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STUDY OF THE LOAD-BEARING CAPACITY OF STRUCTURES OF LONG-TERM OPERATION OF THE FORMER "MODULE" PLANT IN UZHGOROD

Karkhut I.I., Ph.D., Associate Professor,
Karkhoot1@gmail.com, ORCID: 0000-0002-9205-5118
National University "Lviv Polytechnic"
12, S. Bandery str., Lviv, 79013, Ukraine
Luchko J.J., Doctor of Technical Sciences, Professor,
Luchko.diit@gmail.com, ORCID: 0000-0002-3675-0503
Lviv National Agrarian University
1, Volodymyr Velykogo str., Dublyany, 80831, Ukraine

Abstract. In this work, based on an analysis of literary scientific and technical sources and completed field studies, the problem of degradation of reinforced concrete and metal structures of long-term operation is formulated and its relevance is noted. The authors analyzed a number of works on this issue. Examples of the use of modern methods and materials for strengthening reinforced concrete and stone structures with damage and defects to restore their load-bearing capacity are described. The paper presents the results of a visual review and instrumental study of reinforced concrete and metal load-bearing structures of the former “Modul” plant, built according to the II-03c and II-60c series, as well as external self-supporting expanded clay concrete wall panels, brick walls, staircases and partitions. General information about the building and its design is provided. The objectives of the study included establishing the actual technical condition of the building’s structures and the possibility of its subsequent reliable operation after repurposing. During the examination, non-destructive testing methods and laboratory tests of materials were used to obtain actual strength indicators, humidity, the degree of corrosion damage to materials, and geometric characteristics of structures for their identification. The main reasons that necessitated the research and development of recommendations for eliminating identified defects and damage, as well as shortcomings of long-term operation, have been identified. Data are provided on detected defects and damage that occurred over a long period of time. According to current standards, the general technical condition of the building has been established as satisfactory (category 2) and appropriate conclusions have been formulated regarding the need for repair work. Based on the results of field surveys, relevant calculations and conclusions, recommendations for the repair and elimination of identified defects and damage were developed.

Keywords: frames, structures, reinforced concrete, steel, walls, brickwork.

Introduction. Currently, buildings and structures play a vital role for the society of any country and have a significant impact on people’s lives. The quantity and quality of modern buildings and structures erected is an objective indicator of the development of the economy of civilized states, science, culture, production and the well-being of the people. All of them must meet certain operational properties and maintain them throughout their entire service life, including through constant supervision, which in many cases is not carried out. The importance of this problem is associated, first of all, with the technical condition of buildings and structures and engineering systems built in the 70–90s and today are in mostly satisfactory technical condition. However, some of them, as a result of physical wear, have become unusable, and in some cases potentially dangerous for further use. The presence of a significant number of buildings and structures, the construction of which was stopped in the 90s, in particular due to a lack of funding and changes in production technologies, also highlights the problem of studying the residual resource when assessing the load-bearing capacity of buildings, the condition of structures and their possible repurposing. Of particular concern is the technical condition of large-panel residential buildings, in which the design service life is expiring, and over the past 25–30 years they have experienced accelerated physical and moral aging. You should also pay special attention to one of the most important problems – housing. In particular, out of 10.4 million residential buildings in the country, 4.7 thousand are in disrepair, and 36 thousand are classified as dilapidated and unsuitable for further use. Every third building needs major or current repairs.

It is especially important that such work is necessary now, when the country faces the difficult task of restoring the building stock, which requires a significant amount of research into damaged buildings and structures and addressing the issue of ensuring the requirements for their reliable operational suitability. To improve the technical condition of buildings and structures, relevant regulations were developed and adopted by government agencies. In particular, in accordance with Article 11 of the Law of Ukraine On Architectural Activities (687-14) and resolutions of the Cabinet of Ministers of Ukraine dated July 11, 2007 No. 903, the procedure for technical supervision during construction was approved. These regulations had a significant impact on the quality of construction and compliance with the requirements for the correct long-term operation of buildings and structures.

Analysis of the latest research and publications. The basis for reliable and durable operation of buildings and structures is the prevention of premature physical and moral wear and tear, as well as the elimination of damage that occurs, which is achieved by periodic inspections and preventative repairs. An analysis of scientific and technical sources [1–7] gives grounds to state that a scientific direction has been formed and developed in the research of structures of buildings and structures of long-term operation, experiencing the aggressive action of the air, soil and water environment, which is based on the research and application of modern materials and technologies

Let's consider some of them: in work [1] the main design and technological solutions for strengthening load-bearing reinforced concrete structures with concrete and reinforced concrete are outlined and highlighted. In particular, the strengthening of such structures with unloading elements is described. The main practical methods for calculating structures to be strengthened are presented. Recommendations for strengthening subsidence foundations of buildings and structures are substantiated and developed, and examples of calculations are given.

The works [2, 3] present the basic principles of technical operation and reconstruction, as well as the basics of organizing technical operation. In particular, work [2] sets out the basics of organizing the technical operation of structures of buildings and structures, presents the main fundamental issues of urban reconstruction and expedient solutions for reconstruction. Methods for modernizing buildings are also described, taking into account volumetric planning solutions, design features and technical condition. Recommendations have been developed for the repair and strengthening of structural elements using modern technologies and materials. And in work [3] the bases for organizing the technical operation of buildings and engineering structures are outlined. The features of technical operation and the feasibility of decisions on its organization, development prospects are given.

The work [4] thoroughly reflects the methods of inspection, reconstruction of buildings and structures and strengthening of their structural elements. Practical approaches to the reconstruction of buildings for various purposes are considered, taking into account the actual technical condition, as well as the technical and economic feasibility of changing the functional purpose. In particular, in work [5], based on the results of a technical inspection of industrial and civil facilities, the characteristic signs of degradation of reinforced concrete structures are summarized. The significant damage and defects identified during the inspection associated with long-term operation in the air are described. These are design errors, shortcomings and defects that were made during the construction and operation of objects using the example of reinforced concrete structures of rotating kilns at a cement plant in Nikolaev, the corrosion destruction of an overpass at the Transnistrian hydroelectric power station, the destruction of structures at the Three Concrete plant in Stryi, as well as examples of many other objects (more than 40), where the authors studied the degradation of reinforced concrete structures. Based on these studies, the main errors made at the design stage, defects and shortcomings in construction and shortcomings in the long-term operation of buildings and structures were identified. Modern technologies and materials for repair and renewal work are also proposed.

The work [6] presents the results of studies of bridges built in Ukraine after the floods of 1998-2001 and long-term operation. Real situations are considered using the example of a monolithic frame-cantilever reinforced concrete bridge over the Tisa River in the city of Khust, destroyed during a flood in 1998 and restored in 2000.

A fragment of a map of the roadway of this bridge is shown, which shows defects - cracks that appeared after less than 2 years of operation. Instrumental control revealed a large variation in the strength of concrete during the construction of the roadway of the bridge. It was found that between some spans there is no design gap between the ends of the beams, which can have a significant impact on the stress-strain state of the structures. Also presented are the results of an examination of six steel-reinforced concrete bridges with spans of 11.8 m and 23.6 m, built after the 1998 flood in Kobyletskaya Polyana and Kosovska Polyana. The figures show the structure of the roadway of bridges during the construction period and tests for static and dynamic loads. It should be noted that the condition of these steel-concrete bridges, built in 2000, is better than those mentioned earlier, but they also have significant defects in the form of cracks.

If the examination of the above bridges revealed the low quality of their construction, then in the structural elements of long-term operation bridges we have a natural degradation of the physical and mechanical properties of the material. These data are confirmed by the example of a survey of an overpass in the city of Mukachevo, which has been in operation for 30 years. A scheme for reducing the service life of a structure is presented. In total, this work describes design errors, defects and shortcomings in the construction of long-term reinforced concrete (steel-concrete) bridges and overpasses identified by inspections.

In work [7], based on field surveys, the main problems of degradation of reinforced concrete structures of buildings and structures of long-term operation are established. Their relevance is noted. The authors drew attention to the need for systematic technical diagnostics of such structures. In particular, based on a thorough analysis of many buildings and structures of long-term operation, the reasons have been identified that significantly influence the accelerated deterioration of the operational condition of structures. They boil down to the following: errors made at the design stage, defects and deficiencies in construction, deficiencies in the operation of building structures and structures. Based on the research results, relevant conclusions are given and recommendations for carrying out repair work are given.

Works [8, 9] discuss methods for repairing reinforced concrete structures with long-term damage to ensure crack resistance, strengthening vertical and inclined sections using steel reinforcement (clamps, bends), and in work [10] using fiber, non-metallic fiber and carbon tapes etc. Some of these methods are effective when there is access along the entire height of the bending elements to inclined sections, and when access is only to the top and bottom edges, they are used to strengthen normal areas. When studying crack formation processes in bending elements [11], the appearance and development of critical inclined cracks were studied. The formation of other dangerous cracks has not been studied. Reinforced concrete elements such as slabs with inclined cracks are described in [12]. Concrete cross sections without reinforcement and with a multilayer arrangement of horizontal fasteners, which significantly increase the strength and crack resistance of inclined cross sections, were studied. In this case, the calculations took into account the dowel effect in the reinforcement [13].

The purpose of the work is to determine the actual technical condition, develop recommendations for eliminating identified defects and damage for further reliable operation based on an analysis of scientific and technical sources and field studies.

Scientific novelty and practical value. The analysis of scientific and technical literature and the results of field surveys and theoretical calculations made it possible to obtain new data on the actual stress-strain state of reinforced concrete frame structures and its changes over 40 years of operation. At the same time, the actual parameters of the depth of carbonization of concrete determined during the survey, the percentage of corrosion of working reinforcement of reinforced concrete structures and the decrease in the strength of concrete during this period of operation in the climatic conditions of

Transcarpathia were taken into account. This made it possible to establish the actual technical condition of the building's structures, taking into account the reduction in the load-bearing capacity of reinforced concrete frame elements compared to the design one, and to develop recommendations for its restoration, taking into account the repurposing of the building. The practical significance of the work is to obtain data for the development of a building reconstruction project, which made it possible to reduce construction costs and reduce its time. The presented recommendations for repairs made it possible to use modern energy-efficient materials and technologies [16], ensure the restoration of the load-bearing capacity of structures and bring them to normal technical condition (category 1).

Materials and research methods. The main load-bearing reinforced concrete, stone and steel structures of the building were examined to identify defects and damage during long-term operation, establish their danger, influence on the technical condition and its deterioration. To obtain geometric characteristics (dimensions of cross sections of steel profiles and precast reinforced concrete elements, diameters of reinforcement, thickness of the protective layer of concrete), all available non-destructive testing methods were used. The dimensions and deviations from the design position were determined by the visual method, using tape measures and a 2T-30P theodolite, Greisinger-13 tape measures were used to determine the distance, and the thickness of the protective layer of concrete, the diameter and degree of corrosion of the reinforcement of reinforced concrete elements were determined using the magnetic method (Profometer S5). The moisture content of materials was determined by the method of contact electrical conductivity (GMH 3830). The strength of welds was monitored using the ultrasonic method usingдефектоскопів UD2-70 flaw detectors; the strength of concrete was determined with a 58CO181/G device. Some of the materials (bricks and mortar) were tested in laboratory conditions using hydraulic equipment (P-125 press and MP-100 tensile testing machine). All measuring instruments and testing equipment used were verified in accordance with the established procedure. The methods were certified in Ukraine and made it possible to determine the studied parameters of structures and materials with the appropriate confidence probability (at least 95%). This made it possible to reliably determine quantitative indicators of a decrease in the characteristics of structures and materials, deviations from design ones, and to establish the actual technical condition (category) of the building as a whole.

Presentation of the main research material. An inspection of the structures of a non-residential building of the former Modul plant after long-term operation was carried out to order from the building owner in accordance with Agreement No. 58-2023 dated June 06, 2023 by a team of leading experts of the private entrepreneur Karkhut I.I. The result was to determine the actual technical condition of the building's structures and develop recommendations for repairs to ensure further reliable operation after its repurposing.

The objectives of the survey included a visual inspection of the main load-bearing and enclosing structures: roofs and roofs, reinforced concrete roofing and floor slabs, columns and crossbars of frames, steel frames and braces, brick walls and partitions, concrete foundations in order to identify and establish the causes of defects and damage, disadvantages of long-term use. Based on the analysis of the survey results and calculations, it is necessary to establish the actual technical condition, check the load-bearing capacity and develop recommendations for eliminating defects and damage during reconstruction.

Structural solution of the building. The building consists of three sections. The building of section 1 is rectangular in plan with axial dimensions of 36×24 m, three-story with a technical floor and a shelter in the basement, built in the late 1960s. Section 1 is interlocked with section 2. The frame is reinforced concrete according to series II-03c. The pitch and runs of the crossbars are 6 m in the axes. The height of the first and second floors is 3.3 m, the third floor is 4.2 m. Frame columns with a cross section of 300×300 mm with rectangular consoles. Ribbed coating slabs 300 mm high. Slabs in interfloor ceilings of type PK-57-15-8A-III, ordinary and connected. The overlay of the shelter in the basement is reinforced concrete monolithic ribbed with concrete walls. External self-supporting walls made of expanded clay concrete panels measuring 6×1.2×0.24m. The foundations of the shelter under the building are columnar on a natural basis. More detailed data on the design of section 1 are given in [14]. Sections 2 and 3 in a complete prefabricated reinforced concrete frame according to series II-60c. The floors are prefabricated reinforced concrete, external self-supporting walls are made of expanded clay concrete panels and brickwork 380 mm thick. Section 2 is interlocked with L-shaped section 3. The building sections are three-story (four-story) with shelters in the basements. The section structures are made in the form of transverse prefabricated multi-storey frames with a pitch of 6 m. The grid of columns is 6×9 m. The frame crossbars are continuous with purlins of 9 m in the axes. The total length of the sections in plan is 102 m between the axes, width 36 m. The second and third sections were built in 1976. The height of the 2nd and 3rd floors is 4.8 m, the first floor is 6 m. The columns of the first floor along the middle axes are 600×400 mm in section, the upper floors are 400×400 mm. Columns of the outer axes with a cross-section of 450×400 mm. More detailed data of the 2nd and 3rd sections are given in [8].

Field inspections of the structures of the Module plant in Uzhgorod revealed:

Section 1. During a visual inspection, traces of slight penetration of moisture between the covering and floor slabs and cracks in the seams of the slabs were found. The causes of the detected defects and damage were leaks from the roof during the long-term operation of the flat roof before repair for about 30 years.

The defects found in the enclosing structures are as follows: leaks in the joints of sheets of profile flooring, leaks in junctions with walls and in ridges. Destruction of the brick walls of the staircases was detected to a depth of 30–40 mm due to periodic freezing (Fig. 1, a). Corrosion of metal structures of frames on the technical floor is insignificant (local) and uniform on the surface. The technical condition of the metal structures is satisfactory.

The main defects and damage to the shelter structures under Section 1, identified during the inspection, are minor corrosion damage to the floor structures and self-supporting walls, in particular corrosion of reinforcement clamps, violation of the tightness of the waterproofing of walls and foundations, cracks in the protective layer of concrete up to 0.20 mm and in individual places 0.3-0.4 mm along the working reinforcement.

The overlap of the shelter is reinforced concrete monolithic ribbed. The main defects and damages detected during visual inspection are the following: cracks on the surface of the slab up to 0.3 mm wide (Fig. 1, b), carbonization of concrete to a depth of up to 15 mm and a decrease in the strength of concrete up to 15–20% (Fig. 1, *b*). Photographic recording of defects, damage and shortcomings of long-term operation is shown in Fig. 1 and in work [14]. It should be noted that the detected defects and deficiencies are located in separate areas of the floor slab and column capitals without a clearly defined system (Fig. 1, *e*). In our opinion, the main reason for their occurrence and development was prolonged flooding of the shelter.

Consequently, in terms of the totality of defects and damage from long-term operation, the technical condition of the load-bearing structures of the shelter floor according to the classification of current standards is satisfactory and in order to bring them to normal technical condition they need to be repaired with the elimination of identified defects.

Thus, according to the definition of tables [15], the condition of the load-bearing and enclosing structures of Section 1, taking into account the repairs carried out at the time of the inspection (06.06.2023), can be qualified as satisfactory. In this condition, there are no defects or damage that could reduce the durability of structures and their performance.

Sections 2 and 3. When conducting a full-scale inspection of the structures of Sections 2 and 3, the following defects and shortcomings of long-term operation were identified: significant defects in the roof, in particular leaks and cracks in the seams of the rolled covering, blockage of water intake funnels, which leads to stagnation of water on the surface (photo [14]). The technical condition of the waterproofing carpet is unsatisfactory.

The soaking of reinforced concrete structures in leakage areas is significant. Local destruction of the protective layer of concrete and minor corrosion of the working reinforcement were revealed, but further soaking can worsen the technical condition of the load-bearing reinforced concrete structures of the coating, floor and frame as a whole. There are no defects in the ceiling and frame in the form of excess cracks with an opening width of more than 0.3 mm. The technical condition of reinforced concrete and steel structures can be assessed as satisfactory.


a


b


c


d


e


f

Fig. 1. 1. Degradation of structures of buildings of the former Modul plant in Uzhgorod: *a* – destruction of the masonry walls of the staircase made of brickwork to a depth of 50 mm in Section 2 from periodic freezing and thawing; *b* – traces of flooding of the shelter to a height of 2 m in the basement of Section 1 (carbonization of concrete and reduction in concrete strength); *c* – cracks along the edge of the floor slab on the third floor of Section 2 (corrosion of the working reinforcement in the edge of the slab); *d* – cracks in the rib of the floor slab on the second floor of Section 2 (destruction of the protective layer of concrete, carbonization of concrete, peeling of the protective layer, corrosion of the reinforcement of the floor slab and capital); *f* – periodic flooding of the shelter in the basement of Section 2, resulting in the appearance of damage shown in Fig. 1 *a*– *f*

In brick partitions and walls in some places where soaking occurred, minor destruction of the masonry up to 20 mm was found. In the walls of staircases, destruction is caused by local freezing and thawing to a depth of 40-50 mm (Fig. 1, *a*). Minor defects were also identified in the form of loss of mortar from masonry joints of walls and partitions, which have a local effect on the load-bearing capacity of structures.

In the shelter under Sections 2 and 3, the main defects discovered during the inspection were the complete destruction of the equipment of engineering systems and stone brick partitions as a result of flooding (Fig. 1 and work [14]). The floor is prefabricated monolithic. The main structural defects detected during a visual inspection are the following: cracks in concrete walls and floor slabs with an opening width of mainly up to 0.25 mm, and in some places up to 0.35 mm (Fig. 1, *c, d, e*); penetration of moisture through cracks in structures.

Carbonization of the concrete of floor slabs, columns and capitals in the shelter, and peeling of the protective layer of concrete were revealed (Fig. 1, *c, d, e*). Corrosion of mounting and working reinforcement was detected in the ribs of floor slabs and columns and capitals, corrosion of embedded parts (Fig. 1 *c*, *d*, *e*) and surface corrosion of concrete.

As a result of a visual inspection, damage and shortcomings of long-term operation were identified and localized, and their descriptions were made. All detected defects as of June 26, 2023 generally have a local effect on reducing the strength and rigidity of individual load-bearing structures and can be eliminated during repair work. The general technical condition of the 2nd and 3rd Sections of the building according to the classification tables [15] is satisfactory, taking into account the reduction in the level of loads during repurposing. Structures require ongoing repairs to eliminate detected defects and damage. It is recommended to eliminate detected defects and damage to load-bearing reinforced concrete structures using modern materials and technological solutions given in [16].

Instrumental examination of load-bearing structures. An instrumental examination was carried out to establish the actual physical and mechanical characteristics of the masonry and concrete structures, the position and diameter of the reinforcement of reinforced concrete elements necessary to perform verification calculations and establish compliance with regulatory requirements. In addition, the degree of development of defects (cracks) and their parameters were determined to determine the effect on the load-bearing capacity of structures. A list of instruments used for instrumental examination and determination of geometric dimensions, crack opening and characteristics of materials of load-bearing structures is given in [14].

During the survey, the geometric parameters of reinforced concrete structures of coating and floor slabs of series II-03c and II-60c were determined, in particular the location of class A-III reinforcement in them. The average deviation values from 3–5 measurements turned out to be close to the normalized ones. Measurements of the dimensions and defects of panel and brick walls and partitions of sections, load-bearing walls of staircases and ventilation shafts with a thickness of 250–380 mm were carried out. Vertical and inclined power cracks in the masonry and panels were not detected. Weathering and loss of mortar from the joints was recorded in small areas, the depth of destruction of the masonry due to thawing was up to 40 mm.

The strength of materials was determined using a non-destructive method to perform verification calculations during reconstruction (Table 1). The strength of brickwork and mortar was determined using samples taken from the masonry in accordance with the requirements of current regulatory documents. Protocols based on the results of determining the strength of mortar and brick are given in [14].

Table 1 – Results of testing the strength of materials of load-bearing structures

No.	Name	Strength characteristics		
		Actual, Section 1	Actual, Sections 2 і 3	Design
1	Monolithic sections of the floor	M350	M250-M300	C20/25
2	Hollow slabs	M250-M300	-	C20/25
3	Ribbed slabs	-	M250-M300	C20/25
4	Columns 300×300 mm	M400	-	C25/30
5	Columns 400×400 mm	-	M450	C30/35
6	Columns 400×600 mm	-	M450	C30/35
7	Columns 450×400 mm	-	M450	C30/35
8	Girders 6 м, 9 м	M400	M400	C30/35
9	Wall panels	M300	M300	C20/25
10	Flights of stairs	M300	M300	C20/25
11	Lintels	M300	M250-M300	C12/15
12	Facade racks	M300	M300	C20/25
13	Porotherm blocks	M150	M150	M150
14	Solid ceramic brick	M75-M100	M75-M100	M75
15	Construction mortar	M75	M75	M75

Consequently, when conducting an instrumental examination, non-destructive methods were used: magnetic to determine the diameter, position and degree of corrosion of the reinforcement; surface impact to determine the strength of concrete; surface contact for determining the moisture content of concrete, reinforced concrete structures and brickwork. The strength of masonry walls and partitions: masonry mortar, brick, hollow blocks, was determined in laboratory conditions using a P-125 press and an MP-100 tensile testing machine. The characteristics determined in this way made it possible to clarify the nature and extent of damage and the technical condition of all structures. Certain characteristics of structures and materials from visual and instrumental examination are given in [14].

Conclusions. The analysis of scientific and technical sources and a number of field surveys and theoretical studies, visual and instrumental examination of the load-bearing and enclosing structures of the building and shelter in the basements, life support systems, and verification calculations allow us to draw the following conclusions:

1. The degree of development of the identified defects at the time of the survey (06/06/2023) allows us to unequivocally state that they do not significantly affect the load-bearing capacity of the main structures of all sections of the building and shelter, taking into account the reduction in the level of loads during repurposing.

2. The physical and mechanical characteristics of the materials of the load-bearing structures of the inspected building have deteriorated during the period since commissioning. Their load-bearing capacity decreased slightly (up to 20%) compared to the design one. But in general, they meet the minimum requirements of current standards, including those for construction in areas of high seismic activity.

3. The technical condition of the inspected load-bearing structures is satisfactory (category 2) and their load-bearing capacity under actual loads after repurposing is ensured. The technical condition of the shelter's life support systems is emergency, and they need to be completely replaced. The physical wear and tear of the shelter structures is 24% – the condition is satisfactory and their repair is economically feasible.

4. Maximum calculated vertical loads on the columns of the first floor frames: columns 300×300 mm – 1.40 MN, columns 600×400 mm – 4.20 MN, columns 450×400 mm – 3.15 MN. It is possible to reconstruct a building with a superstructure in accordance with the presented proposals while maintaining the frame-braced structural scheme without reinforcing the load-bearing structures of frames, walls and overlaps.

5. Enclosing structures must be lightweight to reduce forces from seismic influences. If it is necessary to fill cavities and level floor marks, it is recommended to use expanded polystyrene concrete screeds with a specific gravity of 400-500 kg/m^3. Partitions should be made of hollow materials or frame type. External walls and filling of openings should be brought into compliance with energy efficiency requirements. Staircases must be brought into compliance with the requirements of current standards. Existing timber roof structures must be dismantled. All layers of flat roofs with insulation that are unsuitable for use should be removed and replaced with energy efficient ones. All internal networks of the inspected sections of the building and the life support systems of the shelters are also subject to replacement.

6. After selecting materials for the superstructure, check the load-bearing capacity of columns and girder frames to make a final decision regarding the need to strengthen them. The renovation project must be carried out by certified professionals. Before dismantling begins, it is necessary to fence off the building and carry out work in compliance with safety requirements in construction. The accepted level of reconstruction is "a" "restoration of the condition of structures to the level prior to damage" according to DBN V. 1.1–12:2014 "Construction in seismic regions of Ukraine".

References

[1] A.B. Golyshev, P.I. Krivosheyev, P.M. Kozeletskiy i dr., *Usileniye nesushchikh zhelezobetonnykh konstruktsiy proizvodstvennykh zdaniy i prosadochnykh osnovaniy*. Kyyiv: Logos, 2004.

[2] A.I. Havrylyak, I.B. Bazarnyk, R.I. Kinash i in. *Tekhnichna ekspluatatsiya, rekonstruktsiya i modernizatsiya budivel′.* NU «L′vivs′ka politekhnika», 2006.

[3] A.I. Havrylyak, *Osnovy tekhnichnoyi ekspluatatsiyi budivel′ ta inzhenernykh system*. NU «L′vivs′ka politekhnika», 2009.

[4] I.H. Ivanyk, S.I. Vikhot′, R.S. Pozhar i in., *Osnovy rekonstruktsiyi budivel′ i sporud.* Lviv, NU «L′vivs′ka politekhnika», 2010.

[5] J.J. Luchko, "Osnovni faktory seredovyshcha, yaki vplyvayut′ na dehradatsiyu transportnykh sporud iz zalizobetonnykh i metalevykh hofrovanykh konstruktsiy", *Teoriya i praktyka rozvytku ahropromyslovoho kompleksu ta sil'kykh terytoriy: metarialy XXII Mizhnarodnoho naukovo-praktychnoho forumu*, 2021, vol. 2, pp. 203-206.

[6] J.J. Luchko, I.I. Karkhut, I.B. Kravets, "*Doslidzhennya zbudovanykh mostiv yaki buly zruynovanykh povenyamy na Ukrayini v 1998 i 2001 rokakh ta tryvaloyi ekspluatatsiyi*, *Mosty i tuneli: Teoriia, doslidzhennia, praktyka*, vol. 20, pp. 26–38, 2021.

[7] J. Luchko, B. Nazarevich, V. Kovalchuk, "Degradating concrete and reinforced building structures and long-term structures", *Bulletin of Odessa State Academy of Civil Engineering and Architecture*, Issue 86, pp. 35–46, 2022.

[8] I. I. Karkhut, *Obstezhennya zavodu «Modul'» ta rekomendatsiyi z podal'shoyi nadiynoyi ekspluatatsiyi*. Lviv, FOP Karkhut I.I., 2023.

[9] S. Maksymovych, O. Krochak, I. Karkhut, R. Vashkevych, "Experimental Study of Crack Resistance and Shear Strength of Single-Span Reinforced Concrete Beams Under a Concentrated Load at a/d = 1", *Proceedings of EcoComfort 2020*, vol. 100, 2021. https://doi.org/10.1007/978-3-030-57340-9_34.

[10] Z.Ya. Blikharskyy, I.I. Karkhut, *Calculation and design of bent reinforced concrete elements*. Lviv: Vydavnytstvo Lvivskoi politehniky, 2017. https://vlp.com.ua/node/20235.

[11] Z. Blikharskyy, R. Khmil, P. Vegera, "Shear strength of reinforced concrete beams strengthened by PBO fiber mesh under loading", In MATEC Web of Conferences, vol. 116, 02006, 2017. https://doi.org/10.1051/matecconf/201711602006.

[12] T. Bobalo, Y. Blikharskyy, R. Vashkevych, M. Volynets, "Bearing capacity of RC beams reinforced with high strength rebars and steel plate", MATEC Web of conferences, vol. 230, 02003, 2018. https://doi.org/10.1051/matecconf/201823002003.

[13] J. Selejdak, Y. Blikharskyy, R. Khmil, Z. Blikharskyy, "Calculation of Reinforced Concrete Columns Strengthened by CFRP", *Proceedings of CEE 2019. CEE 2019*, vol. 47. 2020. https://doi.org/10.1007/978-3-030-27011-7_51.

[14] Y. Blikharskyy, R. Khmil, Z. Blikharskyy, "Research of RC columns strengthened by carbon FRP under loading", *MATEC Web of conferences*, 174, 04017, 2018. https://doi.org/10.1051/matecconf/201817404017.

[15] DSTU-N B V.1.2-18-2016. Nastanova shchodo obstezhennya budivel′ i sporud dlya vyznachennya ta otsinky yikh tekhnichnoho stanu. K.: DP «UkrNDNTS», 2017.

[16] J.J. Luchko, B.Z. Parneta, B.L. Nazarevych, *Metody zakhystu vid koroziyi zalizobetonnykh konstruktsiy i sporud.* Lviv. Kamenyar, 2016.

ДОСЛІДЖЕННЯ НЕСУЧОЇ ЗДАТНОСТІ КОНСТРУКЦІЙ ТРИВАЛОЇ ЕКСПЛУАТАЦІЇ КОЛИШНЬОГО ЗАВОДУ «МОДУЛЬ» У М. УЖГОРОДІ

Кархут І.І., к.т.н., доцент,
Karkhoot1@gmail.com, ORCID: 0000-0002-9205-5118
Національний університет «Львівська політехніка»
вул. С. Бандери, 12, м. Львів, 79013, Україна
Лучко Й.Й., д.т.н, професор,
Luchko.diit@gmail.com, ORCID: 0000-0002-3675-0503
Львівський національний аграрний університет
вул. Володимира Великого, 1, м. Дубляни, 80831, Україна

Анотація. У даній роботі на основі аналізу літературних науково-технічних джерел та виконаних натурних досліджень сформульовано проблему деградації залізобетонних і металевих конструкцій тривалої експлуатації та відзначено її актуальність. Авторами проаналізовано низку робіт із вказаної проблематики. Описано також приклади застосування сучасних методів та матеріалів для підсилення залізобетонних та мурованих конструкцій з пошкодженнями і дефектами для відновлення їх несучої здатності. В роботі представлено результати візуального огляду та інструментального дослідження залізобетонних і металевих несучих конструкцій колишнього заводу «Модуль», побудованих за серіями ІІ-03с і ІІ-60с, а також зовнішніх стінових самонесучих керамзитобетонних панелей, цегляних стін, сходових кліток та перегородок. Наведено загальні відомості про будівлю та її конструктивне рішення. В задачі дослідження входили встановлення дійсного технічного стану конструкцій будівлі та можливості її подальшої надійної експлуатації після перепрофілювання. При обстеженні застосовані методи неруйнівного контролю та лабораторні дослідження матеріалів для отримання фактичних показників міцності, вологості, ступеня корозійного пошкодження матеріалів, геометричних характеристик конструкцій для їх ідентифікації. Встановлені основні причини, які викликали необхідність дослідження та розробки рекомендацій з усунення виявлених дефектів і пошкоджень, недоліків тривалої експлуатації. Наведені дані про виявлені дефекти і пошкодження, що виникли протягом тривалого терміну. Згідно чинних норм встановлено загальний технічний стан будівлі – задовільний (категорія 2), та сформульовані відповідні висновки щодо необхідності проведення ремонтних робіт. На основі результатів натурних обстежень, відповідних розрахунків та висновків були розроблені рекомендації з ремонту та усунення виявлених дефектів і пошкоджень.

Ключові слова: каркаси, конструкції, залізобетонні, сталеві, стіни, цегляна кладка.

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