Збірник наукових праць. Галузеве машинобудування, будівництво
Academic journal. Industrial Machine Building, Civil Engineering
http://journals.nupp.edu.ua/znp
https://doi.org/10.26906/znp.2024.62.3481

UDC 692.2:669.9]:620.193]:620.179

Oleksandr Semko
National University «Yuri Kondratyuk Poltava Polytechnic»
https://orcid.org/0000-0002-2455-752X

Yurii Avramenko *
National University «Yuri Kondratyuk Poltava Polytechnic»
https://orcid.org/0000-0003-2132-5755

Alina Zyhun
National University «Yuri Kondratyuk Poltava Polytechnic»
https://orcid.org/0000-0002-1743-2294

Igor Petrikei
National University «Yuri Kondratyuk Poltava Polytechnic»
https://orcid.org/0009-0000-5686-3970

Artem Pleshynets
National University «Yuri Kondratyuk Poltava Polytechnic»
https://orcid.org/0009-0004-8352-9010

Diagnostics of load-bearing building structures of construction industry enterprises operating under the influence of technological fluids

Diagnosing load-bearing structures in construction industry enterprises exposed to technological fluids presents a unique set of challenges. These fluids, ranging from corrosive chemicals to abrasive slurries, can significantly accelerate the deterioration of concrete, steel, and other building materials. Effective diagnostics require a multi-faceted approach that considers the specific fluids involved, their concentration, temperature, and exposure duration. Visual inspections, supplemented by non-destructive testing (NDT) methods like ultrasonic testing, ground-penetrating radar, and impact-echo, are crucial for identifying hidden damage such as corrosion, cracking, and delamination. Furthermore, material sampling and laboratory analysis provide a definitive assessment of the extent of chemical attack and its impact on the structural integrity. Ultimately, a comprehensive diagnostic program enables informed decisions regarding repair, rehabilitation, or even replacement of affected structures, ensuring the safety and operational continuity of the enterprise.

Keywords: building structures, technical condition, reinforcement.

*Corresponding author E-mail: avramenko.pntu@gmail.com

Introduction

Operation of building structures in an industrial environment, especially at construction industry enterprises, is often accompanied by the influence of aggressive technological fluids. These fluids, depending on their chemical composition, can initiate corrosion processes of metal elements, destruction of concrete, and other materials, which leads to a decrease in the load-bearing capacity and durability of structures. Therefore, timely and accurate diagnostics of the technical condition of load-bearing structures operating in such conditions is extremely important for ensuring safe and uninterrupted operation of enterprises.

Review of the research sources and publications

The results and methods of diagnostics of load-bearing building structures of construction industry enterprises operating under the influence of technological fluids are presented in the works of leading scientists [1-11].

Definition of unsolved aspects of the problem

The problem of diagnostics of load-bearing building structures operated in aggressive environments remains relevant and multifaceted, despite significant progress in this field. One of the key unresolved aspects is the insufficient accuracy and reliability of existing diagnostic methods, especially in the early stages of damage. Traditional methods, such as visual inspection or measurement of geometric parameters, are often unable to detect hidden defects or microcracks, which are precursors of more serious damage. In addition, the influence of combinations of various aggressive factors (chemicals, temperature fluctuations, humidity, biological corrosion) on the durability of structural materials has not been sufficiently studied. This makes it difficult to predict their residual strength and safety.

Another important aspect is the need to develop more effective and cost-effective methods for monitoring the condition of structures in real time. Existing methods are often labor-intensive, require specialized equipment and qualified personnel, which makes their application limited. Diagnostics of structures located in hard-to-reach places or those that are already in a state of emergency is also a significant challenge. For such cases, innovative approaches are needed, such as the use of unmanned aerial vehicles, remote sensing sensors and intelligent data analysis systems.

Finally, the lack of comprehensive models for predicting the durability of structures that would take into account the specifics of aggressive environments and the behavior of various materials is a significant problem. It is necessary to develop models that would be based on a deep understanding of the mechanisms of destruction and would take into account the uncertainty and variability of aggressive factors. Only by addressing these unresolved aspects will it be possible to ensure reliable and safe operation of building structures in difficult conditions.

Problem statement

The aim of the work is a comprehensive diagnostics of load-bearing building structures of construction industry enterprises operated under conditions of exposure to technological fluids. This involves the detection and assessment of defects, damage and changes in the physical and mechanical properties of materials caused by an aggressive environment. The results of the diagnostics will serve as the basis for the development of substantiated decisions on ensuring the reliability and durability of buildings and structures, as well as optimizing strategies for their repair and strengthening.

Basic material and results

To ensure reliable and safe operation of buildings and structures, especially those in contact with aggressive process fluids, it is critically important to have a high-quality diagnosis of the condition of their load-bearing structures. The impact of these fluids can cause corrosion, erosion, cracking and other types of damage, which over time weaken structures and can lead to emergency situations. Therefore, there are various diagnostic methods that allow you to identify potential problems at an early stage and take the necessary measures to prevent their development.

These diagnostic methods can be conditionally divided into several categories, depending on the principle of their action. The first includes visual methods, such as inspection of structures, measurement of cracks, fixation of deformations, which allows to detect obvious damage. This is followed by non-destructive inspection methods, which include ultrasonic inspection, radiography, acoustic emission and others, which allow to assess the internal structure of the material and detect hidden defects without damaging the structure. Finally, destructive methods, which include the selection of material samples for laboratory research (analysis of chemical composition, mechanical tests), allow to obtain detailed information about the properties of the material and the degree of its damage.

The combination of various diagnostic methods, depending on the specific conditions and types of structures, provides a comprehensive assessment of the condition of load-bearing elements. The choice of methods, their sequence and scope of research are determined individually, taking into account the type of technological fluid, structural materials, as well as the requirements of regulatory documents. Regular and comprehensive diagnostics is a necessary condition for maintaining the durability and safety of structures operated under the influence of technological fluids.

One of the types of construction industry enterprises operating under the influence of technological fluids is water treatment buildings in the water supply system.

If we consider the Poltava region, namely the Kremenchuk district, the source of the water supply system is the Kremenchuk reservoir on the Dnipro River. The Vlasivka water intake, which is located in the village of Vlasivka, takes in Dnipro water from the reservoir (Fig. 1), which then enters the microfiltration on drum microfilters. Water is taken from the reservoir by two siphon pipelines with a diameter of 1200 mm, which pass through the body of the earthen dam. The water intake head is placed in the reservoir at a distance of 320 m from the dam. The head is located at a depth of 14 m from the water surface.

After passing through the microfilters, the Dnieper water enters the 1st lifting pumping station, which supplies it through 3 parallel pipelines to the distribution chamber on the territory of the water treatment facilities (WTP). In the distribution chamber, water is divided into 2 directions. In the first direction, water is supplied to the water treatment facilities for the production of drinking water. Then, drinking water is supplied by the 2nd lifting pumping station to the water supply network of the city of Kremenchuk. In the second direction, the Dnieper water is supplied through separate water mains to the enterprises of the Northern Industrial Complex as technical water.

If we consider the general characteristics of the technological process of drinking water preparation, we can distinguish two technological lines:

The main stages of the first stage of wastewater treatment:

1. Mixing reagents with water:
- "Amopol" - ammonization;
- liquid chlorine - primary chlorination;
- coagulant - coagulation.
2. Clarification of water in horizontal clarifiers (HV).
3. Filtration of settled water on rapid filters (RF).
4. Secondary chlorination in the clean water tank (RCV) of the 1st stage.

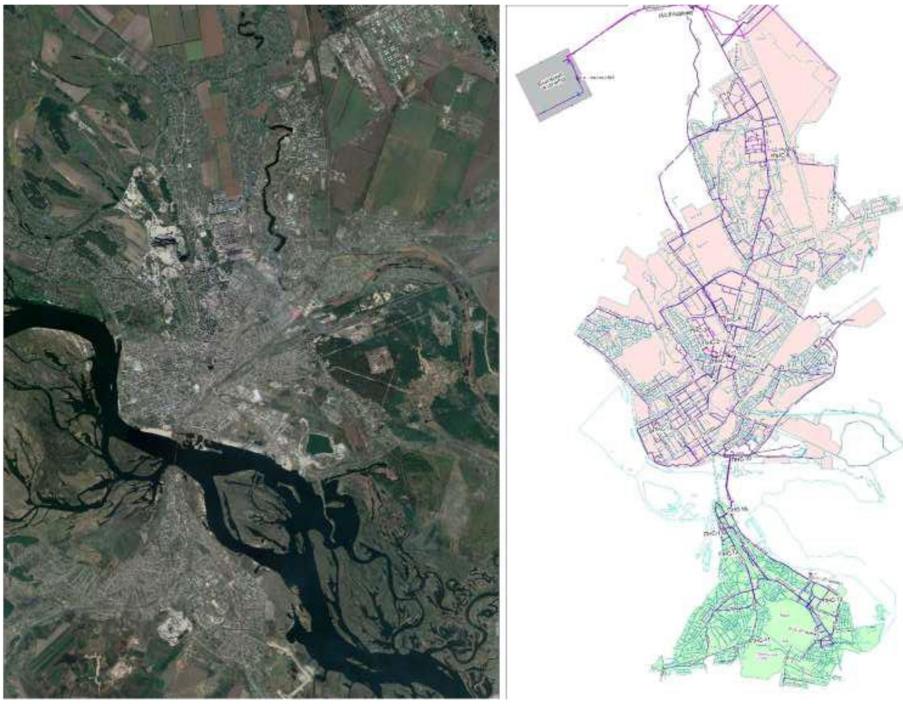

Figure 1 – Plan of water supply networks of buildings and structures of the city of Kremenchuk

The main stages of the second stage of wastewater treatment:

1. Feeding "Amopol" before microfilters.
2. Filtration through microfilters (MF).
3. Mixing reagents with water:
- liquid chlorine - primary chlorination;
- coagulant - coagulation.
4. Contact lighting.
5. Secondary chlorination in the clean water tank (PWT) of the second stage.

The water treated with reagents is supplied through a pipeline to the filtration hall of contact clarifiers (CL), where the water purification process by contact clarifier method takes place in the intergranular space of the filter material.

The regeneration of the filtering load is carried out in accordance with generally accepted requirements. The supply of washing drinking water is carried out through a drainage tubular system from bottom to top. The washing water is discharged into the industrial sewage system with subsequent discharge into the Sukhyi Kagamlyk River without preliminary treatment.

The CL filtrate enters the collecting collector, where a chlorine water solution is supplied (secondary chlorination), and then into clean water tanks, from where it is supplied to the city's water supply networks by pumps of the 2nd lifting pumping station (No. 6 on the plan).

The authors conducted a technical condition survey and developed recommendations for further reconstruction of the building structures of the block of contact illuminants of the water treatment plant section of the water supply system of the Kremenchukvodokanal enterprise of the Kremenchuk City Council of the Kremenchuk district of the Poltava region.

The load-bearing and enclosing structures of the building were subject to inspection.

The building of the contact lighting unit of the water treatment plant section is a frame structure with overall dimensions of 36×66.5 m, consisting of two longitudinal runs and a transverse run. The runs in the axes G-Zh (1-10) and Zh-K (1-10) are 18 m wide, the transverse run in the axes 11-13 (G-K) is 12 m wide.

The step of the extreme and middle columns is 6 m. The general view of the building is shown in Fig. 2.

In the spans in the axes G-Zh (1-10) and Zh-K (1-10), contact illuminators are located, in the axes E-Z, a technological platform was covered at the mark +3.900 for the hall of contact illuminators (Fig. 2), under which a pipeline gallery is located.

After a thorough analysis of defects and damage to building structures, the following categories were separated:

The first is load-bearing reinforced concrete structures.

The reinforced concrete columns of the middle and outer rows have longitudinal cracks in the protective concrete layer, local spalling of the protective concrete layer, significant areas of destruction of the protective concrete layer, and corrosion damage to the working longitudinal reinforcement (Figs. 3 -5), which requires reinforcement.

The general condition of the reinforced concrete columns is condition 3 - "unsuitable for normal operation." The second is metal elements and structures.

Metal half-timbered columns made of two channels No. 20 are significantly corroded, in the lower part of the column in the space between the channels, debris and remains of corroded metal have accumulated (Fig. 6), which requires reinforcement, cleaning from traces of corrosion, and restoration of the paint and varnish protective coating.

The general condition of the metal half-timbered columns is condition 3 - "unsuitable for normal operation."

Figure 2 – General view of the building

Figure 3 – Damage to reinforced concrete columns of the middle row

Figure 4 – Damage to reinforced concrete columns of the outer rows

Figure 5 – Damage to reinforced concrete columns of the outer rows

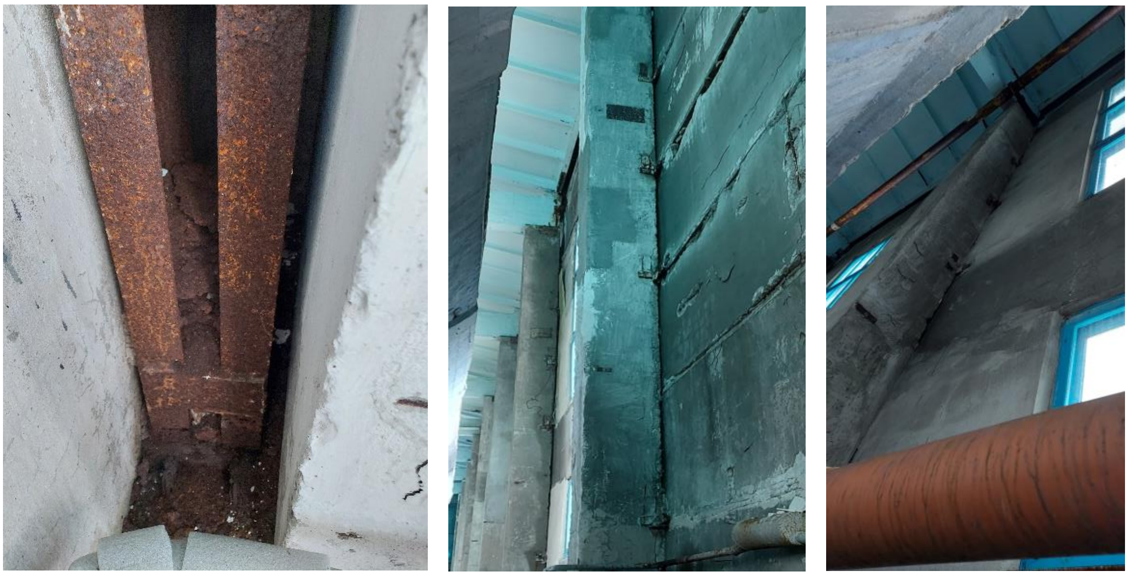

Figure 6 – Damage to half-timbered columns and metal embedded parts

The third is wall enclosing structures.

Wall enclosing structures – wall panels and window partitions made of aerated concrete masonry – were exposed to moisture both from the outside and from the inside of the building due to waterlogging from overflows through the parapet of precipitation due to freezing of pipes and drains of the drainage system and due to moisture condensation inside the room. The result is the destruction and delamination of the plaster layer on the masonry and on the panels, frost damage to the aerated concrete masonry, destruction of the protective layer of concrete on the panels with exposed reinforcement, corrosion of the reinforcement up to 2 mm, the formation of through holes in the panels, masonry and, especially, at their edges (Fig. 7). It is recommended to restore the protective plastering of the building's enclosing wall structures (internal and external), to restore the protective paint coating.

The general condition of the wall enclosing structures is condition 3 - "unsuitable for normal operation."

Conclusions

There are several effective methods for strengthening reinforced concrete columns, each with its own advantages and used depending on the specific situation. Among the most common are a metal angle and strip cage, increasing the cross-section with concrete with additional reinforcement, and the use of composite materials such as carbon fiber.

The choice of a specific strengthening method depends on many factors, including the degree of damage to the column, the amount of required increase in load-bearing capacity, space constraints, and economic feasibility.

Reinforcement of steel columns is an important process in ensuring the durability and reliability of building structures. Over time, steel columns can lose their load-bearing capacity due to corrosion, mechanical damage, or increased loads on the building. Reinforcement allows you to restore or even exceed the original characteristics of the column, extending its service life and preventing emergency situations.

There are several methods for strengthening steel columns, each of which is selected depending on the specific conditions and requirements of the project. The most common are the addition of steel overlays (plates or angles), the use of composite materials (for example, carbon fiber), and increasing the column cross-section by welding or bolting.

Figure 7 – Damage to wall panels

Effective reinforcement of wall structures not only ensures the safety and durability of the building, but can also significantly extend its service life, avoiding the costly dismantling and construction of new walls.

In general, the choice of the optimal method depends on the existing condition of both the structural elements and the building as a whole, the required degree of reinforcement, economic feasibility and impact on the functioning of the building during the work.

An important condition for successful reinforcement is a thorough diagnosis of the existing condition, identification of the causes of damage and correct calculation of the necessary reinforcement parameters.

Also, it is critical to adhere to the technology of work execution and use of quality materials to ensure the durability and reliability of the reinforced structure.

References

1. Galat, V., Slyusarenko, Y., Dombrovskyi, Y., Shuminskii, V., Mykolaiets, M., & Krylov, Y. (2022). Technical state assessment of overflow dam of the dniprovska hydroelectric power plant. Science and Construction, 31(1). https://doi.org/10.33644/2313-6679-16-2022-2

2. Gogol, M., Zygun, A., & Maksiuta, N. (2018). New Effective Combined Steel Structures. International Journal of Engineering & Technology, 7(3.2), 343. https://doi.org/10.14419/ijet.v7i3.2.14432

3. Products and systems for the protection and repair of concrete structures. Test methods. Corrosion protection test. (n.d.). https://doi.org/10.3403/30131378

4. Farenyuk, G., Vaynberg, O., & Shuminskyi, V. (2020). Reliability and safety of hydraulic structures of the Dnieper and Dniester cascades of HPP. Science and Construction, 25(3), 3-12. https://doi.org/10.33644/scienceandconstruction.v25i3.1

1. Galat, V., Slyusarenko, Y., Dombrovskyi, Y., Shuminskii, V., Mykolaiets, M., & Krylov, Y. (2022). Technical state assessment of overflow dam of the dniprovska hydroelectric power plant. Science and Construction, 31(1). https://doi.org/10.33644/2313-6679-16-2022-2

2. Gogol, M., Zygun, A., & Maksiuta, N. (2018). New Effective Combined Steel Structures. International Journal of Engineering & Technology, 7(3.2), 343. https://doi.org/10.14419/ijet.v7i3.2.14432

3. Products and systems for the protection and repair of concrete structures. Test methods. Corrosion protection test. (n.d.). https://doi.org/10.3403/30131378

4. Farenyuk, G., Vaynberg, O., & Shuminskyi, V. (2020). Reliability and safety of hydraulic structures of the Dnieper and Dniester cascades of HPP. Science and Construction, 25(3), 3-12. https://doi.org/10.33644/scienceandconstruction.v25i3.1

5. Eurocode 4. Design of composite steel and concrete structures. (n.d.). https://doi.org/10.3403/30459578

6. Галінська Т.А. Картавий Я. Оцінка технічного стану стальних двотаврових балок, переріз яких ушкоджений поверхневою корозією. Матеріали всеукраїнської Інтернет – конференції молодих учених і студентів «Проблеми сучасного будівництва» (21-22 листопада 2012 року). – Полтава: Полт НТУ, 2012. – С.139 – 142.

7. Amir Poursaee, 15 - Corrosion protection methods of steel in concrete, Editor(s): Amir Poursaee, In Woodhead Publishing Series in Civil and Structural Engineering, Corrosion of Steel in Concrete Structures (Second Edition), Woodhead Publishing, 2023, Pages 319-326, https://doi.org/10.1016/B978-0-12-821840-2.00014-6.

8. ASTM International. (2019). "Standard Guide for Evaluating Corrosion Effects on Load-Bearing Structures."

9. ISO 13823:2017. "General Principles on the Design of Structures for Durability."

10. Construction and Building Materials. (2020). "Influence of Technological Fluids on Concrete and Steel Structures."

11. International Conference on Structural Health Monitoring. (2022). "Advancements in Non-Destructive Testing for Industrial Structures."

5. Eurocode 4. Design of composite steel and concrete structures. (n.d.). https://doi.org/10.3403/30459578

6. Galinska T.A. Kartavy Ya. Assessment of the technical condition of steel I-beams, the cross-section of which is damaged by surface corrosion. Materials of the All-Ukrainian Internet - conference of young scientists and students "Problems of modern construction" (November 21-22, 2012). - Poltava: Polt NTU, 2012. - P.139 - 142.
7. Amir Poursaee, 15 - Corrosion protection methods of steel in concrete, Editor(s): Amir Poursaee, In Woodhead Publishing Series in Civil and Structural Engineering, Corrosion of Steel in Concrete Structures (Second Edition), Woodhead Publishing, 2023, Pages 319-326, https://doi.org/10.1016/B978-0-12-821840-2.00014-6.

8. ASTM International. (2019). "Standard Guide for Evaluating Corrosion Effects on Load-Bearing Structures."

9. ISO 13823:2017. "General Principles on the Design of Structures for Durability."

10. Construction and Building Materials. (2020). "Influence of Technological Fluids on Concrete and Steel Structures."

11. International Conference on Structural Health Monitoring. (2022). "Advancements in Non-Destructive Testing for Industrial Structures."

Олександр Семко
Національний університет «Полтавська політехніка імені Юрія Кондратюка»
https://orcid.org/0000-0002-2455-752X

Юрій Авраменко *
Національний університет «Полтавська політехніка імені Юрія Кондратюка»
https://orcid.org/0000-0003-2132-5755

Аліна Зигун
Національний університет «Полтавська політехніка імені Юрія Кондратюка»
https://orcid.org/0000-0002-1743-2294

Ігор Петрікей
Національний університет «Полтавська політехніка імені Юрія Кондратюка»
https://orcid.org/0009-0000-5686-3970

Артем Плешинець
Національний університет «Полтавська політехніка імені Юрія Кондратюка»
https://orcid.org/0009-0004-8352-9010

Діагностика несучих будівельних конструкцій підприємств будівельної індустрії, що працюють під впливом технологічних рідин

Діагностування несучих конструкцій на підприємствах будівельної галузі, які піддаються впливу технологічних рідин, представляє унікальний комплекс завдань. Ці рідини, від корозійних хімікатів до абразивних суспензій, можуть значно прискорити руйнування бетону, сталі та інших будівельних матеріалів. Ефективна діагностика вимагає багатостороннього підходу, який враховує конкретні рідини, їх концентрацію, температуру та тривалість впливу. Візуальні перевірки, доповнені такими методами неруйнівного контролю, як ультразвуковий контроль, георадар і ехо-сигнал, мають вирішальне значення для виявлення прихованих пошкоджень, таких як корозія, розтріскування та розшарування. Крім того, відбір проб матеріалу та лабораторний аналіз забезпечують остаточну оцінку ступеня хімічного впливу та його впливу на цілісність конструкції. Зрештою, комплексна програма діагностики дозволяє приймати обґрунтовані рішення щодо ремонту, відновлення або навіть заміни пошкоджених конструкцій, забезпечуючи безпеку та безперервність роботи підприємства.

Ключові слова: будівельні конструкції, технічний стан, підсилення.

* Адреса для листування E-mail: avramenko.pntu@gmail.com