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.2021.56.2514

UDC 658.382

Risk-oriented approach to identifying hazards in the construction industry of Ukraine

Zyma Oleksandr[1*], Pahomov Roman[2], Redkin Oleksandr[3]

[1] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0001-7484-7755
[2] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0001-9169-8296
[3] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0002-6449-050X
*Corresponding author E-mail: zymaae@gmail.com

An attempt to improve the analytical method for determining the criteria for the risk degree in the construction industry was presented in this paper. The risk management process as a set of actions that is part of the overall business management was analyzed. Features of systemic occupational safety risk management were identified. The stages of an occupational safety management system design based on hazard identification were presented. The main objectives of the risk-oriented approach to ensuring the systems' reliability based on the acceptable risk concept were formulated. A method for determining the criteria by which the risk degree of an accident or an injury is assessed, for the possibility of planning supervisory activities at the enterprise was proposed

Keywords: construction, injuries, risk degree, risk criteria, risk-oriented approach

Ризик-орієнтований підхід визначення небезпек у будівельній галузі України

Зима О.Є.[1]*, Пахомов Р.І.[2], Редкін О.В.[3]

[1] Національний університет «Полтавська політехніка імені Юрія Кондратюка»
[2] Національний університет «Полтавська політехніка імені Юрія Кондратюка»
[3] Національний університет «Полтавська політехніка імені Юрія Кондратюка»
*Адреса для листування E-mail: zymaae@gmail.com

У даній роботі наведена спроба удосконалення аналітичного методу визначення критеріїв ступеня ризику на об'єктах будівельної галузі. Проведено аналіз обставини та причини нещасних випадків на підприємствах будівельної галузі та виробництва будівельних матеріалів. Визначено параметри на яких повинна ґрунтуватися оцінка ризиків аварій, нещасних випадків і надзвичайних ситуацій на потенційно небезпечних об'єктів, а моделювання відповідних небезпечних подій та ситуацій, їх вплив на здоров'я населення. Проаналізовано процес управління ризиком, як комплекс дій, що є частиною загального управління бізнесом. Визначено особливості системного управління ризиками безпеки праці. Розроблено і наведено стадії проектування, впровадження контролю і корегування системи управління безпекою праці на основі ідентифікації небезпек, яка базується на ризик-орієнтованому підході і відповідає сучасним тенденціям і вимогам нормативної бази України. Сформульовано основні завдання ризик-орієнтованого підходу забезпечення надійності складних технічних систем для безпеки людей і довкілля, розглянуто методи оцінювання ступеня небезпеки промислових об'єктів та наукових засад концепції прийнятного ризику. Визначено оціночний показник, за яким вид економічної діяльності суб'єкта господарювання з питань безпеки праці відноситься до одного з трьох ступенів ризику (високий, середній, незначний), а також розглянуто питання встановлення прийнятного ризику на об'єктах будівельної галузі. Запропоновано методику визначення критеріїв на основі ризик-орієнтованої моделі, за якими оцінюється ступінь ризику виникнення аварії або нещасного випадку для можливості планування наглядової діяльності на промисловому підприємстві. На основі аналізу статистичних даних про травматизм на підприємствах будівельної галузі були визначені види економічної діяльності з високим ступенем ризику

Ключові слова: будівництво, травматизм, ступінь і критерії ризику, ризик-орієнтований підхід

Introduction

Analyzing the circumstances and causes of accidents at the construction site, it was found that the vast majority of them occur due to falls from a height during the construction of buildings with a monolithic-frame method. Mistakes of various kinds can cost lives, deteriorating health, and cause significant material loss. In practice, it is not possible to achieve absolute safety, there is always a certain excess risk.

Risk, according to the Law of Ukraine High-risk objects", is the probability degree of a certain negative event that may occur at a certain time under certain circumstances [1]. This is the possibility of any event that contributes to the emergence of negative results in human activities. In the life safety theory, the risk is understood as the negative action results of any factor or their complexity.

Risk is a term that has universal meaning, it refers to an action that can or should occur with uncertainty.

Risk is a chance at which something unforeseen and undesirable can happen. Risk is the probability of negative action in the area of human presence.

Risk is a quantitative characteristic of the impact of hazards created by human activities, i.e. the number of deaths, morbidity, disability caused by exposure to a particular hazard. Risk is directly related to the concept of damage, i.e. with the probability of death or damage to the object, the less studied the risks, the more damage. In this regard, there is a need for information accumulation and analysis on various adverse events in order to clarify the general trends and patterns of events manifestation.

Construction, in comparison with the coal, chemical, socio-cultural sphere and trade, transport, etc., belongs to one of those industries which are characterized by the probability of a significant number of risks. In addition, an important role is given to financial risks in the construction industry, which arises due to unpredictable changes in legislation or the economy, given the construction process investment and capital intensity duration. These risks may adversely affect the results.

The main measures to reduce construction risk levels include the development of plans. Such plans should include the following tasks: risk management and motivational regulation.

In the construction industry, the level of risk can increase from insignificant to unacceptable. Reducing the risk level depends on the personal qualities of the employee involved in the work process, as well as on measures to reduce it.

Determination of accident risk assessments should be based on the results of monitoring the technical condition of potentially dangerous objects, statistical data on accidents and emergencies of man-made nature, comprehensive monitoring of dangerous geological and hydrometeorological processes, the state of natural complexes, and modeling of relevant dangerous events and situations. their impact on public health.

The application of risk assessment methodology allows the development of mechanisms and strategies of various regulatory measures to improve the safety of industrial facilities; establish limits on the variability of risk values and uncertainties associated with limited initial data or unresolved scientific problems.

Review of the research sources and publications.

The essence of risk management and its place in the activities of enterprises are revealed in the works of N. Vnukova, M. Golovanenko, T. Golovach, L. Donets, O. Dubrova, I. Ivchenko, O. Kuzmin, V. Kravchenko, V. Lukyanova, E. Stanislavchyk, A. Starostina, D. Stefanych, and others.

The analysis of well-known publications [5…9] showed that although today there are some studies in the field of theory and practice of risk assessment, but there are still methodological implementing problems of risk-oriented approach to risk assessment.

Definition of unsolved aspects of the problem

The methodology of analysis and assessment of accident risk at industrial facilities has been actively developing, so the development of new and improvement of existing approaches, models, and methods of accident risk assessment and their computer implementation remain an urgent task for our country.

Problem statement

The main purpose of this article is to improve the analytical methods for determining the criteria for the risk degree in the construction industry.

Basic material and results

An effective risk management process cannot be a set of fragmented actions, as it must be formed into a set of actions that is part of the overall business management. Features of systemic occupational safety risk management are:

– a continuous process that covers the entire organization;

– carried out by employees of all levels of the organization;

– used during the strategy development and formation;

– is used by the whole organization, at each level, and by each unit and includes risk portfolio analysis at the organization level;

– aimed at identifying events that may affect the company and managing risks so that they do not exceed the risk appetite;

– provides management with reasonable guarantees of goals achievement.

In the absence or lack of statistical data on risks in the industrial enterprise, in particular, in the workplace, when solving the problem of occupational safety risk management, the risk manager should:

I. At the planning stage:

1. Identify hazards.
2. Identify possible danger and choose the damage rate.
3. Identify the possible consequences of the danger.
4. Determine the damage probability (frequency).
5. Quantitatively or qualitatively assess (calculate) the risk.

II. At the implementation stage:

1. Have the skills and abilities to meet the requirements of functional responsibilities and authorities, resources, and roles.

2. Conduct training, to determine competencies.

3. Inform about the order of communication, participation, and information.

4. Have the skills and abilities to manage documentation, operations, and determine compliance.

5. Develop the measures to prevent emergencies and respond to them in case of occurrence.

III. At the stage of verification:

1. The presence of internal audit.

2. Records management.

3. Determine the effectiveness.

4. Assess compliance with the law.

5. Investigate incidents, inconsistencies, corrective and preventive actions.

IV. At the stage of adjustment:

1. Analysis by management.

2. Sources of information for hazard identification are:

– normative-legal and technical acts, scientific-technical literature, local normative acts, etc.;

– results of state sanitary and epidemiological supervision;

– the results of production control over compliance with sanitary rules and the implementation of sanitary and anti-epidemic (preventive) measures;

– results of workplaces certification;

– results of sanitary-epidemiological assessment;

– the results of monitoring the technological process, production environment, workplace, the work of contractors, external factors (roads, catering, climatic conditions, etc.);

– results of analysis of questionnaires, forms, etc.;

– results of audit (survey) of colleagues and employees;

– practical experience.

September 15, 2015, a new version of the international standard ISO 14001:2015 "Environmental Management Systems" was officially released.

March 12, 2018, a new version of the international standard ISO 45001:2018 "Occupational Health and Safety Management Systems" was released. The transition period to the new versions is 36 months (3 years) [4, 5]. According to these normative documents, in the specified terms, at each enterprise, the labor safety management system on the basis of danger identification which is based on the risk-oriented approach should be created (corrected).

The risk-oriented approach (ROA) in the field of security is based on the position that any hazards (in the industrial sphere, in everyday life), despite their diversity, have the same nature of origin and the same logic of events. The ROA's main tasks are to create a scientific basis for ensuring the reliability of complex technical systems for human safety and the environment, to develop methods for assessing the danger degree of industrial facilities, and the scientific basis of the acceptable risk concept. Reducing the risk of danger requires certain costs and involves investing in natural, manmade, and social spheres. The dependence of the total (technical plus socio-economic) risk on the society's total costs for security is described by a curve that has a minimum in the case of achieving the optimal ratio between investments in the natural, technical and social spheres. The acceptable risk area is within the total risk minimum dependence of exposure to the society general costs aimed at security. Risk management is the search for a trade-off between the cost of reducing the likelihood of a dangerous event or loss from it and the benefits of using hazardous technologies, materials, products, and so on.

There are three risk determining methods:

– apriori – the use of which allows determining the numerical value of the risk in advance, regardless of experience, for example, in the case when a dangerous event did not occur;

– a posteriori – the use of which allows determining the numerical value of risk according to previous experience, for example, according to statistics;

– aesthetic – the use of which involves expert assessment of processes and phenomena by experts, as well as by conducting opinion polls of certain groups or the general population.

In the a priori risk definition, the dangerous event possibility is calculated as a classical interpretation of probability. The dangerous event probability is defined in this case as the ratio of the number of situations in which this event occurs to the total number of situations in which it can occur (provided that all situations are equally possible and incompatible). The use of the apriori calculation type is limited because situations that can be described mathematically with the necessary accuracy are rare in practice.

In a posteriori risk determination, the probability frequency concept is used. Due to this concept, it is used the real data on the dangerous event occurrence over a fairly long time period and under the same observation conditions. The probability calculation, in this case, is reduced to the relative frequency occurrence calculation of a dangerous random event in the aggregate of all possible random events. These calculations are based on the law of large numbers and, due to the availability and sufficient objectivity of statistical data, have wide practical application.

The application of the risk determination aesthetic method is mostly forced due to the lack of necessary mathematical and statistical information about the events, the probability of which must be assessed. However, it should be borne in mind that expert evaluation involves not only the use of objective materials but also based on the experts' understanding of the real situations patterns. Therefore, despite some limitations of the esthetic method's effective capabilities, it is widely used in practice.

The best results in predicting the risk magnitude give a comprehensive, simultaneous application of all three methods: apriori, a posteriori and aesthetic.

The theoretical and methodological basis of risk research is created by risk theory. Its development takes place in two main directions:

1) the practical application of a special part of applied mathematics - mathematics of stochastic processes;

2) the economy of probabilistic losses and identifying ways to reduce or prevent them.

Quantitative hazard analysis always begins with a preliminary study, the main purpose of which is to identify the hazard source. Danger sources identification, danger development research, and its analysis are obligatory components of a technique called preliminary analysis of dangers (PAD). PAD conducting in practical conditions is simplified and formalized through the use of pre-prepared questionnaires, special questionnaires, tables, pre-analysis matrices, etc.

In order to quantify the accidents probability using methods based on modeling random processes of accidents occurrence and development, and to assess the losses due to the implementation of adverse events often use deterministic methods. This comprehensive application of deterministic and probabilistic methods makes it possible to calculate the accidents risk at industrial facilities.

Among the most common quantitative methods in assessing the risk of software accidents are logical and probabilistic methods, including "event tree", "failure tree", "minimum paths" and "minimum intersections", as well as statistical methods of data processing on the failure of technological systems. Statistical methods are used with minimal assumptions, but require a large amount of statistical information.

The combination of available statistical information and additional information, including the knowledge and experience of experts, allows reducing the requirements for the required volume of statistical data. Thus, in the absence of statistics on accidents over a period of time, such expert methods as the Delphi method, the method of hierarchy analysis, morphological analysis, fuzzy logic methods, etc. are used to assess the negative event probability. In addition, the calculation of accident risk is also performed using the probabilistic method, which is used to estimate the frequency or probability of rare adverse events with severe consequences, statistics on which are virtually absent.

Acceptable risk is the estimated indicator by which the economic activity type of the business entity on occupational safety is one of the three risk levels (high, medium, insignificant) is [2].

Criteria for the risk degree, based on the risk concept, in our opinion, should be determined by assessing the risk degree from economic activity and the value of the maximum allowable level and depending on it to establish a gradation for high, medium, and low risks.

In the countries of Europe (Germany, France, Austria, Ukraine) to assess production use:

1. Injury frequency rate (k_{fr}) (quantitative indicator), ie the ratio of the accidents total number for the relevant period N_0 to the total number of employees p in this period, which is per 1000 employees:

$$K_{fr}=(N_0/p)\times 1000.$$

2. Integrated indicator of production occupational risk (I_{pr}). It is determined by the ratio of the costs for the relevant period for compensation to the persons injured at work ($\sum E_{cc}$) to the actual labor costs ($\sum E_{lc}$) for this period:

$$I_{pr}=\sum E_{cc}/(\sum E_{lc}\times 100)$$

3. Severity traumatism rate (k_t) (qualitative indicator), ie the ratio of the total number of disability days D to the number of accidents N_0:

$$K_t=D/N_0.$$

4. Disability rate (k_d) determines the number of lost working days per 1000 workers:

$$K_d=(D/p)\times 1000.$$

5. The risk of an accident (R) is defined as a quantitative measure of danger, which takes into account the probability of negative consequences (accidents) of economic activity and the possible amount of losses from them. The risk of danger realization is calculated within the probability frequency concept according to the formula of relative frequency occurrence of a dangerous accidental event in the aggregate of all possible accidental events:

$$R = n / N$$

where n is the number of events with undesirable consequences over a period of time; N is the maximum possible number of similar events for the same time interval.

But none of the above indicators take into account the permanent loss of ability to work and death and therefore can not fully characterize the level of injuries. This requires the use of at least one other indicator. This indicator is the ratio of death and injuries (k_{fi}):

$$k_{di} = \frac{N_{di}}{N_0}100\%,$$

where N_{di} – the number of accidents that resulted in death and injury.

It is proposed to calculate the risk assessment in the construction industry for harm to the health of workers during economic activity by multiplying the one accident probability during the year by the probability of losing one worker during the year the corresponding number of working days due to the accident. To do this, use the following indicators:

– the average annual number of accidents (accidents with temporary disability and fatal accidents) for the last three years;

– the average number of employees in the construction and construction materials industry for the last three years;

– the average annual number of lost working days due to disability for work due to accidents at work for the last three years.

This study proposes the following procedure for assessing the level of safety in the construction industry and the building materials industry:

– the frequency of accidents in the relevant case of economic activity is calculated by the formula:

$$L_A = N_{av}/(E_{av}\times 240),$$

where L_A – frequency of accidents per year; N_{av} – the average annual number of accidents in the last three years; E_{av} – the average number of employees for the last three years; 240 – the average number of working days per year, including vacation.

$$N_{av} = (N_{av1}+N_{av2})\times 1000,$$

where N_{av1} – the average annual number of accidents in the last three years, excluding fatal accidents; N_{av2} – the average annual number of fatal accidents in the last three years; 1000 – the coefficient that transforms the number of fatal accidents into the number of accidents with temporary disability. According to the International Labor Organization (ILO), the average ratio of fatal and total accidents at work in Western Europe is 1:1000.

The probability that an accident may occur during a year is calculated by the formula:

$$P_A = 1 - e^{-LAt}$$

where P_A – the probability of an accident during a year; t – interval equal to one year.

The disability rate in the relevant type of economic activity is calculated by the formula:

$$L_D = D_{av}/(E_{av}\times 240),$$

where L_D – disability rate; D_{av} – the average number of working days lost due to accidents at work.

The loss probability by one employee during the year of the working days' corresponding number due to an accident (R_D) is calculated by the following dependence

$$P_S = 1-e^{-LDt}$$

Thus, the occurrence of an accident during the year can be calculated by the formula:

$$R = P_A \times P_D.$$

Acceptable risk, in relation to which the degree of risk will be divided into three indicators – high, medium, insignificant – can be considered the risk of an accident in Ukraine, calculated on the arithmetic mean, taken over the past three years (R_{av}).

According to the International Regulated Scale of Mortality Risks, several benchmarks are distinguished according to the degree of acceptability: the risk is neglected, the risk is acceptable, the risk is extremely acceptable, the risk is excessive.

With neglected risk, the probability of a dangerous event is so small that it does not exceed the natural (background) level.

With an acceptable risk, the probability of a dangerous event is considered acceptable by society (acceptable), based on the achieved levels of life, economic and socio-political development, as well as the state of science and technology.

The numerical value of the minimum risk of fatal hazards corresponds to the average risk on the International orderly scale of mortal hazards ($R_I = a\times 10^{-6}$).

Thus, the following criteria can be used to assess the risk: high risk is a risk that exceeds R_{av}, the medium risk is equal to or less than R_{av}, but more than R_I, insignificant is equal to or less than R_I.

The application of these indicators will make it possible to determine the criteria by which the risk degree of an accident is assessed for the possibility of planning supervisory activities.

If the conditionally acceptable risk is 2×10^{-5}, then the assessment of the risk degree is carried out on the basis of the data shown in table 1.

Table 1 - Risk assessment criteria

Risk level	Risk degree
$>2\times 10^{-5}$	High
$2\times 10^{-5} – 1{,}01\times 10^{-6}$	Average
$\leq 10^{-6}$	Insignificant

Based on the analysis of statistical data on injuries at industrial enterprises, high-risk economic activities were identified. For enterprises in the construction industry, the data are shown in table 2.

Table 2 - Types of economic activity in Ukraine with a high-risk degree (construction industry)

№	Types of economic activity	P_A	P_D	$R\times 10^{-3}$	Risk degree
1.	Erection of metal structures	0,223	0,000934	21	
2.	Other special construction works	0,205	0,00097	19,9	
3.	Construction of main pipelines, communication lines, and power supply	0,251	0,000537	13,5	
4.	Production of precast concrete and reinforced concrete products	0,178	0,000722	12,8	Високий
5.	General construction	0,181	0,000424	7,68	
6.	Installation of heating, ventilation, and air conditioning systems	0,1508	0,00033	4,98	

Conclusions

The authors of the article are convinced that the introduction of an international system of occupational safety risk-oriented management in industrial enterprise activities allows to identify hazards and assess occupational risks. The proposed method of preventing hazards or dangerous situations allows to ensure the stability of development, increase the level of security, through the implementation of all activities in controlled conditions.

The considered indicators provide an opportunity to determine the criteria by which the risk degree of an is assessed in order to be able to plan measures to improve working conditions.

References

1. *Закон України «Про об'єкти підвищеної небезпеки»* [Електронний ресурс]. – Режим доступу: http://zakon3.rada.gov.ua

2. *Закон України «Про основні засади державного нагляду (контролю) у сфері господарської діяльності»* [Електронний ресурс]. – Режим доступу: https://zakon.rada.gov.ua/laws/show/877-16#Text

3. ISO 45001:2018 *«Системи менеджмента охорони здоров'я і безпеки праці – Вимоги і рекомендації до виконання»* [Електронний ресурс]. – Режим доступу: https://pqm-online.com

4. ISO 14001:2015 *«Системи екологічного менеджмента – Вимоги і настанови до виконання»* [Електронний ресурс]. – Режим доступу: https://www.certification.ua

5. Богданова О.В. (2016). Комбінований метод оцінки ризику травматизму для промислового підприємства. *Проблеми охорони праці в Україні*, 31, 52-63

6. Борис О.П. (2018). Ризик-орієнтований підхід у системі орцінювання пожежної безпеки. *Інвестиції: практика та досвід*, 22, 137-140 https://doi:10.32702/2306-6814.2018.22.137

7. Герасименко О.М. (2019). *Ризик-орієнтований підхід до забезпечення економічної безпеки підприємства: концептуальні засади*. Черкаси: Видав. О. Третяков

8. Schwab K. (2016). The Fourth Industrial Revolution: what it means, how to respond. [Electronic resource]. - Access mode: https://www.weforum.org

9. Марущак С.М. (2008). Комплексна оцінка ризику в процесі забезпечення економічної безпеки підприємства. *Науково-методичний журнал Чорноморського нац. університету ім. Петра Могили*, 86(99), 108-114

10. Zhdakaeva M. V. (2021). *Analysis of risk assessment models used to implement the labor safety management system algorithm* https://doi:10.1007/978-3-030-69421-0_108

11. Baiburin D. A. (2018). Evaluation of building collapse risk with damage localization. *IOP Conference Series: Materials Science and Engineering,* 451(1) https://doi:10.1088/1757-899X/451/1/012066

12. Bamforth P. (2003)/ Probabilistic approach for predicting life cycle costs and performance of buildings and civil infrastructure. *Proc. 2nd Int. Symposium on Integrated Lifetime Engineering of Buildings and Infrastructures*, 553-558

13. Raizer V.D. (2010). *Theory Reliability of Structures.* Mjscow: Publishing house ASV

14. Bobryashov V.M., Bushuev N. (2020). On the features of production, design and reliability assessment of enclosing composite structures with effective thermal insulation. *IOP Conference Series: Materials Science and Engineering*, 919(2) https://doi:10.1088/1757-899X/919/2/022007

15. Pshenichkina V.A., Babalich V.S., Sukhina K.N., Dubovsky M.E. (2020). Reliability assessment of reinforced concrete structures during commissioning. *IOP Conference Series: Materials Science and Engineering*, 913(2) https://doi:10.1088/1757-899X/913/2/022013

16. Bobryashov V.M., Bushuev N. (2020). On the features of production, design and reliability assessment of enclosing composite structures with effective thermal insulation. *IOP Conference Series: Materials Science and Engineering*, 919(2) https://doi:10.1088/1757-899X/919/2/022007

1. *Law of Ukraine "On high-risk facilities"* [Electronic resource]. - Access mode: http://zakon3.rada.gov.ua

2. *Law of Ukraine "On the basic principles of state supervision (control) in the sphere of economic activity"* [Electronic resource]. - Access mode: https://zakon.rada.gov.ua/laws/show/877-16#Text

3. ISO 45001: 2018 *"Occupational Health and Safety Management Systems - Requirements and Recommendations for Implementation"* [Electronic resource]. - Access mode: https://pqm-online.com

4. ISO 14001: 2015 *"Environmental management systems - Requirements and guidelines for implementation"* [Electronic resource]. - Access mode:https://www.certification.ua

5. Bogdanova O.V. (2016). Combined method of risk assessment of injuries for industrial enterprises. *Problems of labor protection in Ukraine*, 31, 52-63

6. Boris O.P. (2018). Risk-oriented approach in the system of fire safety assessment. *Investments: practice and experience*, 22, 137-140 https://doi:10.32702/2306-6814.2018.22.137

7. Gerasimenko O.M. (2019). *Risk-oriented approach to ensuring the economic security of the enterprise: conceptual principles*. Cherkasy: Published O. Tretyakov

8. Schwab K. (2016). The Fourth Industrial Revolution: what it means, how to respond. [Electronic resource]. - Access mode: https://www.weforum.org

9. Marushchak S.M. Complex risk assessment in the process of ensuring the economic security of the enterprise. *Scientific method magazine Petro Mohyla Black Sea National University*, 86(99), 108-114

10. Zhdakaeva M. V. (2021). *Analysis of risk assessment models used to implement the labor safety management system algorithm* https://doi:10.1007/978-3-030-69421-0_108

11. Baiburin D. A. (2018). Evaluation of building collapse risk with damage localization. *IOP Conference Series: Materials Science and Engineering,* 451(1) https://doi:10.1088/1757-899X/451/1/012066

12. Bamforth P. (2003)/ Probabilistic approach for predicting life cycle costs and performance of buildings and civil infrastructure. *Proc. 2nd Int. Symposium on Integrated Lifetime Engineering of Buildings and Infrastructures*, 553-558

13. Raizer V.D. (2010). *Theory Reliability of Structures.* Mjscow: Publishing house ASV

14. Bobryashov V.M., Bushuev N. (2020). On the features of production, design and reliability assessment of enclosing composite structures with effective thermal insulation. *IOP Conference Series: Materials Science and Engineering*, 919(2) https://doi:10.1088/1757-899X/919/2/022007

15. Pshenichkina V.A., Babalich V.S., Sukhina K.N., Dubovsky M.E. (2020). Reliability assessment of reinforced concrete structures during commissioning. *IOP Conference Series: Materials Science and Engineering*, 913(2) https://doi:10.1088/1757-899X/913/2/022013

16. Bobryashov V.M., Bushuev N. (2020). On the features of production, design and reliability assessment of enclosing composite structures with effective thermal insulation. *IOP Conference Series: Materials Science and Engineering*, 919(2) https://doi:10.1088/1757-899X/919/2/022007