.

Ukraine will have to be rebuilt at accelerated pace after the end of the hostilities. It will cause a dramatic growth of demand for the building staff and we should start our preparation for this just now, providing higher commissions placed by the state for the training of relevant specialists during the admission campaign to vocational schools, colleges and universities in 2022.

The number of the projects similar to "Great Construction" introduced in 2020 is likely to grow. Such projects will be spread in various spheres. The problem of Ukraine's reconstruction after the war will contribute to its investment attractiveness. Equipment, construction materials and labor resources will be needed in order to rebuild the strategic facilities at the territory of the state. However, the rapid recovery of both the construction industry and the country as a whole will require financial, logistical and personnel support from partner countries.

Modernization of construction infrastructure will be necessary to ensure the efficiency of the construction industry as well as the introduction of modern forms of providing enterprises with the means of mechanization and advanced innovative technologies; improvement of their physical facilities; expansion of the sales of construction products; project financing; attracting new highly qualified personnel, monitoring the quality of the objects under construction and operation; enhancement of the regulatory framework for construction; use of world experience to develop and implement economic incentives in construction. At the same time, the reconstruction of Ukraine will require strengthening national, including economic security measures, among which the economic security of the construction industry will be of paramount importance.

Strengthening the economic security of restored Ukraine should be based on increasing the competitiveness of the industries important for the development of the national economy, which cannot be achieved without construction.

The system of economic security of the construction industry should be formed taking into account the state-regulatory, technological, managerial, and financial aspects (Fig. 7) [3, 5, 20–24].

The economic security of the construction industry requires the development of such mechanisms and tools that would ensure active investment and innovation, the increase of the production of competitive products, profitable operation of the enterprises, social and environmental protection.

In our opinion, it is advisable to apply the conceptual model of economic security of the construction industry, which consists of three groups of measures: information-analytical, regulatory, controlling (Fig. 8).

The suggested set of measures has a recommendatory theoretical and methodological content. Its implementation requires the selection of tools that will be used to identify and neutralize threats and risks to the economic security of the construction industry in both short and long term.

4 Conclusion

In conclusion, it should be noted that the construction industry plays a key role in the country's economy, which necessitates its economic security in order to stabilize the national economy under modern conditions. This requires not only monitoring the level of economic security, but also responding adequately to changes in the external environment, the emergence of potential and real threats. The prospect of further

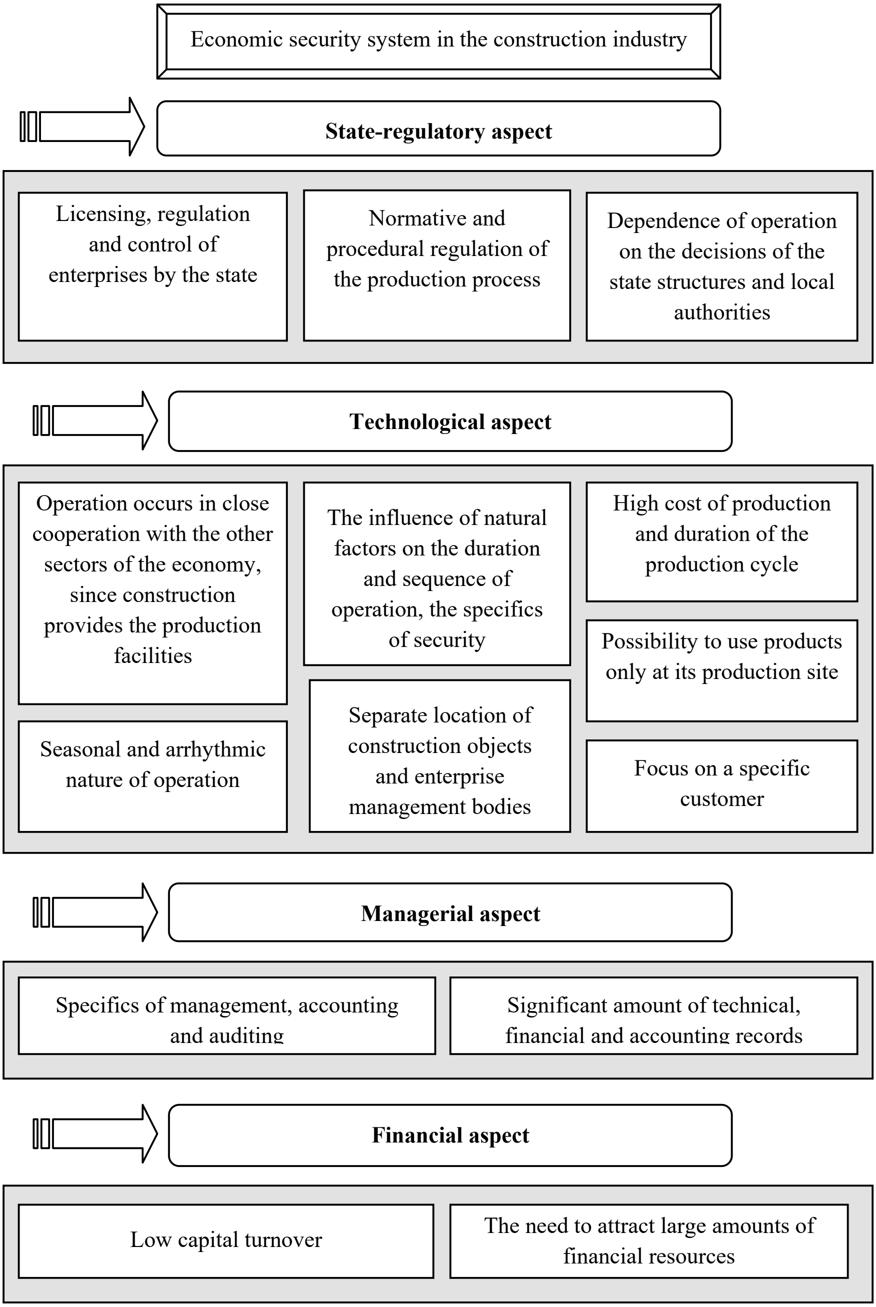

Fig. 7 Features of the formation of the economic security system of the construction industry. *Source* Developed by the authors according to [3, 5, 20, 21]

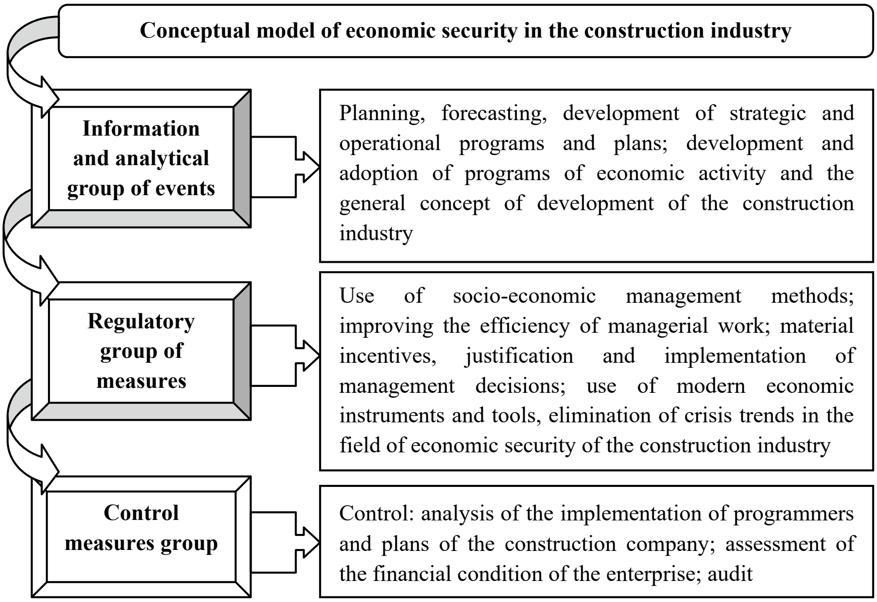

Fig. 8 Conceptual model of economic security in the construction industry. *Source* Developed by the authors

research to ensure the economic security of the construction industry is to develop tools for the implementation of the suggested conceptual model of economic security of the construction industry.

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The Formation of the Bank Optimal Loan Portfolio in the Conditions of Increasing Business Environment Risks

Olha Komelina and Yuriy Kharchenko

Abstract The article explores approaches of building an effective risk management system, which is important for both the economy business sector and the banking system. The dynamics of changes in the business environment creates a high probability of not receiving support or reducing the market value of the bank's capital. At the same time, it is necessary to assess the potential possibility of obtaining additional profit in the implementation of financial risks accepted for the bank. The changing influence of external or internal factors on entrepreneurial activity determines the potential ability of a business to obtain credit resources for development. It is proposed to use the formation of the bank's optimal loan portfolio in terms of positioners' insolvency risk to apply the classical portfolio theory and take into account the correlation coefficients between them. The formation model of the bank optimal credit portfolio for the criteria of expected income is used. The study results allow us to assess the bank lending risks, taking into account the future possibility of the borrower insolvency.

Keywords Credit risks · Business environment · Bank lending · Loan portfolio · Optimization model

1 Introduction

Achieving stability of business economic development largely depends on the availability of credit resources. That is why this problem should be studied from two sides. Firstly, from the standpoint of financial risk management in bank lending to businesses. Secondly, from the standpoint credit resources availability for business and ensuring its sustainable development.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_59

2 The Analysis of Modern Research

These issues have been widely studied in national and foreign literature [1–9]. Example, models of credit scoring started with the introduction of Altman's simple z-model in 1968. D. Pokidin focuses on the use of SVM as a model for default prediction [6]. Ruoyu Cai, Mao Zhang is study investigates the link between two major risks in the banking sector [7]. I. Voloshyn proposes a model for predicting the expected drawn amount of credit facilities [8]. Attila Csajbok, Pervin Dadashova, Pavlo Shykin, Balazs Vonnak have constructed an analytical framework for the timely detection of risks connected with the rapid growth of consumer lending, based on an econometric model for the equilibrium level of household and consumer loans. Results from an estimation on a panel of countries were extrapolated to the Ukrainian banking sector [9].

3 Purpose of the Article

The aim of the study is to apply the classical portfolio theory to form the optimal loan portfolio of the bank in a situation of insolvency risk of individual borrowers and taking into account the correlation coefficients between them.

4 The Main Material of the Study

In the modern market of banking services, the risk is growing. It is caused by the constant action of exogenous and endogenous factors. In such a situation, building an effective risk management system becomes even more important. The main risk is considered to be the probability of income or reduction loss of the market value of the bank's capital due to adverse external or internal factors, the corporate governance state, as well as the potential for additional profit in the certain acceptable financial risks event. Thus, in the conditions of objective existence of banking risk, there is a need of a certain mechanism that allows to take into account the risk while making management decisions.

The main purpose of the bank's loan portfolio management is to ensure maximum profitability at an acceptable level of risk. The level of profitability of the loan portfolio depends on the structure and its volume, as well as the level of interest rates on loans. Also significantly affected by the specifics of the market sector served by the bank, i.e. the probability of future insolvency of borrowers. When forming the structure of the bank's assets, the decisive factor is the each type of active operations profitability level. However, high profitability is usually accompanied by an increased level of risk, so both factors must be taken into account by the bank's management.

The economic-mathematical model proposed in the first figure [1], provides an opportunity to reduce the risk of obtaining the total consolidated income of the loan portfolio in the amount less than expected. This model takes into account the maximization of the expected total consolidated net income of the loan portfolio and the income variance minimization. The individual attitude to the possible risk of a particular creditor is taken into account as well.

If the bank satisfies the loan request and the borrower fulfills the loan agreement, the net income of bank D, which is reduced to T_0, will be calculated by the following formula:

$$D = -Q + \sum_{i=1}^{m} \frac{V_i}{1 + r_i}, \tag{1}$$

m—the number of future payments;

i—number of separate payment (i = 1, …, m);

Q—the size of the loan;

V_i—the size of future payments;

r_i—the discount rate.

In formula (1), the discount rate for the time point T_i is equal T_0:

$$r_i = (1 + r)^{T_i - T_0} - 1,\ i = 1,\ \ldots,\ m, \tag{2}$$

r—standard daily rate of credit resources usage;

T_0—calendar time of the loan;

T_i—the time calendar moments of future payments.

During the optimal loan portfolio formation in the deterministic case, a set of n loan requests for the time T_0, which have passed the preliminary examination, can be satisfied by the bank. It is necessary to form a loan portfolio that would provide the bank with the maximum consolidated income from the placement of available T_0 credit resources, R provided a guarantee of full repayment by the borrower. The model of the problem is written as follows:

$$\left.\begin{array}{c} D_\Sigma = \sum\limits_{j=1}^{n} D_j x_j \ \rightarrow\ \max \\ \sum\limits_{j=1}^{n} Q_j x_j \le R \\ x_j \in \{0;\ 1\},\ j = 1,\ \ldots,\ n \end{array}\right\}, \tag{3}$$

n—the number of credit requests that have passed the preliminary examination;

j—number of a separate credit request;

D_j—consolidated net income on the j request from among those considered for time T_0;

X_j—an unknown logical variable that reflects the fact of including a j-loan request in the loan portfolio ($x_j = 1$) or failure ($x_j = 0$);

Q_j—the size of the loan on j request for time T_0.

But while lending, there is always a risk $p \in [0; 1]$ of the future borrower's insolvency. In such a situation, it is necessary to calculate the expected consolidated net income $\overline{D}$ and the variance of the consolidated net income σ^2. The total consolidated net income of the bank (loan portfolio income) is a random variable $\overline{D}_\Sigma$, the expected value of which is defined as the sum of the expected net income $\overline{D}_j$ of each of the loan requests $x = (x_1, \ldots, x_n)$ for $j = 1, \ldots, n$.

While calculating the variance value of the total consolidated net income of the loan portfolio σ_Σ^2, in addition to data on the variance of consolidated net income for individual loan requests, the correlation coefficients between the possible individual borrowers' insolvency of the j and k loan requests should be taken into account ρ_{jk}. Thus, the optimal loan portfolio is formed according to the criteria of expected income and standard deviation of total consolidated net income.

The objective function of the model includes maximizing the expected income and minimizing the loan portfolio income dispersion, i.e. reducing the risk of obtaining total consolidated net income in the amount less than expected. A certain compromise between the two criteria in the objective function provides the parameter k, which is determined by the level of risk aversion of a particular bank. Then the economic-mathematical model of the problem will look like the following formula:

$$\left.\begin{array}{c} z = \sum\limits_{j=1}^{n} \overline{D}_j x_j - k \sum\limits_{j=1}^{n} \sum\limits_{k=1}^{n} \rho_{jk}\sigma_j\sigma_k x_j x_k \rightarrow \max \\ \sum\limits_{j=1}^{n} Q_j x_j \le R \\ x_j \in \{0; 1\},\ j = 1, \ldots, n \end{array}\right\}. \quad (4)$$

The offered model was used in the study of many credit requests that have passed the preliminary examination and can be fulfilled. It is taken into account that the amount of the loan for 1 year cannot exceed 20,000 USD and the financial resource of the bank for a certain type of loan is 120,000 USD. The optimal loan portfolio under these conditions must be determined.

During the model construction, a table is first developed with the loan repayment schedule and the amount of future payments, which are reduced to T0. Next, the bank net reduced income on credit requests and also the total bank reduced income are calculated as the sum of the bank net reduced income on satisfied credit requests. The target function is the maximum total reduced income of the bank on satisfied loan requests (3). Under deterministic conditions, the optimal loan portfolio was obtained, which consists of 8 satisfied requests in the amount of 118,000 USD. That is, the financial resource is almost completely used. It will provide the bank with a

Table 1 The results of calculating the optimal loan portfolio

Date	01-02-2021	01-03-2021	01-04-2021	…	01-02-2022				
Daily percentage rate			0.001			NVP	X	Di*Xi	Qi*Xi
1	−10,000	1166.882	1131.281	…	833.188	1900.26	0	0.00	0
2	−5000	583.441	565.641	…	416.594	950.13	1	950.13	5000
3	−15,000	1750.324	1696.922	…	1249.782	2850.39	1	2850.39	15,000
4	−12,000	1400.259	1357.538	…	999.826	2280.31	0	0.00	0
5	−20,000	2333.765	2262.563	…	1666.376	3800.52	1	3800.52	20,000
6	−8000	933.506	905.025	…	666.550	1520.21	1	1520.21	8000
7	−15,000	1750.324	1696.922	…	1249.782	2850.39	1	2850.39	15,000
8	−10,000	1166.882	1131.281	…	833.188	1900.26	0	0.00	0
9	−20,000	2333.765	2262.563	…	1666.376	3800.52	1	3800.52	20,000
10	−8000	933.506	905.025	…	666.550	1520.21	0	0.00	0
11	−15,000	1750.324	1696.922	…	1249.782	2850.39	1	2850.39	15,000
12	−20,000	2333.765	2262.563	…	1666.376	3800.52	1	3800.52	20,000
13	−12,000	1400.259	1357.538	…	999.826	2280.31	0	0.00	0
14	−5000	583.441	565.641	…	416.594	950.13	0	0.00	0
15	−10,000	1166.882	1131.281	…	833.188	1900.26	0	0.00	0
Sum	−185,000					Together	8	22,423.10	118,000
	120,000	A credit limit							

maximum total reduced income of 22,423.10 USD. The results of the calculations are presented in Table 1.

In a risk situation, the correlation coefficients between the insolvency of individual borrowers (expert estimates) are taken into account and the expected net present value (NPV), standard deviation of NPV, expected income from loans and loan amount are calculated. The controlled parameter is a logical variable. The additive objective function (4) has three values with different coefficients of risk aversion (moderate, medium, high). After building the model, the parameters for different credit policy strategies are calculated. The optimal loan portfolio formation results for a high level of reluctance are shown in Table 2.

The obtained data for different coefficients of risk aversion are copied into a separate Table 3.

Thus, after analyzing the results, we can say that using a moderate risk aversion ratio in the formation of the bank's loan portfolio will be optimal decision to issue 11 loans amounting to 115,000 USD, medium—6 loans amounting to 55,000 USD, and high—3 loans in the amount of 18,000 USD. That is, preference is given to credit requests with a smaller amount and a minimum future probability of the borrowers' insolvency. As the risk aversion increases, the number and amount of loans issued decrease. That is, for these conditions, the bank almost completely uses the available credit resources only with a moderate risk aversion ratio.

Table 2 The results of the calculation for a high level

∑V	Qi	p	D	σ	Xi	Di*Xi	Qi*Xi
1900.262	10,000.00	0.00010	1899.072	118.997	0	0.000	0.00
950.131	5000.00	0.00010	949.536	59.498	1	949.536	5000.00
2850.394	15,000.00	0.00015	2847.716	218.605	0	0.000	0.00
2280.315	12,000.00	0.00010	2278.887	142.796	0	0.000	0.00
3800.525	20,000.00	0.00015	3796.955	291.474	0	0.000	0.00
1520.210	8000.00	0.00010	1519.258	95.197	1	1519.258	8000.00
2850.394	15,000.00	0.00020	2846.824	252.417	0	0.000	0.00
1900.262	10,000.00	0.00015	1898.477	145.737	0	0.000	0.00
3800.525	20,000.00	0.00020	3795.765	336.557	0	0.000	0.00
1520.210	8000.00	0.00020	1518.306	134.623	0	0.000	0.00
2850.394	15,000.00	0.00010	2848.609	178.495	0	0.000	0.00
3800.525	20,000.00	0.00010	3798.145	237.993	0	0.000	0.00
2280.315	12,000.00	0.00010	2278.887	142.796	0	0.000	0.00
950.131	5000.00	0.00010	949.536	59.498	1	949.536	5000.00
1900.262	10,000.00	0.00015	1898.477	145.737	0	0.000	0.00
Together						3418.3303	18,000.00

Table 3 The final data

The borrower	The level of risk aversion			The amount of issued loans		
1	1	1	0	10,000.00	10,000.00	0.00
2	1	1	1	5000.00	5000.00	5000.00
3	0	0	0	0.00	0.00	0.00
4	1	1	0	12,000.00	12,000.00	0.00
5	0	0	0	0.00	0.00	0.00
6	1	1	1	8000.00	8000.00	8000.00
7	0	0	0	0.00	0.00	0.00
8	1	0	0	10,000.00	0.00	0.00
9	0	0	0	0.00	0.00	0.00
10	1	0	0	8000.00	0.00	0.00
11	1	1	0	15,000.00	15,000.00	0.00
12	1	0	0	20,000.00	0.00	0.00
13	1	0	0	12,000.00	0.00	0.00
14	1	1	1	5000.00	5000.00	5000.00
15	1	0	0	10,000.00	0.00	0.00
The amount of loans	11	6	3	115,000.00	55,000.00	18,000.00
z	11,942.762	3976.232	1455.725			

5 Conclusion

Measuring, minimizing and controlling the level of credit risk is an important task of bank risk management. With the help of the proposed model, it is possible to take into account the maximization of the loan portfolio expected total consolidated net income and the income variance minimization during the formation of the loan portfolio. The model also uses data on the correlation coefficients between the individual insolvency of borrowers' loan requests and parameters, which determines the level of risk aversion of a particular bank. That is, the risk of the creditor receiving total consolidated income in the amount less than expected is reduced. Optimizing the structure of the loan portfolio allows you to balance and contain the risk of the entire portfolio, as well as control the risk inherent in certain markets, customers, loan instruments and operating conditions.

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Non-financial Indicators of the Construction Business Management Effectiveness Evaluation

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Abstract The article deals with scientific approaches to understanding the concept of "efficiency" of an organization, in particular from a management point of view. The main problems that prevent the successful evaluation of the effectiveness of modern construction company management are highlighted. Authors proposed a methodology for evaluating the effectiveness of management activities that can be implemented in modern Ukrainian construction company. It is shown that although the problem of performance evaluation has been studied in various Ukrainian studies, the scientific results do not have certain instructions that could be implemented in the practical directions of today. The set of partial financial and non-financial indicators, which should be measured, is generalized to form strong prerequisites for an objective and independent evaluation of the activities of construction company executives. The performance evaluation of the management subsystem includes the effectiveness assessment of management personnel, the effectiveness of management technology, the effectiveness of management organizational structure of. Among the indicators for assessing the effectiveness of management as an integrated set of management and managed subsystems are indicators: the effectiveness of organizational culture, the effectiveness of managing operational activities, personnel, financial activities, marketing, investment and innovation activities. It is proved that financial indicators are the overwhelmingly significant part of the performance evaluation indicators of modern construction company. Non-financial indicators receive less attention even at the theoretical level, although they remain an integral part of a comprehensive management assessment. Among the reasons for the unpopularity of non-financial indicators, the authors identified: the lack of quantitative non-financial indicators of a uniform dimension; the blurry and uncertainty of information support, sources for calculating non-financial indicators; complexity of obtaining initial data; failure to fulfil part of the non-financial indicators of the criterion function, which leads

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_60

to ambiguity in the interpretation and evaluation of the results. The value of non-financial indicators is seen not only in supplementing the financial in creating a more objective picture, but also in exposing the root causes of obtaining the ultimate construction company financial results.

Keywords Management effectiveness · Effectiveness assessment · Non-financial indicators · Financial indicators · Construction company

1 Introduction

The problem of assessing the effectiveness of managerial activity over the last decades has caused controversy among a wide range of scholars. Economists have taken a number of approaches to understanding and solving this problem, among which, however, one dominant has not yet been observed.

In today's economic literature, there are many scientific approaches, complex and specific ways of calculating the effectiveness of management. According to researchers Y. Lapygin and A. Ursul [10, 17], the effectiveness of management is the result of the relationship between cost (efficiency) and efficiency. An alternative is A. Malytskyi's theory, which proposes to consider control efficiency as a synthesis of potential, realized and achieved efficiency [9].

Non-financial indicators of management effectiveness at foreign construction company are determined and evaluated in the framework of specialized questionnaire techniques intended for self-assessment by managers. One of them is L. Svatushke's technique [1], according to which the manager himself determines the real level of managerial efficiency by evaluating the elements of his activity. The same principle is based on the questionnaires of G. Shchokin and V. Stepanov [16, 18].

Contrary to best practice abroad, the importance of applying non-financial performance to management is constantly ignored in the scientific literature of Ukraine—the focus is on the financial aspect and the available research is selective or overly schematic. A scientific study is needed that would, by synthesizing the findings, give an idea of a non-financial way of evaluating management.

2 Purpose of the Article

The purpose of the article is to formulate scientific and theoretical bases for evaluating the effectiveness of management activities using non-financial indicators.

3 Research Methods

Methods of research: analysis—in the detection of multiple views in scientific literature on the concept of managerial effectiveness; abstraction—when trying to isolate system of assessment of construction company management from its environment; generalization—when forming a comprehensive list of different types of indicators that form the basis of management evaluation; comparison—when formulating a fundamental difference in the interpretation of concepts.

4 Results

The intuitive notion of efficiency is often perceived as equivalent to quality or success (profitability, efficiency), but in a scientific sense, efficiency is rigidly defined as the ratio of a useful result (effect) to the cost (in any expression) of achieving it. The negative (loss) and positive (achievement) impact of a purposeful action, process or decision are compared, and the result of the comparison is quantified, compared to established norms or standards and used to consider the feasibility of making changes to the object of performance evaluation. In this context, it is easy to determine the effectiveness of management activities as the ratio of the overall performance of managers (implementation of management functions, development and implementation of necessary decisions, achievement of different types of goals set, the realization of potential organizational capabilities) to the costs associated with obtaining these management results [4, 5].

The concept according to which the effectiveness of management is characterized by the comparison of results and costs of the management system, researchers call functional [6] (sometimes referred to as “economic”, but such a term in this context is inappropriate, since it leads to confusion with cost-effectiveness as a type of efficiency alongside technical and social, characterized by cost measurement of results and costs).

The result of managerial work within the functional concept is measured by both positive changes in indicators that relate to both directly managerial work (complexity of managerial work, number of managerial staff, loss of management time, staff turnover), and organizational results. The simplest and most basic approach to understanding the effectiveness of management defines it as the ratio of the performance of managers to the costs associated with the implementation of this activity, ie it is a characteristic of the effect from the point of view of the optimality of use of resources—material, financial, labor, information [7]. However, practical experience, first, requires the deepening of this approach and its specification, and secondly, it reveals the conceptual shortcomings of such a methodology for calculating management effectiveness, which is based only on the mathematical correlation of effect and cost.

According to Y. Lapygin and A. Ursul, management efficiency is the result of the relationship between cost and required efficiency, where cost efficiency is the inverse to the academic version of efficiency (the ratio of costs to the achieved result), and effective—the ratio of the actual achieved result to the goals [10, 17]. These types of performance are related: need determines the productive and the productive—the cost.

Somewhat different is A. Malytskyi's opinion on this problem. He proposes to consider management effectiveness as a synthesis of potential, realized and achieved (actual) efficiency [9]. Performance achieved involves determining the ratio of the result to the resources expended and comparing the obtained data with the normative values. Realized efficiency characterizes the degree of achievement of the goals of construction company (management apparatus, specific manager) and is defined as the ratio of each actual indicator to the planned. The potential management effectiveness is characterized by construction company ability to respond to new market demands in a timely and accurate manner and to adapt to the changing environment. Such ability depends on the quality of work of the management apparatus in the development and implementation of strategic and tactical plans, accounting and control of construction company.

From the definitions of the components of efficiency in two approaches, it can be seen that in the cases of necessary and effective and, accordingly, potential and realized efficiency, this term loses its primary scientific meaning and acquires the meaning of efficiency, degree of achievement of goal. This semantic transition is characteristic of vast majority of performance metrics, because of what is actually mixed, such as a manager's achievements and his ability to make good use of available resources.

However, determining the dependence of the results on the relevant costs to assess management effectiveness hampers a number of problems. First, it is not possible to establish a strong correlation between specific costs and outcomes given the presence of external and incidental situational factors affecting management output.

Second, efficiency as a mathematical relation does not in itself reveal the potential for improving the quality of work. In the case of incomplete use of resources and a correspondingly reduced result, the effectiveness of the manager's activity will be practically or completely similar to the effectiveness of his activity with full utilization of resources and, accordingly, a higher result. This problem is particularly relevant for small firms that are in the early stages of implementing systems for assessing management effectiveness and have not yet developed sound criteria for interpreting the values obtained.

Third, not all managerial outcomes can be quantified at any given time—and their qualitative expression makes it impossible to divide arithmetically or to subject the process of comparing effect with costs. Awareness of these problems forced researchers to seek approaches to defining the notion of control efficiency that would not relate to the classical mathematical definition of efficiency.

Targeted approach to determining the effectiveness of management is a concept according to which the organization's activities are aimed at achieving certain goals, and the effectiveness of management is characterized by the degree of achievement of these goals. The criteria used to reflect the result of management activities, comparing their values with those desired, are the following: sales volume of products (services); market share; the amount of profit and its types; volume or diversification of the range; sales growth rate; quality of products (services).

In essence, the target approach is identical to the effective efficiency as a component of the Lapygin-Ursula approach and the realized efficiency of A. Malytskyi. However, despite its attractiveness and simplicity, the application of the target concept is associated with a number of problems, the most significant of which are: the degree to which the goal is met is difficult to measure if organization doesn't produce tangible goods and/or is non-profit making; controversial is the existence of a general set of uniquely attainable, defined "official" goals of organization (not an abstract credo or general purpose) [19]. Composite is close to the goal approach. According to this concept, the effectiveness of management is determined by the degree of influence of management work on the organization as a whole, the degree of participation of managers in such activities [9].

An approach to determining the effectiveness of management based on the achievement of a "balance of interests" (also a behavioral approach) implies that construction company activities are aimed at meeting the expectations, expectations and needs of all individuals and groups interacting with the organization and with construction company. Determining the effectiveness of management is based on measuring the degree of satisfaction of the needs of all entities interested in the results of the organization—external (suppliers, consumers, owners, the state) and internal (units, groups, individual employees). The main criterion for assessing the effectiveness of management under this concept is to minimize the satisfaction gap between all those interested in the results of construction company of the groups. Methods for both direct calculations and indirect evaluation (peer reviews, questionnaires, etc.) are used to determine the indicators that characterize the achievement of managers of this criterion.

According to system concept of management effectiveness, the results of construction company activities are significantly influenced by environmental factors, and therefore the effectiveness of management is characterized by degree of adaptation of construction company to its external environment. The system concept is based on two principles:

1. The survival of construction company depends on its ability to adapt to the demands of the environment.
2. In order to meet these requirements, the full cycle of "inputs – process – outputs" should be the focus of management [19].

The notion of effectiveness of management activities is clearly not one of those in which researchers show a convergence of opinion. Such inconsistency causes the complexity of any scientific consideration of the management system itself with the use of precise categories, the complex and heterogeneous nature of the management process, the considerable situational nature of the work of construction company operating there, evaluation and goal setting, as well as the huge diversity of social and production and economic results that are not reduced to a single meter.

The extremely high degree of interpenetration of the work of managers and their subordinates makes it impossible to consider the results of the management system in isolation from the managed system. In international practice, to assess the effectiveness of management is proposed to use indicators that do not measure the effectiveness of managers as individual employees, constituent staff of construction company, but instead serve to evaluate the effectiveness of the whole enterprise as a direct consequence of managerial work. Obviously, in such a case, it is advisable to talk about the effectiveness of purely top management, professionals who shape the internal environment of construction company and determine the direction of its activities.

Approaches to defining the concept of performance can be dramatically different, so there is a phenomenon of convergence or identification of these concepts. To avoid any misunderstandings, it is worthwhile to point out the semantic aspects of using them when evaluating management performance.

The criterion of effectiveness is a certain characteristic, on the basis of which the conclusion is made about the effectiveness or inefficiency of the investigated object (another reason may be a comparison with the corresponding values of competing firms, values of previous periods, targets, expected or forecast values). In science, the wording "evaluation of the effectiveness of management by criterion…" is accepted. For example, the maximum effect derived from each unit of cost (maximum result estimate) or the minimum cost per unit of effect (minimum cost estimate) may serve as a feature.

In the literature, the evaluation of management effectiveness is often reduced to the evaluation of construction company, through the analysis of various financial indicators such as profit, profitability, market value of construction company [2, 9, 13]. In the United States, recommendations for assessing the performance of construction company are set out in the Statement on Management Accounting Measuring entity performance (SMA 4D) standard of management accounting. This document proposes to use such indicators to evaluate the effectiveness of the company (and its management) [5]: net profit and earnings per share (EBIDTA, EPS); company value (MV, MVA); cash flow indicators (CVA, CFROI, etc.); return on Investment (ROI); residual income (RI).

These indicators are the most common and indirect way to determine the effectiveness of management. They relate to the situation of construction company on the largest scale, consider only the most significant manifestations and the end results of its activity. All cause and effect relationships that led to the values obtained, most aspects of internal activity and management decisions found in the global results remain unaddressed. Therefore, there is a need to consider a system of diversified indicators that affect all components of management activities and, in their totality, provide an objective and weighted picture of management processes, their comprehensive presentation.

The global problem of evaluating management effectiveness is that governance is not, by its nature, a self-contained independent system, a vacuum phenomenon. It is wrong to consider the results of the management of the result of purely managerial activity, because in reality the finished product form is provided by ordinary employees, not managers [19].

Management effectiveness is often directly dependent on the effectiveness of the controllable system, which is why we propose to extend context of analysis of controllability through common indicators that logically include the effectiveness of the subordinate system. Such indicators evaluate activities that cannot be defined as purely managerial; they refer to management as an integral phenomenon, which combines work of managers and subordinates, and indirectly indicate the result of management activities.

We consider it important to note that part of the existing performance indicators focuses on the effectiveness of management as a purposeful process, while the other part—on the face of the manager as an employee, specialist. Although management effectiveness is a direct consequence of the manager's activities, the interpretation of such indicators and the corresponding measures in two cases will be dramatically different (focus on management technology or staff management), so in our view, the use of both types of indicators is necessary for objective the reproduction of the state of affairs in construction company management.

One of the key classification features in dividing management performance is the use of monetary (financial) values in their calculation. This distinguishes between financial and non-financial indicators. Financial indicators have a monetary measure (the result of cash transactions) and are related to the financial results of the enterprise, and to calculate them are data of all applicable types of internal reporting and forms of external audits. Non-financial indicators do not have a monetary measure, money is not involved in their calculation [3], instead they are expressed in pieces, percentages, units of time or in qualitative categories.

For clarity, the overall effectiveness of management is divided by marketing, production, financial, innovation, personnel and other components of construction company [5]. With this in mind, it is possible to form a list of key performance non-financial indicators for management of various types (Tables 1 and 2).

The activity of construction company can be conditionally represented as a chain of results, at each link of which the manager has a direct or indirect influence. Accordingly, each result can be an indicator of the effectiveness of such an impact. However, to increase the objectivity of performance appraisal, it is necessary to consider those results that are as close as possible to the beginning of the chain and affect the formation of each successive link. Therefore, these non-financial indicators relate mainly to the baseline, primary results that, in the course of construction company operation, act as catalysts for the more general ones. Obviously, the lack of product quality, customer satisfaction, or staff productivity can be used as key non-financial indicators of management effectiveness, however, estimating the values of these outputs requires clarifying their factor components (Table 1).

Naturally, financial performance is a major part of management performance indicators. This is due to established traditions to evaluate the activity of construction company based on the data of its accounting, first and foremost, financial statements. Non-financial indicators receive less attention even at the theoretical level, although they remain an integral part of a comprehensive management assessment. Among the reasons for the lower popularity of non-financial indicators are:

Table 1 Non-financial indicators to evaluate the performance of the management subsystem

Composite assessments	Indicator
Evaluation of the effectiveness of management personnel	The coefficient of quantitative and qualitative staffing of management staff
	The share of management personnel with over 5 years of experience in the enterprise and in the industry
	Sustainability ratio of management staff
	The staff turnover factor
	Management staff replacement rate
Evaluation of the effectiveness of management technology	The coefficient of efficiency of work with documents and other sources of information
	Information utilization rate
Evaluation of the effectiveness of management technology	Coefficient of coverage of automation control functions
	The coefficient of growth of technical equipment of administrative work
Evaluation of the effectiveness of the organizational structure of management	Coefficients of observance of standards of management of links of management
	Duplication ratio of functions

Sources developed by author based on source [5]

1. Absence of quantitative non-financial indicators of uniform dimension, which complicates the process of determining and comparing the result with the data of previous periods, goals, forecast values or indicators of competitors [12]. The issue of establishing non-financial units of measurement has to be considered on a case-by-case basis, which makes it impossible to apply the automation of valuation. For example, for a trading company, the obvious alternative is to measure the sales of products in natural-material form (pieces, tones, etc.), but this approach loses its sense in the presence of at least minimally diversified assortment with different prices or when providing services of different type and complexity. In countries where full-fledged public non-financial reports remain widespread and the samples available are non-standard and predominantly promotional (as in Ukraine), the problem described may also lead to management attempts to manipulate the non-financial information received for its own benefit [11].
2. Uncertainty of information support, sources for calculation of non-financial indicators; the complexity of obtaining the raw data. If the non-financial performance indicators of HRM can be calculated on the basis of generally accepted documents, in order to evaluate the effectiveness of organizational culture, the company has to use third-party services, improve the formalization of reporting, for which no formal regulations have been developed or develop their own methods (observation, polling, fidgeting) and submitting information in non-standardized forms. It becomes apparent that such processes require additional

Table 2 Non-financial indicators to evaluate the effectiveness of management as an integrated set of management and managed subsystems

Composite assessments	Indicator
Assessment of organizational culture effectiveness	The level of organization of the business units
	Level of work discipline
	Level of satisfaction with working conditions
	The level of social and psychological climate in the team
	The level of safety and health protection
	Level of conditions of social development and social protection of personnel
	Coefficient of compliance with the environmental performance of operating activities
Evaluation of the effectiveness of personnel management	Coefficient of completeness of implementation of management decisions
	Coefficients of quantitative and qualitative staffing of the company
	Coefficient of the staff turnover factor of the enterprise
	Coefficient of replacement of personnel of the enterprise
	Assets ratio of current assets
Evaluation of the effectiveness of marketing activities management	The share of production of the enterprise in the national market
	Coefficient of change in the volume of sales of products
	The share of high-tech equipment in the total value of fixed assets
	The growth rate of intellectual property rights

Sources developed by author based on source [5]

costs (as an option, additional staffing) and the reliability of the data thus obtained is reduced.

3. Failure to fulfill part of the non-financial indicators of the criterion function, which leads to ambiguity in the interpretation and evaluation of the results obtained [5, 12]. Measuring the degree of satisfaction of the interests of the groups involved in the work of construction company should be combined with measuring the costs of achieving a certain level of satisfaction, that is, with the involvement of the financial component; performance indicators of the manager with information sources should be supplemented by the values of completeness

of processing and use of these sources; when assessing formalization or structural centralization, it is necessary to make adjustments to the type of activity, psychotypical staff composition, timeframes for completing tasks, etc.

Despite the significance of the above problems, researchers of the issue of non-financial performance indicators unanimously argue that their application is still absolutely necessary for the full and comprehensive reproduction of the state of management and business in the enterprise as a whole. Moreover, often the value of non-financial indicators is seen not only in supplementing the financial when creating a more objective picture, but also in exposing the root causes of obtaining the final financial results of construction company.

Thus, N. Bilynska states "Non-financial aspects of an enterprise's activity potentially affect its financial performance, which makes them an important source of strategic planning and forecasting of its results" [3].

The estimation given in Table 1 non-financial performance management allows you to diagnose most of the positive and negative results of management: staff efficiency, product quality, its compliance with current and future requirements, the number of contacts with customers, the introduction of new technologies. These results will lead to financial consequences for construction company in the future, such as: volume and profitability of sales, level of net profit, market share, and financial independence.

Conversely, to find out the possible reasons for changing the financial performance, you can refer to non-financial values for the same period and for previous periods. It is obvious that, for example, a decrease in sales volumes (financial indicator) may be facilitated by a drop in the quality of products produced under conditions of poor labor discipline or staffing (non-financial indicator), and the loss of market share (financial indicator) may be caused by low values implementation of management decisions (non-financial indicator) on the introduction of innovative technologies.

This link between non-financial and financial performance is enshrined in the Balanced Scorecard (BSC), a strategic performance management tool developed by American researchers R. Kaplan and D. Norton in the early 1990s [14, 15]. BSC is used to provide the functions of gathering, systemizing and analyzing the information needed to make strategic management decisions, which assesses the performance of the company, its divisions and CEO (heads, executives) on the basis of four balanced parameters: shareholder relations (external finance), relationships with clients, in-house business processes, as well as level of innovation and personnel training [8]. Last 3 parameters (which are almost entirely composed of non-financial indicators) provide the fourth component—long-term financial success of the company:

- customer relations: number of customers, market share, customer loyalty index, customer satisfaction index;
- internal business processes: timely delivery, production cycle efficiency (MCO), level of labor productivity, production preparation time, the impact of administrative errors;

– opportunities for training and staff development: staff turnover, number of employees who have undergone training or advanced training, time for training, employee satisfaction index.

5 Conclusions

These performance indicators provide an overview of possible ways of non-financial management system evaluation. Development or choice of specific indicators, the method of their calculation (including the possibility of providing them with financial or non-financial form), as well as the establishment of normative values and importance of indicators in the final assessment is in accordance with a number of situational characteristics of construction company: industry and type of activity, spectrum partners, the size of construction company and its position in the market, legislative requirements, foreign policy conditions, management strategy, plans, general values.

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Role of Partial Credit Guarantee Scheme in Enabling Growth of SME

Emil Mahabbat Mammadov, Aleksandr Belov, and Lyudmyla Svistun

Abstract Despite their importance Small and medium sized enterprises (SMEs) in Azerbaijan and in other developed and developing countries suffer from limited access to financing due to high costs of small-scale lending, information asymmetry, high risks attributed to SMEs and collateral requirements. Thus, the lack of SME access to finance is to the large extent the consequence of weaknesses in enabling environment for finance. Shortfall in enabling environment becomes major constraint for economic growth and diversification and/or causes regionally-unbalanced growth. These deficiencies motivate government to make policy interventions toward SME financing expansion. Largely interventions come in form of credit guarantee schemes (CGS), direct lending facilities and lending by state-owned financial institutions. In turn, partial credit guarantee schemes are considered as most market friendly intervention type. There are also notable examples when countries like South Korea employed PCG as countercyclical policy tool to face difficulties came from economic downturn. The diverse and resilient SME sector is the center piece of the Azerbaijan government's strategic agenda to diversify the economy away from oil. Credit Guarantee Schemes were introduced in Azerbaijan as a measure of Government to make financing accessible for SMEs and to reduce effect of negative impact of two recent major events: the drop in worldwide oil prices and COVID-19 pandemic. The objective of this paper is to review characteristics of Credit Guarantee Schemes and assess preliminary outcomes of Partial Credit Guarantee mechanism implementation in Azerbaijan.

Keywords Credit guarantee systems · SME · Information asymmetry · Sustainable development

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_61

1 Introduction

SMEs are an important part of economy and make a key contribution to the net creation of jobs, especially smaller and young firms. In developing economies SMEs provide two-third of all formal jobs and contribute to a large share of GDP [1].

Nevertheless, many of SMEs, with economically viable projects, due to lack of necessary amount and type of assets that could serve as collateral for the loan cannot obtain the necessary financing from the conventional system of financial intermediation. Besides, banks are often do not accept some kind of collateral such as stocks, receivables, inventory, etc. This phenomenon is often stated as the SME financing gap, i.e., an insufficient supply of credit to SMEs [2] (Fig. 1).

2 Purpose of the Article

The diverse and resilient SME sector is the center piece of the Azerbaijan government's strategic agenda to diversify the economy away from oil. Credit Guarantee Schemes were introduced in Azerbaijan as a measure of Government to make financing accessible for SMEs and to reduce effect of negative impact of two recent major events: the drop in worldwide oil prices and COVID-19 pandemic.

The objective of this paper is to review characteristics of Credit Guarantee Schemes and assess preliminary outcomes of Partial Credit Guarantee mechanism implementation in Azerbaijan.

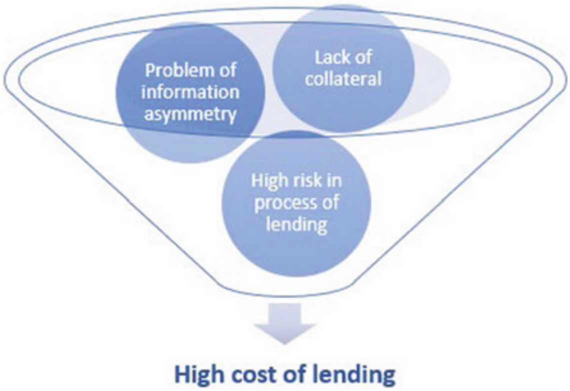

Fig. 1 Obstacles to accessing finance by SME

3 Main Part

3.1 Research Methodology

Systematic conceptual approach and analytical generalization methods were used in the research process. The research database consists of the materials of the AECM, MCGF, other scientific articles on implementation of credit guarantee schemes.

3.2 Results, Discussions

Financial institutions reluctancy to extend uncollateralized loan to SMEs, even at high interest rates, is in part due to the high costs of obtaining adequate information on the true credit quality of small and possibly young companies. Large companies can be expected to employ particular corporate standards and reporting forms, whereas for SMEs it is even hard to divide lines between company and personal assets. Moreover, SMEs have shorter Credit history and operational records. As a result, we may see how information asymmetry arise between lender and borrower. Nowadays, banks widely use collateral requirement as counterweight designed to reduce risks rising from information asymmetry. Consequently, collateral requirements become one of major obstacles for SMEs in the process of accessing finance. Existence of information asymmetry affects heavily decision-making process in financial institutions putting lenders to more disadvantaged position. Due to this fact, lender will have less information relating to borrower, such as project risk, the effectiveness of the project, plans, accounting data and etc. Therefore, lender will spend significant resources to process of information collection, procession and operational processes monitoring. Nevertheless, this is not easy task for financial institutions due to the fact that, SMEs information is very diverse and imperfect as result of absence of standardized reporting married with weak accountancy. Accordingly, financial institutions will have limited options for reducing potential risk of credit loss:

(a) Keep credit supply below demand
(b) Raise interest rates
(c) Increased requirement for collateral.

Consequently, information asymmetry converted by financial institutions in the process of risk reduction into limited supply, high interest rates and relatively high requirement for collateral make difficult for SMEs in accessing finance.

Another problem which comes from information related problems is adverse selection. Adverse selection starts when probability of default increases with increase in interest rates. Increased interest rates demotivate safe borrowers from taking loan and drive them out of applicants list while riskier ones remain. As a result, this leads to an increasingly riskier loan portfolio and banks do not rise rates above certain level. Instead, they prefer to focus on quality. Desire of bank to control adverse selection and lending admin costs may push them toward decision making process based on firm-size and collateral selection. Thus, larger companies with aligned reporting systems, transparent business processes and valuable mortgages could be in advantageous position from cost benefit point of view for the lenders. The vivid example of adverse selection pointed in research by Stiglitz and Weiss [3].

As direct credit programs have rarely had expected success, many countries found solution in making CGS funds a central part of their strategy to reduce SMEs financing constraints. Guarantees allow the risk to be partially shifted from a lender to guarantee scheme and are particularly useful in times of increased volatility when lenders are facing increased risk due to the economic downturn, and uncertainty as to how long the pandemic will continue. Guarantees help to protect against risk, reduce the constraints facing SMEs in accessing financing and get finance flowing to SMEs again. Another effective tool for minimizing risks in lending is the loan securitization mechanism [4].

CGSs have been used for over decades in developed countries while their use in developing countries is more recent. These schemes seek to expand lending to SME, sometimes focusing on specific regions or sector through sharing lending risk. Besides, they can catalyze processes of development in emerging economies where SMEs financing gap is generally wider than in developed economies.

Credit guarantee scheme have several objectives and its goals can be classified into following levels:

- At macro level: economic development, reduce unemployment, reduce poverty, improve market lending to SMEs;
- At micro level, credit guarantee scheme serves as an intermediary with the objective to support for borrower and incentive for lenders.

In times of financial downturns CGSs can be used as a part of a counter-cyclical public policy toolkit to support lending to SMEs. Public sector involvement is usually judged to be necessary to supply guarantee products in sufficient amounts. Particularly, during financial crisis in 2008 most of European countries have chosen CGS as an instrument to face turbulences in economy. According AECM (European Association of Guarantee institutions), in 21 countries credit guarantee operations rose by 22% from 2007 to 2009 to ensure that SMEs have enough financial resources to operate and deal with financial crisis. Considering the fact that during economic downturns financial institutions tend to increase requirements for collateral [2], CGS starts to play role of an effective tool to support SMEs to overcome this obstacle by partly substituting requirement for collateral with the protection provided by Credit Guarantor. Well priced and well-designed CGS effectively reduce cost of lending through sharing of default risk and reduction of loan's risk price. Practically collaterals and guarantees often used side by side on the same loan. This approach of employing partial guarantees is designed to control and reduce borrower's incentive to default. On the other hand, if significant part of risk is taken by CGS, lenders may not have incentives for proper screening and credit monitoring and could be encouraged to consider higher-risk borrowers who are willing to pay higher interest rates on loan. This moral hazard can be controlled through adoption of proper risk sharing in order to make certain that the borrower, the lender and guarantor will retain sufficiently high level of potential loss in case of default to ensure repayment of the loan [5].

As an example, moral hazard could be reduced by designing rules governing collection process in such a way that they will suspend guaranty pay-out until recovery actions are initiated by lender. In fact, Partial Credit Guarantee Schemes (PCG) better solve above mentioned problems and help to avoid risky lending incentives. Taking part of the risk can increase motivations of lender to accurately assess and monitor borrowers and consequently reduce loan losses. Depending on strategic goals of country and market conditions guarantee coverage in PCG may differ from country to country (Fig. 2).

According AECM median coverage among EU CGSs is 70%, while minimum coverage is 40% [6]. At the same time 85% of observed CGSs apply coverage ratios less or equal to 80%.

Obviously, to extend loans to comparatively riskier borrowers, banks will intend to apply for higher coverage. We can see this risk to coverage relationship in Table 1. For example, in France and the Netherlands the coverage ratio is higher for innovative firms and start-up loans, in Korea, risky firms with low credit scores get higher coverage, etc.

Consequently, higher coverage ratio for riskier types of borrowers could be a good way to develop additionality while giving some flexibility.

However, the complete absence of collateral may generate adverse selection and moral hazard effects and ultimately result in large losses for the scheme. Hence, presence of collateral up to reasonable limits will mitigate this risk.

On the other hand, to reach financial sustainability PCGs should be capable to absorb losses and preserve an acceptable equity base. Thus, existence of effective credit risk management systems at participating banks and at the scheme itself significantly impacts on the sustainability of PCGs. Well established guarantee schemes around the world have developed internal credit scoring systems and provide assistance to partner banks in SME risk analysis and management by sharing their expertise and methodologies in building credit scoring models. Moreover, Malaysia and Korea, guarantee schemes have developed their own SME credit bureaus.

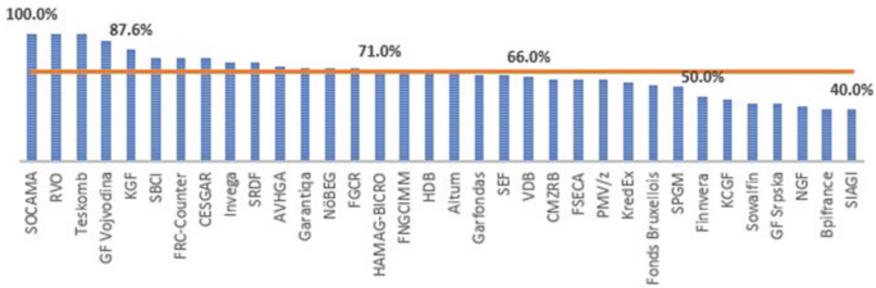

Fig. 2 Average coverage rates by CGS

Table 1 Coverage rations in selected benchmark countries

Country	Coverage ratio, %			Link to exposure
	Min	Median	Max	
Canada	85	85	85	No scalability
Chile	50	65	80	80% to small, 50% to medium firms
Colombia	40	60	80	Depending of type of loan
France	40	55	70	40–50% in general, 60% innovations, 70% start-ups
India	75	80	85	75% in general, 85% in micro loans
Korea	50	70	90	Firms with highest score 50%
Malaysia	30	65	100	According to type of loan
Netherlands	50	65	80	50% in general, 60% innovations, 80% start-ups
Taiwan	50	65	80	According to type of loan
USA	75	80	85	75% on loans > $150,000, 85% on loans ≤ $150,000
Azerbaijan	15	65	85	Depending on risk score

Consequently, in order to sustainably operate and to contribute to the financial sustainability of the guarantee scheme PCG funds tend to have Fees connected to the risk exposure.

Fees in PCGs play multiple roles. General role of fees is insurance to obtained risk. By linking price of guarantee to the risk exposure PCG funds use it as a straightforward insurance instrument. Thus, funds will aim higher fee for riskier applications and consequently to applications with higher coverage ratio.

Secondly, fees are critical source of revenue for PCG funds. It allows to funds to achieve financial sustainability. Finally, fees play important role in building additionality. By properly calibrating fees and making them sufficiently high PCG.

funds could discourage banks to use guarantee for clients with lower risk profile, who can obtain loans without additional guarantee.

Despite the fact that, all benchmark schemes reflected in Fig. 3 employ risk-based fees, only 21% of existing PCGs practice risk-based pricing [7]. For example, in Korea, Malaysia and Taiwan, fees vary according to the credit rating of the borrower. Though, in Chile, the fees vary according to the quality of partner financial institutions' portfolio quality as measured by the default rate.

Hence, PCGs around the world utilize different approaches in guarantee pricing depending on market risk profile, level of institutional development of country's financial system and on mission of PCG itself.

In line with proper risk management and pricing, robust PCG should have predictable and prompt claims payment mechanism. Researches[6] show that in 66% of guarantee schemes around the world, banks are responsible for the recovery of defaulting loans and in 34% of the schemes' payouts are made after the borrower defaults. Moreover, 42% of the schemes, make payments when legal actions are already initiated by bank.

Country	Fees		Link to exposure
	Official definition	Basic standardized rate (% p.a.)	
Canada	2% of the loan amount + 1.25% p.a. calculated on the loan balance	2.3%	No scalability
Chile	1% to 2% p.a.	1.5%	Higher fees for banks with higher default rate
Colombia	0.95% - 3.85% p.a.		Fees are connected to product and coverage ratio
France	0.6% to 0.9% p.a. of the loan value	1.3%	Fees are linked to coverage ratio
India	1.5% upfront + 0.75% p.a.	1.5%	For loans over EUR350K fees vary according to firms credit ratings
Korea	0.5 % to 3% p.a.	1.2%	Higher fees for low credit rating along with higher coverage ratio
Malaysia	0.5% to 3.6% p.a.	1.5%	Higher fees for low credit rating
Netherland	2% to 3.6% one-off	1.7%	Fees are linked to the coverage ratio
Taiwan	0.75% to 1.5% per annum	0.8%	Fees are linked to risk profile
USA	2%-3.5% of the loan amount + annual rate of 0.55% of the outstanding guarantee balance	1.9%	Higher fees for larger loan amounts
Azerbaijan	0.4% to 0.5% of the guarantee amount upfront and 0.35% to 2.8% p.a.	1.1%	Fees are linked to risk profile and coverage ratio

* Flat rates were converted into per annum rates in order to ensure comparability across displayed guarantee schemes.

Fig. 3 Guarantee fees in selected benchmark countries

Traditionally, the economy of the Republic of Azerbaijan has been heavily dependent on oil. A steep drop in oil prices around mid-2014 put pressure on both fiscal and current account balance of the economy, which eventually resulted in heavy depletion of foreign exchange reserves of the country. Over years, the Government of Azerbaijan implemented various policy initiatives targeted towards structural economic transformation of Azerbaijan. These resulted in improved business environment and investment climate, restored macroeconomic and financial stability and increased foreign exchange reserves. In addition, exchange rate fluctuations stabilized and inflation rate moderated.

Development of a strong private sector is an essential pre requisite for economic diversification in Azerbaijan and can help to reduce dependency on oil revenues. Access to finance is one of the major constraining factors that limit growth of private businesses in the country. To diversify the economy away from oil, the Azerbaijan government put strong and diversified SME sector is the center of strategic agenda. Setting up of Credit Guarantee Scheme was envisaged under the "Strategic roadmap on production of consumer goods in Azerbaijan at the level of small and medium-sized enterprises", which was approved in December 2016. The objectives were to increase financial inclusion, diversify financial services delivery channels and enhance access to finance by SMEs.

Credit Guarantee Scheme was introduced by establishing a non-profit legal entity named “Mortgage and Credit Guarantee Fund of the Republic of Azerbaijan” (or MCGF). Main goal of fund is to support non-oil and non-governmental sector entrepreneurs. MCGF employs Credit rating system which categorizes applied projects into three risk profiles: low, medium and high risk. Projects which are classified as high risk are subject to refusal.

MCGF employs hybrid approach for guarantee pricing. Guarantee fees calculation derive from both factors, riskiness and coverage ratio of loan. However, portfolio quality is used as eligibility criteria in evaluation of perspective partner financial institutions (FIs). Thus, authorized banks pay one-time commission of 0.4% and annual fee of 0.35–2.8% depending on riskiness (probability of default) and coverage ratio. Wider range for coverage ratio 15–85% applied by MCGF in order to embrace requirements of larger group of SMEs (Fig. 4).

Moreover, this coverage ratio range provide adequate protection against default for FIs by sharing risk with MCGF, while preserving incentives for effective loan origination and monitoring.

Probability of default (PD) based pricing, on the other hand, designed to reflect expected losses and to provide lenders with adequate incentives to participate in the scheme and properly use and monitor guarantees.

By end of December 2020, MCGF from 15 SMEs through banks on issuance of credit guarantees. After assessing received applications eligibility to receive credit guarantees, 303 applications were approved by MCGF, whose aggregate value was to the tune of 230 million manats (USD 135 million).

Figure 5 reflects portfolio quality in form of Probability of Default Pareto Chart. Despite the fact that portfolio is still young (program was started in late 2018), 90% of portfolio have PD less than 3%. Obviously, partner FIs were very cautious in

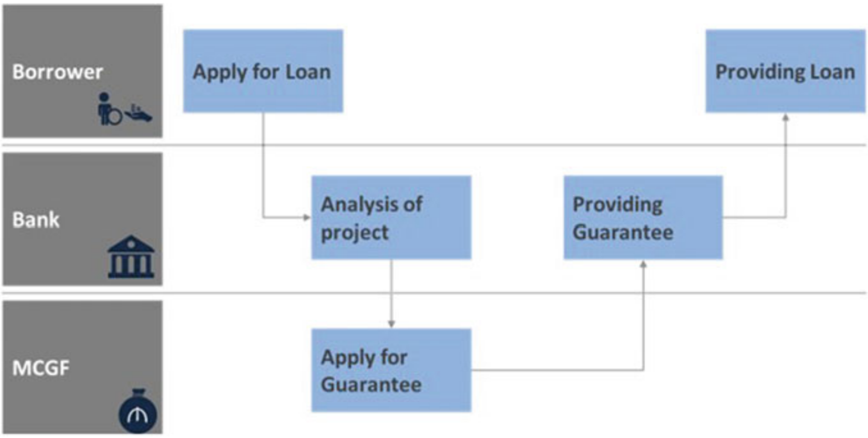

Fig. 4 Application approval process

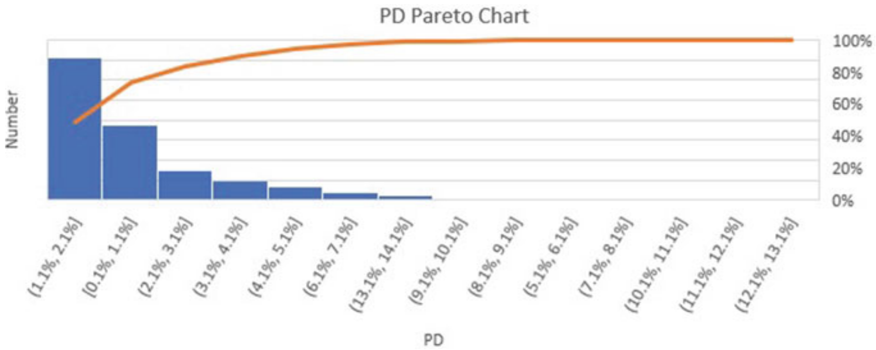

Fig. 5 Guarantee loans probability of default Pareto Chart

early stages of program and MCGF should expect slightly increase of PD with new applications.

4 Conclusion

Even though PCGs have important contribution to SME finance, especially in the period when governments are making an effort to remedy the shortages in credit information, country specific improvements in design could arguably allow these schemes to reach a larger number of constrained SMEs with the same volume of resources. PCGs could play role of effective vehicle to deliver public support for SMEs' in accessing finance given that mechanisms are in place to limit the adverse selection of high-risk borrowers and the moral hazard associated with existing borrowers. It should also be noted that PCGs have great role in helping banks to expand lending, reduce loan origination costs and capital requirements.

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Centralized Management of Thermal Energy Consumption Mode of Cities

Nurmammad Mammadov and Volodymyr Byba

Abstract In the article analyzes the problems that arise in the central heat supply systems of large cities. The main difficulty lies in the fact that the heat supply systems are characterized by incomplete and inaccurate initial and operational data. To describe the behavior of the mode of consumption of thermal energy in modern buildings at various levels of generalization, it is proposed to use an algebraic approach. A technique for controlling the heat consumption for centralized heat supply is proposed.

Keywords Heat supply · Modern building · Thermal energy · Qualitative methods · Environment

1 Introduction

The structural change in the Azerbaijani economy in the field of thermal energy has had a strong impact on the methodology for managing the thermal regime of modern buildings. The decline in production does not allow the full use of the accumulated information base of thermal loads to solve the planned tasks of managing the mode of consumption of thermal energy for modern buildings. In this regard, to solve planning and control problems, it is necessary to use short time series for the consumption of thermal energy and, in their analysis, apply the methods of fuzzy set theory, Bayesian procedures, cluster analysis and qualitative methods.

Economic models in the tasks of providing thermal energy to modern buildings are characterized by a simple structure. The main difficulty in using these models

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_62

lies in the fact that their description is characterized by heterogeneity, unreliability, incompleteness and inaccuracy of the initial and operational data.

Most often, in such models, one has to operate with qualitative information expressing such characteristics as "slow", "fast", "strong", "weak", etc. When studying such models, the most significant characteristic is the change in parameters, which in the most general form can be expressed by indicating the trend of change: "increased", "decreased", "did not change". Recently, qualitative methods have been increasingly used to describe such models [1].

2 Methods and Materials

We will consider the concept of "change" as a linguistic variable defined by the term-set {"increased", "decreased", "did not change"}. These three values of the linguistic variable form the highest level of generalization of the description of the mode of consumption of thermal energy for modern buildings. One can refine these meanings by considering each of them as linguistic variables with meanings {"strong", "weak"} defined on some subject scale. For a variable "unchanged", the term-set can be defined as {"almost", "absolutely"}. Such a description forms a second, lower level of generalization [2].

The values of linguistic variables can be specified in the form of fuzzy numbers or fuzzy sets, with the help of which it is possible to generalize exact quantitative estimates of parameter changes given in the area of real numbers [1]. Thus, we get a hierarchy of generalization levels by parameters (Fig. 1).

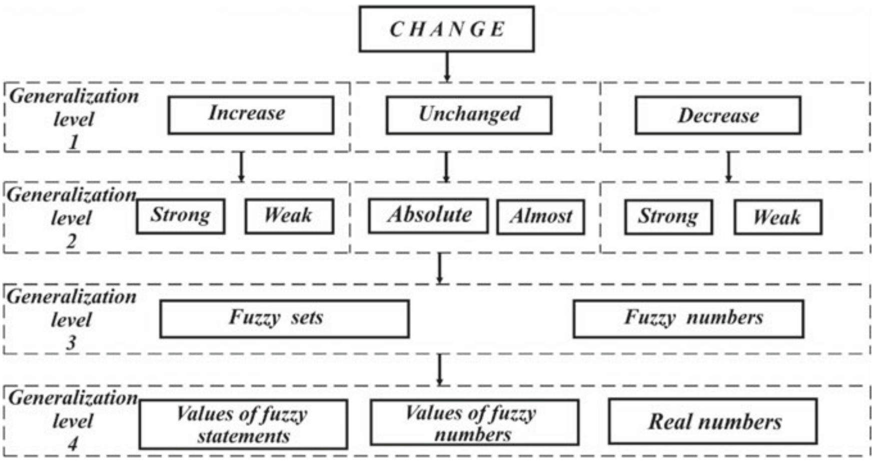

Fig. 1 Hierarchy of generalization levels of modes of construction of thermal energy for modern buildings

The transition from one level of generalization to another one is possible both from the bottom up and from the top down, which requires appropriate transformations.

To describe the behavior of the mode of consumption of thermal energy in modern buildings at various levels of generalization, it is proposed to use an algebraic approach.

The lower level is formed by fuzzy sets or fuzzy numbers defined in the sense of Zadeh [1]. The problem of mapping fuzzy models into qualitative ones, the tasks of identification, current situation and forecast of the next situation (statistical decision-making model) are considered in [3–11].

3 Results

In the problems of economic planning and distribution of thermal energy for modern buildings, there arises the problem of describing the behavior of this complex system at a qualitative level in the presence of external disturbances (climatic parameters of the environment, thermal performance of external enclosing structures, orientation of the building, etc.). Therefore, here we consider typical qualitative term-sets, and introduce basic qualitative algebras from which more complex functional algebras are built on the basis of composition laws, study the set of mappings between them, and construct categories of qualitative algebras.

Some of the qualitative algebras we use are not completely defined. However, we assume that algebraic operations on qualitative term-sets are closed. Therefore, we consider that the indefinite value "?" belongs to the same term-set.

Let us introduce some definitions.

By the behavior of the system we mean:

- the process of changing states caused by changes in the values of the parameters of the outside air, reflecting the state of the mode of consumption of thermal energy at any time;
- in general case, the process of changing the mode of consumption of thermal energy for modern buildings, caused under the influence of external factors (climatic parameters of the environment, organizational and operational factors, etc.).

Let's define the basic concepts:

- parameter is static characteristic of the mode of consumption of thermal energy and its components (flow rate and temperature); is determined by the value and reflects the state of the mode of consumption of thermal energy at any time.
- These concepts are interconnected by the following postulates:
- impact is a dynamic characteristic that reflects the activity of the system, the result of which is a change in the mode of consumption of thermal energy.
- change in the value of thermal energy parameters generates a disturbance in the mode of consumption of the entire building;

- the impact, defined as the nature of the influence of the cause on the effect, changes the values of the thermal energy parameters in accordance with the generated disturbance;
- impact characteristics (duration of operation, operating conditions of the building as a whole, etc.) may vary depending on the values of other parameters.

Various definition domains can be chosen to describe the parameters and influences.

The spatial characteristics of the parameters and the impact on the mode of consumption of thermal energy contain indications of the sign, the amplitude of the magnitude and the direction of change (for the impact). Their description can be performed, for example, using elements from term-sets {"–", " + "}, for signs, {"zero", "small", "medium", "large"}, for amplitudes, {"decreases", "does not change", "increases"}, to specify the direction of change and {"weak", "strong"}, to indicate the degree of change.

The time aspect of the description is characterized by the operating conditions of the building at different points in time. The value of the time interval can be different depending on the purpose and operating conditions of the building (hours, days, weeks, etc.). A simplified diagram of the cause-and-effect interaction of environmental parameters and the mode of consumption of thermal energy in a modern building are shown in Fig. 2.

An analysis of the term sets used to describe the mode of distribution of thermal energy showed that three conditional types can be distinguished:

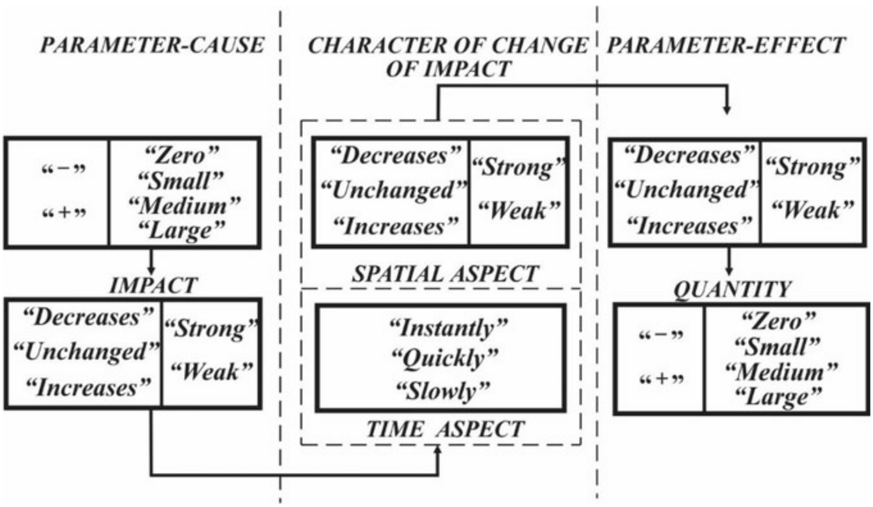

Fig. 2 The scheme of cause and effect interaction of environmental parameters and mode of consumption of thermal energy of modern buildings

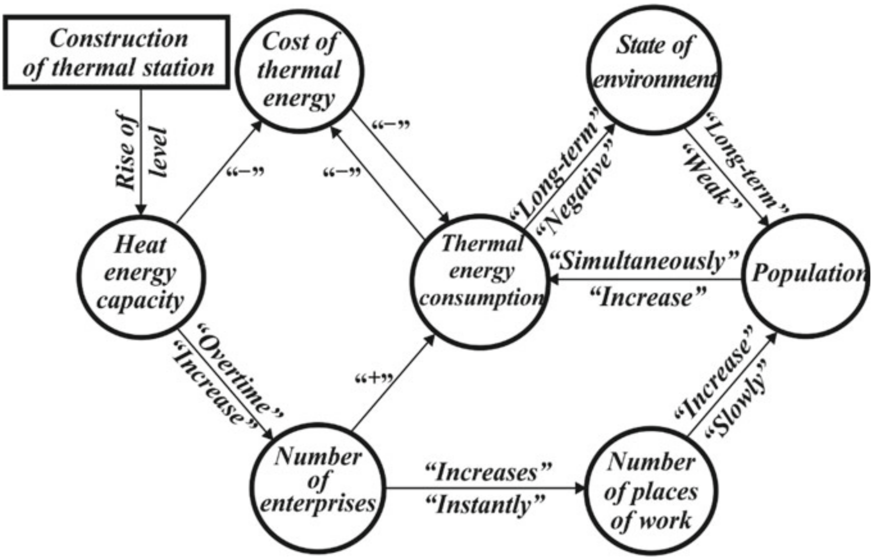

Fig. 3 Signed digraph for "Thermal energy consumption"

{"−", "+"}	- description of the sign of magnitude,
{"↓", "↔", "↑"}	- description of direction
{"0", "1", "2",...}	- description of amplitude

For a graphical representation of the behavior of the entire mode of heat consumption, one can use sign digraphs, the vertices of which are all parameters that affect the mode of heat consumption in a given city, and the arcs reflect their influence on each other and are loaded with information about the nature of influences (Fig. 3).

4 Discussion

In the simplest case, for example, the arc sign "+" means that an increase in one of the parameters leads to an increase in the other parameter, and the "−" sign means an inverse relationship. Let's trace the chain "heat capacity—number of enterprises—number of jobs—population".

During the construction of a new thermal power plant (external impact on the system), the level of heat capacity in the city increases, which makes it possible to increase the number of enterprises "over time". Obviously, with an increase in the number of enterprises, the number of jobs "instantly" increases, thereby creating prerequisites for a "slow" increase in the population in a given city. Population growth leads to a simultaneous increase in the level of consumption of thermal energy, which in turn has a "long-term" "negative" ("−") impact on the state of the environment, which "weakly" and "long-term" "positively" ("+") affects on the population.

This representation makes it possible to apply the structural methods developed for digraphs to determine the stability of urban heat supply systems. The proposed methodology, based on qualitative models, allows you to explore the mode of consumption of thermal energy, i.e. determine the behavior of the entire system under various external influences (meteorological, organizational, etc.).

The results obtained make it possible to use the available information with great efficiency and take advantage of the fuzzy and high-quality description of the mode of consumption of thermal energy.

5 Conclusions

The article analyzes the operational problems that arise in the central heating systems of large cities. A new method for controlling the mode of consumption of thermal energy for district heating is proposed.

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Systematization of Threats to Financial Security of Individual, Society, Business and the State in Terms of the Pandemic

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Abstract The article highlights the need to monitor factors, risks and threats to financial security at different levels of the social hierarchy. The tools are examined for identifying threats to financial and socio-economic security. The study generalizes international experience of monitoring the financial security of the state and business in terms of the COVID-19 pandemic. Threats to Ukraine's financial security have been identified with the help of modern approaches adapted to the conditions of the pandemic. Reserves of digitalization of business are investigated. The identification of risks and threats to social security of Ukraine by its components has been carried out. The article analyzes the impact of the pandemic on rising unemployment. The number of households in crisis conditions caused by the pandemic and quarantine measures is estimated as an indicator of socio-economic security. The impact of the pandemic on financial and social security is summarized at different levels of the social hierarchy. It is proved that updating the list of indicators and qualitative enrichment of the analytical system of threat identification with dynamic indicators of digitalization of the economy will enable identifying additional threats to financial security at different levels of the social hierarchy. Additional risks for the national financial system related to globalization and digitalization of the state financial system are identified, which are not taken into account by the current methodological recommendations for calculating the level of economic security of Ukraine. Additional risks for the national social system connected with intrastate machinery, social and political changes are identified, which are not taken into account by the current methodological recommendations for calculating the level of economic security of Ukraine. It is proved that due to the slow implementation of reforms in the social and economic spheres of security activities, the existing socio-economic security system turned out to be vulnerable to an intense crisis event, i.e. the COVID-19 pandemic, which has led to a number of threats.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_63

Keywords Financial security · Threats · Personal security · Business security · Society security · Pandemic · COVID-19 · Digitalization · Globalization

1 Introduction

The study of threats to the financial security of the state is of current importance due to the impact of the COVID-19 coronavirus pandemic, hostilities, challenges of the dynamic environment, processes of globalization, servitization and digitalization of economic relations, as well as political and social instability that have a lasting impact and may increase crisis phenomena. Therefore, there is a demand for systematic and extensive monitoring of risks, challenges and threats, which allows us to respond timely to destructive changes, adapt to new adverse conditions, counteract existing problems and prevent possible problems, promote effective macroeconomic development and rapid and effective recovery after overcoming crisis phenomena caused by the pandemic, measures to combat the spread of the disease and a full-scale military invasion of Russia into Ukraine.

Scholars such as Thaler et al. and others have made significant contributions to the study of threats to financial security of the state, mechanisms for counteracting negative security factors, and theoretical and methodological aspects of monitoring financial stability. However, despite the topicality of this issue in connection with the unprecedented level of globalization and digitalization of the world economy, comprehensive studies of the emergence, spread and systematization of threats to financial security of Ukraine at various levels of socio-economic hierarchy (individual, society, business and the state) during the pandemics caused by COVID-19 have not been carried out yet.

The aim of the study is to improve methodological tools for identifying threats to financial security at different levels of the social hierarchy (security of individuals, societies, businesses and the state), taking into account the scope and likelihood of threats in accordance with new conditions caused by the pandemic, based on the systematization and adaptation of the accumulated world experience.

2 Threats to Financial Component of Socio-Economic Security at Different Levels (Security of the Individual, Society, Business and the State)

Complex socio-economic systems operate under the ever-increasing influence of external and internal factors. This impact can be both positive, i.e., to promote and stimulate the quality development of the system, and negative, due to the disincentive effect of threats on key parameters of the system.

From a theoretical point of view, according to the current legislation of Ukraine, threats are phenomena, trends and factors that make it impossible or difficult or can make it impossible or difficult to realize national interests and preserve national values [1], and therefore functional properties of the system with any level of social hierarchy: individuals, society, business and the state [2]. They are implemented due to untimely response or ineffectiveness of measures to counter challenges of exogenous and endogenous origin [3]. According to the results of systematization of previous research, the causal relationship among negative security factors is that it is the challenges that lead to risks that, if left untreated, become threats [4]. It is important to note that the financial component of economic security is a system that arises from the interest of relevant actors in preserving its properties and counteracting the negative impact of threats.

The most common catalysts for threats with the maximum level of negative impact are crisis phenomena that can make the system impossible to function, and after the acute phase of the crisis in the recovery period, there are additional threats caused by the relevant adverse event. Currently, this is the COVID-19 pandemic, which has spread to all countries in the world at an unprecedented level of digitalization, which is expressed in the spread of infodemic [5] and the emergence of atypical challenges to financial security and direct security threats at various levels of the social hierarchy, unpredictable in nature. Therefore, formation of mechanisms to ensure financial security of the individual, society, business and the state in a crisis period with the maximum level of uncertainty becomes particularly relevant.

Thus, at the macro level, financial security is the degree of protection of the state financial interests, condition of financial, monetary, budgetary, tax, currency, banking, investment, customs, tariff, settlement and stock systems, characterized by balance, resistance to internal and external negative influences, ability of the state to effectively form and rationally use financial resources sufficient to meet its needs, by fulfilling obligations and ensuring socio-economic development.

However, under epidemic danger, financial security at different levels of the social hierarchy should be considered in synergy with social security, which provides such a state of society, taking into account all major areas of production, protection of internal constitutional order, external security, culture, society, social conditions and social benefits–material, sanitary-epidemiological, environmental, psychological, etc. which determine the standard of life of a person and society as a whole and guarantee minimal risk to life, physical and mental health.

When identifying and assessing threats to socio-economic security and its financial component, it should be emphasized that under pandemic, different areas of economic activity have different levels of sensitivity to the impact of atypical threats. In this regard, from a methodological point of view, the interpretation of averages in assessing risks and threats can have significant errors, and the model of the impact of threats on the level of financial security of the state–deviation, which leads to its unreliability and heterogeneity of risks [6]. Thus, some threats may be overestimated and others underestimated. If a small revaluation creates only one additional threat of unnecessary costs, which leads to a delay in budgetary resources, the underestimation can lead to a whole cascade of risks and threats.

Failure of ensuring or insufficient financial security ensuring at all levels of the social hierarchy, representing the interests of an individual or business as part of a financial system, and a state as a regulator or an ultimate beneficiary of public protection, cause risks that are rapidly realized into real threats. Therefore, financial security is the key to effective security activities in the system of socio-economic security of the state and stable and satisfactory dynamics of national development. This stability of the financial system should be understood as the degree of protection or invulnerability to adverse shocks arising from the implementation of financial risks.

However, in a pandemic without a sufficient level of social security, ensuring all components of economic security, including financial one, will be complicated by a number of other directly related factors, including lack of qualified personnel, public distrust, populism of political opponents, increasing administrative cost of solving problems. Therefore, it is now important to analyze the most dangerous threats to financial security that emerged in the pre-crisis period and will be exacerbated, given the new conditions of economic cooperation, under the influence of pandemics and quarantine restrictions on the spread of the disease.

The main resultant indicator of the impact of the COVID-19 pandemic can be considered as the dynamics of the GDP, which is shown in Fig. 1.

As it can be seen from the graph, with the increase in the incidence of COVID-19 in Ukraine there is a decrease in GDP due to the introduction of quarantine restrictions. Thus, in the second quarter of 2020, in contrast to the same indicator in 2019, Ukraine's GDP growth rate decreased from 113.7 to 102.5% [7, 8]. At the same time, with increase in the incidence rate in the next quarter, Ukraine's GDP growth rate slows down and vice versa–with a slowdown in the pandemic rate, GDP growth resumes.

Fig. 1 Dependence of GDP dynamics on the number of COVID-19 infected in Ukraine during 2019–2021

Fig. 2 Dynamics of the Ukraine financial security level during 2010–2020

However, GDP is a generalized indicator that indicates existence of threats to financial security but does not allow to identify them. Using methodological recommendations for calculating the Ukraine economic security level, the financial security of the state as a whole and including its individual components was assessed (Fig. 2).

It should be noted that in pre-crisis 2019, indicators of four out of the six elements of financial security were negatively affected and therefore financial security level in Ukraine does not reach even 50% of optimal value, and the financial system approached the crisis unprepared and vulnerable. Thus, it can be noted that during the whole period there was an improvement in the level of budget security in the financial structure. The constant growth for the period under review is in debt security, but the indicator is in the critical zone. Other indicators improved during 2014–2017, in contrast to non-banking security indicators, the level of which decreased significantly in 2019, in particular due to the low level of development of the stock and insurance market [9].

For tactical decisions, it is worth assessing financial security at the business level, as it is more sensitive to any world events. For this purpose, using international experience, Merton's adapted model [10] should be used to estimate the expected market losses. Thus, the first indicator is the probability of PD default, which in the credit rating of Ukraine B + [11] can be estimated at 0.10–0.12 [10] as the 6th class of the debtor of the financial sector. This simplification, caused by lack of sufficient development of Ukraine's stock system, does not fully reproduce the real situation, but makes it possible to quickly assess the situation.

For the lower limit, it is assumed that LGD remains constant over time at 10% (conservative estimate of past losses) on the volatility of the PFTS index. For the upper limit, the average LGD over a three-year time horizon increases by 15% points to 25%. For default risk exposure (EAD) data on credit risk exposure are used, which according to the H7 standard is 19.76% [12]. Thus, with LGD of 10%, possible losses in loan portfolios in the financial sector of Ukraine are about 21.73%, with a maximum limit of 25%, losses can be up to 54.35% [13]. It should be understood that the “index basket” includes the most liquid stocks, which conclude the largest number of transactions, and therefore the result is generally somewhat understated and average.

However, even based on the inflated performance of Ukraine’s top companies, the conclusions are still disappointing, so, despite a slight decline in shareholder interest in these “blue chips”, a significant impact has a high level of credit risk mechanisms need to be established to ensure the financial security of business and counter threats.

At the same time, at the beginning of 2020 Ukraine’s investment attractiveness decreased to the level of 2015 from 2.95 to 2.51 points [14], thus confirming the thesis of lack of investment funds to quickly overcome the economic crisis caused by the COVID-19 pandemic and at the same time, this will reduce the competitiveness of Ukrainian firms that are left without these funds and lose their positions, which is a real threat to the financial security of business.

As a promising area of countering threats is the use of digitalization reserves [15–17]. Thus, the expected increase in e-commerce in 2020 was 15% [18, 19], but the pandemic was a catalyst for the development of online commerce and the increase this year was 33% [20], indicating an increase in commercial digitalization reserves of about 15%, so active support for IT companies and business digitalization can cover possible economic losses with a minimum of LGD [21].

The percentage of servitization (the process of manufacturers expanding the range of their services that go beyond the standard delivery of goods or typical after-sales service [22]) can be assessed by comparing the level of retail sales with 2019, so in April 2020 there was a drop of 14.9%, in May–by 3 0.1%, and a gradual increase began in July by 1.4%, however, an increase in indicators compared to January 15.7% occurred only in October, then retail trade grew by 15.2% compared to 2019. year [23]. Thus, for the servitization of trade, it turned out to be 7 months, which means significant losses and immobility of economic entities.

Consequently, financial security at the business level under the influence of the pandemic and quarantine restrictions from COVID-19 is formed under the influence of a number of threats, including the deployment of a non-payments spiral, an increase in the risk of direct investments, loan portfolios without a corresponding increase in profitability. However, the processes of digitalization and servitization provide a positive counter to direct financial threats to the business.

Next, financial security at the level of society through the prism of social security of citizens should be considered using methodological tools for determining the integral assessment of economic security and social security in its composition (Table 1).

Since financial security is not the goal in itself, the direction of budgetary funds and resources becomes an important issue, in matters of protecting the population [24, 25], which is of particular relevance in a pandemic, an increase in the incidence of the population, and other social consequences resulting from the introduction of quarantine restrictions. It should be noted that the calculation of some indicators is impossible due to the deliberate refusal of the responsible institutions to calculate certain indicators, and data for 2021 are mostly not available due to the pandemic and military operations in Ukraine.

Table 1 Dynamics of indicators of Ukrainian social security for 2015–2021

Indicator	Retrospective period, years						
	2015	2016	2017	2018	2019	2020	2021
Share of the population with average monthly income below 75% of the median level of total income, %	22.1	20.1	23.3	23.2	29.0	26.5	28.9
The ratio of the average monthly nominal wage to the subsistence minimum per one able-bodied person, times	3.3	3.6	4.3	4.9	5.3	5.4	6.0
The ratio of the average old-age pension to the subsistence minimum for persons who have lost their ability to work, times	1.6	1.5	1.4	1.8	1.7	1.8	1.9
The ratio of total income to 10% is the most and least provision of the population, times	4.5	4.3	4.4	4.7	5.1	5.1	5.7
The share of expenditures on food products in consumer cash expenditures of households, %	57.9	56.2	54.7	54.2	52.4	51.7	51.4
The volume of the consolidated budget for health care expenditures, % of GDP	3.6	3.2	3.4	3.3	3.2	4.2	3.7
The volume of consolidated budget expenditures for education,% of GDP	5.8	5.4	6.0	5.9	6.0	6.0	5.7
The number of HIV-infected persons diagnosed for the first time in their lives people per 100,000 population	37.2	40.2	43.1	40.9	44.0	42.2	42.0
The number of patients with active tuberculosis diagnosed for the first time in their lives, people per 100 thousand people	56.0	54.8	52.0	52.0	46.4	32.6	33.8
The total number of students in daytime general educational institutions, percent of the total resident population aged 6–17	78.5	78.7	79.1	79.9	79.9	79.6	79.8
The amount of unpaid wages as of January 1 (July 1) to the wage fund for December (June) of the reporting year, %	7.1	4.8	3.4	3.2	3.3	3.0	2.5
Employment rate of the population aged 15–70 years, percent of the population of the corresponding age group	56.7	56.3	56.1	57.1	58.2	56.2	55.7

The first indicator of Ukrainian financial security through the social prism is the share of the population with per capita equivalent total incomes below 75% of the median level of income. Growth from 19.6 to 32.2% indicates a significant stratification and inequality in society. There is also a decrease in the ratio of the average monthly nominal wage to the subsistence minimum per able-bodied person from 4.4 in 2018 to 2.6 in 2019. There is also an increase in the minimum wage without a corresponding increase in business profitability. From these indicators, it can be concluded that part of the income is shadowed, even with an increase in the minimum wage, which leads to a slowdown in financial activity. At the same time, a satisfactory indicator of the ratio of the total income of 10% of the most and the least well-to-do population testifies against the thesis of the inequality in society.

Consolidated budget spending on health has been at a critical level throughout the period, and one of the budget plans for 2020 provided for a decrease in this figure to 2.9%, which is too low in a pandemic. Given the onset of the COVID-19 pandemic in 2020, this long-term neglect of the problem became the reason for the unpreparedness of the system for a crisis and led to human losses. Now, when medicine is in need of large budget funds, it is precisely because of the pandemic that there are no sources of income, which leads to the threat of budget imbalance and an increase in public debt under unfavorable conditions during a period of special need. Similar threats are caused by the amount of spending on education.

However, the pandemic of coronavirus disease COVID-19 in 2020–2021 is not the only epidemic in Ukraine, as evidenced by 42.5 HIV-infected people with this diagnosis for the first time in their lives per 100,000 populations. The same is true for patients with active tuberculosis. This requires additional budgetary resources from the authorities, which they did not invest in solving the problem before, and which are not enough during the crisis.

The existing methodology ignores the almost overcome diseases of diphtheria and measles in the past. Thus, according to UNICEF [26], in 2017, only 75% of parents were positive about vaccinations, which is three times more than in 2008. In 2019, 88% of parents said they were trying to stick to their immunization schedule, compared to 63% who gave the same answer in 2014. However, ongoing outbreaks of measles and diphtheria still occur, and the pandemic has made accessing vaccinations more difficult. All this, together with the already indicated burden on the medical system and the lack of financial resources in it, is an extreme threat to the health of the nation and counteracting the epidemics of coronavirus disease, human immunodeficiency virus, active tuberculosis, diphtheria, and measles.

The calculated indicators signal the following threats: lack of funds for households; insufficient spending of the consolidated budget for health care, which in 2020 played a key role in countering the coronavirus pandemic; the HIV epidemic; tuberculosis epidemic; rising unemployment. Employment is at a satisfactory level, while crime rates and the amount of unpaid wages are at an unsatisfactory level, but these indicators have deteriorated significantly over 2020–2021.

Social security indicators do not include indicators of other diseases that can be easily transmitted from person to person, have high mortality or severe bad after effects. Most of these diseases can be overcome through mass vaccination, but due to state inaction in the field of education in Ukraine there is a threat of measles or diphtheria, along with the spread of HIV and tuberculosis. Ignoring these problems in the past has created a difficult epidemiological situation where resources that could have been spent on the COVID-19 pandemic are being sprayed across the system among other major threats, diverting funds and complicating infrastructure. The question of the mass vaccination from COVID-19 possibility in distrust of vaccines and public authorities, the anti-vaccinees movement, general infodemic and financial crisis remains unsolved even during the vaccination campaign and therefore Ukraine lags far behind European vaccination rates.

The last stage of the assessment is the impact of the pandemic and quarantine restrictions on a person's financial security current analysis. For clarity, mass statistical methods will be used in the subsequent analysis, as the personal approach does not reflect the overall picture.

The size of three most vulnerable groups, including pensioners, unemployed and house properties with children, should be determined. According to UNICEF [26] and some indicators of the State Statistics Service, it is possible to determine the groups at risk size (Fig. 3). The key indicators were selected using the McKinsey methodological approach, the Institute for Fiscal Studies and the Federal Bank of New York.

Thus, under influence of the pandemic, poverty of all households in absolute terms increased to 10% as of the second half of 2020, so the risk of poverty for households with children was 51.3%, which means a threat to human capital development, personal financial and demographic security could be an additional burden on the financial and social security system and complicate the fight against the spread of COVID-19 coronavirus disease due to a lack of resources for self-sufficiency in food and medicine.

As for the issues of citizens' trust in the actions of the state aimed at counteracting the spread of coronavirus disease, according to the latest data, 45% of respondents believe that measures taken by the authorities to overcome coronavirus

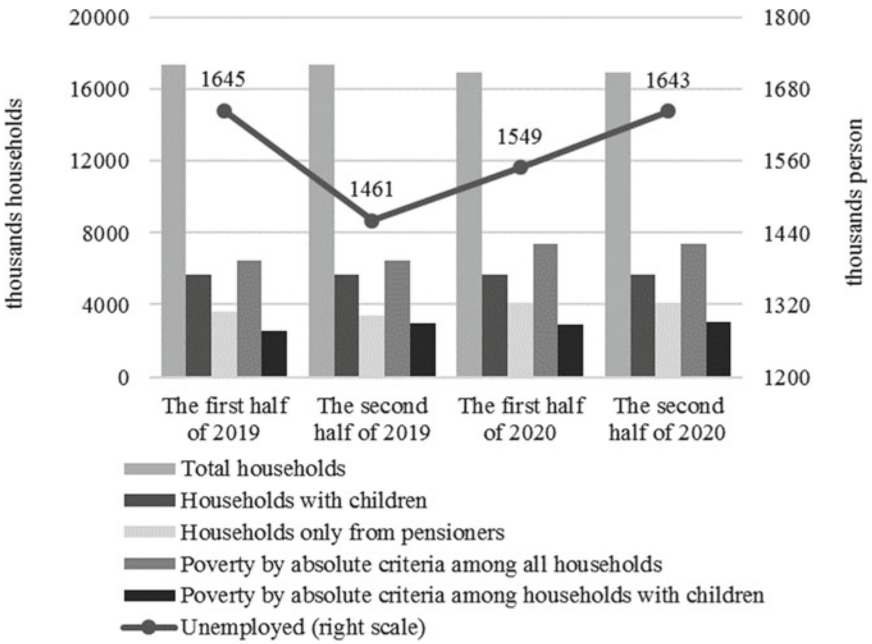

Fig. 3 Households at their own financial security from the impact of COVID-19 risk in Ukraine in 2019–2020 years [7]

are optimal. 65% support "strict" quarantine and are going to follow the rules, 33%–on the contrary, do not support. 77% support the cafes closure, about 60% support schools and kindergartens close under "strict" quarantine. 36% rated their emotional state over the past week as calm, 33%–as tense. 31% of respondents are satisfied with the activities of President Zelenskyi in the fight against the coronavirus epidemic, 52%–are not satisfied. 30% are satisfied with the activities of the Ministry of Health to overcome the epidemic, 54% are dissatisfied [27].

It shows the distrust of citizens in the actions of state institutions, reinforced by intuitive assessment of their own social and financial security, as unsatisfactory, which in this case is justified and fair. Such distrust is transformed into vaccination against COVID-19 hesitancy: 47% of Ukrainians are ready to free of charge vaccination, 38% would even pay for vaccinations, 49% are not ready to agree even to free vaccination [18].

3 Conclusion

Under influence of pandemic, there is predictable slowdown in economic development and decrease in the level of financial security both at the level of the state as a whole and at the level of individuals, businesses and society. Such decline is caused by the disruption of international economic ties and quarantine restrictions to counter the spread of the coronavirus COVID-19 disease, which have complicated or made it impossible to do business. One of the first to experience such impact is the building industry, which is sensitive and inflexible enough to protect itself from negative influences and is an indicator of existing and future threats: poverty growing, budgetary shortages, creating additional pressure on the banking and non-banking insurance infrastructure, etc.

Although the Ukrainian economy had a 15% reserve for the digitalization of production, it was not enough. As an example, it took 7 months to retail trade to resume growth comparing to last year. First of all, in financial sphere, it has negative impact on loan portfolios, so the loss on liquid assets for investors and banks can be 54.35% with a quick resumption of business, but if the resumption is insufficient, then the losses may exceed 100%. The financial security of Ukraine is also threatened by social investments from individuals in real estate. The similar crisis has also happened and the economic recovery, along with the lost potential did not happen, and therefore, although the pandemic did not become catastrophic for the system, there will be a lot of risks and threats after it, that can become more active after the crisis. Therefore, the process of economic recovery should begin with the identification and prevention of such factors.

It also means that poor businesses, as well as industries that have lost their ability to exist, will be closed and lead to unemployment rising. So, in the first half of 2020 year, 143 thousand people were unemployed. It has a special impact on the growth of poverty, as households lose their means of support, so about 3046 thousand households fell below the poverty line during the same period. So almost half of such increase is made up of households with children who find themselves in a vulnerable situation when the income earner was sacked, or when the company is unable to pay maternity leave due to its liquidation. In addition, the Keynesian management of the state only accelerates inflation and shred the citizens savings without helping those in need of targeted subsidies, as well as funds for reprofiling and obtaining new professional skills.

Thus, the state for 2014–2019 years did not provide sufficient social and financial security, and therefore in 2020–2021 years it got into a crisis situation. From the impact of pandemic and quarantine restrictions, 7376 households in need of benefits or resources, including 5644 households with children were at risk of losing their means of support. At the same time, healthcare also needs resources, where the epidemic of tuberculosis and the immunodeficiency virus has not been overcome yet. As financial security is in unsatisfactory condition, and needs additional funds and reforms itself, but investments will decrease due to an increase in riskiness without corresponding return, then it will not be enough resources for everything, so it threatens to level out all the achievements from the reforms in 2014–2019 years and will need new resource infusions. Therefore, crisis countering should be comprehensive at the all industries level, prevent pending threats and stimulate digitalization as the main tool for rapid recovery, keeping its risks in mind.

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The Energy Efficiency of the Digital Economy

Volodymyr Onyshchenko, Svitlana Onyshchenko, Kseniia Verhal, and Aliona Buriak

Abstract Digitalization describes the growing application of information and communication technology across the economy, leading to increasing volumes of data, rapid progress in advanced analytics, and greater connectivity between humans, devices and machines. In addition to the positive effect that information technology has on the economy, it should be noted the presence of a negative effect. The dual nature of this impact also applies to the energy efficiency of digital technologies. The authors investigate the impact of digital economy deals with energy efficient, the major ways in which information and communication technology can be expected to affect CO_2 emissions are defined in the article. The article identifies the main elements that interact with each other and in general determine the energy efficiency of information technology. Such components include–users, networks, data centers. It is established that the influence of these components must be taken into account in various processes–production, use, disposal. The authors also identified the effects of the digital economy on energy efficiency–direct effects, indirect effects, rebound effect.

Keywords Digital economy · Digitalisation · Information and communication technology · Energy efficiency · Impact of digital economy

1 Introduction

Digital economy is defined as an economy that focuses on digital technologies [1], brief cycles of innovations and digital information [2]. It is based on digital and computing technologies and covers all activities that are supported by the web and other digital communication technologies like business, economic, social, cultural etc. During the last 70 years information and communication technology (ICT) had massive and accelerating growth and now its are integrated into every aspect of our life. Digitalisation describes the growing application of ICT across the economy,

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_64

leading to increasing volumes of data, rapid progress in advanced analytics, and greater connectivity between humans, devices and machines (including machine-to-machine).

The COVID-19 pandemic has accelerated the process of digital transformation, but it also has shown the significant benefits and value of ICT for the whole world.

The positive impact of digital economy and ICT deals with the energy efficient. The introduction of digital technologies helps reduce energy consumption in production and reduce CO_2 emissions in industrial systems, as well as improve the quality of products. According to the GeSI's Smarter3030 report by 2030, digital technologies could cut energy use by 20% [3] The ICT sector is central to the transition to a low carbon economy. ICTs represent 2% of worldwide energy consumption and related carbon emissions. ICT can also facilitate carbon reductions across sectors world-wide, to a much higher order of total emissions [4]. Nevertheless, the digitalisation has both positive and negative impacts on the environment. Thus, some reports (the Shift Project, the High Council for Climate Change) mention a significant increase in the negative environmental externalities of digital technologies–the digital industry's energy intensity increases by 4% yearly [5, 6]. As the climate crisis looms larger, it's become even more important to emphasize the energy efficient of the digital economy.

2 Main Body

The impact of the digital economy on the environment can be realized from the position of 3 tiers: users, data centers, and networks.

1. Users. In January 2022, the digital world is about 4.95 billion internet users (62.5% of total population), 4.62 billion active social media users (58.4% of total population) [7]. Moreover each user has own display devices (television sets, computer screens and video projectors), connected objects (Bluetooth speakers, watches, thermostat, lighting, etc.), accessories (chargers, keyboards, mice, USB sticks, etc.), M2M applications (meters, video surveillance, healthcare monitoring, transportation, and package or asset tracking), that had to be manufactured, require electricity supply and will need to be disposed of in the future. In total, the number of people with smartphones is 6.37 billion and other phones is 7.10 billion in 2021 [8]. In January 2022, including both smart and feature phones, the current number of mobile phone users was 7.26 billion, which makes 91.54% of people in the world cell phone owners. Globally, the total number of Internet users in 2021–4.7 billion people [9].

An online activity triggered a demand for up to 42.6 million megawatt-hours of additional electricity to support data transmission and to power data centers [10].

Globally, devices and connections are growing faster (by 10.0% yearly) than both the population (1.0%) and the Internet users (6.0%), that increase in the average number of devices and connections per household and per capita [9].

2. Networks. In the middle, the network connects user terminals to each other and to data centres. It mainly consists of the equipment that constitutes the "local loop" also called "last mile". That is 1.1 billion DSL/fibre routers, 10 million GSM relays (2G to 5G) and about 200 million other active WAN (extended network outside the buildings) and LAN (local network inside the buildings) equipment. The number of devices connected to IP networks will be more than three times the global population by 2023. There will be 3.6 networked devices per capita by 2023, up from 2.4 networked devices per capita in 2018. There will be 29.3 billion networked devices by 2023, up from 18.4 billion in 2018. Machine-To-Machine (M2M) connections will be half of the global connected devices and connections by 2023. The share of Machine-To-Machine (M2M) connections will grow from 33% in 2018 to 50% by 2023. There will be 14.7 billion M2M connections by 2023 [11].
3. Data centres. The most significant contributions of green house gases are attributable to the data center segment, with a share of 45%, followed by fixed and mobile telecommunications at 24%. A few thousand data centres host around 67 million hosted servers, with accompanying computer equipment in comparison, the few thousand data centres are marginal with at most 67 million hosted servers and hardly any other computer equipment accompanying them [11]. Recent predictions state that the energy consumption of data centres is set to account for 3.2% of the total worldwide carbon emissions by 2025 and they could consume no less than a fifth of global electricity. By 2040, storing digital data is set to create 14% of the world's emissions, around the same proportion as the US does today. The amount of energy used by data centres continues to double every four years, meaning they have the fastest-growing carbon footprint of any area within the IT sector.

The total life cycle carbon footprint of the ICT sector is approximately 730 million tonnes CO_2 equivalent (Mt CO_2-eq) or 1.4% of total global greenhouse gas emissions [12]. This includes the electricity used by all equipment in the system during their use but also all other parts of the life cycle, like the manufacturing of networks, data centers, phones, computers and other user equipment. Furthermore, the figure includes the construction of ICT-related buildings and, for instance, employee travel and transport (see Fig. 1).

There are three major ways in which ICT can be expected to affect CO_2e emissions:

1. The direct effects. These effects are mainly caused by energy consumption in production, distribution and use of ICT. Estimates of the direct effects of the global ICT sector amount to 1.4% of overall global CO_2e emissions [6].
2. The indirect effects. The effects relate to the impact that ICT has on other sectors of the economy. Thus, ICT could help reduce carbon dioxide emissions by 6–15% by 2030 through smart applications, the increasingly efficient use of energy and dematerialization (that is, digital solutions that replace more energy-intensive solutions). MacKinsey Consultants have found that through ICT applications in the highest energy-consuming industries, including motor vehicle manufacture, shipping, air transport, building and construction, there could be an accumulated

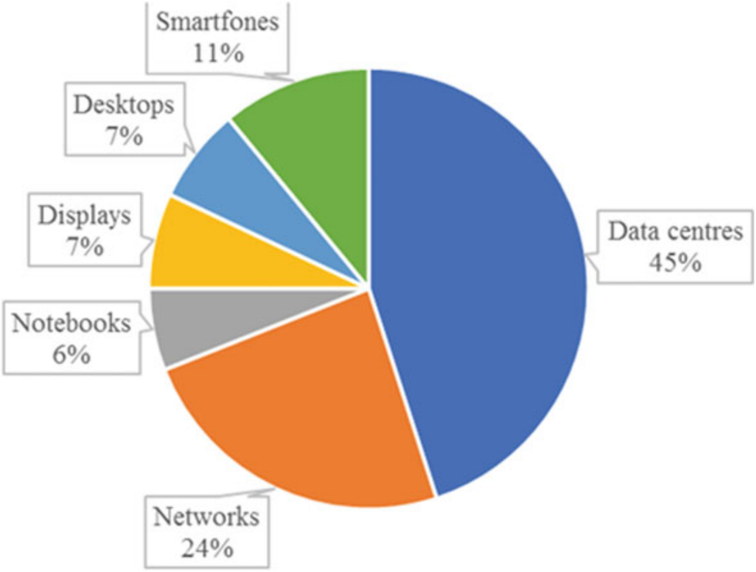

Fig. 1 Information and communications technology sector carbon footprint share 2020, by product/segment [14]

reduction in emissions equivalent to 4.52 gigatonnes of carbon equivalents (4.52 $GtCO_2e$). The McKinsey study indicated that total energy savings across these industries could amount to over EUR 363 million. Digitalization also can be applied to decarbonization strategies to address the climate crisis. For example, the buildings sector is a significant contributor to greenhouse gas (GHG) emissions, responsible for nearly a whopping 40% of global carbon dioxide emissions. As emissions from the built environment continue to rise, digital technologies including AI, smart meters, and Internet of Things devices can process data in ways that enable humans to make energy-efficient choices or automatically optimize energy use. This can bring about huge energy and emission savings, reduce ratepayer costs, and improve grid flexibility. The growing use of ICT is driving efficiency gains in the transportation sector as well. For example, improved analytic capabilities and sensor installations can optimize routes for ships and aircrafts, leading to lower energy use and maintenance costs. Electric vehicle (EV) smart charging is another digitalization strategy that greatly benefits the grid by reducing peak electricity demand. Research suggests that by 2040, there could be 500 million EVs on the road, highlighting the importance of enabling vehicle-to-grid integration through smart technologies [13].

3. The rebound effect ("take-back effect"). The third major way that ICT affects CO_2e emissions is related to the fact that new technologies cause changes in behavior (consumers' substitution waves). As ICT becomes cheaper and more available, people tend to consume more of it. Also, consumers globally paid on

average less for ICT services and the price for high-speed Internet connections dropped dramatically last years. Thus, there is a risk that the potential reductions from indirect emissions-reducing effects could be cancelled out by changes in consumer behavior and actually lead to greater energy consumption and therefore greater emissions. Another variant of the rebound effect is a far-reaching effect in other industries of economy. It's a Global Rebounds. Common examples include video conferencing technologies or online shopping which could reduce the need to physical travel or reading news on a smartphone. These have the potential to both decrease and increase environmental impact. Where these new technologies evolve to be more energy intensive than their alternatives, where they are used in addition rather than as a substitute (e.g., e-books being used alongside paper books), or where they allow intensified activity or growth in other industries because they are cheaper, more productive or more convenient (e.g., more regular checking of news on a smartphone than with traditional newspapers leading to increased need for news production), the impact of the economy as a whole in terms of energy use, resource use or GHG emissions can increase [15].

The interaction of all these components of the digital economy, that determine its environmental efficiency can be represented in the Fig. 2.

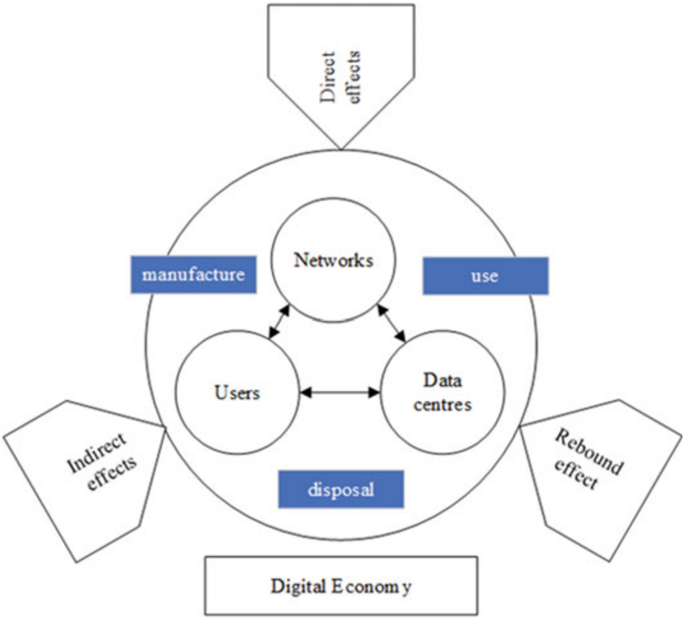

Fig. 2 The components the factors that determine environmental efficiency of the digital economy

3 Conclusions

Given the urgency of environmental issues, such as climate change, water scarcity and pollution, which are increasing every year one of the critical challenges of our era is to balance the competing demands for more widespread use of ICTs with their energy-efficient deployment, and safer e waste disposal at the end of their useful life. The main task of using ICTs is to help other industries realise greener objectives, whether these are self-imposed or externally regulated. ICT solutions, including IoT, machine learning and automation, have great potential to reduce carbon emissions globally, in numerous sectors and industries.

Realization of such potential is possible by implementation of the following strategic decisions:

– Using of the digital technologies to decarbonize their operations and value chains (big data analytics; decision-making technologies–artificial intelligence/machine learning and digital twins; enabling technologies such as cloud, 5G, blockchain and augmented reality; and sensing and control technologies–cloud internet of things, drones and automation);
– Reducing emissions from the digital technologies themselves;
  internal environmental policy (creating digital tools, minimising travel through remote working, monitoring, reporting, evaluating employees' environmental performance, etc.).
– Implementation of socio-economic principles that are adopted, both at the company and societal level.

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Business Information Security

Svitlana Onyshchenko, Stanislav Bilko, Alina Yanko, and Svitlana Sivitska

Abstract The article highlights the problem of business information security under digitalization processes spreading, which, being a driver of all the sectors of economy development, at the same time have led to destructive phenomena, namely information wars, information terrorism, large-scale cyber-attacks. Negative impact of the latter, which is seen in huge financial losses, raises the issue of business information security. It is proved that ensuring timely identification of potential and real threats to business information security is necessary in order to minimize and prevent the causes of their manifestation, to develop a set of preventive measures. An information security system is suggested, which is based on a clear algorithm of defined procedures that will ensure reliability, confidentiality, integrity and availability of information resources of the entity, as well as neutralize potential and minimize real risks and threats to the company's information environment, including cyberspace. A number of preventive work approaches to minimize risks to business information security are defined, based on general rules of information security and provide implementation of high-tech strategies for digital protection against cyber threats. The main modern methods of counteracting threats and cyber threats are identified, which allow businesses to identify the possible number of threats, analyze losses, including financial ones, from attacks made, as well as implement preventive measures to minimize risks. Based on the analysis of the annual global financial losses from cyber-attacks and the dynamics of financial investments in cyber security, the need to implement an information security system for each business entity has been proven.

Keywords Digitalization · Information security · Cyber security · Business · Risks · Threats

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_65

1 Business Information Security Under External Challenges and Threats

Hybrid aggression from the Russian Federation has brought up issues of all types of security for citizens, business, and the state, including information security as well. Military invasion is accompanied by war in the information field: information terrorism, large-scale cyber-attacks–these are destructive phenomena that have invaded the modern world. They cause no less damage than direct hostilities. The need to support the national economy during external aggression implies the need to ensure business functioning on the basis of information security.

Problems of business information security, including those in context of supporting financial security of the state are widely relevant in the works of foreign and domestic researchers [1–5]. At the same time, in terms of external aggression, the need to form a security-oriented information environment of business functioning has become especially relevant.

It has to be noted that the problem of business information security, though becoming a priority in the current environment of growing external threats, has become even more relevant since the deepening of digitalization processes.

Undoubtedly, digitalization has become the main development driver for all the spheres of the national economy in the recent years. Technology, smart applications and other innovations in the digital economy have enabled improving the quality and availability of services, solving a number of problems in the areas of health, public administration, education, taxation etc. The COVID-19 pandemic had a significant impact on the deepening [6, 7] of IT technologies use in business processes.

Based on the expert assessments from a number of international organizations, the main advantages that businesses have received in terms of strengthening the digitalization processes, the following can be identified:

(1) Approach to the consumer. In terms of digitalization, the need for intermediaries has significantly decreased. Most companies have developed their own websites, entrepreneurs have opened online stores and have the opportunity to work directly with potential customers;
(2) Cost optimization, which first of all involves reducing marketing costs;
(3) Business processes acceleration, due to reducing the time of communications;
(4) Increasing the efficiency of responding to changes in the market environment;
(5) Increasing the flexibility of the proposed products and their high adaptability to new expectations or the consumer needs [8, 9].

In addition to the positive impact on business development, studies by international organizations also confirm positive effect of digitalization on the level of employment. Thus, according to McKinsey company [10], one new job in the ICT sector stimulates creation of 2–4 additional jobs in the economy as a whole. PWC estimates that a 10% increase in digitalization reduces unemployment by 0.84% [11].

At the same time, rapid development of digitalization processes has become a source of not only new opportunities, but also risks and threats primarily to business information security.

Business information security is a state of information resources and related information tools and systems of the business entity, which guarantees ensuring its activities with the necessary information in a high-quality and uninterrupted way provided a high level of its protection from internal and external threats [12, p. 213].

Accordingly, in terms of deepening the economy digitalization, along with traditional threats to business information security, such as industrial espionage, intentional and unintentional disclosure of confidential information and trade secrets by employees, unfair actions of competitors, including damage to business reputation, interference of third parties in information systems and networks, etc., creates a number of additional threats to information resources and business technologies, methods of diagnosis and counteraction to which have not been fully developed yet [13]. First of all, these are threats related to cyber-attacks, disclosure of personal data, spyware and viruses, phishing, threats connected with updating computer programs etc.

According to official statistics, the level of cybercrime in Ukraine is constantly growing (Fig. 1).

It should be noted that Ukraine ranks second in the world in the number of cyber-attacks, which indicates a low level of protection of the information environment. Thus, according to official Microsoft data, 19% of all cyber-attacks recorded in 2021 were committed against Ukraine (the United States ranking first with 46%). For comparison, the share of Belgium, Germany and Japan does not exceed 3% [15]. At the same time, the main types of cyber-attacks that pose the greatest threat to information security in business are extortionist programs, insider attacks, phishing, targeted cyber-attacks and DDoS attacks.

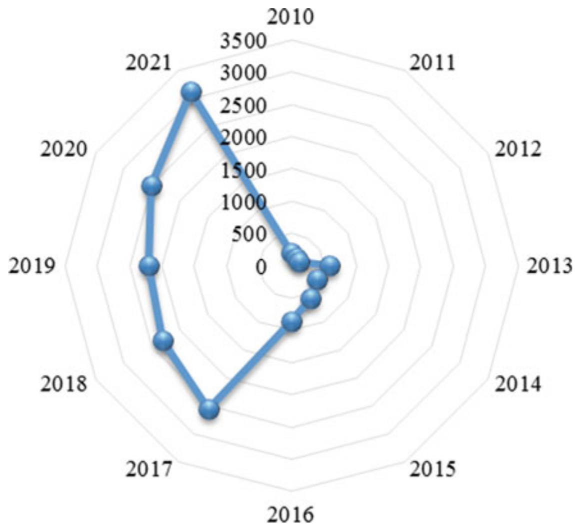

Fig. 1 The level and dynamics of cybercrime in Ukraine in 2010–2021.* Made according to [14]

Extortionist programs or cryptographic programs encrypt information on the company's devices, which can lead to a complete shutdown of business. In some cases, information cannot be recovered.

Insider attacks are one of the most complex types of cyber threats because they are directly related to the human factor. An insider is usually an employee of the company, who causes damage both intentionally and accidentally. This type of cyber-attack is difficult to predict.

Phishing is one of the most common and effective attacks. It is observed when a cyber-attacker emails malicious files or links that infect PCs when opened. This is where the penetration into the organization's network begins.

Targeted cyber-attacks, DDoS attacks, are attacks on a computer system aiming to bring it to failure. They create conditions under which system users cannot access provided system resources or they get limited significantly.

The latter type of cyber-attacks is often used by the Russian aggressor to cover up destructive actions. In particular, the last large-scale and long-lasting DDoS attack on Ukrainian banks and government websites was carried out on February 15, 2022. According to official data, no data leakage, distortion or destruction of elements of the IT infrastructure or financial losses were recorded [16].

These types of threats to information security of business cause the greatest financial losses and, of course, affect the level of financial security of the country as a whole.

In 2020, the losses of the world economy as a result of cyber-attacks amounted to more than 1 trillion US dollars, which was 1% of the world GDP. Compared to 2018, this figure increased by more than 50%. According to official McAfee data, only 4% of the companies surveyed did not face cyber-attacks in 2021. The rest, 96% of companies, have been victims of cyber-attacks to one degree or another. After all, even without suffering direct financial losses from cybercrime, the companies faced with their negative impact on employee productivity, distribution of working time, the image of the company as a whole. The most dangerous for business are cyber-attacks aimed at stealing intellectual property and cyber espionage, which are often accompanied by ransom demands. Nearly 2/3 of all material damage from cyber-attacks is related to financial crimes and loss of intellectual property [17].

Given the above, there is a need to justify a system of business information security that can predict the likelihood, neutralize potential risks and threats to the company's information environment, including cyberspace, and minimize real ones.

2 System of Business Information Security

Taking into account sustainable growth of external and internal threats to business information security and increase of financial losses in case of their occurrence, the issue of the development of the efficient information security system has gained its relevance and topicality for business owners and managers. The system of business information security should be presented as follows (Fig. 2).

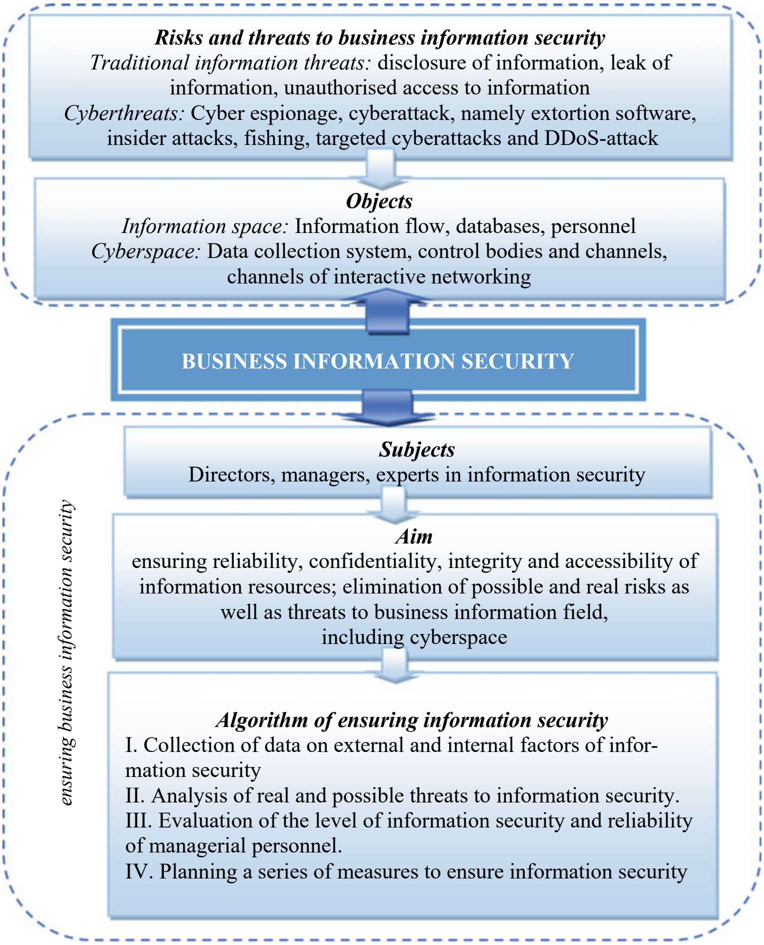

Fig. 2 System of business information security

It should be noted that making a system of business information security should be based on international standards, including ISO/IEC 27,001 and ISO/IEC 27,002, that represent management system model which defines general process organization, data classification, access system, planning directions, staff responsibility, use of risk evaluation, etc. in the context of information security. ISO/IEC 27,001 Standard provides economic entities with the possibilities to evaluate risks, implement the means of control to mitigate them, monitor risks and improve information security if necessary. ISO/IEC 27,002 Standard is used to set up the system of efficient information security and improvement of information security methods [18].

The system of business information security should be based on the clear algorithm of set procedures, which allow ensuring reliability, confidentiality, integrity and accessibility of economic entity's information resources as well as eliminating possible and minimizing real risks and threats to business information field [19], including its cyberspace. Business owners should consider the fact that promptly and reliably identified risks of business information security, including cyber risks, allows forecasting their impact, foreseeing the probability of their occurrence, developing relevant preventive measures.

A number of approaches to risks prevention concerning business information security is singled out nowadays. The main of them include the following.

'Avoid' (get away from risk) provides for the optimization of business processes through the exclusion from their use of the information whose loss may be critical for the business. So if the firm is not able to provide customers' personal data security, its operation should be arranged without the collection of them.

'Except' as an approach lies in the conscious risk taking without changing business processes, since the latter appears to be more costly than the risk itself. It is appropriate in case of low risk impact on the business.

'Mitigation' means the reduction of risk impact on business. Its implementation is possible with the help of regular monitoring and identification of It-architecture vulnerability to hackers. The sufficiency level of business information security is evaluated according to the monitoring results. If it is insufficient, the business should get insured. In case of business loss, the insurance funds will help e.g., pay fines and cover expenses on the business process resumption. Apart from the aforementioned mechanisms, economic entity can implement the development of additional security elements by the security engineers. They will analyze the threat models, emergencies, etc. and determine the requirements to be used by the developers. After that, the security system can be also tested through its presentation for public hacking aimed at its vulnerability verification by independent 'experts' [20, 21].

After the introduction of measures to prevent business information security risks, it is advisable for management to systematize those threats that are the most real, assess the level of information security and the reliability of management personnel. Based on the results obtained, strategic and operational measures to ensure information security have been developed.

Measures to counter threats to business information security should be based on general information security rules and provide for the introduction of high-tech digital security strategies against cyber threats. In particular, the main areas of countering threats and cyber threats to the safe functioning of a business can be defined as:

- Creation of backup copies of key files to minimize damage from ransom ware attacks;
- Installation and regular updating of security software to counteract known digital threats;
- Regular scanning of all devices connected to the corporate network and prohibition of the use of unverified portable devices;
- Conducting regular trainings and courses for employees in order to teach them the basic rules of cyber security;
- Control of access to accounts and databases;

– Conducting regular security testing of corporate products by conducting penetration tests and participation in bug bounty programs [20].

It is worth noting that the most effective methods of ensuring protection of a business from cyber-attacks are periodic penetration tests and the use of bug bounty programs. In particular, penetration tests enable assessing the degree of access ease to characteristics and data of a company's information system, determining the possible number of threats, analyzing business losses, including financial ones, from implemented attacks, and also implementing preventive measures to minimize risks. In terms of content, penetration tests or penetration test (pen test) are a simulation of a cyber-attack on information systems in order to check their security.

As for bug bounty programs, they are based on the involvement of independent IT specialists (the so-called "moral hackers") in order to identify vulnerabilities in the company's web resources. Performers–ethical hackers–receive a financial reward from the customer, the amount of which depends on the type of problem identified and its scale.

Of course, effective information security system implementation requires significant capital investments from the business. At the same time, investing in information and cyber security is rightfully defined as one of the most effective strategies for preventing financial losses. In addition, a company that is not tainted by cases of loss of data or customer funds is considered a reliable partner and has the opportunity to increase its potential income [22]. Therefore, investment of companies into creation of an effective information security system is an effective way to adapt business to conditions of external environment variability. To confirm this thesis, it is advisable to make a comparison between the level of financial investment in cyber security and financial losses as a result of cyber-attacks, although the real scale of the latter is almost impossible to determine (Fig. 3).

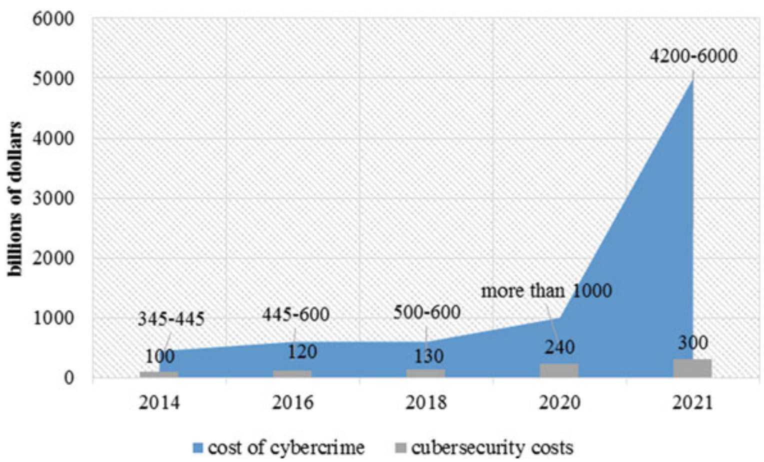

Fig. 3 Estimated average cost of cybercrime and cubersecurity costs

Based on the presented info graphics, built on the official data of research Cyber security Ventures [23], it is legitimate to note the insufficient level of financial investment in cyber security as a component of information security. Over the past five years, from 2017 to 2021, their total volume amounted to 1 trillion USD USA. While the losses from cyber-attacks in 2020 alone amounted to more than this sum, and in 2021 increased to 4.2–6 trillion USD USA. According to experts, in 2025 the amount of financial losses from cybercrime will reach 10.5 trillion USD USA. Regarding the financing of cyber security measures, its growth is projected at 10–15% in the next 5 years.

Thus, considering the results of the study, it is necessary to state the need to build an effective system of information business security. After all, the losses from crimes in the information and cyberspace are much higher than the financial investments that are appropriate in the implementation of security systems in the enterprise [24, 25]. At the same time, business owners have the opportunity to choose the method of organizing the information security system–from the creation of a security service at the company to the use of specialized companies services.

3 Conclusion

In the course of the research it is substantiated that the spread of digitization processes along with the undeniable benefits for the development of both the world and national economies, has led to the emergence of such destructive phenomena as information warfare, information terrorism, cyber-attacks and more. In today's world, information is the most valuable business asset of most companies. In this regard, there is an urgent need to form a security-oriented information business environment, ensuring information business security.

Taking into account the growth of external and internal threats to business information security, increasing the level of financial losses in case of their implementation, a system of business information security is suggested, which is based on a clear algorithm of defined procedures that will ensure the reliability, confidentiality, integrity and availability of the entity information resources, as well as neutralize potential and minimize real risks and threats to the company's environment, including cyberspace. A number of approaches to preventive work to minimize risks to information business security are outlined and the main modern methods of counteracting threats and cyber threats are identified.

The expediency of financial investments in the creation of an effective information security system, which is an effective direction of business adaptation to the changing environment, increase resilience to external risks and threats, are proved.

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Inclusive Development Index

Svitlana Onyshchenko, Vitaliia Skryl, Alina Hlushko, and Oleksandra Maslii

Abstract The essence of inclusive development of the construction industry in Ukraine in modern conditions is considered. It has been established that the principle of inclusiveness and barrier-freeness is the most relevant vector for the development of the construction economy both in the countries of the European Union and Ukraine in particular. It is this vector that is a step towards ensuring the realization of all the rights of a modern person, which gives him the opportunity for a high-quality and fulfilling life. Today, the problem of overcoming social inequality of all segments of the population, obtaining access to social housing, which will usually lead to certain economic benefits, is being solved. To solve such problems, there is a need to develop a model of inclusive development. The analysis of the components of inclusive development made it possible to form such a model. Methodological approaches to assessing the level of inclusive development are analyzed, the advantages and disadvantages are identified. The analysis of the level of inclusive development of Ukraine according to the WEF method is carried out. It is substantiated that the achievement of the inclusive development index directly depends on the Home and Financial Asset Ownership. The conditions and proposals for increasing the level of inclusive development of Ukraine in different scenarios are analyzed.

Keywords Inclusion · Inclusiveness · Assessment methodology · Inclusive growth · Inclusive development index

1 First Section

International human rights standards are based on the idea of the participation of every individual in public life on the basis of equality and non-discrimination. The extension of the principles of inclusive accessibility and accessibility in the construction industry in Ukraine is not only a reflection of time and an actual vector of development of the construction economy of European countries.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_66

Inclusive development of the construction industry in Ukraine is another step towards ensuring the full realization of human rights to access and opportunities and quality of life.

The generalization of views on the problem of inclusive development of the construction sector in Ukraine and the EU shows that at different times it faced society with different urgency and to some extent solved by different methods depending on the political system, economic situation and ideology of construction and architecture.

The EEA-Eionet 2021–2030 European Strategy aims to develop smart, sustainable, inclusive growth, and the OECD is implementing the Knowledge and Innovation for Inclusive Growth project, which analyzes the impact of innovation and innovation policy on inclusive growth [1].

The main goal of any construction project in Ukraine should be to overcome social inequality of different segments of the population, give them free access to social housing and obtain additional economic benefits. It is inclusive development that will help to establish equity in income distribution, overcome poverty, eliminate the disparity in international development and improve living standards.

2 Propositions to the Measurement of Inclusive Development

The concept of inclusive development still lacks a clear-cut definition. We claim that inclusive development comprises of both a fair distribution and preferable development returns. As Anand and Sen [2] argue, development should be human-centered. The reason for this being that humans are both the end as well as the means of development. All development measures and policies are to serve humans and their quality of life. Therefore, looking only at gross domestic product (GDP) and its growth rates does not show the whole picture of inclusive development [3–5]. Examining income levels and stocks of (material) wealth does not allow inferences about a human's individual preferences and to what extent they are satisfied. Therefore, they can only be intermediate goals with instrumental value.

Scott and Talmage [6] define inclusiveness as a "community outcome that results from methods of inclusion that utilize diversity as a resource." In this light, inclusiveness shows the scale of "inclusion of all individuals and groups, specifically individuals or groups who were previously not included or excluded". This goes along with the appreciation of diversity in personal characteristics and life plans. The term inclusive suggests that individuals have equal access to the social, political and economic mainstream as well as chances to assert their preferences. This normative aspiration requires all parts of society to benefit from development.

Thereby, inclusive development is related to equality but both concepts are not the same. A society with a highly unequal distribution that impairs access to and participation in that society can hardly be perceived as inclusive. Material inequalities may be justified, however, as long as they represent different preferences among members of a society. These inequalities do not impact the individuals' life fulfillment. When considering goods and means for the satisfaction of basic human needs, individual preferences are more homogenous, espescially when the point is meeting minimum thresholds to secure human survival. Here, vast inequalities are harder to justify. On the other hand, a just distribution in a society will not necessarily ensure a high level of inclusiveness. When all individuals are equally poor, they are still constrained in pursuing their life plans.

It is believed that inclusive development, above all, shows the level of development of society, namely: the ability to meet their own needs, the right to work and rest, education, medicine, access to cultural values and other rights. The urgency of inclusive development is due to the fact that in all countries the population is constantly growing. An inclusive environment means that each individual feels the importance of their life and is involved in different activities. The state is obliged to give everyone the opportunity to realize their potential, to be an active full member of society and to receive such a part of the results of work as a result of distribution, which will ensure reproduction. Equal access to labor results implies an even and sufficient distribution of labor results between the employee, the entrepreneur and the state through a balanced amount of wages, profits and taxes. If a worker receives a decent wage, he and his family have access to opportunities, including affordable housing. And access to education, medicine and labor creates the preconditions for better work and higher wages. I would like to emphasize that access to opportunities and access to work results are directly proportional. Unfortunately, post-Soviet countries do not provide equal access to opportunities or fair access to work, which is usually due to high levels of corruption in the country. An inclusive model should harmonize human, natural and productive capital not only in terms of quantity but also in terms of quality. The model of inclusive development is presented in Fig. 1.

Thus, an inclusive development model should harmonize human, natural and productive capital not only in terms of quantity but also in terms of quality. The main key aspects of inclusive development are investment in human capital, job

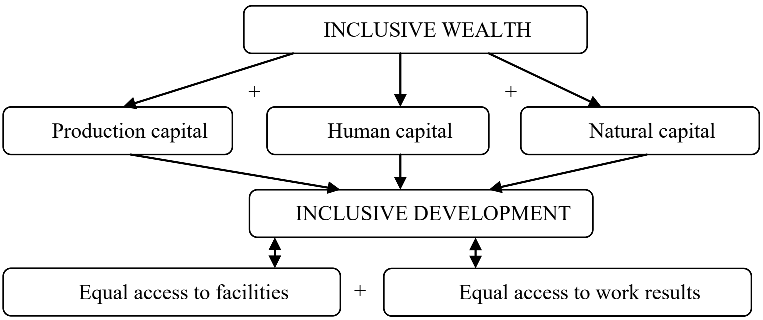

Fig. 1 Model of inclusive development

creation, structural transformation, progressive tax policy, social protection, non-discrimination, social inclusion and participation, and strong institutions. Studies of the content and features of inclusive economic development and opportunities to achieve it in countries with different levels of socio-economic development have been at the center of scientific research in many countries and international institutions, including the Organization for Economic Cooperation and Development (OECD), UNDP, Commission, International Monetary Fund (IMF), World Economic Forum (WEF), World Bank, International Center for Inclusive Growth Policy. But each of the presented models has certain advantages and disadvantages.

Let's consider in more detail the model proposed by WEF. According to experts from the World Economic Forum WEF, this approach is more comprehensive and allows to take into account not only traditional macroeconomic indicators, but also the welfare of the population and its quality of life. The WEF calculates a composite index that ranks countries based on their combined KPIs—Development Inclusion Index (IDI). This new global index has a more complex content of the relative state of economic development compared to the generally accepted ratings based on GDP per capita. Ukraine ranks 47th in the IDI rankings, the lowest in five years.

According to the WEF, inclusive growth is economic development in which there are opportunities for all segments of the population, equitable distribution of tangible and intangible benefits in society to improve its well-being. In this context, it is not only about bridging the gap between rich and poor, but also about equal conditions for education, health care, security and housing. Therefore, an inclusive approach to growth involves a long-term strategy based on productive employment. So according to this method IDI which comprises 12 variables which are grouped into three domains:

1. Growth and Development
    - GDP p.c.
    - Labor productivity
    - Healthy life expectancy
    - Employment
2. Inclusion
    - Net income Gini
    - Poverty rate
    - Wealth Gini
    - Median income
3. Intergenerational Equity and Sustainability
    - Adjusted net savings
    - Carbon intensity of GDP
    - Public debt
    - Dependency ratio (non-working age/working age population).

The IDI summarizes these National Key Performance Indicators. All quantitative data indicators are converted to a scale using a linear min–max transformation. Thereby, it is possible to aggregate the data from the indicator up to the index level. For outliers, a benchmark is applied to reduce the bias on the arithmetic mean of the whole sample. Thereby, the order of, and the relative distance between, country scores is preserved to allow for unbiased comparison. Because of its comprehensive formulation, the IDI enables a better assessment of inclusive development outcomes across different institutional setting [7]. In Figs. 2, 3 and 4 and Table 1 shown the components of the index (sub-indices) of inclusive growth and development of Ukraine.

As shown in the Fig. 4, according to the WEF calculation, the IDI index of Ukraine is 3,67. Ukraine is one of the countries with developing economics. Of course, the value obtained in comparison with countries with developed economics differs significantly. Thus, Norway (6,2) and Luxembourg (5,86) have the highest IDI values. Ukraine still has a long way to go and move to the rank of developed economics. Let‘s consider in more details the dependence of the IDI index on key performance indicators. Figure 5 reveals the components of the Asset Building and Entrepreneurship sub-index. The value of this sub-index is below average. The components of the Home and Financial Asset Ownership are even critical. Therefore, it is worth paying more attention to improving these components of the sub-index. It should be noted that in Ukraine the right of every citizen to housing is enshrined in Article 25 of the UN Universal Declaration of Human Rights. The apartment is not only for protection, it creates conditions for the realization of other basic human rights: privacy, family, health, education, etc.

The right to housing is enshrined in the constitutions of many states. However, the policy for its implementation varies greatly from country to country and is not always successful. Many large cities around the world today are showing the crisis

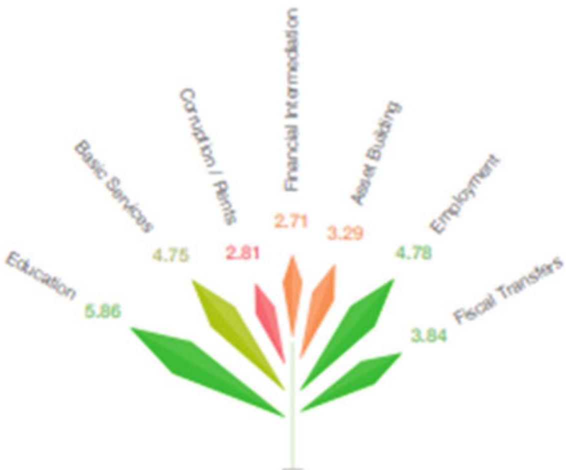

Fig. 2 Components of inclsive growth and development of Ukraine according to WEF

PILLAR	VALUE	RANK	WITHIN ECONOMY GROUP
Education and Skills	5.86	1 / 34	
Access	6.10	1 / 36	
Quality	5.02	1 / 37	
Equity	6.46	2 / 35	
Basic Services and Infrastructure	4.75	10 / 37	
Basic and Digital Infrastructure	4.34	14 / 37	
Health Services and Infrastructure	5.15	8 / 37	
Corruption and Rents	2.81	33 / 37	
Business and Political Ethics	2.76	30 / 37	
Concentration of Rents	2.87	32 / 37	
Financial Intermediation of Real Economy Investment	2.71	28 / 37	
Financial System Inclusion	3.41	16 / 37	
Intermediation of Business Investment	2.02	31 / 37	
Asset Building and Entrepreneurship	3.29	24 / 37	
Small Business Ownership	3.85	21 / 37	
Home and Financial Asset Ownership	2.74	26 / 37	
Employment and Labor Compensation	4.78	2 / 37	
Productive Employment	4.52	13 / 37	
Wage and non-wage compensation	5.03	1 / 37	
Fiscal Transfers	3.84	6 / 36	
Tax Code	3.06	37 / 37	
Social Protection	4.62	1 / 36	

Fig. 3 Pillars in detail [8]

of affordable housing. Investment real estate, tourism and market regulation mechanisms in this area are constantly increasing the cost of rent, displacing residents from their homes.

In Ukraine, these processes have their own characteristics. On the one hand, due to the high percentage of property owners, low tax on it and outdated housing. On the other hand, due to the lack of a clear housing policy and regulations in the rental market.

A feature of the housing sector in Ukraine is the high percentage of property owners: more than 90% of Ukrainians live in apartments they own. But this does not mean the absence of housing problems [9].

According to the State Statistics Service, 54% of Ukrainians live in overcrowded apartments and houses, and 45%—in buildings where no major repairs have ever been carried out. At the beginning of 2015, according to the Ministry of Regional Development, there were 650,000 families and single people registered ("apartment queue"), and this is the only category of people who were entitled to free housing. Since 2015, such statistics are not kept in Ukraine. According to experts, as of early 2022, six million Ukrainians need their own housing.

In Ukraine, a number of government programs have been launched to help citizens exercise their right to housing. But over the past year, many of them have been suspended. At the beginning of 2022, the housing stock is provided through

Inclusive Growth and Development Index (IDI)

	Value	Rank	Trend
Overall 1-7 (best)	3.67	47 / 79	-3.2% ▼

National Key Performance Indicators

	Value	Rank	Trend
Growth and Development 1-7 (best)	2.99	51 / 79	+4.6% ▲
GDP per capita $	2,824	44 / 79	-0.9% ▼
Labor productivity $	17,157	45 / 79	+0.5% ▲
Healthy life expectancy years	64.1	39 / 79	+1.9 ▲
Employment %	55	51 / 79	+1.1 ▲

	Value	Rank	Trend
Inclusion 1-7 (best)	4.28	17 / 79	+2.7% ▲
Net income inequality Gini	25.5	1 / 79	-3 ▼
Poverty rate %	0.1	1 / 79	-0.1 ▼
Wealth inequality Gini	91.7	73 / 79	+1.4 ▲
Median income $/day (PPP) per capita	11.4	17 / 79	+1 ▲

	Value	Rank	Trend
Intergenerational Equity 1-7 (best)	3.74	75 / 79	-13.9% ▼
Adjusted net savings* % GNI	-0.5	67 / 79	-3.6 ▼
Carbon intensity of GDP KtCO2/$bn GDP	347	76 / 79	-37.2 ▼
Public debt % GDP	80.1	72 / 79	+43.2 ▲
Dependency ratio % working age population	43.3	10 / 79	+0.6 ▲

Fig. 4 Inclusive growth and development index (IDI) [8]

Ukrfinzhitlo [10–14]. The construction of modern housing is already taking into account new building codes and regulations. State building norms and other normative documents that influence or directly regulate the creation of inclusiveness and barrier-free space include:

DBN B.2.2–40: 2018 Inclusiveness of buildings and structures. Main provisions of DBN B.2.2–5: 2011 Landscaping.

DBN B.2.2–9: 2018 Buildings and structures. Public buildings and structures. Substantive provisions.

DBN B.2.3–5: 2018 Streets and roads of settlements DBN B.2.2–12: 2019 Planning and construction of territories DBN B.2.5–28: 2018 Natural and artificial lighting.

Table 1 Inclusive Growth and Development Index (IDI) [8]

Inclusive Growth and Development Index (IDI)				
Overall 1–7 (best)	Value	Rank	Trend	
	3.67	47/79	−3.2%	▼
National Key Performance Indicators				
	Value	Rank	Trend	
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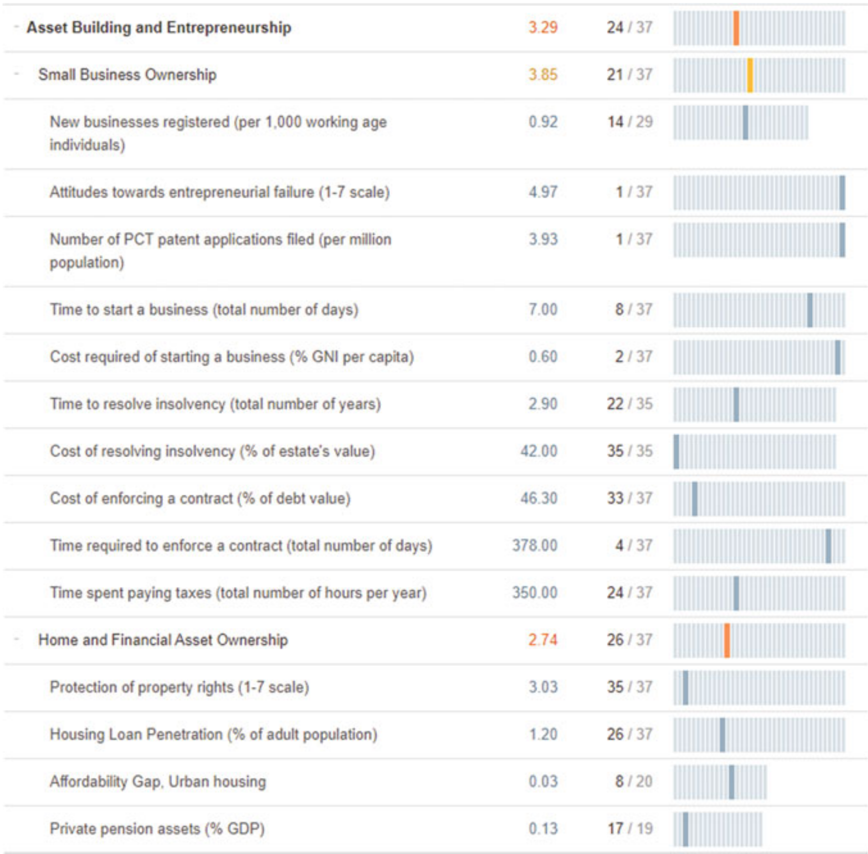

Asset Building and Entrepreneurship	3.29	24 / 37
Small Business Ownership	3.85	21 / 37
New businesses registered (per 1,000 working age individuals)	0.92	14 / 29
Attitudes towards entrepreneurial failure (1-7 scale)	4.97	1 / 37
Number of PCT patent applications filed (per million population)	3.93	1 / 37
Time to start a business (total number of days)	7.00	8 / 37
Cost required of starting a business (% GNI per capita)	0.60	2 / 37
Time to resolve insolvency (total number of years)	2.90	22 / 35
Cost of resolving insolvency (% of estate's value)	42.00	35 / 35
Cost of enforcing a contract (% of debt value)	46.30	33 / 37
Time required to enforce a contract (total number of days)	378.00	4 / 37
Time spent paying taxes (total number of hours per year)	350.00	24 / 37
Home and Financial Asset Ownership	2.74	26 / 37
Protection of property rights (1-7 scale)	3.03	35 / 37
Housing Loan Penetration (% of adult population)	1.20	26 / 37
Affordability Gap, Urban housing	0.03	8 / 20
Private pension assets (% GDP)	0.13	17 / 19

Fig. 5 Asset Building and Entrepreneurship [8]

DSTU 8713: 2017 Landscaping. Creating lawns. General requirements.

DSTU 2587: 2010 Road safety. Road marking. General technical requirements. Control methods. Rules of application.

DSTU EN 1176–1: 2019 Equipment and coverage of children's playgrounds. Part 1. General safety requirements and test methods (EN 1176–1: 2017, IDT).

DSTU B B.2.6–77: 2009 Constructions of buildings and structures. Metal fire doors. General technical conditions.

This approach shows some shifts in the inclusiveness of housing. But this is not enough. That is why we propose to calculate the forecast of changes in the IDI index under different conditions of the percentage ratio Growth, Inclusion, Intergeneration equity. The value of IDI for Ukraine −3.67 is provided by the components Growth (33%), Inclusion (33%), Intergeneration equity (33%). Table 2 shows the calculation of the change in the IDI index under different conditions of change of

Table 2 Forecast values of the IDI index of Ukraine under different conditions of change of priority

Ukraine	Growth	Inclusion	Intergeneration equity	IDI
	2,99 (%)	4,28 (%)	3,74 (%)	
Standard Ratio	33	33	33	3,67
Emphasize growth	50	25	25	3,5
Emphasize growth & Inclusion	40	40	20	3,66
Emphasize inclusion	25	50	25	3,82
Emphasize growth & Intergenerational equity	40	20	40	3,55
Emphasize intergenerational equity	25	25	50	3,69
Emphasize inclusion and intergenerational equity	20	40	40	3,81

priority Emphasize Growth, Emphasize Growth & Inclusion, Emphasize Inclusion, Emphasize Growth & Intergenerational Equity, Emphasize Intergenerational Equity, Emphasize Inclusion and Intergenerational Equity.

The calculations in Table 2 once again show the importance of the inclusive component in reaching the highest level of the inclusive rosette index of Ukraine. It is the state of the construction industry, the affordability of housing and its accessibility that significantly affect the value of the IDI index. Given the gradual development of the construction industry in Ukraine, synergistic conditions will be created for mining, manufacturing, engineering and other industries, which will affect the development of the labor market in the regions of the country and become the foundation of inclusive economic development.

- conducting state tenders to stimulate innovation in construction in the field of inclusive development;
- providing benefits and government loans to construction companies working with inclusive projects, which will ensure the development of entrepreneurship and increase the share of working population;
- creating favorable conditions for lending and investing to foreign organizations;
- improving the conditions of mortgage lending for the population;

Such initiatives are an investment in the future of the state. Undoubtedly, a great victory is the fact that despite the difficult external and internal socio-economic conditions, Ukraine is gradually developing infrastructure for living, learning and working people.

3 Conclusion

Summing up, we can draw conclusions about the feasibility of implementing an inclusive development model in Ukraine. Inclusion is accessibility and a way to overcome social inequality. The calculations indicate a low level of inclusive development of Ukraine. The components of indices and sub-indices made it possible to calculate forecast options for changes in the level of inclusive development index of Ukraine. The analysis showed that the development of the construction industry will increase the level of inclusiveness in Ukraine. Today, almost 7% of the population of Ukraine needs to improve their living conditions. Summarizing the results of the study, we can identify key areas of development of the construction industry that will promote inclusive development:

1. Creating equal opportunities for all citizens.
2. Implement fair and efficient income distribution measures through effective and honest government.
3. Decent wages that will promote human development and the realization of human potential and minimize the credit dependence of citizens.
4. Implementation of programs on mass employment with sufficient household incomes and elimination of the phenomenon of "working poor".
5. Stimulation of entrepreneurial activity.
6. Creating favorable conditions for investment and the formation of an innovative model of development of the construction industry.
7. Humanization of the economy.
8. Social cohesion and activity in society.

Inclusive development not only increases the country's GDP, but also forms a strong socio-economic system, where every citizen plays an important role because he has the opportunities, resources and tools to ensure self-development, decent and quality living, including private housing.

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The Mechanism of Information Security of the National Economy in Cyberspace

Svitlana Onyshchenko, Alina Yanko, Alina Hlushko, Oleksandra Maslii, and Vitaliia Skryl

Abstract The article highlights the problem of information security of the national economy in cyberspace in a hybrid war. Modern cyber technologies create completely new dimensions for information warfare, affecting all sectors of the economy. Therefore, the article is devoted to effective methods of data processing and monitoring of the economic network in order to understand the principles of their use and prevent hacking. It's justified that the use of computer data processing systems based on machine arithmetic is an effective tool for protecting economic data from cyber attacks, as existing threats are not adapted to non-positional code structures. Based on the use of the properties of non-positional machine arithmetic, significant advantages are given, namely for the processing of large arrays of economic data, compared to the binary positional number system. The possibility of creating a mechanism for effective monitoring and response to information security threats to the national economy by creating an intrusion detection system based on network sensors is considered. Examples of monitoring and different scenarios of blocking attacks by network sensors are given.

Keywords Computer processing system integer economic data · Information security · Intrusion detection system · Intrusion prevention system · Machine arithmetic · Non-positional code structures · Scenarios of blocking attacks · Unauthorized access

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_67

1 The Importance of Information Security of the National Economy in the in Terms of External Threats

Nowadays, information technology covers almost all areas of activity in which there is a need for technology management and data processing using computer technology, using automation techniques. The economic sphere is no exception, where the volume and turnover of information are constantly growing, and automation and digitalization make it possible to make this process less costly in terms of staff and costs, and more stable and reliable [1]. Also, given that technology does not stand still, this process is constantly evolving, which allows you to digitize and automate the process, efficiently and reliably store economic data, process and distribute processed information, and possibly continuously monitor the state of the economic system in real time, which is quite relevant especially in times of emergency, pandemic and war.

In terms of information technology development, characterized by on the one hand the intensification of modern information technology in all sectors of the national economy, and on the other hand, increasing the scale and frequency of cyber attacks, the emergence of new risks and security to economy [2].

Particular attention should be paid to this issue, especially during the military aggression, which is relevant for Ukraine today. In times of war, the economy of any country is straining and needs maximum protection and restructuring of certain strategic goals with a change in priority areas of the concept of spatial economic development, this may include redistribution of domestic resources in favor of military or other institutions, fiscal policy, social expenditures, financing of medicine, change of the education system, etc. [3]. Any military action is accompanied not only by military invasion, but also by economic war, and it's in it that is an important component of victory.

Strategic research by RAND Corporation and other leading global think tanks indicates the growing role of the economy in existing and future conflicts. This situation leads to the development by states of different approaches and strategies to protect the economy [4, 5]. However, modern economies are mostly high-tech, which makes critical not so heavy industry than access to microprocessors, computer boards, data centers (servers), and so on. The development of precision weapons, automation of control systems, the use of artificial intelligence, in general, the increasing use of cyberspace create the need to purchase expensive and complex equipment, which is primarily aimed at data security and reliability.

In Ukraine during the war, a very important element of victory is not only countering the enemy at the front, but also ensuring information security, which, in turn, is an integral part of the economic country. The progress of cyber technologies has created completely new dimensions for information warfare, which affects all sectors of the economy [6]. Predicting the development of new cyber attacks, where a possible threat to the national economy is growing exponentially. This situation creates a need for a focus on collecting, processing and analyzing information more than ever before in history.

Access to information, capacity of the above-mentioned data centers, analysts and software of financial structures are important not only for punches, but also for understanding hundreds of changes in the performance of almost any sector of the economy—from changes in the number or nature of transfers from abroad to unauthorized access to the state budget. The ability to analyze and protect information often goes beyond the purely military segment, but directly affects the economic situation, and as a result of the ability to fight.

In conditions of destabilization, growing impact of challenges, risks and threats, the basis for ensuring the reliability of economies at different levels is the coordination of their elements, which in practice is realized by finding sources of threats, preventing their implementation, minimizing impact and using of adaptive tools to increase the security of the economic system [7]. Therefore, the urgency of developing an effective information security policy of the economy is beyond doubt.

2 Security of the Economic System in Cyberspace

The concept of security of any system is a multifaceted concept that can be considered from different aspects and implemented in many ways and methods [8]. Today, the security of the economy in the information space needs to be considered from the point of view of protection against hacker attacks and prevention of existing cyber threats, from unauthorized access and use of information (storage, editing and destruction) [9]. The question arises as to what is the object of protection of the economic system of the country: elements of the banking structure, sites of state economic institutions, etc. Of course, in protecting the economy from cyber attacks across the country in terms of informatization, digitalization and computerization, it is necessary to consider the economic system as a computer network, because all existing threats and attacks in cyberspace are carried out from the global Internet to which all economic structures are connected. The economic network of any country is a complex system of communication between the various elements of the economic structure, implemented on the basis of computers of different functional purposes and network equipment. As a result, it is carried out:

- the ability to quickly transmit information over long distances (economic data, various transactions);
- prompt search for information and exchange of information online and offline;
- the possibility of interactivity and prompt feedback;
- access to information—access to places of concentration information (HTTP, FTP servers, database servers);
- signaling (e-mail, short message services);
- compatible use of technical resources (network printers, data warehouses, application servers);
- load distribution (clustering, parallelization);
- remote control (monitoring, remote execution of processes);

– ensuring reliability (clustering, redundancy (devices and channels)) [10].

Usually the economic system consists of public and private organizations and institutions that use different topologies, technologies and equipment in building networks [11]. To approach comprehensively, this article will consider the protection of the economy in two ways: first, the reliability of data processing, and secondly, the development of an effective and operational intrusion detection system.

In cyberattacks of any scale, an attacker scans the network using specially prepared scripts (scenarios) that detect potentially weak nodes. Selected nodes are attacked by referring certain bits (packets, frames, etc.), and the attacker gains administrator rights to them. Trojans (again certain types of data) that run in the background are installed on the captured nodes. Therefore, data processing is one of the key to protection against hacker attacks, as hacking mechanisms and all cyber-attack scenarios, regardless of their type (DoS, DDoS-attacks, etc.) consists first in the possibility of access, and then capture, block, edit or destroy data. In other words, attacking the network hackers send disguised data, usually as service information that is actually part of the hacking code. Therefore, a very important element of information security of the economic sector is the development of effective monitoring of cybersecurity systems, which consists in the first in the filtering of traffic (network data). Currently, there are many information security monitoring systems based on Zabbix, DellFoglight and Microsoft SCOM and others, but the algorithm of which is well known to attackers, and hacking such a system is a matter of time. Reliability of data processing and intrusion detection, which are the main elements of monitoring, are very important because they are one of the tools for building effective information security of the national economy.

3 Improving the Reliability of Economic Data Processing Using Non-positional Code Structures

Modern methods and tools of infocommunication and network technologies cannot fully ensure reliable monitoring and processing of ever-growing arrays of information in the economy [12]. A significant increase in the reliability of economic data processing is possible through the use of new machine arithmetic, as the existing positional binary number system has shortcomings, and existing methods of unauthorized access, hacking attacks, viruses and other types of hacking, taking and violating the integrity of information are constructed with using a binary position code.

Therefore, it is necessary to look for opportunities to use such arithmetic, in which the data were protected, and the system itself was highly productive [13]. In this regard, the non-positional number system in residual classes is noteworthy, which opens wide opportunities for building not only new machine arithmetic, but also a fundamentally new circuit implementation of computer systems, which in turn significantly expands the use of machine arithmetic and is reliable because the existing threats are not adapted to non-positional code structures and which significantly reduces the threat to the data.

This circumstance has led to the need to find ways to improve the efficiency of computer data processing systems (CDPSs). The results of research conducted in recent decades in the field of information technology by various groups of scientists and engineers to improve the accuracy, survivability, as well as the reliability of the calculations of CDPSs, showed that when performing arithmetic operations on integers significant advantages over the binary code and positional number system in general has a non-positional number system [14]. In general, there are a number of areas and areas of science and technology, where there is a need for reliable and high-precision integer arithmetic calculations, including economics. As a result, growing interest in using new mathematical models and architectural solutions of computer processing systems integer economic data (CPSIED) by using non-positional machine arithmetic (MA). It's caused primarily by the following circumstances:

– great interest in MA is shown by banking structures, where it is necessary to reliably process large data sets in real time, that is, high-performance tools are needed for highly reliable calculations with self-correction of errors, which is typical for non-positional code structures;
– increasing density of elements on one crystal does not always allow for quality and complete testing (monitoring), in this case, it is increasingly important to ensure resilience to the failure of the CPSIED;
– cryptocurrency, which requires huge computing resources and reliability, exceeding the existing capabilities of modern binary CDPSs;
– the current level of development of microelectronics is approaches the limit of its capabilities in terms of security, existing and promising computer systems and components for real-time processing of large arrays of economic data;
– modern development of integrated circuitry allows a new look at the principles of construction of devices using MA and provides ample opportunities for the use of new design methods (e.g., methodology of designing systems on a chip—SoC) in the development of individual computing units and computer systems in general [15].

Unfortunately today Ukraine unlike theoretical developments, lags from foreign microelectronics of a number of leading countries, in this case it is advisable to use existing theoretical developments and practical experience in creating effective CPSIED based on MA. Therefore, the use of the properties of non-positional arithmetic (independence, equality and low-bit residues that determine the non-positional code structure in MA) compared with the binary positional number system, has the following significant advantages:

– the ability to create a system of control and correction of the CPSIED with effective detection and correction of failures and refusals (which is a tool for attackers in cyberattacks);

- the ability to control (monitor) and correct errors in the dynamics of the computational process of the CPSIED [16];
- the possibility of effective use of passive as well as active fault tolerance, taking into account the operational reconfiguration of the structure of the CPSIED, which significantly increases security [17];
- manifestation of a special feature of the structure of the CPSIED in the MA, which ensures the absence of the effect of errors reproduction (for example, Trojans);
- suitability of the structure of the CPSIED in MA for operational diagnostics of units and nodes of computer structures.

The results of the analysis of problems of integer processing of economic data and monitoring of the set of positive properties of MA determine the following classes of problems and algorithms in which the non-positional number system is significantly more effective than the positional one, namely:

- cryptographic transformations used in cryptocurrency;
- processing of integer, vector and matrix large arrays of real-time data and storage of high-bit data (2^{32}–2^{128} bits);
- control, monitoring, diagnostics and noise-tolerant data coding in CPSIED [18].

It is the use of the CPSIED on the basis of MA that is an effective tool to protect economic data from attacks from cyberspace. Because all scenarios and mechanisms of hacking hacks are designed for binary code, not for non-positional code structures. Therefore, it is necessary to perform binary code conversion when processing data (because digital information of economic structures is a combination of 0 and 1—it is a binary code) in a non-positional number system based on MA. And then implement software or hardware implementation of data protection mechanisms, according to the principle of organization and functioning of the economic network based on network sensors [19].

4 Network Sensors as an Effective Intrusion Detection Tool

Effective security analysis requires the collection of data from many different sources, each of which only partially reflects the state of the network [20]. The most difficult task in conducting data-based analysis is to collect a sufficient amount of data on the reproduction of rare events. Sufficient, but not redundant, otherwise it will be impossible to perform a search query. Data collection is surprisingly simple, but comprehension and analysis of the obtained data is much more difficult. In security, this problem is complicated by the probability of occurrence of real cyberthreats. Most network traffic doesn't pose a threat, many of the small number of actual attacks will be truly innocent, such as blindly scanning empty IP-addresses and so on [21].

Effective monitoring of economic network information is based on data collected from numerous sensors that generate different types of data and are created by different people for different purposes. A sensor can be anything from a network sensor to a firewall log—something that collects information about your network and can be used to assess information security. Building an effective system of sensors requires a balance between its completeness and redundancy. The ideal sensor system is complete, but not excessive. Completeness means that each event is carefully described, and lack of redundancy means that sensors do not duplicate information about events, as this can only harm security policy in general. These perhaps unattainable goals are an ideal model for building a monitoring solution.

The data analysis process described in this article aims to develop knowledge in the field of cybersecurity in order to make effective decisions in this area. These can be expert decisions: reconstruction of events ex post facto in order to determine why the attack took place and what contributed to its implementation, or to assess the damage. Preventive measures can also be taken: installing speed limiters, installing intrusion detection systems, or developing strategies that can limit a hacker's influence on the network. From this list, we would like to single out the intrusion detection system, because when building a system of protection against cyber attacks, the main goal is to successfully detect threats, block intrusion attempts and neutralize attacks. That is, the main goal of cybersecurity of the information space of the economy is data protection, economic network as a whole, which will ensure sustainable economic development in the digital communication environment, timely detection, prevention and neutralization of real and potential threats to the national security of Ukraine's economy in cyberspace. That is why it is necessary to develop an effective mechanism aimed not at eliminating the consequences of cyberattacks and restoring the sustainability of infocommunication, technological systems of the economy, but at increasing reliability by using information protection measures to prevent, detect and neutralize cyberattacks. One such protection mechanism is the intrusion detection system (IDS) using various means and methods.

Systems aimed at protecting information, both open and restricted, should consist of software and hardware that provide analysis, monitoring, control of the information and communication system of the economic sector. Attack patterns are constantly changing, so when using automated defenses, it may turn out that hackers can now use them to attack ourselves. Therefore, in this article it is recommended to use programmable sensors, which are the embodiment of software and hardware implementation of network protection, the purpose of which is scanning, data processing and decision-making whether it's useful network information or a threat of unauthorized access.

None of the sensors can perform all the functions alone. Network sensors do a lot of work, but they are easy to confuse when managing traffic flows, they are inefficient for encrypted traffic, can only assume the presence of activity in the host [22]. Host sensors provide more comprehensive and accurate information on phenomena for which they have sufficient tools to describe. In order to effectively combine the sensors, they are considered in three planes: review area (Vantage), sensor level (Domain) and sensor action (Action) [23].

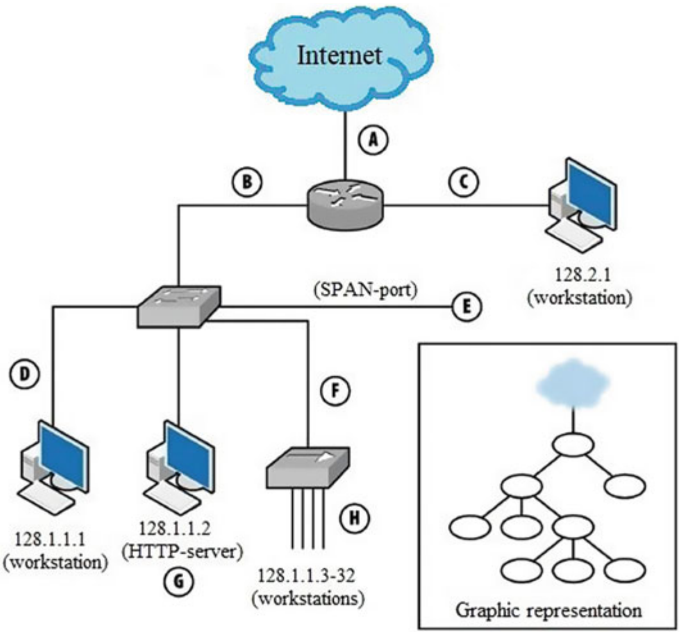

Fig. 1 Network positioning of sensors and graphic representation

Review area (Vantage). The sensor's reviewing area gives an idea of which packages the sensor will be able to study. The scope is determined by the relationship between the sensor location and the network routing infrastructure. To understand how processes affect the field of review area, look at Fig. 1. This figure shows unique potential sensors in capital letters, each of which performs its function.

Each of these sensors has a different area of review, so it will see different areas of traffic. You can roughly calculate the area of review of the sensors inside the network using a simple graph consisting of vertices and edges, as shown in the lower right corner of Fig. 1, and then trace which of the edges intersect between the vertices. As we see, none of the sensors cover the entire network. In addition, in the process you will have to deal with excess traffic. For example, if you use sensors H and E, you will see traffic from 128.1.1.3 to 128.1.1.1 twice. When choosing a location for the sensor, you should try to cover the network completely, without wandering in the redundant data.

When equipping the network, it is necessary to determine the correct location of sensors in *three stages*: creating a network map, identifying potential points of installation of sensors and determining the optimal network coverage.

The first stage involves the development of a network map, understanding how its elements are connected to each other, as well as identifying potential points of installation of sensors (Fig. 1 is a simplified diagram of such a network).

In *the second stage*, when assessing the reviewing area, it is necessary to find potentially acceptable points of installation of network sensors and determine the area visible from these points. This value can be expressed as a list of IP address/port combinations.

The third stage involves selecting the optimal installation points. The goal is to select the points that monitor the network with the least amount of traffic. For example, sensor E, among others, sees all the data of sensor F, so it makes no sense to choose both points. When choosing installation points, you almost always have to deal with excess traffic. Applying filtering rules will help in this situation. For example, to process traffic between hosts 128.1.1.3–32, a sensor must be installed at point H, and this traffic will pop up again and again at points E, F, B, and A. If you configure the sensors at these points so that they are not reported traffic coming from addresses 128.1.1.3–32, the problem of duplication becomes irrelevant.

Sensor level (Domain). Sensor location level gives an idea of the information it collects. The sensor can collect data at one of three levels: network, host and service.

Network. Sensors at this level, i.e. network sensors collect information about network traffic. Examples of such sensors include VPNs, most IDSs, NetFlow data collection programs such as YAF (Yet Another Flowmeter is a reference implementation for the IETF IPFIX standard and standard packet capture software for SiLK tools), and as well as TCP data collection programs such as *Snort* and raw *tcpdump* data [23].

Host. Host sensors monitor processes that take place on the host, such as logging in, logging out, accessing files, etc. The host sensor can provide information that is not provided by the network sensor, such as information about the actual access to a particular host or about using external USB peripherals. Host sensors include intrusion prevention system (IPS) tools such as Tripwire or McAfee’s HIPS (Host IPS) app, as well as system and security logs. Host sensors provide information about low-level operations, but do not tell much about running services [22]. Obviously, we can only use such sensors on hosts that you know of. Unauthorized hosts must be identified before we can verify them. Also very important is the fact that the security professional must know about the existence of the host sensor before actual use.

Service. Service sensors are generated by certain processes, such as HTTP and SMTP-server logs. Service sensors monitor properly formed (legitimate) events within the service (for example, an HTTP-sensor detects a failed appeal to URL but will not record session 80 of the port during which compatible HTTP commands were sent). Unlike host and network sensor, service sensors record mostly interactions with a particular service: sending emails, executing HTTP requests, etc. As in the case of the host sensor, need to know the existence of the service before using the sensor from its level.

Sensors installed at different levels provide more complete information than individual sensors, even if they have the same area of review. Host sensors provide more information (because it sees many hosts) than another sensors and can provide, for example, unencrypted port payload data that is not available to the network sensor. At the same time, if you take into account the amount of network data, their value is small: you have to analyze more records to understand the event, and it is often difficult to determine whether the host responded to network traffic. Network sensors can help with investigations and serve as an aid to host sensors when this information isn't available to it.

Sensor action (Action). The action of the sensor shows how the sensor interacts with the collected data. The sensor can perform one of the following actions:

Report. This action is to provide information on all the phenomena that this sensor sees. Report sensors are simple and important for obtaining basic information. They are also important for creating signatures and alarms for phenomena for which alarm and lock sensors are still ineffective due to configuration features. Report sensors include NetFlow data collection programs, *tcpdump*, and server logs.

Event. Event sensors differ from report sensors in that they collect numerous data to create an event in order to form a specific set of this data. For example, a host's IDS can parse a data icon, detect a malicious signature in memory, and send an event by notifying that its host has encountered malware. As a last resort, event sensors act as black boxes that create events in response to internal processes triggered by experts. IDS and antivirus are event sensors.

Control. The control sensor, like the event sensor, collects numerous data and studies it, and then responds. Unlike an event sensor, a control sensor modifies or blocks traffic when sending an event. Control sensors include IPS packet management system, network security systems, anti-spam systems and some antivirus. The action of the sensor affects not only the formation of the report, but also how it interacts with the analyzed data. Control sensors can modify or block traffic [22].

Figure 2 shows how different sensors interact with data. Figure 2 shows the operation of three sensors: *R*—sensor report, *E*—event sensor, *C*—control sensor. Event and control sensors are signature matching systems that respond to the "ATTACK" line. Each sensor is located between the Internet and a single network.

R, sensor reports, simply compiles reports on the analyzed traffic. In this case, it includes in the report both normal and harmful traffic, without affecting it, and also effectively summarizes the analyzed data. The event sensor *E* creates an event only in response to harmful traffic, ignoring the normal. *E* doesn't stop the traffic, it just sends the event. Control sensor *C* sends an event when it sees harmful traffic, ignoring the normal. However, *C* blocks abnormal traffic and prevents it from reaching its destination. If after sensor *C* will be installed another sensor, it will never recognize traffic which blocks [23].

Developing the right structure for a cyberattack detection system requires an understanding of how different sensors collect data, how they complement, duplicate, and interact with each other, and an understanding of effective data storage principles to enable rapid analysis. Therefore, an extremely important task in developing an effective mechanism for monitoring and detecting network intrusions is the location of sensors in accordance with the review area and functional purpose (sensor levels

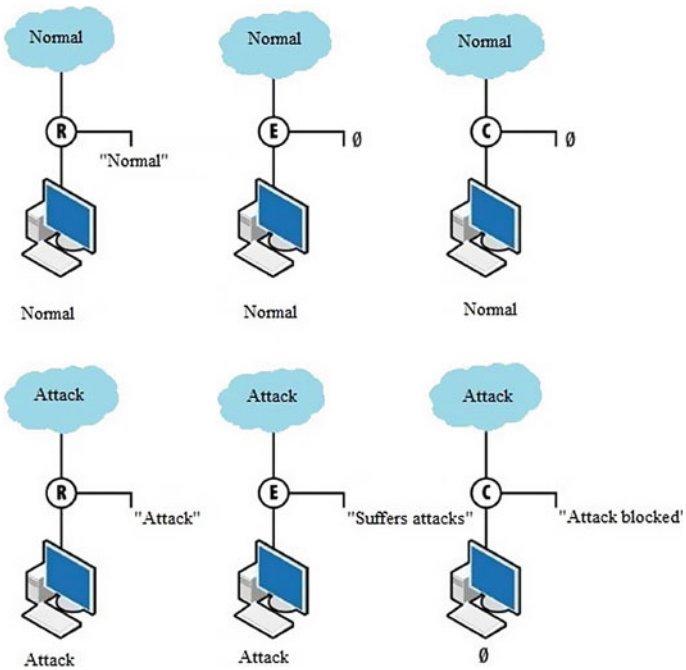

Fig. 2 Scenarios of blocking attacks by sensors

and sensor actions). To do this, first of all security professionals need to analyze in detail the structure of the network (topology, technology, network equipments and their interaction) [24, 25].

There are usually other means of monitoring to detect potential threats: network detectors, anti-virus programs, etc. This method of protection against cyberattacks was considered on the basis of building an effective system of sensors, as these sensors have a significant field of view, and at the same time have great resources for processing and analyzing packets, thus providing better monitoring results.

5 Conclusion

It is proved that one of the main threats to the stable functioning of the national economy of Ukraine during the period of military aggression is the insufficient level of information security. The generalization of international experience in the field of information security allowed us to conclude that, first of all, it is necessary to ensure the categorization of information, prediction and timely detection of threats. Therefore, the possibility of creating a mechanism for effective processing of economic data, network monitoring and responding to threats to information security of the national economy was considered.

The main approaches of possible security measures are considered. A deeper idea of information security of the economic sphere is given. The process of increasing the reliability and security of economic data processing based on the use of new machine arithmetic, which will automatically act as an element of data encryption, was analyzed. For each attack scenario, the most effective mechanisms for protecting and developing an effective information security policy were selected and developed.

Implementation of the proposed measures, subject to coordinated activities of all identified participants in this process, will increase the level of information security of the national economy of Ukraine, ensure its resilience to external and internal, real and potential risks and threats.

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Architectural Heritage Information Potential in Modern Commemorative Practices (On Latin America Example)

Iryna Perederii, Ruslan Hula, Anna Ageicheva, and Liudmyla Derevianko

Abstract Emphasis is placed on the unique historical phenomenon of the formation of Latin American culture as an organic synthesis of European, Indian and African cultures with the complex application of commemorative practices in art genres. The complex of scientific approaches to the disclosure of the content and essence of the concept of "historical memory" in the European scientific discourse is analyzed. Emphasis is placed on the diversity of views of researchers in studying the features of socio-political processes of formation of individual and collective historical consciousness of man, society, society. A general description of the role and place of Latin American architecture in the world cultural and historical process is given. Peculiarities of formation, functioning and transformation of commemorative practices using the information potential of architectural monuments on the example of architecture tendencies development analysis of Latin America at the colonial period are considered. Peculiarities of application of dominant architectural styles in the process of urban planning as a reflection of the pan—European vector of art development are revealed. The dominant architectural forms, tendencies of architectural construction of different regions of Latin America and the influence of national practices of commemoration of the colonizing states on the formation of urban infrastructure are characterized. The role of cultures of the indigenous population of the Latin American cultural region in the formation of unique architectural schools in Latin America is indicated.

Keywords Historical memory · Commemoration · Commemorative practices · Latin America architecture · Colonial period

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_68

1 Basic Concepts of Commemoration

One of the most important components of the spiritual and cultural development of any nation, which undoubtedly affects its overall progress, is historical memory. It is expressed at the level of personal (in relation to the personality and his/her individual perception of the world), community, as well as state experience [1, p. 101].

It is a fact that political elites tend to use history, and sometimes manipulate it to form identities. Historical politics is now a peculiar mechanism for actualizing loyalties. According to the Russian researcher M. V. Kirchanov, historical politics is also developing as a form of memory securitization. It contributes to the unification of memory culture and the blurring of alternative versions of historical and political memory [2, p. 73]. Despite accusations of expressive tendencies of "governmentalization" of historical science, historical politics, politicization and ideologization of historical knowledge form an inevitable process. Despite the fact that the answers to the question "what is history for" should seem to be the same for historians around the world, each country has its own answers, because in every state the community of historians has its own institutional traditions and style of national historiography [3].

There is no doubt that similar European mechanisms and strategies for dealing with the past were used in the 1990s by political elites in South American countries such as Chile, where democratic transition processes promoted historical debates and political "clashes" of alternative historical monuments.

The realization of historical memory policy is implemented through commemorative practices (practices of preserving historical memory). It should be reminded that commemoration is a conscious act of transmitting worldview significant information about the past by perpetuating certain persons and events through the creation of "places of memory" (author of the concept P. Nora). And commemorative practices form a set of ways that contribute to the consolidation, preservation and transmission of the memory of its historical past in society. They include the creation of museums and memorial complexes, construction of monuments, state and local celebration of memorable dates, publication of historical documents, holding various educational events, etc. [4].

At the same time, the relatively "selective nature" of commemoration should be noted. Historical memory provides for the use of the phenomenon of the "useful past", the past that contributes to the consolidation of the nation on the examples of heroic victories, scientific and cultural, economic achievements. At the same time, in the process of political nation building it is not advisable to overemphasize the events that have a negative background, causing a sense of mental inferiority and historical pessimism, such as military defeats, loss of state sovereignty, punitive and terrorist practices, etc. [5].

One way or another, any nationally significant objects of material and spiritual culture can be the means of commemoration, even those that were not created specifically for commemorative purposes, but which a priori reflect the historical past in a certain way. The national architectural heritage of any country particularly belongs to such means. After all, it defines the identity of cities as centers of cultural and historical inheritance. To our minds, this is the very context in which the American historian, sociologist and philosopher of technology, a specialist in the theory and history of architecture, urban planning and urbanism Lewis Mumford calls cities as museums, indicating the fact that they are the materialization of the memory of the history of civilization development and allow to understand the current problems of our time. By the way, L. Mumford, like many other scholars, shared the opinion that we systematically try to reconstruct the present from the past and present it as history [6, p. 42].

2 The Architecture of Urban Planning in Latin America of the Colonial Period (Late XV–Early XIX Centuries) as a Form of Commemorative Practices

The history of the development of Latin American architecture can be divided into the following periods: ancient (pre-Columbian), colonial (late 15th–early nineteenth century), post-independence (early 19th–early twentieth centuries). Significant typological differences in the architecture of the twentieth century, which were associated with intensive economic and technological development, as well as with important political and ideological processes, allow us to identify it in a separate period. All periods are characterized by unique architecture with their bright identity. During the last five centuries, Latin American architecture has been strongly influenced by Europe and the USA. Baroque, romanticism, classicism, eclecticism, and modern rationalism replaced each other. In the middle of the last century there was a keen interest from the world community in the achievements of Latin American architects. The interest in architecture and architects of Latin America has increased again in recent years due to the active construction work that is taking place here.

A unique example of the historical memory synthesis of European, Amerindian and African cultural traditions is the development of Latin American architecture during colonization (late 15th–early nineteenth centuries). This time period was characterized by the originality and pronounced national identity of architecture based on leading European practices. The peculiarities of the architectural process were:

- introduction of stylistic traditions based on the leading European architectural styles of the colonizing countries into the practice of urban planning in the colonies;
- active development of urban planning;
- strict regulation by laws, which initially presupposed clear planning, houses and squares location;
- domination in civil construction of religious and administrative buildings: churches, cathedrals, monasteries, chapels, town halls, as an implementation of the leading European architectural forms of the time in the practice of local town planning;

– the use of decorations that synthesized various Spanish, Portuguese and Native American stylistic references;
– the presence of a peculiar African-American architectural zone, where there was definitely an African element in the syncretic culture (Brazil, colonies of Spain, France, Holland, England in the Caribbean Sea area) [7].

The architecture of Latin America at the time of colonization is a striking example of the implementation of commemorative practices in the process of urban planning.

Tradition and conservatism were inherent in the architecture of the Spanish colonies. Structural and spatial solutions have not greatly changed over time. Construction was strictly regulated by laws, which stipulated clear planning, houses and squares location. The leading architectural forms of the time were churches, cathedrals, monasteries, chapels and town halls. The main feature of colonial architecture was the use of decoration, which synthesized different stylistic solutions. In these areas local features were largely determined by the involvement of Native American builders, stone carvers, and artists.

At the same time, the architecture of Portuguese Brazil was very different from that of the Spanish colonies. There were no “Laws for the Indies” in the country, so its cities did not have the regular layout in a New Spain style. Grandiose churches were also built and their appearance was not monumental. Brazil’s religious buildings were more chamber-like, filled with sunlight, more “secular”.

At the same time, Brazil, together with the colonies of Spain, France, Holland and England in the Caribbean in colonial times formed an African ethno-cultural zone, where the African element in the population and in its syncretic culture became particularly significant.

Colonial period of architectural development (late XV—early XIX century) was represented by New Spain, Peru, territories where ancient architecture had developed and the architecture of the Portuguese colonies.

Early period (or the conquest period) (late XV–XVI centuries).

A new stage in the integration of Latin American architecture came as a result of the conquest. There was a purposeful total destruction of the Amerindian culture and its material carrier and embodiment—architecture. At the same time a program of building churches, fortresses, palaces, mansions, and cities was unfolding, and in its scope was almost unparalleled in previous building history. One hundred years after the beginning of the conquest, 70,000 churches and 5,000 monasteries had been built in the Spanish colonies alone. Hundreds of towns were founded, designed according to special instructions which were part of the “Laws for the Indies” and built. The rigidly rectangular grid of colonial towns, despite their very different origins, developed in a peculiar way the traditions of the ceremonial ensembles of pre-Columbian civilizations’ towns.

The dominant stylistic trends of the period were isabelline, plateresque and, to a lesser extent, herrerian style.

The Isabelline (Manueline in Portugal) was an architectural style of the late 15th and early sixteenth centuries characterized by a refraction of the Moorish architectural traditions and the Mudejar style (synthesis of Moorish, Gothic and Late

Renaissance art elements), using the Late Gothic base, elements of Italian art with its individual decorative elements. The most common features of the Isabelline are the predominance of heraldic and epigraphic motifs, especially symbols such as the pomegranate and arrows, which refer to Catholic monarchs. Also distinctive is the use of plaster or beaded reliefs carved in stone.

The Plateresque is a style developed in the first half of the sixteenth century which absorbed features of Gothic, Arabica and early Renaissance. An example of this synthesis are the shields and turrets on the facades, the neoclassical style columns and the facades, divided into three parts. The main features are changes in the area of facade composition. Typical of the style, the facades are practically examples of jewelry art, so meticulously executed. Mostly floral motifs are used, but there are also many medallions, heraldic objects and animal figures. In Plateresque architecture a logical system of vertical and horizontal segmentation is also expressed, with a defined center in each tier. The facades are saturated with classical architectural and sculptural forms, bas-reliefs, busts, statues of ancient gods, openwork carving with Moorish motifs and preservation of Gothic forms.

The herrerian style—an architectural style of the Spanish regional branch of Renaissance in the second half of the sixteenth century. Its peculiarity was rigid geometric forms, strict laconicism and asceticism, cold rigidity of geometric volumes. In general, the style did not take root in Latin America. However, some of its forms—vaults with plinths supported by columns and pilasters, cylindrical vaults—were widespread in the architecture of the Spanish colonies in the late 16th-early seventeenth century.

The second period (seventeenth century) had lasted from the 30 s of the XVII century till the first quarter of the XIX century stylistics of architecture of the Spanish colonies and the period was determined by baroque art. This style which was transferred to the colonies in XVII century becomes dominant in building practice. Over the ocean Baroque style spread not only because of direct pressure of the metropolis and creole nobility chase for ancestral fashion. With its dynamism, emotional sublimity it was in tune with culture of other ethnic components of colonies population: as architectural and decorative traditions of aborigines as well as emotional state of mentality of black slaves exported from Africa. Indifference to the volume and composition of the plan, organicity, which included in the Spanish and Portuguese Baroque stylistically different motives, the richness of the decor were those qualities which ensured its rapid spread and sustained prosperity on the American continent.

The process of interpenetration, assimilation and synthesis of the two (European and Amerindian) mother cultures was particularly fruitful in places where large Amerindian civilizations had developed before—Mexico and Guatemala, Peru and Bolivia. Although they had nothing in common with the conquering culture, the overall high level of their culture helped to adopt the building techniques new to the Amerindians more quickly than in other areas.

Many houses, churches and whole cities (Mexico City, Cuzco, Quito) were built on the ruins of Amerindian structures, but this was a new architecture, alien to the natives. The spatial organization of churches here reaches an extreme simplicity, and the excess of decor—unthinkable even in Spain bacchanalia fantastic in variety and originality of forms. The construction was done according to canonized European samples, usually by indentured labor of Amerindian under the guidance of masters from the Iberian Peninsula: Spaniards and Portuguese, representatives of a similar, although in many respects different, but close culture. In addition, Spanish and Portuguese architecture went through similar stages in the sixteenth and eighteenth centuries.

The period was characterized by the construction of a large number of houses of worship and secular buildings. The development of "ultra Baroque" in Mexico takes place at this time. Mexican Baroque churches are generally more enclosed than their European counterparts. Particular attention is paid to the main altar. The rich ornamentation of the altars lingers on the central theme. Columns and pilasters were an important element of Mexican Baroque. The columns and the spaces between them were usually lavishly decorated. The Mexican Baroque retained elements of Spanish Gothic and Moorish architecture.

At the same time, the Baroque of Peru and Bolivia at that time were devoid of the extremes of excessive Mexican "ultra Baroque" decoration. Along with less close links to the metropolis, local tradition also played an important role. The Incas were engineers rather than architects. The buildings are made of dry, beautifully hewn blocks of stone. They are expressive in their austere power and sparing in their decoration. Only a broad band of bas-reliefs consisting of repeated motifs adorns the upper parts of the walls, the so-called Sun Gate, ritual structures of the Quechua and Aymara Amerindian. Each of the churches is characterized by static and clear composition, laconicism of lines and forms, expressiveness of juxtaposition of extended smooth planes and plastic massive volumes. All parts of the temple—tower, chapels, nave—are perceived as an independent element of architecture. With the forcible transfer of European models to the autochthonous environment, alien symbolism, and the complexity of Christian concepts, a simplification of Christian temple composition had to happen.

In Ecuador, Colombia, and Venezuela, unlike other Spanish colonies, a strong influence of Italian architecture, mainly of the Italian Renaissance, much less the Baroque, was felt, in which certain motifs of Amerindian art quite dissolved.

The third period (18th—beginning of the nineteenth century). The architecture of 18th-century is not simply Spanish and Portuguese, which underwent little change away from the metropolis, but a variant of Baroque art in its own right. This variety is characterized by less originality than the Spanish, Portuguese, Italian Baroque. A large number of local schools, born of the feudal insularity of certain areas, cultivated their own motifs, widespread only here.

Brazilian Baroque developed in this period. Colonial Brazilian architecture was predominantly European in character. One of the reasons for this was the lack of a skilled workforce of native Amerindian, due to which it did not receive a coloring specific to Mexico and Peru, which retained visible traces of pre-Columbian architecture. Its peculiarity is the decoration of building facades with polychrome or, more often, white and blue ceramic tiles called azulejos. Often these tiles were used for compositions on mythological or evangelical subjects.

Through a complex set of socio-historical conditions the architecture of Brazil developed considerably behind the Spanish colonies, which reached their greatest boom only in the middle and second half of the eighteenth century, when the economy and architecture of most of the Spanish colonies were in decline. Very fruitful was the influence on the architecture of Brazil of that time of the ideas and sentiments of the national liberation movement and the formation of national consciousness connected with it.

In American colonies Baroque trends in architecture of the Iberian Peninsula often reached a greater stylistic certainty and expressiveness than in metropolitan areas. But still the architecture of Latin America remained peripheral and lagged behind the development of European architecture [8, c. 99–118].

3 Conclusion

The architecture of Latin America in the late fifteenth century and the first quarter of the nineteenth century is characterized by great diversity, which together constitute a cultural and historical phenomenon unparalleled in world culture. The historical experience of Latin American urban development shows a unique synthesis of commemorative practices. But this process, which took place in its own way in different parts of the vast continent, is not limited to elements of imitation of European models. The main thing is that during this period nations were formed and the foundations of national cultures were laid. The best examples of architecture are an organic combination of European, Amerindian, and African comemoranda [9, 10]. The architecture of the main centers of the Spanish colonies developed under the influence of local traditions. It is the traditions of pre-Columbian art that determine the identity and color of the architecture of Mexico, Peru and Bolivia. The complex transformation of European and autochthonous architectural traditions has led to the creation of incomparable masterpieces of Mexican, Peruvian, Bolivian and Brazilian Baroque. During the colonization period, the tradition of European architecture was reinterpreted and transformed under the influence of local socio-economic and climatic conditions.

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Construction Technologies and Investments in Reconstruction of the National Economy of Ukraine

Liana Ptashchenko, Lyudmyla Svistun, Yuliia Khudolii, and Arif Huseynov

Abstract The article is dedicated to the issues related to the need of rebuilding the national economy of Ukraine. An analysis of the national economy destruction caused by Russian aggressor is conducted. A comparative analysis of Ukraine's reconstruction of after the Second World War is conducted, with attention focused on unfair and ineffective policy of the USSR Central Government in relation to the Ukrainian Republic. The current state of destruction caused by Russian aggressor is generalized and the emphasis is made on the constant growth of the scale of destruction caused by rocket attacks on the civilian population and infrastructure by Russian fascists. Both foreign and Ukrainian experts are of the opinion that the Marshall Plan 2 should be developed to rebuild Ukraine's national economy. The authors support the idea and believe that it will be extremely difficult for Ukraine to rebuild without the support of strong countries of the world. President Volodymyr Zelenskyi and his team are developing a reconstruction strategy that should cover all the economy sectors and social sphere. The authors of the article are of the opinion that reconstruction should be carried out in all sectors of the economy with the focus on construction. This is due to the social and economic significance of the industry development since many citizens were left homeless, hospitals, educational institutions and industrial enterprises are destroyed. Foreign experience of fast construction is being considered. Since construction is a rather costly industry, significant funds will be needed for the rapid restoration of Ukraine's social and industrial infrastructure, and sources of investment in rebuilding Ukraine's national economy are being considered. Today a new world paradigm of human coexistence is emerging, and it is Ukraine that unites progressive humanity in the fight against the new fascism, Russian dictatorship and aggression. The extent to which the world is ready to support Ukraine in its quest to striving to rebuild and restore its economy will prove the viability of this paradigm.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_69

Keywords National Economy of Ukraine · Construction · Marshall plan · Investments · Restoration · Financing

1 Introduction

Today, global changes are taking place in social, political and economic relations all over the world. The reason for these changes is the war in Ukraine, the people of which are fighting incredibly bravely for their homeland, for their own independence and European traditions against the world "second" army of the Russian horde. These changes concern the global paradigm of human coexistence on the principles of indifference, commonwealth and mutual assistance. Such stresses in society contribute to the reformatting of values. Mankind is beginning to come to the conclusion that there is nothing more valuable in the world than life. Everything can be restored, rebuilt, accumulated and fixed, except death.

When this article is being written, the war continues, but the authors believe that when it is published, all the territories of independent Ukraine will be completely liberated, and only in some places there will be fighting for the occupied territories. The President of Ukraine Volodymyr Zelenskyi and his Office are making a strategy for rebuilding the national economy, which was brutally destroyed by the Russian occupiers.

Reconstruction will require significant investment resources and the aim of the article is to consider possible technologies for rapid construction and sources of investment in the reconstruction of infrastructure, cities and the national economy of Ukraine.

2 Main Material

Experts from Kyiv Institute of Economics have estimated the damage inflicted on Ukraine by Russian invaders. According to preliminary data, the damage to Ukraine's infrastructure in the war started by Russia amounted to 1.8 trillion hryvnias or 62.6 billion dollars as of March 17, 2022. This is evidenced by the analysis carried out within the project "Russia will pay" by the KSE Institute team (analytical unit of Kyiv School of Economics) and volunteers from partner organizations, including the Center for Economic Strategy and Prozorro. Sales".

In total, according to the KSE Institute, at least 411 educational institutions, 36 health care facilities and 1,600 residential buildings have been damaged, destroyed or seized in Ukraine since the beginning of Russia's military aggression against Ukraine on February 24. Destroyed houses in rural areas are currently extremely difficult to count, since many villages have been captured or surrounded by racists. In addition, more than 15,000 km of roads, 5,000 km of railways were "lost", 15 airports, 350

Table 1 Destruction of the objects of the national economy of Ukraine as of March 17, 2022

Object name	Number	Billion dollars
Health care facilities	36	2,466
Nuclear power plants	1	2,416
Institutions of secondary and higher education	273	1,280
Residential buildings	1600	1,245
Factories, enterprises	45	643
Administrative buildings	30	492
Kindergartens	124	427
Military airfields	10	390
"Mriia" AN-255 Plane	1	300
Shopping malls	7	120
Thermal and hydroelectric power plants	7	101
Other		107
Total		62,648

bridges and bridge crossings were destroyed or disabled. The consequences of such destruction are summarized in Table 1 [1].

These calculations are based on analysis of public messages from citizens, government, local authorities regarding losses and damage throughout the country. The evaluation data is increasing, since missile strikes in the cities and villages of Ukraine are continuing. Also, an assessment does not take into account information on damage caused by combat operations, mines, damage to natural resources, animal farms, and stocks of companies in warehouses and shops, moving and military property, property of telecom operators.

As reported by Denys Shmyhal, Prime Minister of Ukraine, according to preliminary calculations, the restoration of Ukraine after a war with Russia will require 565 billion dollars [1].

This gives grounds to claim that reconstruction of the national economy of Ukraine will require active development of construction industry and involvement of foreign companies to restore social and economic infrastructure. Besides, despite the substantial financial support of the countries worldwide and international organizations, other possible sources of funding for Ukraine's national economy reconstruction should also be considered, since reparations of the Russian Federation should not be relied upon.

It is advisable to turn to history and compare consequences of devastation caused by World War II in Ukraine.

It was estimated that 16,000 industrial enterprises, 882 mines of the Donetsk coal basin, 10 main railways, more than 35,000 agricultural communities (collective and state farms) were destroyed during the war and Hitler's occupation of Ukraine, and 417 towns and cities were turned into ruins. Demographic losses accounted for almost a quarter of the total population. Every sixth inhabitant of Ukraine died in the war [2], 2.4 million people were deported to Germany. The total amount of losses suffered by the population and economy of Ukraine amounted to almost 1.2 trillion rubles.

What are the features of the national economy of Ukraine renovation after the World War II? It was traditional for the planned economy of the Soviet Union and all its republics to adopt and approve five-year plans. Thus, in August 1946, at the VIII session of the Verkhovna Rada of the Ukrainian Soviet Socialist Republic (USSR), the "Law on the Five-Year Plan for the Reconstruction and Development of the National Economy of the Ukrainian SSR for 1946–1950" was adopted [2]. The peculiarity of this plan was that the USSR central government did not provide for full funding and, accordingly, direct restoration of the economic complex of the Ukrainian Republic to the pre-war state. After all, according to estimated indicators, Ukrainian economy received only 15% of all-Union investment, while Ukraine suffered 42% of all material losses of the Soviet Union in the war.

According to the fourth five-year plan, the country's political authorities did not envisage full restoration of the prewar role of the USSR in the economic complex of the USSR. According to benchmarks set by the union plan, the main task of the first postwar five-year plan was to restore the pre-war level of industry and agriculture by increasing labor productivity by 36%. The main priorities were identified as restoration and further rise of heavy industry, railway transport, revival of the coal industry of the republic, metallurgical plants of Donbas and Prydniprovia, chemical industry, which posed a hidden threat of increasing disparities and distortions in Ukraine's economy, primarily in the significant lag of light industry and agriculture [3]. In the process of reconstruction, administrative apparatus ignored the experience of European countries economic potential restoring, according to which preference was given to technical re-equipment of various sectors of agriculture, agricultural development, light and food industries as well as stabilization of the national currency. The success of industrial growth in Ukraine, the same as in the USSR as a whole, was ensured mainly by attracting additional labor, i.e. extensively. Thus, economy reconstruction and its successful development depended on solving the problem of labor resources. With the total republic population reduction by a third (about 3.9 million civilians were killed during the Nazi occupation, 200,000 Ukrainians did not return to their homes [4], fearing to end up in Soviet concentration camps), the number of able-bodied citizens significantly reduced. Since American plan to help the victims of the war (Marshall Plan) was rejected by the Stalinist authorities, the approved economic plans were to be financed from internal reserves, in search of funds for reconstruction, the main emphasis was made on economizing, reducing funding for agriculture, light industry and social sphere. The mechanism of "the population funds mobilization" was in action. High rates of reconstruction were also ensured by low wages of workers and employees [5].

These negative aspects should be taken into account when formulating the Strategy for Reconstruction of the National Economy of Ukraine after the war with the Russian fascists. Since one of the sectors of the national economy that will be actively developing is construction, we suggest considering the world experience of rapid construction.

Reinforced concrete is believed to be ideal for the construction of multi-store buildings, since it is cheap, durable and enables building both quickly and efficiently. This material is actively used for the construction of multi-store buildings considering its above mentioned qualities. Let us note that building materials market is developing rapidly and new mixed structures are emerging. For example, the combination of wood and concrete is successfully used for the construction of bridges, ceilings and old buildings repairing. Besides, a popular type of housing construction is brick-monolithic technology, which is efficient, high quality and reliable. Brick is a natural building material. It guarantees the best sound insulation and acts as a kind of climate control: it is able to absorb excessive moisture from the air and give them away in dry weather. Bricks remain unchanged and do not require cosmetic repairs longer than other materials. This technology in combination with a monolithic frame can significantly increase the pace of construction while maintaining high quality.

The main market advantage of prefabricated houses compared to traditional ones undoubtedly is in a sharp reduction in construction time. After all the details of the future house planning are agreed upon with the customer and its components are assembled at the construction company, the direct construction of the house "on site" can be carried out in a relatively short time. Thus, the full construction period (from getting the order to the final assembly of the object) can average to about six months. This is especially relevant for providing housing for displaced persons from the war zone to the cities and rural areas of central Ukraine [6].

Another obvious advantage of prefab houses (at least those of their modern varieties, which are offered today by leading companies in the prefabricated housing market) is a guarantee of a single factory quality control of all the buildings components and environmental aspects, since using environmentally friendly building materials are used and construction waste at sites is minimized.

We also believe that attention should be paid to the technologies used by Japanese engineers in high-rise construction. Thus, the widespread use of automatic floor jacks has led to a sharp reduction in the duration of construction work: high-rise buildings in Japan are erected about twice as fast as those made by traditional methods. Automated equipment delivers modular elements of the future building assembled in factory conditions to construction site: from columns and beams to floor panels and internal finishing details. Construction begins with installation of a special stepped platform to cover the upper floor of the building (thus creating a kind of protection against possible adverse weather conditions). Then construction is carried out according to the traditional scheme, i.e. from the bottom up. Without describing such technologies, it should be noted that automated system allows not only dramatically reducing construction time, but also achieving a significant reduction in specific labor costs and work-related injuries. Thus, according to experts, the construction twenty-storey building according to this technology on average reduce labor costs by 30%, if measured in man-hours, and the time of construction work is reduced by almost half compared to traditional methods [7].

Programs of mass construction of high-rise and ultra-high-rise residential buildings are actively implemented in many countries of South-East Asia. These programs are especially popular, primarily there where there is an acute shortage of land for new development—in Singapore, Hong Kong, Taiwan and South Korea.

Experience of these countries can be used in rebuilding the social infrastructure of the national economy of Ukraine.

Besides, new highly efficient and inexpensive construction technologies should be used as much as possible in the construction of buildings and structures for rapid reconstruction. One of the alternatives is self-framing metal buildings, which is one of the metal-based construction technologies, opening up new opportunities for improving the quality and accuracy of construction, reducing costs and time.

It should be noted that the technology was developed in the 50 s of the twentieth century in North America (actively used in Canada and the United States) to build a large number of low-rise buildings. After that, the construction of self-framing metal buildings became popular in other parts of the world. Since 1950, Japan has joined the construction of self-framing metal buildings and began to successfully use steel buildings in the office and commercial activities. After Japan, other countries joined the construction of self-framing metal buildings. As a result, by the end of the XX century, thin-walled profile began to be used not only in office, administrative and residential buildings, but also in industry and production spheres. Today, the United Kingdom has the highest percentage of self-framing metal buildings systems in the total volume of housing construction—about 20%. For comparison, according to domestic market operators, the same figure in Ukraine does not exceed 2%.

Compared to materials such as wood and concrete, self-framing metal buildings technology has the following advantages:

- durability over 100 years is provided by full galvanizing of framework elements;
- self-framing metal buildings frame is 30–40% lighter than classic welded metal structures and 10–15 times lighter than the reinforced concrete version. Light weight saves a lot of foundations and transportation costs;
- quick and easy installation with involvement of a minimum number of workers and the use of light lifting mechanisms. For example, a team of three builds a 450 m^2 house in 19 days;
- possibility of installation in any weather, and also under tough conditions;
- high seismic resistance (up to 7 points) and resistance to temperature changes;
- high resistance to insects and bacteria [8].

Thus, to rebuild social infrastructure in Ukraine, we consider it appropriate to invite construction companies from the United States, Japan, China, Canada and Sweden.

In addition, state building codes in Ukraine will have to be revised and updated.

The pace and scale of technological progress in the industry will depend on the degree and speed of transition to automated methods of construction and mass implementation of robotics and technologies with minimal human intervention. Therefore, the national economy must be rebuilt on the basis of innovation and scientific and technological progress [9].

Since construction is a very costly industry [10], significant funds will be needed to quickly restore Ukraine's social and industrial infrastructure. Today, foreign and

Ukrainian experts mention the need to develop The Marshall Plan 2 for the reconstruction of Ukraine's national economy. In particular, Boris Johnson, the Prime Minister of the United Kingdom told the leaders of the Visegrad Group (Poland, Hungary, Slovakia and the Czech Republic) that it is necessary to develop a "The Marshall Plan for Ukraine". Although the sources of funding for such a plan have not been identified yet. Johnson's allies claim that one of the sources of financing could be confiscation and sale of London property of the aggressor country sanctioned oligarchs [11].

The Marshall Plan *(European Recovery Program, Marshall Plan)* has historically been a successful example of a systematic integrated movement of capital from rich to poor countries for the mutual benefit of all parties. It led to emergence of new plans for long-term assistance to countries or their associations, and gave impetus to creation of various international organizations in the field of assistance to poor countries [12]. Although the emergence of the Marshall Plan was associated with devastation caused by World War II, it is still an important symbol of effective international cooperation, an example of economic diplomacy. Even under predominance of the US interests, independence or self-interests of European countries was not affected [13]. That is why today it is important to develop such a plan for reconstruction of Ukraine, which would not reduce the national independence and dignity of the country and accelerate Ukraine's integration into the EU and the international freedom-loving community as a whole.

Given that occupiers are losing land battles in all directions, they are ruthlessly destroying social and industrial infrastructure of Ukrainian cities and villages with missile strikes, so the cost of damage is constantly growing.

In this context, an important issue is consideration of funding sources for measures aimed at restoring the national economy of Ukraine. It should be noted that before the war in Ukraine the State Program of Economic Stimulation was implemented to overcome the negative effects caused by restrictive measures to prevent the emergence and spread of acute respiratory disease COVID-19 caused by coronavirus SARS-CoV-2, 2020–2022. The Program was financed from the state budget, local budgets and other sources not prohibited by law. The amount of expenditures required for the implementation of the Program is determined annually during the preparation of draft state and local budgets for the year, taking into account their real capabilities [14].

Still the current situation and complete destruction of Ukraine's national economy by the Russian fascists require significant funds for reconstruction. Therefore, the issue of the Marshall Plan for Ukraine becomes relevant. The main financial investors can become the United States, the EU, the Great Britain, the Baltic States and other countries around the world, not indifferent to ensuring democratic foundations of independence in the world. Besides, the funds will come from charitable organizations, through issuance of government bonds to restore the national economy of Ukraine, for loan financing and instruments of the financial market [15], as well as from concerned citizens of the democratic world. It will also be advisable to use crowd-funding platforms. The authors have previously considered such a promising source of funding for the construction industry as crowd-funding.

Crowd-funding refers to such forms of financing of social projects. Many refer to crowd-funding as a "new phenomenon". However, this is not so new as we think; as a concept, it has existed for several centuries. The novelty lies in technology and thinking, which give the process of "crowd financing" a new impetus, [16] allow solving seemingly unsolvable financial problems.

Also popular is the Indiegogo world-wide crowd-funding platform. There are no restrictions on the type of project and the geographical location of the company. The most successful areas on this platform are projects that improve the way of life and the surrounding eco-environment. This platform is quite attractive for the implementation of social projects. If you need to have the status of a local resident to authorize on Kick-starter and the possibility of accumulating funds, then for Indiegogo—only a bank account.

In addition, on Indiegogo recently appeared the option of "endless crowd-framing", when the deadline for completing the campaign is not specified. The most successful projects were Indiegogo smartphone Ubuntu Edge (more than $13 million), Hive Flow Hive (11,320,000$), Clever helmet Skully ($2,800,000), Family robot Jibo ($2,300,000). There are also other crowd-aiming platforms, which place special projects.

Today, many countries of the world are creating their own platform funding crowd-funding platforms. There are also other crowd-aming platforms, which place special projects.

Today, many countries of the world are creating their own platform fundiwn crowd-funding platforms [17].

These are such platforms as "Spil'nokosht – Big Idea", "Na-Starte", "Idea Box", "Travel Starter". The analysis of the projects, which are placed on the Ukrainian crowding platforms, made it possible to conclude that crowd-shipping activity in Ukraine is not developing actively. So, on the "Na-Starte" platform there are proposed the categories, which are designed mostly for small commercial projects [18–22]. Therefore, large crowd-funding platforms, such as Indiegogo, should enter the Ukrainian market to support the financing of large-scale construction.

Let's summarize the possible sources of funding for reconstruction of the national economy of Ukraine in Fig. 1.

3 Conclusions

The war in Ukraine started by the Russian aggressor is a war against humanity, freedom and independence. Inviolability and courage of the Ukrainian people have united most of the world in the struggle for the moral values of civilized countries. Today, a new world paradigm of human coexistence is emerging, and it is Ukraine that unites progressive humanity in the struggle against the new fascism, Russian dictatorship and aggression.

As a result of the war in Ukraine, cities and villages, objects of industrial and social infrastructure were destroyed. However, the economy works as much as possible in

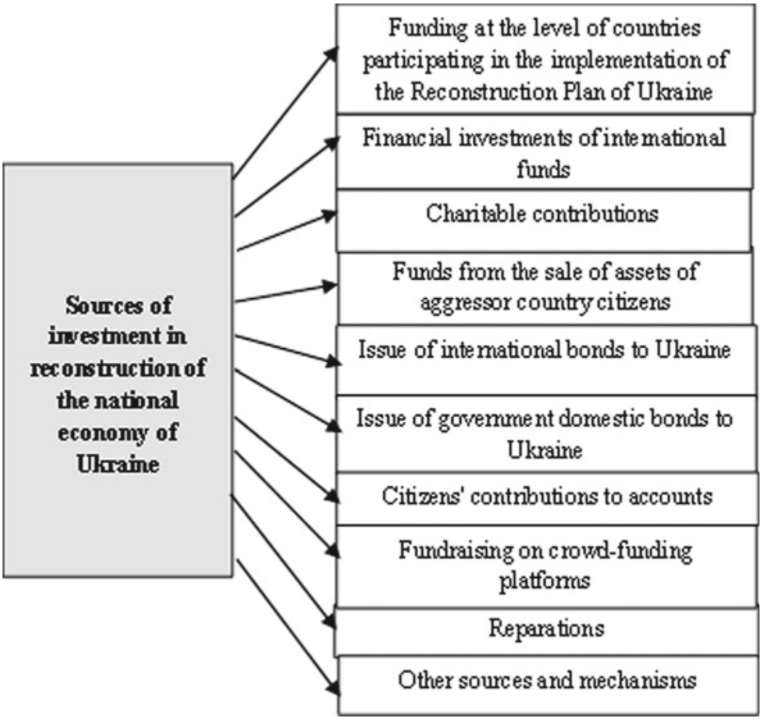

Fig. 1 Sources of financial resources for the reconstruction of the national economy of Ukraine [Made by the authors]

wartime, and the government is developing a strategy to rebuild Ukraine's national economy. The authors of the article believe that reconstruction should be carried out in all sectors of the economy, but with a focus on construction. This is due to the social and economic importance of the industry development, as many citizens were left homeless, hospitals and educational institutions were destroyed as well as industrial enterprises. After all, the biggest multiplier effect should be provided by construction companies related to residential and industrial construction, since this sector of the economy is closely related to other industries. Considering the world experience and technologies of rapid construction, we believe that without foreign construction companies, it will be extremely difficult for Ukrainian society to cope with the objectives of returning to normal life in Ukraine in the coming years. In addition, despite the world's readiness to implement the Marshall Plan for the reconstruction of Ukraine, additional sources of funding for these processes were considered. This is due to the fact that reconstruction must be based on reliable, modern and energy-efficient technologies, and this requires significant financial investments. The authors summarize the main directions of obtaining investment resources for the reconstruction of the national economy of Ukraine, which suffered as a result of the war with the Russian aggressor.

In further research, the authors will consider the problems of development of the oil industry and alternative energy as strategic areas of energy security of Ukraine and its independence from the resources of Russia.

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Forecasting Sales Volume in Construction Companies

Bashar Shirinov and Nataliia Mahas

Abstract In the article, the role of forecasting sales volume in construction companies, methods of forecasting annual sales volume, and the functioning of production program are studied. The author explained the importance of forecasting in the effective use of the potential of firms in the future, commented on the need to differentiate the stages in the preparation of forecasts. Methods of forecasting annual sales were analyzed. According to the author, interpolation and extrapolation of dynamic series give more accurate results when performed on the basis of analytical method development of the series. In the article, based on the information on the sales volume of the construction company in 2001–2017, the author gives an extrapolation of the dynamics series by analytical method, and gives a forecast for the sales volume of the construction company for 2022.

Keywords Heat flow construction firms · Production process · Sales · Forecasting · Profitability · Method · Analysis · Plan

1 Introduction

In modern conditions, the basis for the efficient organization of the production process, its continuous operation and high-quality implementation of the plan tasks is sales forecasting. The main indicator planned here is the volume of sales of a certain type of product. Therefore, the management of the enterprise must determine what and how much they will sell on the market. In other words, it is a matter of choosing the products that an enterprise can produce, so that the demand of consumers for these products is greater and increasing [1, 2].

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_70

Forecasting, which is an integral part of the planning system in the activities of firms, gives preference to the option of efficient use of potential opportunities of the firm in the future [3–6].

In the preparation of forecasts, the following stages should be distinguished:

– writing, analysis and specification of materials for forecasting;
– problems of improving product quality and analysis of modern trends;
– development of forecasts in the composition of complex programs.

At the initial stage of planning current sales, information on the total quantity and assortment of products to be produced in the planned year, data on the long-term forecast of sales volumes for the current period are taken into account as ori for the projected annual sales volume [7–10].

2 Methods for Forecasting Annual Sales Volumes

Methods for predicting the annual sales volume may include:

– Forecasting based on the assumption that the market environment will be the same with the phase of the next period (year). This method ensures that the situation in the market will remain the same. The main role for such training can be played, for example, the volume of basic orders of the enterprise. Usually, the turnover exceeds this indicator to a certain, as well as a predetermined percentage, and the price of this percentage, in turn, is determined on the basis of the experience of the previous period. The application of this method requires the research institutions to conduct special long-term research about the consumers of the product, to collect and process significant amounts of statistical information and actual material [11]. Its application is more expedient in "natural monopolies", in the fields of raw materials and energy.
– Forecasting based on past period. In this case, the development of the previous method cannot be ruled out. Extrapolation methods are widely used in forecasting based on past periods. This method is suitable for areas and bases with stable economic conjuncture, constant or slightly varying range of products and services, where technology changes do not occur so often, where the commodity turnover dynamics are stable. In the process of applying this method, it is impossible to take into account the rapid changes that occur in the nature of commercial activity, in the structure of consumer demand. As for the competition, this method also does not take it into account.
– The method of assessment, generalization of the sale of the enterprise by individual commercial agents and heads of sales departments. Market analysis is replaced by the opinion of people who "hear" the reaction of consumers and the changes in their preferences. However, this information should be processed and the subjectivity of the respondents ' opinions among them should be eliminated. The accuracy of such a method is higher than that of previous methods. But the

organization of such work requires considerable expenses. This includes, first of all, the costs for the payment of the labor of the executors directly of their functions and the costs for the payment of the labor of specialists involved in the processing of information. Since in the previous method planning was included in the function of the head, there were no additional costs. In order to ensure the possibility of using this method, it is necessary to develop a procedure for controlling these costs and financing them. The approach to the issue of sales planning from the point of view of the problem attitude requires special attention to the pricing policy of the enterprise. Through it, the price of individual goods is determined. In a market economy, from the point of view of the buyer, price is an incentive not only for saving, but also for buying goods of better quality. Therefore, how the customer perceives the price (the actual price level) when determining the price has a huge impact on his purchasing behavior in negotiations. Enterprises primarily have to based on the state regulation in this sphere of production, changes in the structure of the sphere, commodity categories, assortment groups, in the state of the market, etc. it should be based on the results of marketing research on situations [12].

3 Analysis of the Sequence of Dynamics by the Analytical Method

To predict the order, the study of the dynamics of socio–economic phenomena and the discovery of their main features in the past order provides grounds. Forecasting is carried out on the basis of identification of unknown future levels of the order. The definition of the unknown levels of the past and the future is called extrapolation of the sequence of dynamics. If the interpolation and extropolation of the sequence of dynamics is carried out on the basis of qualitatively identical circles, it can give the right result. For periods with a long duration and having various patterns of development, the extropolation of the sequence of dynamics cannot correctly characterize the real situation. Because it is impossible to take into account in advance the influence of all factors on the change of events for a long time. Therefore, it is advisable to conduct the extropolation of the series of dynamics used for forecasting in a short time. When the sequence of dynamics, interpolation and extropolation are carried out on the basis of analytical method, it gives more correct result [13]. Let us analyze the sequence of dynamics by analytical method based on the product sales volume of the construction company in 2001–2017 (Table 1). Based on the data of the same table, the trend for the range has been determined:

The parameters of the equation are based on the information of Table 1:

$$a_0 = \frac{\sum y}{n} = \frac{13575.2}{17} = 798.54 \tag{1}$$

$$a_1 = \frac{\sum yt}{\sum t^2} = \frac{6386}{408} = 15.65 \tag{2}$$

Table 1 Volume of product sales of the construction firm in 2001–2017

Years	Product sales thousand manat	t	t^2	yt	$\bar{y}_t$
2001	746.3	−8	64	−5970.4	673.34
2002	749.3	−7	49	−5245.1	688.99
2003	743.4	−6	36	−4460.4	704.64
2004	742.7	−5	25	−3713.5	720.29
2005	716.3	−4	16	−2865.2	735.94
2006	710.7	−3	9	−2132.1	751.59
2007	733.7	−2	4	−1467.4	767.24
2008	735.0	−1	1	−735.0	782.89
2009	711.7	0	0	0	798.54
2010	742.5	1	1	742.5	814.19
2011	772.6	2	4	1545.2	829.84
2012	826.7	3	9	2480.1	845.49
2013	862.9	4	16	3451.6	861.14
2014	895.0	5	25	4475.0	876.79
2015	925.8	6	36	5554.8	892.44
2016	958.9	7	49	6712.3	908.09
2017	1001.7	8	64	8013.6	923.74
Total	13575.2	0	408	6386	13575.18

$$\overline{y}_t = a_0 + a_1 t = 798.5 + 15.65t \tag{3}$$

This means that the sales volume of the construction company's products is increasing on average by 15.65 thousand Manats per year

This serie ends in 2017. In 2018 the price of t will be 9, in 2019 (+10), in 2020 (+11), in 2021 (+12), in 2022 (+13). At this time, the volume of product sales of the construction firm for 2018 will be

$$\overline{y}_{2018} = a_0 + a_1 t = 798.5 + 15.65 * 9 = 939.35$$

$$\overline{y}_{2019} = a_0 + a_1 t = 798.5 + 15.65 * 10 = 955$$

$$\overline{y}_{2020} = a_0 + a_1 t = 798.5 + 15.65 * 11 = 970.65$$

$$\overline{y}_{2021} = a_0 + a_1 t = 798.5 + 15.65 * 12 = 986.3$$

$$\overline{y}_{2022} = a_0 + a_1 t = 798.5 + 15.65 * 13 = 1001.95$$

thousand Manats

Planning of resources is carried out on the basis of sales forecasting. After that, it is necessary to begin the preparation of the production program. Planning begins with the analysis of production economic activity. The level of use of production capacities, the level of Organization of Labor and production, scientific achievements in the field of technology, the level of efficiency of economic means of increasing labor productivity are analyzed.

The Plan is drawn up according to the "order portfolio". Forecasts on orders that will appear are also used here. Therefore, the preparation of the action plan of the enterprise begins with the preparation of the project of its individual parts:

– production and implementation plan
– material-technical supply plan
– personnel and salary plan
– perspective plan on new techniques and capital investments
– financial plan

In practice, the number of sections of the Enterprise plan and their names differ depending on the size of the enterprise, field affiliation, accepted tradition, but the content of the plan work remains unchanged. After the plan's sections are worked out, they are studied and balanced in terms of material and financial resources, as well as in terms of execution. For example, the supply of raw materials, materials, components of the enterprise is directly related to the financial plan, as well as the duration and volume of production and production. Product launches, in turn, are associated with the availability of labor force and production capacities.

Current planning is a set of plans for various types of enterprise activities. The development of current plans begins with sections. The issues facing the divisions require the development of plans for activities and available resources sufficient for their solution. As a result, plans for sections are made in the form of budgets or estimates [14].

4 Conclusions

Practical plans determine the loading of equipment, the implementation of individual operations of the technological cycle, the placement of workers taking into account the time allotted for it, the available production capacities, material resources, staff. All this allows you to accurately coordinate the movement of individual elements and information in the production process, which includes the optimal implementation of production processes, the rational use of resources, timely and complete implementation of production tasks, the work of units.

Thus, a balanced plan of enterprise activity is achieved, i.e., a dynamic system of interaction of production, technical, economic, organizational-administrative and social measures is formed, which is directed to achieve the ultimate goal; it is envisaged the rules and queuing for the execution of works; deadlines and executors for the entire range of various operations provided for in the plan are determined; the sources and volume of financing and also the costs that can be issued for each event are determined. The plan must necessarily indicate in detail the characterization and scale of the final results of the work of the enterprise as a whole, the results of the work on the date and also on each event of the workshops and other sections.

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Semantic and Etymological Analysis of Building and Economic Terminology

Svitlana Sivitska, Liudmyla Cherednyk, Myron Hohol, and Konul Aghayeva

Abstract The article dwells on the study of the etymology of certain groups of words in the building industry and economics, presents reconstruction as the main research stage of the history of the word, analyzes the ways and methods of describing its internal form. There has been found out as a result of the research that the method of reconstruction of the term enables not only to identify its origin, but also to clarify the internal form of the word, which provides for a better understanding of its semantics. According to the results of the study, there is reason to believe that the terminology of the building industry began to take shape much earlier, and it motivates the idea that the profession of a builder is one of the oldest ones. Economic terminology, even though it emerged much later, is a large and extremely important layer of the Ukrainian language vocabulary. Terminological systems of both spheres (building and economic) have many borrowings from Latin, German, French, Italian, English, which, in turn, confirms cross-cultural communication of the native speakers. In the process of functioning of the terms, there occasionally occurred some semantic shifts, which is explained by the derivational processes that take place in the language.

Keywords Semantics · Etymology · Reconstruction of the word · Internal form of the word · Terminology · Building industry · Economics

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_71

1 Introduction

Every word functioning in any language of the world has its own history, hidden from its native speakers by the thickness of time. Definitely, the restoration of the history of words is an extremely complex process due to both linguistic and extralinguistic factors that create quite a unique lexical background, the meaning of which is specified by the correlation with real objects and the relations between them.

It is historical lexicology that deals with the problems of the history of words and their etymological origins, and these issues are attracted to by many modern linguists. Among the scholars who devoted their research papers to the study of this field of linguistics, it is worth mentioning such well-known names as O. Potebnia, O. Ponomariv, Zh. Varbot, O. Iliadi, O. Melnychuk and many others.

Of great interest, in our opinion, is the study of the reconstruction of terms of various branches of knowledge that make up a significant lexical layer of the world's languages, and Ukrainian vocabulary in particular.

According to many researchers, "modern Ukrainian terminology is a relatively stable and traditional lexical-semantic system, which is in a state of continuous movement and gradual improvement" [1, p. 477] and which is influenced not only by linguistic but also by social factors.

The purpose of the article is to find out by means of etymological analysis the semantics of the modern terms in the building industry and economics.

The combination of two different areas of human activity, which may seem rather strange at first sight, can be explained. Economic terminology as a complex system of economic concepts and phenomena is now an important layer of the vocabulary of any language, as economics has occupied an important place in all spheres of human activity, and building industry in particular.

The problems of field terminological systems are in the circle of scientific interests of many famous Ukrainian scholars, among which are the works by O. Kvasnitska, A. Matviichuk, H. Chornovol, Yu. Safonov, O. Chuieshkov, T. Panko and others.

The source base of our study is represented by numerous modern terminological dictionaries of building and economic industries, etymological dictionaries and research papers by leading linguists in the field of lexicology and terminology.

2 Results

The processes of reconstruction of word terms in any field are essential. According to Ferdinand de Saussure, one of the most prominent linguists of the XX century, reconstruction is possible only through comparison. "Reconstruction is a necessary tool with which many general facts of synchronic and diachronic order can be relatively easily established"—the scholar wrote [2, p. 221]. Many researchers of our time agree with him.

It should be noted that the main task of word reconstruction is to identify its original form. For this, according to O. Iliadi, it is necessary to "carefully study the components of the deep structure of the lexemes that fell into disuse in the process of word formation. Determining the semantic sources of the words of a certain language only—is one of the aspects of the etymological research result, designed not only to reveal the semantic basis, but also to recreate the relict nature of words" [3, p. 6]. In addition, the restoration of the oldest features of the word becomes possible only as a result of the reconstruction of its original form, which enables a clear definition of the root as a carrier of the lexical semantics and a formant part, which are genetically and semantically identified with the corresponding formations of other languages. This process is extremely troublesome and requires careful study of all components of the deep structure of lexical units.

That is, in the process of reconstructing the origin of the word, its internal form is studied, the doctrine of which can be found in the works of Oleksandr Potebnia, a famous Ukrainian linguist of the XIX century. According to the scholar, the internal form of the word should be considered "as the etymological meaning of the word; the internal form of the word is the ratio of the content of thought to consciousness; it shows how a person imagines his own opinion; the internal form of the word is the center of the image, one of its features that surpasses all the other features; the internal form should be regarded not as an image of the object, but as an image of the image, i.e. idea" [4].

However, as many modern researchers note, the internal form of the word is not the absolute, which helps to determine one hundred percent the meaning of the word. Basically, it is a systemic characteristic of a word or phrase, which is a kind of bridge from the sound shell of the word to its meaning. The peculiarities of the internal form of each word of a particular language is best revealed by comparing it with the variants of expression of this internal form in other languages.

Another factor that, according to researchers, to some extent complicates the study of vocabulary of ancient times, is the discussion caused by a number of unresolved so far issues, among which are: the linguistic situation of antiquity and the reflection of the contemporary language norms in written memos, "origins and periodization of the Ukrainian language, variability and syncretic semantics of ancient lexemes, stylistic originality of written memos and their dialectal stratification, the use of terms to denote the language of written memos, etc." [5]. But, first of all, owing to the reconstruction, it has appeared possible to reveal the secrets of the creation of many words in various fields of science, building industry and economics in particular.

According to historians, the profession of a builder in Ukraine appeared during the heyday of Kyivan Rus after the adoption of Christianity. It was the times when majestic buildings of the world-famous historical monuments of our state began to be erected.

Among them, first of all, is Sophiia Cathedral, built during the reign of Prince Yaroslav the Wise. According to historians, the church was founded by Volodymyr the Great in 1011, and completed by his son Yaroslav in 1037. For a long time, St. Sophiia was the main temple of the whole Eastern Europe, and now has the status of a UNESCO World Heritage Site. The only monument of stone defensive architecture of the times of Kyivan Rus, which has survived to this day, albeit partially, is the Golden Gate, built at the time of Yaroslav the Wise, i.e. being more than thousand years old. St. Michael's Golden-Domed Cathedral, built in 1108 by Sviatopolk, the grandson of Yaroslav the Wise, is just majestic. In 1078, during the reign of Yaroslav the Wise's son Sviatoslav Yaroslavych, the Assumption Cathedral of Kyiv-Pechersk Lavra was erected. Another Kyiv's landmark is the Vydubychi Monastery. Its history dates back to the 1070 s, when St. Michael's Cathedral was built—the oldest temple of the monastery. In the middle of the XIIth century Cyryl's Church was built, one of the most attractive beauties of ancient Kyiv. And even today the magnificent paintings of the church, restored by the famous artist Mykhailo Vrubel, stay greatly impressive. It is noteworthy that among the ancient frescoes are the works by masters of the Kyiv school of the XIX century—Mykola Pymonenko, Kharyton Platonov, Samiilo Haiduk, Mykhailo Klimanov and others.

Undoubtedly, the vast majority of builders at those times were foreigners, although workers were recruited from locals. Among them were those who studied this art and later became masters themselves. There were many such stories. For example, the collective image of the first architects of that time is Syvook, the character of the novel "Dyvo" ("Miracle") by the famous Ukrainian writer Pavlo Zahrebelnyi, dedicated to the construction of Sophiia Cathedral.

It can be assumed that the ancient builders already had some definite terminology. According to modern scholars, it was "that primitive folk terminology that should have become and really became the basis for modern literary technical terminology" [6].

For example, the word "цеглина" (transliterated as tsehlyna 'brick') has come down to us since ancient times. That was the name of one of the oldest building materials. The first stated mention of it can be referred to the Bible. Thus, in the Book of Genesis there is a story about the Tower of Babel, during the construction of which the building material was brick: «І сказали вони один одному: «Ану, наробімо цегли, і добре її випалімо!» І сталася цегла для них замість каменя, а смола земляна була їм за вапно» 'They said to one another, "Come, let us make bricks and burn them thoroughly." And they used brick for stone, and they used tar for mortar' [7, The Book of Genesis 11–3].

It is known from historical sources that in Mesopotamia giant temples and palaces were built of clay bricks. Thus, the entrance to the Assyrian capital of Nineveh was closed by a twenty-meter-high fortress, the teeth of the walls of which were decorated with bricks, covered with blue glaze with a gold shiny stripe. In the sun, the stripe shone brightly, so the city was said to rejects enemies with its radiance.

Unburned raw bricks were widely used in Ancient Egypt (III-II millennium BC). It was also known in Ancient Rome, had dimensions of $45 \times 30 \times 10$ and was used to lay out such complex structures as arches and vaults.

In the territory of Kyivan Rus, plinths were used to build majestic temples—thin and wide plates of clay which were made in wooden molds, dried and burned in kilns. Those were first bricks. Scientists found them during archeological excavations at the site of Tithe Church in Kyiv.

As it is seen, цеглина (tsehlyna 'brick') as a building material has a long history. No less interesting is the etymology of this word, which has passed a long time of its formation, namely: цегла (tsehla 'brick')—Pol. Cegła < Middle-Upper German ziegel < Old-Upper German ziegal, ziagal, ziagala < Lat. tēgula. A separate unit of brick is called "цеглина" (tsehlyna 'a brick').

Lime is also an ancient building material. According to historians, the first mention of it is found in the texts of ancient Egyptians who used it with gypsum in the construction of majestic pyramids. These events took place another 4,000 thousand years BC. It was used in the Roman Empire as well. It was the Romans who discovered the remarkable property of lime, namely, adding to the lime mixture some substances from which the solution acquired the ability to harden. It is believed that this recipe was discovered by the famous Roman architect Vitruvius. It is also known that the Romans added lard, clotted blood of various animals. In Kyivan Rus, for example, during the construction of temples birds' eggs were added to firmly hold the bricks. In terms of etymological reconstruction, the word comes from the Proto-Slavic language: вапно (vapno 'lime') < from Proto-Slavic *vapьno. It should be noted that related roots are in the Prussian language (woapis), one of the dead languages of the Baltic-Slavic language group, which is a branch of the Indo-European language family. In addition, there is a word with the same root in the Latvian (vãpe), Bulgarian, Serbo-Croatian (ва́пно), Czech, Slovak (vápno), Polish (wapno) languages.

One of the main building materials "used to produce modern prefabricated reinforced concrete and concrete structures and concrete products, as well as to construct monolithic concrete and reinforced concrete structures" [8, p. 24] is concrete. As the etymological analysis shows, the word is of foreign origin. According to linguists, it was borrowed from the German language (Beton) or directly from French—beton, where it probably came from Latin—bitumen "silt, sand; mineral resin, asphalt". The word retains the same form, for example, in Bulgarian (бетон), Macedonian (бетон), Polish (beton), Czech (beton), Slovak (beton) and Serbo-Croatian (бето̄н). The modern Ukrainian language possesses such phonetic and word-forming variants as: бетонувати (betonuvaty 'to concrete'), бетоняр (betoniar 'someone who works with concrete), бетонник (betonnyk 'a concrete mixer'), обетонити (obetonyty 'to cover with concrete'), бетоні́т («штучний камінь з бетону») ("bentonite—an artificial concrete stone"). Interestingly, concrete is not a material of the XX–XXI centuries. It was used in Ancient Sumer and Mesopotamia. In Ancient Rome, such majestic buildings as the Colosseum, the Pantheon, the famous Roman roads were built of concrete. And the fact that the forty-three-meter dome of the Pantheon is still intact is the best evidence of the capacities of this ancient, but still relevant building material.

Archaeological data show that stone was perhaps first material that a human learned to process. About 3 million years ago, Homo habilis, i.e. a "skilled human", could already crush and sharpen pieces of stone to make tools. Many millennia later, it began to be used in construction. The word "камінь" (transliterated as kamin 'stone') in the General Slavic version "ками" (kamy) is found in written texts of the XIth century. In general, the word is of Indo-European nature: Ukr. Камінь < Proto-Slavic * kamy < Proto-Indo-European *kāmen. The word under analis is also found in other Slavic languages: Bulgarian (камен), Serbo-Croatian (ка̏мі, ка̏ме̑н), Slovenian (kamen, kȃmik), Czech (kámen), Polish (kamień, kamyk).

For interfloor slabs in houses, such building material as beam is used (in Ukrainian балка (transliterated as balka)). We tried to make an etymological reconstruction of this term and found out that partly through Polish mediation (belka) it was borrowed from German: Middle-Upper German balke (Old-Upper German balko, New-Upper German Bálken) "балка" (transliterated as balka 'beam') comes from West-Germ. *balkan- «тс.», related to Gr. φάλαγξ "tree trunk". It was translated as "beam, log". Related to it are the words derived from a common root, such as бал´єрка (transliterated as baliérka 'a place and a device for cutting boards'), ба́лькей (bálkei 'a beam for a house"), бальо́к (balók 'beam'), бал´яр (baliár 'a master who produces riveting").

A beam that supported the ceiling in a wooden building, in the old Ukrainian house (hut), in particular, was called "сволок" (transliterated as svolok 'main beam under the ceiling in a wooden building, namely, an old Ukrainian house (hut), which was usually located along its longitudinal axis'). The word has Proto-Slavic roots: *sъvolkъ, obviously, from Indo-European *velkti, that is—'procrastinating, pulling'. It is worth recalling that in ancient times svolok had a sacred meaning, as it symbolized the strength of the house, wealth, fertility. Usually, the date of the construction of the house (hut), the name and the year of birth of its owner, good wishes to the family were carved on it. In some regions, it was customary to move a tough svolok from an old house to a new one. Small things were sometimes placed on it—balls of thread, spindles, books, flowers as well as bread. By the way, in our city on Ivanova Hora (Ivan's Mountain) there is a real Ukrainian house (hut), where the famous Ukrainian poet, playwright, public figure, founder of modern Ukrainian literature Ivan Kotliarevskyi lived. This is a typical housing of Ukrainians of XVIII—early XIX centuries. The greatest value in it is the original svolok, on which it is written in Cyrillic: «Створю дім цей в ім'я батька і Святого Духа. Амінь. Року 1705 місяця серпня 1» [I will build this house in the name of the Father and the Holy Spirit. Amen. In the year of 1705, August 1]. Historical detail: the house was destroyed during World War II and rebuilt in the postwar period, but the svolok remained intact. The writer's house was painted in 1845 by another famous Ukrainian, Taras Shevchenko, who was visiting Poltava at the time. In addition, Kobzar described it in his story "Близнюки" ("The Twins").

Everyone knows well such a detail of the building as the balcony—a platform attached to the outer wall of the house at full height, fenced with handrails (or low walls) and connected by a door to the interior, for example: "Скляні двері виходять на великий балкон з видом на море" [9, p. 403] ['Glass doors open onto a large balcony overlooking the sea']. It turns out that the "journey" of this word to the Ukrainians was also not easy. In ancient times, when militant ancient Germanic tribes came to Italy, the locals borrowed the word "balko" from them, which meant 'beam', 'deck'. Later, the Italians transformed it into a melodic «balcone» and began to call in such a way a small platform of beams embedded in the wall. Later it was picked up by the French and took on a new form—«balcon». And in the XVIII century from France it got to other European countries. Thus, the etymological chain of this word will look like this: Fr. Balcon < Ital. balcone < Middle-Upper German balko (‘beam’, ‘deck’).

Ceramic tiles for lining stoves, building walls, etc., which are called “кахлі” (transliterated as kakhli ‘tiles’), have become habitual in the interior of the house. For example: Піч і стіни до половини викладені бездоганною, сніжно-білою кахлею [10, p. 134] [‘The stove and the walls are half lined with impeccable, snow-white tiles’]. There is an assumption of its being borrowed from the Polish language: Pol. kafel, kachel. There is a similar in structure word in Upper Lusatian (kachle—укр. “кахельна піч” (‘tiled stove’)), New-Upper German (Káchel—‘кахля’ (transliterated as kakhlia ‘a tile’)), Middle-Upper German (kachel—‘кахля’; ‘глиняна посудина’ (‘tile’; ‘earthenware dish’)), Czech (kache). It is worth remembering the numerical paradigm of the word: plural—кахлі (kakhli ‘tiles’), singular—кахель (kakhel ‘a tile’). Also, in the singular the following definitions are admissible: masculine—хля (khlia), feminine—кахля (kakhlia).

Any house, any building construction must have a basis, which is called “фундамент” (transliterated as fundament ‘foundation’): Вода просочується з гір скрізь з ґ рунту й стікає по камінцях по вулиці, і для того всі хати ставлять на кам’яному фундаменті [11, c. 244] [‘Water seeps from the mountains everywhere from the ground and flows down the stones on the street, and for this purpose all the houses are built on a stone foundation’]. It turns out that the word we are used to is also a foreign language element. Linguists suggest that the term is borrowed from Latin, possibly through Polish mediation: Lat. fundāmentum—«фундамент» (‘foundation’), connected with fundus—“base, bottom”.

Builders, of course, are familiar with such a term as “крокваʺ (transliterated as krokva ‘rafter’). According to the authors of the etymological dictionary, the word has Proto-Slavic origins: *kroky, genitive case *krokъve [12]. It should be noted that the word with this root can be found in some other slavic languages, namely: Polish (krokwa); Slovac (krokva); Czech (krokev). The commonality of root and semantics in closely related languages is another eloquent evidence of the origin of the word from the same ancient basis.

Such an ancient attribute of the house as window (Ukrainian вікно, transliterated as vikno) also has Proto-Slavic roots. Researchers believe that it originates from Proto-Slavic *okъno, related to *oko. It should be reminded that in the old days of the human society there were no windows in houses. Until the Middle Ages, they simply made slits in the walls, which were covered with animal skins, cloths, films, removed from the abdomen of an animal (it was it that let in a little light). The custom of installing glass windows dates back to the Roman Empire when they were considered a luxury item. For example, in medieval Holland there was even a tax on windows. According to the law of that state at the time, the more windows a house had, the higher the tax was. It was only in the middle of the XV century when windows began to appear in buildings of Ukraine. Traditionally, the Ukrainian house had at least three windows. In addition, quite often the window openings were closed with shutters—small wooden doors, which could consist of one or two leaves. Rectangular windows are most often made in Ukrainian houses.

As noted above, the present is impossible to imagine without economics, because, as argued by the famous British economist of the XIX century Philip Wickstead, the laws of economics—are the laws of life [13, p. 7].

It is known that the term "economy/economics" has a long history. The word has the ancient Greek basis οἰκονόμος, which can be interpreted as "the art of housekeeping." In accordance with the etymological dictionary, it is possible to reconstruct the word-forming chain as follows: Ancient Greek οἰκονόμος < Proto-Indo-European *weik'- + νόμος ("custom, law") < from νέμω ("distribute, hand out, divide; choose; paste") < Proto-Indo-Eurasian * nem-, * neme- ("divide, allocate"). Today, the word "economy/economics" functions as a hyperonym and has two meanings: (1) the sphere of activity related to the production of material goods and management; (2) science that studies industrial and economic relations. In addition, in modern circulation in all languages, such hyponyms as macroeconomics, microeconomics, cryptoeconomics are actively used.

First of all, it should be noted that the vocabulary related to economic development in the Ukrainian language began to take shape in the ancient Ukrainian period. Those were mainly words with common Slavic roots -да-, -куп- and -мін-, for example: продати (transliterated as prodaty 'to sell'), купити (translit. as kupyty 'to buy'), міняти (translit. as miniaty 'to exchange') etc. The following nouns are consistently used as common names of people engaged in trade: купець (transliterated as kupets 'merchant'), торговець (translit. as torhovets 'trader'). Later, the formation of financial terminology was influenced by linguistic and extralinguistic factors, among which are: the development of production, industrial revolutions, the expansion of international relations etc. In the Ukrainian language of the XIV–XVIII centuries as a result of interethnic contacts with Western Europe through the mediation of Old Polish and Old Czech, the following words began to function: ринокъ (transliterated as rynok 'market'), крамъ (translit. as kram 'goods'), квота (translit. as kvota 'quota') etc. The lexical system of expressing debt and credit relations, which was widely represented in the old Ukrainian memos, continues to be used and is further developed, for example:боргъ (transliterated as borg)—"кредит" (translit. as kredyt 'credit'), депозитъ (translit. as depozyt 'deposit'), депозиторъ (translit. as depozytor 'depositor'), експенсъ (translit. as ekspens)—"видаток" ('expense'), оранда (translit. as oranda)—"оренда" (translit. as orenda 'rent'), позика (translit. as pozyka 'loan'), позичка (translit. as pozychka 'loan'), позичальник (translit. as pozychalnyk)—"кредитор" (translit. as kredytor 'creditor'), визичити (translit. as vyzychyty)—"позичити" (translit. as pozychyty 'borrow'), рандаръ (translit. as randar)—"орендатор" (translit. as orendator 'tenant') etc. In the XIX–XX centuries the number of terms borrowed from other languages is growing significantly, for example: аванс (transliterated as avans 'advance'), авізо (translit. as avizo 'aviso'), акцепт (translit. as akzent 'acceptance'), акциз (translit. as aktsyz 'excise'), біржа (translit. as birzha 'exchange'), бухгалтерія (translit. as bukhhalteriia 'accounting'), бюджет (translit. as biudzhet 'budget'), валюта (translit. as valiuta 'currency'), вексель (translit. as veksel 'bill'), дебет (translit. as debet 'debit'), депозит (translit. as depozyt 'deposit'), емісія (translit. as emisiia 'emission'), інвестиції (translit. as investytsii 'investments'), інкасо (translit. as inkaso ‘collection’), капітал (translit. as kapital ‘capital’), квота (translit. as kvota ‘quote’), кредит (translit. as kredyt ‘credit’), пеня (translit. as penia ‘fine’), такса (translit. as taksa ‘tax’), тариф (translit. as taryf ‘tariff’), штраф (translit. as shtraf ‘fine’), чек (translit. as chek ‘check’) and others.

The period from the end of the XX—beginning of the XXI centuries is characterized by the strengthening of the Ukrainian state, respectively, commodity-money relations have determined their leading place in economic systems. Owing to this, financial terminology has considerably developed. Thus, among the economic terms of that period for obvious reasons there appeared many foreign borrowings: бартер (translit. as barter ‘barter’), дивіденд (translit. as dyvident ‘dividend’), єврочек (translit. as yevrochek ‘euros’), маркетинг (translit. as marketynh ‘marketing’) etc.

We have tried to reconstruct some economic terms. For example, the term “бюджет” (translit. as biudzhet ‘budget’). It is known to have appeared in English as early as 1432.The etymological chain of this word is as follows: English budget < Old French bougette—“bag, wallet” < Latin bulga—“leather bag” < probably from Gaelic. The term could enter the Ukrainian language owing to the borrowing from English through German (Budget) or French (budget).

Of interest is the history of the term “вексель” (translit. as veksel ‘a promissory note’), which comes from the German Wechsel (“an exchange”). According to some linguists, the word has a Proto-Indo-European root *weik-/*weig- (“to tie, to wind”). It is known that this word originated in the XII–XIII centuries in Italy due to the development of international trade and banking. The prototypes of the modern “promissory note” were warrants, the so-called loan letters, money receipts. The spread of the bill was facilitated primarily by restrictions on the collection of interest on loans contained in the canonical statutes and civil laws of many medieval European countries. In addition, at that time promissory note fairs were also held, at which promissory note settlements were made. Thus, the largest promissory note fairs in the XIII–XIV centuries were fairs in the French county of Champagne, and in the XV–XVI centuries—in Antwerp and Lyon. In modern banking terminology, such phrases with this word are widespread, which are already perceived as stable expresssions: простий вексель (translit. as prostyi veksel ‘promissory note’), казначейський вексель (translit. as kaznacheiskyi veksel ‘treasury bill’), фінансовий вексель (translit. as finansovyi veksel ‘financial bill’) etc.

The origins of the term “кредит” (translit. as kredyt ‘credit’) should be sought in the Latin language which had the word “creditum” (‘a loan’), derived from “credere” (‘to borrow’). Most likely, into European languages the word came from German Kredit—‘credit’. In Latin the word credere has another meaning—‘to believe, to trust’. The same root is contained in the word кредо (translit. as kredo ‘credo’)—віра (translit. as vira ‘credence’), віросповідання (translit. as virospovidannia ‘creed’), переконання (translit. as perekonannia ‘creed, belief’). This derivational chain is not accidental, because it was assumed that a loan (credit) (i.e. money or other valuables in debt) can only be given to someone you believe or trust.

The word “субсидія” (translit. as subsydiia ‘subsidy’) also has Latin roots, formed from subsidium—‘help’, ‘support’.

The word “чек” (translit. as chek ‘cheque/check’), we are well familiar with, also has a complicated origin associated with the Ancient East. The fact is that the word is borrowed from Iranian ṣakk ‘agreement’, ‘contract’, ‘document’, derived from Persian čäk with the same meaning. It should be noted that in Eastern languages the word “чек” is cognate with the ancient Persian shah—‘ruler, shah (the title of the ruler)’. In the meaning of the financial term, “чек” (‘cheque/check’) came into circulation in the XIV century. Its first form was the receipt of cashiers, who collected interest from depositors for keeping money, at that time full-fledged metal, i.e. gold and silver coins. In this sense, the cheque/check as a receipt acted as a certificate, i.e. a paper certifying the availability of money. In modern interpretation, a cheque/check is a means of transferring property at one’s own expense. It is a monetary document of the prescribed form, which contains an unconditional order of the checker to the credit institution to give out to its bearer the amount of money specified in it. Modern technical modifications of the cheque are plastic cards. It is possible that the word could come into our circulation from the English language—Br.E. cheque, Am.E—check.

A special financial institution that accumulates funds and other valuables (gold, securities), issues loans, securities, performs cash settlements and other operations is now called “банк” (translit. as bank ‘bank’). Given the etymology of the word, it appears to be quite complex and variable. Some researchers claim that the term comes from Italian banco—‘bench’ or ‘table’. The interpretation will get clearer when we recollect that in ancient Greece and Rome, money changers who were slaves sat at dining tables. Even in modern Greece, banks are still called “tables” (naturally in Greek). The same interpretation of the word is found in German—Bank, that is, a counter (bench), behind which in medieval towns the exchange of all kinds of coins was carried out. It was only later that the institution dealing with various financial transactions began to be called like that.

The assumption about the relation of this word to maritime terminology seems to be rather strange, at first sight. It is known that the shoal in the ocean, the depth over which is much smaller than in the surrounding, is called “underwater bank” (from German Bank or Dutch bank). Some researchers, referring to this, believe that maritime terminology was the basis for the emergence of the term “банк” (‘bank’).

In addition, there is a number of interesting, in our opinion, facts about the emergence of a banking institution, and they are closely intertwined with the history of the Templars (from Lat. templum ‘temple’, respectively—Templars ‘temple people’—the Catholic Order of Knights-Monks, founded in the Kingdom of Jerusalem in 1096 after the First Crusade. The Templars guarded the safety of pilgrims on their way from Europe to Jerusalem. It is also known from history that the Order received permission from the Pope to carry out financial transactions. According to legend, the Templar Knights were familiar with accounting and the principle of double entry, cheque calculations and compound interest; there were no more experienced and honest economists throughout Christendom as they were. They are even credited with the invention of cheques, and if the amount of the contribution was exhausted, it could be increased with the subsequent filling from the relatives. That is, all the finances of medieval Europe were concentrated in the hands of the Templars, and therefore we can state that they were the first European bankers.

Today, it is known all over the world that the institution where trade, financial and other transactions are carried out is called “біржа” (translit. as birzha ‘exchange’). We have analyzed this word in terms of reconstruction and history. It has turned out that they are also quite intriguing and interesting. In modern etymology there are two versions of the origin of this term. According to the first one, the origins of the word go to Latin bursa, which is translated as ‘leather wallet’. In modern French, there functions the word boursa, which has two interpretations: an ‘exchange’ and a “students’ scholarship”. It is noteworthy that in medieval Western Europe the word “bursa” was used to call the general treasury of a union or an institution, such as a monastery, fraternity, etc., as well as a dormitory for poor students who studied at the university. In Ukraine in the XVII century, “bursa” was used as a name for a theological school, and its students were called “bursakas”, i.e. people who “live from the state wallet”. According to another version, the appearance of this word is associated with the name of the Dutch merchant van der Burse, whose family coat of arms had the image of three wallets. He provided the place where his house was located for the meeting of merchants, mostly money changers, and thus the first (stock) exchange meeting and the first (stock) exchange building appeared. The advantages of this variant are the coincidence of names and symbols on the coat of arms, which gives ambiguity to the concept. This is the reconstructed etymological chain of origin of this word: Germ. Börse ‘(stock) exchange’ < from French bourse ‘гаманець’ < Greek bursa ‘leather bag’).

The term “валюта” (translit. as valiuta ‘currency’) is common among economists and ordinary citizens. It turns out that this word is of Italian origin, where valuta (‘price’, ‘currency’) echoes with Latin valere ‘to be valued, to be worth’. It should be noted that words with the same root are found in Bulgarian (валута—translit. as valuta), Polish (waluta), Czech (valuta) languages. Nowadays, this term has acquired a new meaning and is understood as foreign money.

The history of the word “аванс” (translit. as avans ‘advance’) is quite unusual. Currently, it is interpreted as a sum of money paid in advance, i.e. prepayment. Linguists have two assumptions as to its origin. Some of them believe that it came from Germany and originated from avancieren ‘to go forward’. By the way, in the written memos of the XVIII century this word was used as a military term: to advance meant ‘to attack’, ‘to move forward’. According to others, the term is borrowed from French, where avanc < avant—‘to farther’, ‘to move something forward’ and advancer—‘to loan’. And since the 60 s of the nineteenth century in dictionaries the word is interpreted in the sense, habitual for us. That is, this term can serve as an excellent example of the semantic shift that has occurred during the use of this word.

It is well known that the financial term “пеня” (translit. as penia ‘penalty’) in the sense of a fine for non-performance of any obligations or payments has been used since the XIII century. It is likely to be of Latin origin: poena—‘punishment’.

However, its word-forming chain indicates much deeper roots: Lat. poena ‘punishment’<from Greek ποινή ‘ransom’; ‘revenge’, ‘punishment’. In addition, the word is related to cognate words from other languages, namely: Av. Kaēnā—a ‘fine’, ‘revenge’, Lith. káina—‘price’, ‘cost’, Psl. cěna (for comparison with Ukr. ціна (transl. as tsina ‘price’).

In modern conditions, a powerful catalyst for economic development is innovation. The term “innovation” came into active use in the XIX century in the midst of the second scientific and technological revolution. It was introduced into the scientific lexicon by the famous Austrian and American economist Josef Schumpeter (1883–1950), who saw innovation “as a new scientific and organizational combination of production factors created by the entrepreneurial spirit; embodiment of scientific discovery; a new function of production, which means a different quality of means of production, which is achieved by introducing new means of production or systems of its organization” [14–29]. The term came to us from English and is formed from two words: Latin “novation” which means ‘novelty’ and English prefix “in”, which presupposes ‘introduction (into something new)’. Accordingly, translated from English, the word is interpreted in Ukrainian as “introduction of something new, restoration”.

3 Conclusions

Thus, a brief semantic and etymological analysis of the building and economic industries presents a long process of their formation and development. The method of reconstruction plays an important role in the study of the origin of terms, which enables not only to find the origins of the word, but also to consider its internal form. According to the results of the study, it can be claimed that among the building terms there are many words with Indo-European roots, which is another confirmation of the ancient origin of this profession. In addition, in the terminology of both branches under consideration there are many borrowings from Latin, German, French, Italian, English, which indicates the integration processes, which are reflected primarily in the lexical structure of the language. In some cases, there can be observed semantic shifts in the meaning of words, which is explained by the phenomenon of semantic derivation as a productive way to update the lexical structure of the language.

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Analysis of High-Tech Trends in the Context of Management Tasks of State's Scientific and Technical Development

Aleksandr Belov, Lyudmyla Svistun, Liana Ptashchenko, Yuliia Popova, and Emil Mahabbat Mammadov

Abstract The article proposes the author's method of "analysis of the acceleration of absolute growth" to analyze the dynamics of exports of high-tech products in the world as a tool of government regulation in this area. The methodology reveals the economic content of the main types of ratios of acceleration and absolute growth of high-tech exports and allows to identify 4 groups of countries in order to develop recommendations for the development of high technology. It can be considered that the best situation is not the constant growth of the indicator, but its growth to a certain critical value and further support at the achieved level. The analysis of high-tech exports to the countries of the world for 2007–2020 is carried out and the growth rate of high-tech exports is interpreted and the countries are ranked according to the rate of export growth in order to assess the prospects of overall economic growth in the country. The sample includes countries whose total exports of high-tech products are about 95% of the world as of 2020 (26 countries), as well as Ukraine and its neighboring countries. It is established that in the long run in the vast majority of the studied countries there are processes of increasing high-tech exports compared to 2007, but with a slowing trend. Volume increases are taking place in Asia, and the opposite trend is in most Western Europe, the United States and Japan. The share of high-tech exports of Ukraine in the world is less than 0.1% and has catastrophic trends. This requires the Government of Ukraine to reconsider its development strategy on the priorities of resuming its own knowledge-intensive production, development of science and technology.

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_72

Keywords R&D · High-tech · Strategic development · Management · Mathematical modeling

1 Introduction

In a rapidly changing world of globalization, the development of high-tech is becoming increasingly important. One of the most important areas of strategic development of states is the high-tech sector, based on strong scientific and technological potential. Knowledge is becoming the most important factor in economic growth, and knowledge-intensive technologies will further determine the level of competitiveness of the countries that own them. Accordingly, effective tools of state regulation of high technology development should be used. In order to form its own economic policy, each state must take into account current trends in this sector of the economy, the analysis of which will be the basis for making adequate decisions in public administration. The strategy of state development in a modern highly competitive society should be based on a strong scientific and technical foundation. One of its indicators is the level of exports of high-tech products as the most knowledge-intensive products of the state economy.

This work is part of a general study to assess the methods and tools for strategic development of the state, which also includes an analysis of the dynamics of innovation, science and technology, industry, education and human potential over the past 12–14 years.

The term high-tech first appeared in the 1960s. Although attempts to assess the impact of science and technology on economic growth and identify the most knowledge-intensive industries have been made previously by scientists such as J. Bernal, M. Holland W. Spraragen in the 1930s, W. Maclaurin in the 1950s and others [1].

High-tech is a product with high R&D intensity, such as the aerospace industry, computers, pharmaceuticals, scientific instruments and electrical equipment. According to OECD research, the following stages are identified as high-tech industries (Table 1).

A classification based on both the direct R&D intensity and the R&D embodied in intermediate and investment goods has been proposed by Hatzichronoglou [2]. Four categories were introduced: high, medium–high, medium–low and low technology.

High-technology industries: Aircraft and spacecraft, Pharmaceuticals, Office, accounting and computing machinery Radio, TV and communciations equipment Medical, precision and optical instruments. Medium–high-technology industries: Electrical machinery and apparatus, n.e.c., Motor vehicles, trailers and semi-trailers, Chemicals excluding pharmaceuticals Railroad equipment and transport equipment, n.e.c. Machinery and equipment, n.e.c. Medium–low-technology industries: Building and repairing of ships and boats Rubber and plastics products Coke, refined petroleum products and nuclear fuel Other non-metallic mineral products Basic metals and fabricated metal products. Low-technology industries: Manufacturing,

Table 1 Official lists of high-tech industries adopted by the OECD [1]

1984	1.Aircraft and spacecraft 2. Pharmaceutical 3. Office settlement and computing machines 4. Radio, television and communication equipment 5. Scientific equipment 6. Electrical equipment
1994	1.Aircraft and spacecraft 2. Pharmaceutical 3. Office settlement and computing machines 4. Radio, television and communication equipment
2001	1.Aircraft and spacecraft 2. Pharmaceutical 3. Office settlement and computing machines 4. Radio, television and communication equipment 5. Medical equipment and optical instruments
2009	1.Aircraft and spacecraft 2. Pharmaceuticals: main products 3. Manufacture of computer, electronic and optical products

n.e.c.; Recycling Wood, pulp, paper, paper products, printing and publishing Food products, beverages and tobacco Textiles, textile products, leather and footwear [2].

Technological efforts are a crucial factor in increasing productivity and international competitiveness. However, because they are unevenly distributed across the economy, technological criteria are important in the analysis of industry indicators and structural changes [3].

In the past, the classification of technologies based on the industry classification of ISIC ed. 2. The methodology uses three indicators of technological intensity, which to varying degrees reflect the aspects of "technology producer" and "technology user": (1) R&D costs, divided by value added; (2) R&D costs divided by the volume of production; and (3) R&D costs plus technologies embodied in intermediate and investment goods, divided into production. These indicators were estimated for 1990 and for a total of ten OECD countries for which the embodied technology indicator was available, using the purchasing power parity in US dollars for 1990 [2].

In 2006, new ISIC Revision 4 industry classification standards were adopted, as a result of which it was revised, and from 2019, the indicators for industries related to high-tech.

2 An Overview of the Latest Sources of Research and Publications

Such scientists as Bernasconi and Harris [4], Rey [5] paid attention to the problems of formation and development of high-tech production in the economy. Among the domestic publications are the studies of V. Heitz, I. Egorov, L. Zavidna, N. Kraus, I. Matyushenko, I. Odotyuk, O. Prokopenko, O. Salikhova, N. Shmygol, L. Svistun [1, 6–14] and others. Most Ukrainian scientists study the possibilities of using high-tech in various sectors of the economy. O. Prokopenko and A. Artyukhov analyzes the main models of technology transfer in Europe, the USA, Japan and China, presents the leading trends in the development of technology transfer in the leading countries [10]. Jie Xiong's and Sajda Qureshi's paper measures the true quality level of Chinese high-tech exports by quality index model, and compares it with the obscured quality and exports quality of 14 countries [15]. Sandu S. and Ciocanel B. assesses, at the European level, the relationship between medium and high-tech exports, on one hand, and some of the main determinants of innovation, on the other hand. Their research results confirm a positive correlation between total R&D expenditure volume and the level of high-tech exports, with variability between countries [16]. J.H. Love and P. Ganotakis learnes the effect of exporting on the subsequent innovation performance of a sample of high-technology SMEs based in the UK [17]. In paper of F. Montobbio and F. Rampa econometric analysis suggests that technological activity is related to export gains in high technology sectors if a country expands in industries with increasing technological opportunities, in medium technology sectors if it moves away from low opportunity sectors, in low technology sectors if it is initially specialized in growing sectors [18]. Chinese scientists find that both high-tech related international export and inward foreign direct investment significantly contributes to emerging countries' ability to produce cutting-edge technologies [19]. Zheng-Xin Wang and Yan-Yu Wang applied the new improved TOPSIS method to evaluate the competitiveness of the Chinese high-tech industry [20].

Studying of these works provides an opportunity to understand the principles of formation and implementation of high-tech sector in the economy, the importance and necessity of its development to become a strong competitive national economy and ensure its sustainable long-term growth. But the issues of detailed analysis of the dynamics of exports of high-tech products and their share in total industrial exports of Ukraine in the framework of global trends need research.

3 The Purpose of Scientific Research

The problem is to determine the optimal share of high technology in the country's economy, which will contribute to its successful development. To study this issue, the world statistics use the following two indicators—exports of high-tech products (High-technology exports (US $)) and the share of exports of high-tech products in total exports of manufactured goods in the country (High-technology exports (% of manufactured exports)). In order to substantiate the optimal values of these indicators, which Ukraine should strive for, it is advisable to study their dynamics in the short and long term on the example of some foreign countries.

To investigate the dynamics of exports of high-tech products (EHt) in the world and in Ukraine, to identify its features, critical points, characteristics.

4 Main Body

4.1 Research Methodology

The author's method of "analysis of the acceleration of absolute growth" developed in previous publications was used as the main method of studying the dynamics of EHt [21–23]. We will briefly reveal the essence and method of calculation by the method of "analysis of the acceleration of absolute growth", which will further conduct research.

From the theory of statistics and economic analysis it is known that the absolute increase of the indicator characterizes its increase/decrease in the study period relative to either the previous (chain increase) or the base (base increase) period: the increase determines the rate of change over time. Accordingly, changing the speed will give us acceleration.

Therefore, the acceleration of the change of the indicator is defined as the difference between the increment (i + 1) / i of the period and i/(i–1), where i = 1… n periods. Mathematically, it will look like this.

Assume that the high-tech export rate (EHt) for some n years was:

$$EHt_1,\ EHt_2,\ EHt_3, \ldots EHt_{(i-1)}, EHt_, EHt_{(i+1)} \ldots EHt_n, \quad (1)$$

The increments (or the rate of change of the value of EHt) $v_{i/(i-1)}$ $v_{(i+1)/i}$, and $v_{(i+1)/i}$, respectively, will be equal to:

$$v_{i/(i-1)} = EHt_i - EHt_{(i-1)},\ Ta\ v_{(i+1)/i} = EHt_{(i+1)} - EHt_i, \quad (2)$$

The acceleration $a_{(i+1)/(i-1)}$ of the change in EHt will be equal to:

$$\begin{aligned} a_{(i+1)/(i-1)} = v_{(i+1)} - v_{(i-1)} &= \left(EHt_i - EHt_{(i-1)}\right) - \left(EHt_{(i+1)} - EHt_i\right) \\ &= EHt_{(i-1)} + EHt_{(i+1)} - 2 \cdot EHt_i \end{aligned}$$

$$a_{(i+1)/(i-1)} = EHt_{(i-1)} + EHt_{(i+1)} - 2 \cdot EHt_i, \quad (3)$$

Acceleration of change in the studied indicator has certain features:

(1) acceleration covers three periods and is a characteristic of the rate of change of absolute values;
(2) the value of acceleration can be as follows:

$a < 0$; when the resulting factor influencing this indicator slows down its development, which is an indicator of the identification at earlier stages of negative trends in the dynamics of high-tech exports;

$a = 0$; when the resulting factor influencing this indicator is neutral and this indicator increases or decreases evenly, moves by inertia.

a > 0; when the resulting factor influencing this indicator accelerates its development, and, depending on the type of indicator (which is the most favorable—its increase or decrease), it is possible to diagnose future problems related to this situation.

In our opinion, the ratio of indicators of growth (rate of change of the indicator) and its acceleration is also important in the analysis of the dynamics of EHt indicators. The main situations that may arise for their different meanings and their economic content are given in the Table 2.

Thus, if we assume that the growth of the studied indicator is a positive situation, and its decrease is negative, then we get two opposite groups: 1 and 4. If the indicator increases rapidly, the country under study falls into the 1st group, if the indicator rapidly decreases—then in the 4th. These are two pole groups. Between them are groups 2 and 3.

If the country falls into the second group—it means that there is a decrease in the studied indicator, but the rate of decrease (ie acceleration) is positive and there is a gradual slowdown in the process of reducing the indicator. This group characterizes

Table 2 The economic content of the main types of the ratio of acceleration and absolute growth of the studied indicators

№ groups	The value of growth	The value of acceleration	The ratio of acceleration and growth	The economic content
1	v > 0	a > 0	a/v > 0	Acceleration of the positive trend of the indicator. The best situation for the country
2	v < 0	a > 0	a/v < 0	Slowing down negative changes in the indicator: the result of making the right management decisions in the country
3	v > 0	a < 0	a/v < 0	Slowing down the positive change in the indicator
4	v < 0	a < 0	a/v > 0	Accelerating the negative change in the indicator—it is necessary to take measures to change the situation. Changes in public administration must be qualitative

Source Author's development

the smooth transition from the fourth group to the first, from negative to positive situation in gradual steps.

If the country falls into the third group, it means that the studied indicator is moving in a given direction with a positive speed, for example, in the direction of increasing, which increases with each passing year, but the acceleration is negative, if the rate slows down. Continuation of this trend after some time will reduce the speed to zero and the movement in the direction of increase will stop, possibly reaching the level of saturation. Then the region will gradually move to the fourth group, in which the movement is in the opposite direction, and even accelerates.

The study assumes that if a country takes measures to change the situation—first there is a change in the sign of acceleration (the country moves to the second group), and only then—and the rate of development to positive (the country moves or returns to the first group).

That is, considering the growth of the system, in our case—the export of high-tech products, we can assume that the best situation is not constant growth of the indicator, but its growth to a certain critical value and further maintaining it at the achieved level. It should be borne in mind that two periods are important for the system: the first is the set of speed (access to a given speed, a given pace of development); the second—uniform forward movement, when a certain speed is reached. In the first period, significant acceleration of movement is possible, in the second—the movement must be uniform. However, when certain obstacles appear, such movement can change smoothly (which is better) or sharply (which is worse). Such obstacles may be force majeure: economic and financial crises, natural disasters, hostilities, key changes in the course of development/movement of the country. At the same time, the main goals must be defined, and all other goals will be subordinated to the general movement.

4.2 Empirical Analysis

4.2.1 Data Selection

Statistics from the World Bank's website for 217 countries were used to analyze the growth rate of exports of high-tech products and rank countries by the rate of growth of exports and assess the prospects for overall economic growth. The main period was 2007–2020, as data for 2021 are not yet available at the time of the study.

The sample of countries for analysis consists of two parts. The first part is the countries, the total volume of exports of high-tech products which is about 95% of the world as of 2020—is 26 countries (see Table 3). The second part is Ukraine and some of its neighbors—Poland, the Russian Federation, Romania, Hungary, Lithuania.

Table 3 Dynamics of Hi-tech export structure in 2007 and 2020

	Country	The share of the country in world exports Hi-tech in 2007 (%)	The share of cumulative total, % in 2007 (%)	The share of the country in world exports Hi-tech in 2020 (%)	The share of cumulative total, % in 2020 (%)	Rating 2020
	World	100,0	100,0	100,0	100,0	
1	China	18,3	18,3	26,5	26,5	1
2	Hong Kong SAR, China	0,1	18,5	11,9	38,4	2
3	Germany	9,1	27,6	6,3	44,8	3
4	Korea, Rep	5,7	33,3	5,7	50,5	4
5	Singapore	5,9	39,1	5,6	56,2	5
6	United States	13,1	52,2	5,0	61,2	6
7	Japan	6,9	59,1	3,6	64,8	7
8	Vietnam	0,2	59,3	3,6	68,4	8
9	Malaysia	4,0	63,3	3,2	71,6	9
10	France	4,6	68,0	3,1	74,6	10
11	Netherlands	4,5	72,5	3,1	77,7	11
12	Mexico	2,3	74,8	2,4	80,2	12
13	United Kingdom	3,7	78,5	2,2	82,4	13
14	Thailand	1,7	80,3	1,6	84,0	14
15	Ireland	1,7	82,0	1,5	85,5	15
16	Czech Republic	0,9	82,9	1,4	86,9	16
17	Belgium	1,5	84,4	1,2	88,1	17
18	Italy	1,6	86,0	1,2	89,3	18
19	Philippines	1,7	87,7	1,1	90,5	19
20	Switzerland	1,9	89,6	1,0	91,5	20
21	Canada	1,6	91,2	0,9	92,4	21
22	India	0,3	91,6	0,8	93,2	22
23	Poland	0,2	91,8	0,7	93,9	23
24	Hungary	1,1	92,9	0,6	94,5	24
25	Sweden	1,2	94,1	0,6	95,1	25
26	Austria	0,9	95,0	0,6	95,7	26
27	Russian Federation	0,23	95,2	0,45	96,1	28

(continued)

Table 3 (continued)

	Country	The share of the country in world exports Hi-tech in 2007 (%)	The share of cumulative total, % in 2007 (%)	The share of the country in world exports Hi-tech in 2020 (%)	The share of cumulative total, % in 2020 (%)	Rating 2020
28	Romania	0,08	95,3	0,24	96,4	32
29	Lithuania	0,07	95,3	0,09	96,5	40
30	Ukraine	0,08	95,4	0,04	96,5	49

Source own calculations based on ("World Development Indicators | DataBank," n.d.) [24–26]

4.2.2 Analysis and Ranking of Source Data

Ranking of countries by the level of distribution of exports of high-tech products in 2007–2020 is carried out in the Table 4.

Data in italics for missing years (Mexico, Vietnam—2007; Malaysia, India—2007, 2008; Philippines 2007–2016; Ukraine 2007–2010) were obtained by estimating the average ratio of these data to 2019 and 2021. In Russia—data for 2020 forecast. Numbers rounded to whole values (for compactness and readability).

The analysis of this table allows us to identify three main trends:

- firstly, in 14 years there has been an absolute increase in exports of high-tech products both in general and from most countries: in China it has more than doubled, in Germany—by 6%, in South Korea and Singapore—by more than 60%, in Vietnam—more than 30 times, Romania—7 times, Poland—5 times. But it is also observed in countries such as: the United States—1.7 times, Japan—1.25 times, the United Kingdom—8.5%, Ukraine—2 times;
- secondly, the balance of the increasing wave of growth of the studied indicator of 2007–2008 is viewed; rising wave 2009–2014 and two periods of its decline in 2008–2009 and 2014–2017;
- thirdly, during the period there is a deterioration of the positions of the developed countries of the Western world and Japan, and strengthening of the positions of Southeast Asia—China, Hong Kong, Singapore, Vietnam, Thailand, Malaysia, the Philippines;
- fourth, there is an increase in the concentration of high-tech exports. If in 2007 (see Table 3) 50% of the market was covered by 5 countries (China, Germany, South Korea, Singapore and the USA), in 2020 there are 4 or even 3 (if Hong Kong is considered part of China, although the World Bank and gives separate statistics on it)—China, Hong Kong, Germany, South Korea. If we make an amendment to Taiwan (with about 9% of its market), recognizing it as part of China, then even 2—China and Germany.

The leader in terms of High-technology exports in 2007 was China, in 2020 also China. The leader of High-technology exports was $ 757.7 USA. The market share

Table 4 High-technology exports (current billion US$)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	343	391	359	475	540	594	656	654	652	595	654	732	716	758
Hong Kong SAR, China	3	2	2	3	1	1	1	1	0	0	294	330	322	340
Germany	170	184	159	181	203	204	210	216	200	206	196	210	209	181
Korea, Rep	107	111	103	132	133	131	143	149	147	136	167	193	154	164
Singapore	109	124	100	132	132	137	144	146	139	136	147	155	151	161
United States	244	247	154	169	169	172	172	179	178	176	157	156	156	143
Japan	129	131	104	130	134	130	112	108	99	99	106	111	104	103
Vietnam	3	3	4	6	12	21	33	36	48	55	74	83	90	102
Malaysia	75	50	56	66	67	67	67	71	64	63	74	90	87	92
France	87	100	89	106	113	115	119	121	110	109	109	118	121	88
Netherlands	84	78	68	78	86	82	81	85	70	71	78	86	87	88
Mexico	44	44	39	49	52	58	59	62	60	62	70	75	75	70
United Kingdom	70	68	49	67	77	74	76	77	76	75	75	77	78	64
Thailand	32	34	30	37	36	37	37	39	39	39	44	45	40	46
Ireland	32	31	26	23	28	26	25	26	31	38	35	36	39	42
Czech Republic	17	20	17	20	27	25	25	27	25	25	30	36	38	40
Belgium	28	32	32	18	20	19	23	27	23	27	25	28	33	35
Italy	30	33	28	30	34	30	32	33	31	31	32	33	33	35
Philippines	31	28	23	17	14	22	23	25	28	27	34	34	36	33
Switzerland	36	44	41	44	51	51	54	57	54	56	30	30	30	29
Canada	31	31	26	27	28	34	33	30	29	27	28	31	32	26

(continued)

Table 4 (continued)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
India	6	8	11	11	15	14	18	18	15	14	15	20	24	22
Poland	4	7	8	10	10	11	14	17	17	17	19	22	20	20
Hungary	20	22	18	20	23	18	17	16	15	16	17	18	19	18
Sweden	22	24	19	23	26	22	22	21	19	19	17	17	18	18
Austria	17	18	14	16	18	18	21	22	18	17	17	17	16	16
Russian Federation	4	6	5	5	6	8	9	10	12	11	10	10	11	13
Romania	1	3	3	5	6	4	4	4	4	5	6	7	7	7
Lithuania	1	2	1	1	2	2	2	2	2	2	2	3	3	3
Ukraine	2	2	2	2	2	3	2	2	2	1	1	1	1	1

Source Own calculations based on (“World Development Indicators | DataBank,” n.d.) [24]

of the leader High-technology exports was 27.5% in 2020. The market share of the leader fluctuated from a minimum of 19.2% in 2007 to a maximum of 29.6% in 2015.

The TOP 5 includes the following countries: China, Hong Kong SAR, Germany, Korea, Rep., Singapore in 2020 (Fig. 1). Their market share was 58.2%. Among the 5 leading countries—4 representatives of East Asia and only one of the developed countries—Germany.

In the TOP 10 countries (countries 6 to 10 are presented in Fig. 2), the situation is similar: dominated by countries from East Asia—Japan, Vietnam, Malaysia, pushing France and approaching the United States. In general, the top 10 countries cover 77.33% of high-tech exports in this sample and more than 80% of the world market for high-tech products.

Outsiders in this sample of countries in 2020 were Austria, Russian Federation, Romania, Lithuania, Ukraine. Their market share was 1.4%. Despite this, it should be noted that high-tech exports of Russia, Romania and Lithuania increased, Austria did not change, and Ukraine decreased by more than 50%.

The following changes took place in the structure of ratings (Table 5): 9 countries improved their positions; unchanged 4 countries; worsened their positions in 17 countries.

Among them, Hong Kong SAR, China rose in the ranking by 25 positions—from 27 to 2. Vietnam rose in the ranking by 18 positions—from 26 to 8. Czech Republic rose in the ranking by 6 positions—from 22 to 16. Korea Rep. rose in the ranking by 2 positions—from 6 to 4. While Japan, France, Russian Federation, Netherlands, each, decreased in the ranking by 3 positions. United States dropped in the ranking by 4 positions—from 2 to 6th place. Philippines and Hungary dropped 4 positions

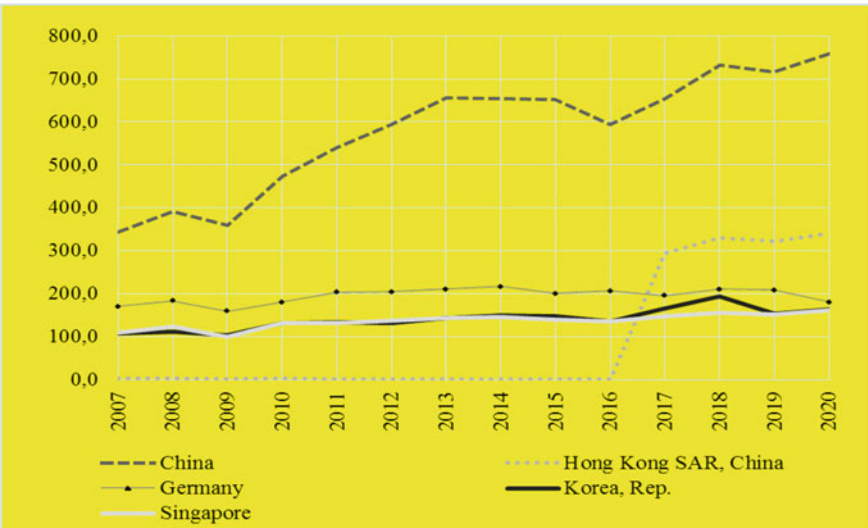

Fig. 1 Dynamics of high-tech exports in the top 5 leading countries in 2007–2020 in billion current dollars USA. *Source* Own calculations based on World Bank data

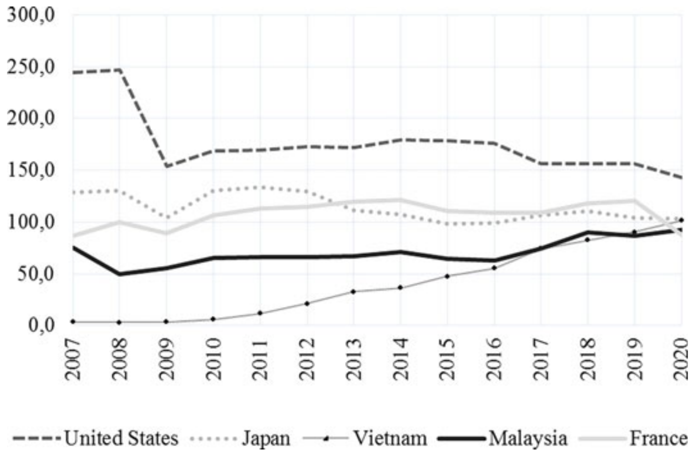

Fig. 2 Dynamics of high-tech exports in the top 10 leading countries (6–10 positions) in 2007–2020 in billion current dollars USA. *Source* Own calculations based on World Bank data

in the ranking. Austria decreased by 5 positions—from 21 to 26. Canada decreased by 5 positions—from 16 to 21. Sweden decreased by 6 positions—from 19 to 25. Switzerland decreased by 8 positions—from 12 to 20.

The results of grouping the country according to the estimated values of absolute growth and "acceleration" of change in the studied indicator in the short term are presented in the table in Table 6, in the long term in the Table 7.

When analyzing the behavior of the indicator in the short term, it should be borne in mind that it calculates the acceleration indicators reflect the dynamics of the last three years.

In general, the following trends were observed in the sample—there are fluctuations between all four groups. But these fluctuations have characteristic differences: in 2009 a gradual exit from the global financial crisis with a sharp accelerated growth in 2010. From 2013 to 2015. there is a smooth transition from 1–3-4 to an accelerated decline in high-tech exports, with some tendencies to exit this state in 2016–2018 (2nd and 1st groups).

Separately by country, it should be noted that in 2010—the year in which almost all countries, except India, Belgium, were in the 1st group—they saw an accelerated growth of the studied rogue. The critical years are 2009 and 2015—in them the largest number of countries were in the 4th group. 2020, although under pressure from anti-pandemic measures around the world, still noted that all sample countries had an accelerated reduction in high-tech exports, while 40% of countries were in Group 1, and 37% (11 countries) 23% (7) of the countries that were in the negative 4th group got there naturally due to the smooth transition from 1 to 3 and the rest to 4.

Let's take a closer look at the dynamics in some of the leading countries.

In China in the short term there were trends very similar to the world, but the transitions were sharper—from 1 to 4 groups and vice versa, without smoothing development through 2 or 3 groups in both growth and decline. Since 2014, there

Table 5 Ranking of countries in 2007–2020

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	The difference of positions between 2020 and 2007	Average rating
China	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	0	1,0
Germany	*3*	*3*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*3*	*3*	*3*	*3*	0	2,4
United States	*2*	*2*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*5*	*5*	*4*	6	−4	3,4
Korea, Rep	6	6	*5*	*4*	*5*	*5*	*5*	*4*	*4*	*4*	*4*	*4*	*5*	*4*	2	4,6
Singapore	*5*	*5*	6	*5*	6	*4*	*4*	*5*	*5*	*5*	6	6	6	*5*	0	5,2
Japan	*4*	*4*	*4*	6	*4*	6	7	7	7	7	8	8	8	7	−3	6,2
France	7	7	7	7	7	7	6	6	6	6	7	7	7	10	−3	6,9
Netherlands	8	8	8	8	8	8	8	8	9	9	9	10	10	11	−3	8,7
United Kingdom	10	9	10	9	9	9	9	9	8	8	10	12	12	13	−3	9,8
Malaysia	9	10	9	10	10	10	10	10	10	10	11	9	11	9	0	9,9
Mexico	11	11	12	11	11	11	11	11	11	11	13	13	13	12	−1	11,6
Thailand	13	13	14	13	13	13	13	13	14	14	14	14	14	14	−1	13,5
Switzerland	12	12	11	12	12	12	12	12	12	12	18	20	21	20	−8	14,1
Ireland	14	16	16	16	16	16	17	19	15	15	15	15	15	15	−1	15,7
Italy	17	14	15	14	14	15	16	15	16	16	17	18	19	18	−1	16,0
Canada	16	17	17	15	15	14	14	16	17	19	20	19	20	21	−5	17,1
Vietnam	26	26	26	25	24	20	15	14	13	13	12	11	9	8	18	17,3
Czech Republic	22	21	21	18	17	17	18	17	19	20	19	16	16	16	6	18,4
Philippines	15	18	18	21	23	19	20	20	18	17	16	17	17	19	−4	18,4
Belgium	18	15	13	20	20	21	19	18	20	18	21	21	18	17	1	18,5

(continued)

Table 5 (continued)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	The difference of positions between 2020 and 2007	Average rating
Sweden	19	19	19	17	18	18	21	22	21	21	23	25	25	25	−6	20,9
Hong Kong SAR, China	27	28	28	28	30	30	30	30	30	30	2	2	2	2	25	21,4
Hungary	20	20	20	19	19	23	24	25	24	24	25	24	24	24	−4	22,5
Austria	21	22	22	22	21	22	22	21	22	23	24	26	26	26	−5	22,9
India	23	23	23	23	22	24	23	23	25	25	26	23	22	22	1	23,4
Poland	25	24	24	24	25	25	25	24	23	22	22	22	23	23	2	23,6
Russian Federation	24	25	25	26	26	26	26	26	26	26	27	27	27	27	−3	26,0
Romania	29	27	27	27	27	27	27	27	27	27	28	28	28	28	1	27,4
Ukraine	28	29	29	29	28	28	28	28	29	29	30	30	30	30	−2	28,9
Lithuania	30	30	30	30	29	29	29	29	28	28	29	29	29	29	1	29,1

Source Own calculations

Table 6 Grouping of regions by level of absolute growth / acceleration in the short term

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	4	**1**	*3*	*3*	**1**	4	2	4	**1**	**1**	4	**1**
Hong Kong SAR, China	4	**1**	4	2	4	2	2	**1**	**1**	*3*	4	**1**
Germany	4	**1**	**1**	*3*	**1**	**1**	4	**1**	4	**1**	4	4
Korea, Rep	4	**1**	*3*	4	**1**	*3*	4	4	**1**	*3*	4	**1**
United States	4	**1**	*3*	**1**	4	**1**	4	4	4	2	**1**	4
Singapore	4	**1**	*3*	**1**	**1**	*3*	4	2	**1**	*3*	4	**1**
France	4	**1**	*3*	*3*	**1**	*3*	4	2	**1**	**1**	*3*	4
Japan	4	**1**	*3*	4	4	2	4	**1**	**1**	*3*	4	2
Netherlands	4	**1**	*3*	4	2	**1**	4	**1**	**1**	**1**	*3*	*3*
United Kingdom	4	**1**	*3*	4	**1**	*3*	4	2	**1**	**1**	*3*	4
Malaysia	**1**	**1**	*3*	4	**1**	**1**	4	2	**1**	**1**	4	**1**
Vietnam	**1**	**1**	**1**	**1**	**1**	*3*	**1**	*3*	**1**	*3*	*3*	**1**
Mexico	4	**1**	*3*	**1**	*3*	**1**	4	**1**	**1**	*3*	*3*	4
Thailand	4	**1**	4	**1**	4	**1**	*3*	*3*	**1**	*3*	4	**1**
Ireland	4	2	**1**	4	2	**1**	**1**	**1**	4	**1**	**1**	**1**
Philippines	4	4	2	**1**	*3*	**1**	**1**	4	**1**	*3*	**1**	4
Italy	4	**1**	**1**	4	**1**	*3*	4	**1**	**1**	*3*	*3*	**1**
Switzerland	4	**1**	**1**	*3*	**1**	*3*	4	**1**	4	**1**	4	4
Czech Republic	4	**1**	**1**	4	2	**1**	4	**1**	**1**	**1**	*3*	**1**
Canada	4	**1**	*3*	**1**	4	4	2	4	**1**	**1**	*3*	4
Belgium	*3*	4	**1**	4	**1**	*3*	4	**1**	4	**1**	**1**	*3*
Poland	*3*	**1**	*3*	**1**	**1**	**1**	4	**1**	**1**	**1**	4	2
Sweden	4	**1**	*3*	4	2	4	4	**1**	4	**1**	**1**	**1**
Austria	4	**1**	**1**	*3*	**1**	*3*	4	2	2	4	4	2
Hungary	4	**1**	**1**	4	2	4	2	**1**	*3*	**1**	*3*	4
India	**1**	4	**1**	4	**1**	*3*	4	2	**1**	**1**	*3*	4
Russian Federation	4	**1**	*3*	**1**	*3*	*3*	*3*	4	4	2	**1**	**1**
Romania	*3*	**1**	*3*	4	**1**	**1**	4	**1**	*3*	**1**	*3*	4
Lithuania	4	**1**	**1**	*3*	**1**	*3*	4	**1**	**1**	*3*	*3*	**1**
Ukraine	4	**1**	**1**	**1**	4	2	4	2	**1**	4	**1**	*3*

Source Own calculations

Table 7 Grouping of regions by indicators of absolute growth/acceleration of the number of scientists who performed research work in the long run

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	*3*	*3*	**1**	**1**	**1**	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Hong Kong SAR, China	4	2	4	4	4	4	2	2	**1**	**1**	**1**	**1**
Germany	4	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Korea, Rep	4	**1**	**1**	**1**	**1**	**1**	**1**	*3*	**1**	**1**	*3*	**1**
United States	4	4	4	4	4	4	4	4	4	4	4	4
Singapore	4	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
France	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Japan	4	*3*	*3*	*3*	4	4	4	4	4	4	4	4
Netherlands	4	2	**1**	2	2	**1**	2	2	2	**1**	**1**	**1**
United Kingdom	4	2	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	2
Malaysia	2	2	2	2	2	2	2	2	2	**1**	**1**	**1**
Vietnam	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Mexico	4	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Thailand	4	**1**	*3*	*3*	*3*	*3*	*3*	*3*	**1**	**1**	*3*	**1**
Ireland	4	4	4	4	4	4	2	**1**	**1**	**1**	**1**	**1**
Philippines	4	4	4	2	2	2	2	2	**1**	**1**	**1**	**1**
Italy	4	4	*3*	4	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Switzerland	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	4	4	4	4
Czech Republic	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Canada	4	4	4	**1**	**1**	2	2	4	4	**1**	**1**	4
Belgium	*3*	4	4	4	4	4	4	4	4	4	*3*	*3*
Poland	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Sweden	4	*3*	*3*	*3*	4	4	4	4	4	4	4	4
Austria	4	4	*3*	*3*	*3*	*3*	*3*	*3*	*3*	4	4	4
Hungary	4	*3*	*3*	4	4	4	4	4	4	4	4	4
India	**1**	*3*	**1**	*3*	**1**	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Russian Federation	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Romania	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Lithuania	4	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Ukraine	*3*	*3*	*3*	*3*	*3*	*3*	*3*	4	4	4	4	4

Source Own calculations

has been a deterioration of the situation (group 4) for 3 years—with the beginning in 2017, the trend towards a smooth exit to the 1st group.

Germany, France in the short term show similar trends, but France is showing more planned transitions to reduce the volume of the indicator.

In the United States in the short term there are many abrupt transitions from 1 to 4 groups and vice versa, which indicates the lack of any sound management of the process. Years from 2015 to 2017 the country is in the 4th group, which indicates an accelerated decline in exports of high-tech then there was a targeted transition to the 1st group through the 2nd in 2018–2019, possibly due to the implementation of Trump's industrial policy, but 2020 dropped the country back to the 4th group.

In the UK, almost the entire study period (except 2012) there is a smoothing of smooth transitions between groups, namely a gradual decrease in the volume of the indicator on the route 1-3-4, as well as a gradual increase of 4-2-1 in 2015–2018.

In the long run, the vast majority of countries studied were in the 3rd group. This means that there are processes of increasing exports of high-tech products in the world compared to 2007, but with a slowing trend. In the 1st group was the whole period only Vietnam and most of the period under study Mexico, Britain, South Korea, ie they were in a phase of accelerated growth. At the same time, such countries as the United States, Japan, Belgium, Sweden, Hungary, and Ukraine have been in the 4th group for the most time, ie reverse processes are taking place in them—a gradual decrease in high-tech exports. This is largely due to developed countries most likely the transfer of their production to other countries—China, Hong Kong, etc.

As for Ukraine, its share of global high-tech exports is less than 0.1%. Its growth compared to 2007, which took place until 2015, was inhibitory and, as is natural, has received a negative vector since 2016.

And against the background of its neighbors, it has catastrophic tendencies, as Poland, Lithuania, Romania, and Russia are increasing their own high-tech export production (albeit at a slower pace) (they are also in the 3rd group). This requires Ukraine to overhaul its own development strategy as a whole, identify priorities based on the restoration and development of its own knowledge-intensive production, development of science and technology according to EU standards, ensure an appropriate level of state support for this sector in the near future.

5 Conclusion

Thus, the results obtained allow us to investigate the general picture of the dynamics of high-tech exports and determine the periods in which there were attempts to influence it by different countries. Calculations show that in the short term these processes took place in different countries in different ways. In the long run, the situation is cross-cutting—the increase in exports of high-tech products throughout the study period occurs in Asia, and the opposite trend is observed in most developed countries of Western Europe, the United States and Japan.

As for Ukraine, first of all, in accordance with the current European policy on increasing the intensity of research funding, it is necessary to increase the average level of R&D spending in the country to the target level of 3% of GDP, which will create preconditions for the revival of its scientific potential, and, accordingly, to increase its high-tech exports and increase the competitiveness of the state. Ukrainian export policy, research and innovation policy must be correlated to achieve maximum effect.

Prospects for further research. In our opinion, further studies of those components of scientific and technical potential and production potential that determine the volume of production of high-tech products deserve special attention: the amount of funding for research, fixed assets, scientific and technical information.

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Improvement of Thermal Characteristics of a Node Between a Tubular Steel Truss and a Column

Oleg Yurin, Tatiana Galinska, and Dmitro Kochkarev

Abstract The article sets out the results of theoretical research on the improvement of heat-protective properties of the node, supporting tubular steel trusses on a metal tubular column, located in the center of the room. The authors of the article used in their studies an existing node, which was used in the auxiliary premises module of Poltava City School № 24. Theoretical research on the existing variant of heat insulation of the nod has been performed in the scientific study. The article states the temperature value on the outer surface of the steel column in the place of its adjoining to the ceiling, which at the design temperature of the outside air proved to be less than the temperature of condensate formation (dew point). The article offers the improved version of the insulation of the node, which provides for the location of heat insulating material in the middle of the column. This method allows to raise the temperature at the point where the column adjoins the ceiling above the dew point. The optimal location of the insulation and its thickness have been defined in this article.

Keywords Node between a steel truss and a column · Heat insulation

1 Introduction

Recently, in the spheres of civil and industrial engineering, load carrying structures and cladding structures, made of metal, have become widely used. Since the metal has high-thermal conductivity λp = 58 Вт/(м·К), the node connecting the column to the

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V. Onyshchenko et al. (eds.), *Proceedings of the 4th International Conference on Building Innovations*, Lecture Notes in Civil Engineering 299,
https://doi.org/10.1007/978-3-031-17385-1_73

roof truss, needs insulation. Without heat insulation, the surface temperature in the upper part of the column can decrease below the dew point, which leads to corrosion of metal ties, humidification of heat insulating material in the covering, which results in the reduction of its thermal characteristics and delamination of the finishing coat on the ceiling. That is, the requirement of the norms [1] $T_{(\text{B}\ min)} > T_{min}$ is not fulfilled. Insulation of the nodes connecting roof trusses to the columns with the use of L-bars and beam channels is not a difficult task, since when they are insulated, metal ties are inside the insulation and their cross sectional area is much smaller than the surface area of heat insulating material. When tubular members are used, the heat insulating material is located only on their outer surface. The heat from the room comes out both through metal constructions and through the air in the middle of the tubular members. Since the air has much higher heat conduction than the heat insulating material, thermal characteristics of the nodes of the tubular members are worse than when using L-bars and beam channels. Therefore, improvement of the nodes of the tubular members is a crucial task.

2 General Problem Statement and Its Connection with Important Scientific and Practical Tasks

The study [2] examines the impact of climate change on the risks of damage to external enclosing structures during freezing and thawing of a brick wall in two parts of Switzerland.

The article [3] investigates the causes of mold on wooden attics. Mechanical ventilation can be used to increase the humidity of the attics.

The article [4] presents the results of research on modeling the temperature-humidity state of the cold attic and proposes optimal solutions to prevent the formation of condensate on the inner surface of the coating.

Article [5] is devoted to the methods of thermal modernization of the housing stock. The influence of the heating system on the optimal amount of additional insulation of enclosing structures has become clear.

The scientific works [6–8] present methods that should be used in the design of apartment buildings to improve their energy efficiency. Optimization of elements of enclosing structures of buildings is completed. Based on the study of optimization results, an estimate of potential energy savings is given.

The articles [9, 10] consider options for additional insulation of the outer corner of the brick wall. Variants of application of additional warming from the outside of a wall, in deepening on an external surface and in the middle of a stone are considered. The optimal amount of additional insulation is determined.

The article [11] considers the problem of thermal modernization of external walls of prefabricated houses of the first mass series in Poltava. We analyzed the state of thermal protection of panel walls taking into account the design of the joint and the thickness of the panels. Recommendations for their thermal modernization according to modern regulatory requirements are developed.

The article [12–16] includes information regarding the results of thermal imaging monitoring of frameless constructions with an insulating coating based on polyethylene foam. It is shown that hotair welding allows minimizing heat losses both at the joints of the sheets and in the areas adjoining to the base and to the side walls of the buildings. Furthermore, the possibility of obtaining a seamless joint during the installation process significantly increases the effectiveness of the insulating coating by means of minimizing cold bridges and eliminating leakages when connecting separate insulating elements.

The authors of publications on the investigation of the ways to improve the thermal insulation of metal construction nodes, have not considered the problem of reduction of heat current through the air inside tubular members in trusses and columns.

Research objective. The purpose of the work was to determine the optimal location of heat insulating material and its thickness inside the metal tubular column. For the criterion of optimality we have taken the minimum essential volume of heat insulating material, providing the temperature value at the point where the column adjoins the ceiling above the dew point.

3 Definition of the Purpose and Objectives of the Study

The statement of basic materials and research results. In this study we have considered the existing node, which was used in the auxiliary premises module of Poltava City School № 24. The location of the major node of two triangular trusses on the metal tubular column of the middle row is shown in (Fig. 1).

The design of the major node and the existing insulation of its elements are shown in (Fig. 2).

The insulation of subunits was made of "ROCKMIN" heat insulating material, which has the thickness of 30 mm and heat conduction $\lambda_p = 0{,}039$ Вт/(м·К). In the design of the garret (attic) floor there was used the same heat insulating material,

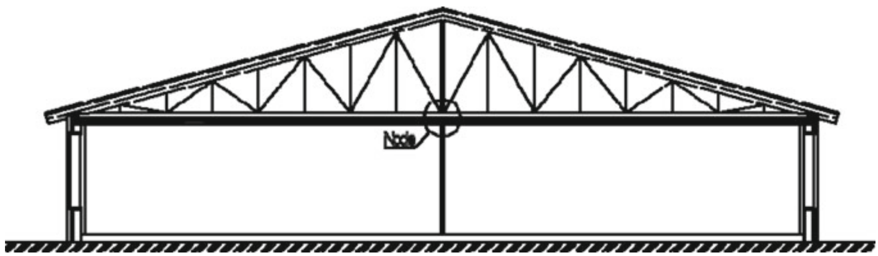


Fig. 1 The location of the major node of two triangular trusses on the metal tubular column of the middle row

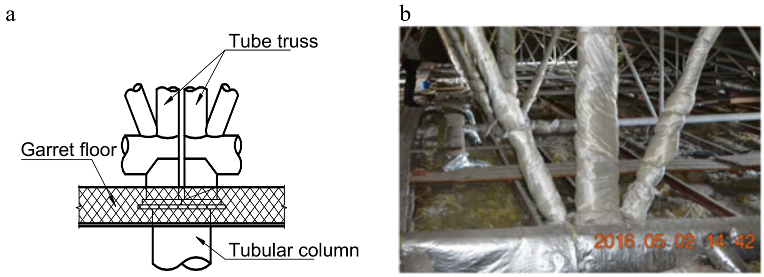


Fig. 2 **a** the design of the major node **b** the existing insulation of its subunits

which has the thickness of 150 mm, laid on 16 mm thick gypsum plasterboards on load bearing elements, made of galvanized siding.

Determination of the temperature at the point where the column adjoins the ceiling was performed on the basis of the heat flow pattern calculation. According to [1], for schools, the inside air temperature was assumed to be equal to $t_в = 21$ °C. The temperature in the attic, due to the insignificant resistance to heat convection of the attic covering, made of the profiled flooring, was assumed to be equal to the calculated outside air temperature for the I-st temperature range, which according to [1], is equal to $t_в = -22$ °C. The design model of the node for the calculation of the temperature field was applied to the axis of symmetry of the column (Fig. 3a). The results of the temperature field calculation are shown in (Fig. 3b).

The analysis of the temperature field showed that, at the calculated outside air temperature, the temperature at the point, where the column adjoins the ceiling, will be T_(в min) = −2,8 °C. This is lower than the dew-point temperature, which, at the design parameters of the inside air, is T_p = 10,2 °C. This leads to steam condensation on the upper part of the column, to the delamination of the finishing

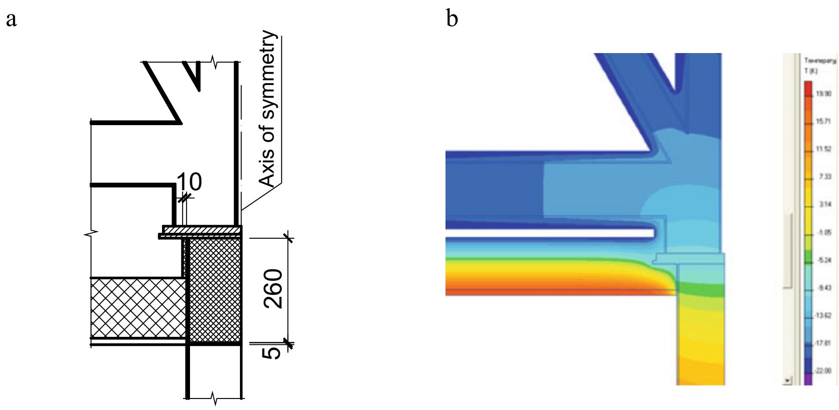


Fig. 3 **a** the scheme, taken up for the temperature field calculation **b** the results of the temperature field calculation

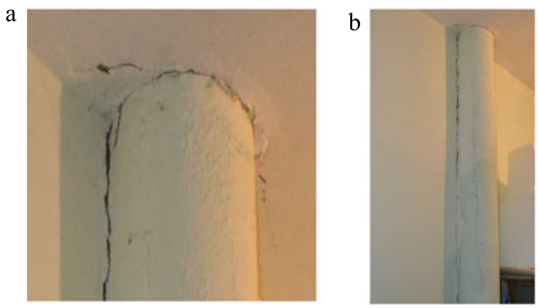


Fig. 4 **a** delamination of the finishing coat on the ceiling; **b** formation, due to temperature deformations, of the trash gap between the wall and the column

coat on the ceiling (Fig. 4a), to humidification of heat insulating material in the garret floor, and as a consequence, to reduction of its resistance to heat convection at the location of the column. In addition, significant difference between the temperature of the overhead and the bottom of the column leads to its significant deformation and the formation of a trash gap between the wall and the column (Fig. 4b).

From this we can make a conclusion, that wrapping of the tubular members with heat insulating material does not significantly increase thermal characteristics of the node.

Such poor-quality thermal characteristics of the node are explained by the fact that most of the heat current from the room passes through the node over the air inside tubular members. This is explained by the fact that heat conduction of the air in the middle of tubular members is much greater than heat conduction of heat insulating material. Heat current passes over the air alongside tubular members to parts of trusses without insulation and flows freely into the attic.

In addition, the analysis of heat-protective properties of the attic covering showed that its resistance to heat convection is equal to R_Σ = 4,12 м^2·К/Вт, which is less than the value normalized by [1] which us equal to R_(q.min) = 4,95 м^2·К/Вт. This is explained by the fact that the auxiliary premises module of Poltava City School № 24 was built at the time when thermal insulation norms in the country were lower.

In further studies, the thickness of heat insulating material on the attic covering was increased to 200 mm. In this case, its resistance to heat convection was equal to R_Σ = 5,403 м^2·К/Вт, which was higher than the normalized value.

In order to bring the node, connecting the column to the truss, to heat transmission norms given in [1], it was proposed to fill the inner part of tubular members with heat insulating material. It is difficult to implement this in members of the girder. It is better to locate heat insulating material inside the tubular column. The heat insulating material, located in the middle of the tubular column, significantly reduces the heat current that passes through the air in the middle of tubular members.

The authors of the article have conducted appropriate research in order to determine the thickness and location of heat insulating material in the middle of the column.

At the first stage of our research we examined the change of temperature at the point where the column adjoins the ceiling with the thickness of the heat insulating material in the middle of the column from 10 to 160 mm. The upper part of heat insulating material coincided with the top of the column. The heat insulating material was in resting contact upon a 5 mm thick metal sheet inside the column. The heat conduction of the heat insulating material was accepted as λp = 0,039 Вт/(м·К).

The research results are shown in Table 1.

As Table 1 shows, the maximum temperature at the point where the column adjoins the ceiling is observed when heat insulating material is 130 mm thick. As the thickness of heat insulating material increases further, the temperature decreases. This is due to the fact that the bottom of heat insulating material was below the ceiling and thereby reduced the heat current coming to the point where the column adjoins the ceiling, from the air inside the column.

At the second stage we have investigated the temperature gradient at the point where the column adjoins the ceiling as the thickness of heat insulating material increased with the corresponding increase in the column height. The bottom of heat insulating material was taken at the level of the ceiling. The thickness of heat insulating material in the middle of the column was taken from 130 to 180 mm.

The research results are shown in Table 2.

As can be seen from Table 2, the maximum temperature at the point where the column adjoins the ceiling becomes higher than the dew point temperature (t_{min} = 10,3 °C > t_p = 10,2 °C) at 270 mm thickness of heat insulating material in the middle of the column. The third requirement of thermal insulation has been fulfilled.

At the third stage we have investigated the temperature gradient at the point where the column adjoins the ceiling as the height of heat insulating material is reduced with the corresponding decrease in the column height and with the application of heat insulating material around the column head (from the top of the column to the top of heat insulating material). The thickness of heat insulating material in the middle of the column decreased from 10 to 30 mm. The optimal variant was determined by the minimum volume of heat insulating material inside the column and around the column head.

Table 1 The temperature gradient at the point where the column adjoins the ceiling (the upper part of heat insulating material coincided with the top of the column)

№	The thickness of heat insulating material, mm	Temperature, °C	№	The thickness of heat insulating material, mm	Temperature, °C
1	10	0.3	9	90	4.8
2	20	1.1	10	100	5.2
3	30	1.7	11	110	5.4
4	40	2.5	12	120	5.6
5	50	3	**13**	**130**	**5,8**
6	60	3.6	14	140	5.8
7	70	4	15	150	5.3
8	80	4.5	16	160	4.7

Table 2 The temperature gradient at the point where the column adjoins the ceiling (the bottom of heat insulating material was taken at the level of the ceiling)

№	The thickness of heat insulating material, mm	Temperature,°C	№	The thickness of heat insulating material, mm	Temperature °C,
1	130	5,8	9	210	8.9
2	140	6,3	10	220	9.2
3	150	6,8	11	230	9.5
4	160	7,2	12	240	9.8
5	170	7.6	13	250	10
6	180	8	14	260	10.1
7	190	8,4	**15**	**270**	**10,3**
8	200	8,7	16	280	10,5

Table 3 The temperature gradient at the point where the column adjoins the ceiling (application of additional insulation around the head of the column)

The thickness of heat insulating material, mm	The thickness of heat insulating material around the column, mm	Temperature,°C	Volume of heat insulating material, m^3		
			In the middle of the column	Around the column head	The general
270	0	10,3	0,014661	0	0,014661
260	10	10,3	0,014118	0,0004806	0,0145986
250	60	10,1	0,013575	0,0027632	0,0,163382

The research results are shown in Table 3.

As the Table 3 shows, the smallest total volume of heat insulating material is observed in the cases of reduction of the thickness of heat insulating material in the middle of the column by 10 mm and application of heat insulating material around the column head with the thickness of 10 mm.

The temperature fields of the node at each stage of the study are shown in Fig. 5.

The diagram of the best option for heat insulation of the node is shown in Fig. 6.

4 Conclusions

The insulation on the outside of tubular metal trusses and columns does not significantly reduce the heat current, that flows through the node, which connects those trusses and columns. This is explained by the fact that the warm from the room goes

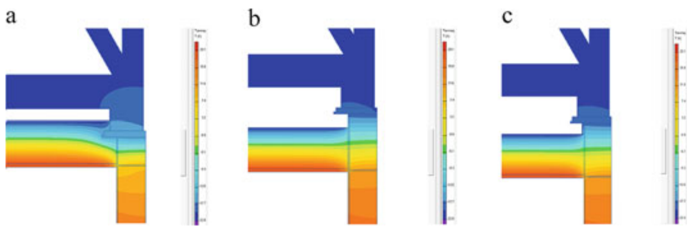
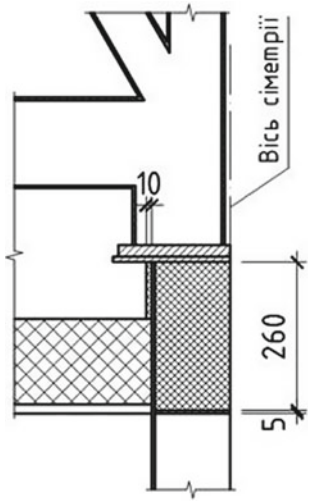


Fig. 5 Temperature fields of the node, connecting tube trusses to columns at three stages of the studying: **a** the first stage; **b** the second stage; **c** the third stage

Fig. 6 The diagram of the best option for heat insulation of the node, connecting tube trusses to the columns



outside both through metal constructions and through the air in the middle of the tubular members.

Poor-quality thermal characteristics of the node, connecting tubular members, lead to steam condensation on the upper part of the column, to the delamination of the finishing coat on the ceiling, to humidification of heat insulating material in the garret floor.

The proposed arrangement of heat insulating material inside the tubular column provides an opportunity to improve thermal characteristics of the node according to the requirements of thermal protection standards. In particular, it will make it possible to raise the temperature at the point where the column adjoins the ceiling above the dew point.

The optimum variant of insulation of the node in the auxiliary premises module of Poltava City School № 24, at which the volume of heat insulating material is minimal, provides for the arrangement in the middle of the column of 260 mm thick heat insulating material and the use of 10 mm thick heat insulating material around the column head. The bottom of the heat insulating material is located at the level of the ceiling.

Since the optimal variant of insulation depends on many factors: the diameter of tubular members of the truss and column, metal thickness, thermal characteristics of the garret floor, the calculated temperatures of indoor and outdoor air, etc., then in each specific case appropriate calculations are needed.

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https://doi.org/10.1007/978-3-031-17385-1

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