Vol. 12, 2023, 217-227

DOI: 10.17512/bozpe.2023.12.24

Construction of optimized energy potential

Budownictwo o zoptymalizowanym potencjale energetycznym

ISSN 2299-8535 e-ISSN 2544-963X

Analysis of the causes of construction accidents as a component of building safety management

Agnieszka Czajkowska[1*] (*orcid id: 0000-0002-7430-4758*)
Manuela Ingaldi[2] (*orcid id: 0000-0002-9793-6299*)
[1] Kielce University of Technology, Poland
[2] Czestochowa University of Technology, Poland

Abstract: Managing safety in construction aims to ensure that buildings are safe for occupants and meet applicable safety standards. These actions help to mitigate potential hazards and provide protection for the lives and well-being of people within the building. This article analyzes the causes of construction disasters in Poland during the years 2020-2021, comparing them with data from 2015-2019. The disasters are categorized into two groups based on their causes: those triggered by random factors and those resulting from human error. Catastrophes arising from random factors account for 70 to 83% of all construction disasters.

Keywords: safety management, structural failures, building industry

Access to the content of the article only on the bases of the Creative Commons licence CC BY-NC-ND 4.0

Please, quote this article as follows:

Czajkowska A., Ingaldi M., Analysis of the causes of construction accidents as a component of building safety management, Construction of Optimized Energy Potential (CoOEP), Vol. 12, 2023, 217-227, DOI: 10.17512/bozpe.2023.12.24

Introduction

The development of the construction industry, driven by the increasing demands of society and the economy, presents a challenge for scientists to improve the quality of materials used in construction. As the demand for modern and durable structures continues to rise, there is a need for ongoing research and enhancement of materials used in this sector (Boadu et al., 2020). In light of the above, scientists are conducting intensive research to identify new opportunities for improving the quality of construction materials (Michałowska-Maziejuk et al., 2023). They are striving to develop innovative solutions (Kumor-Sulerz et al., 2022) that will enable

* Corresponding author: a_czajkowska@o2.pl

the construction of more efficient and durable structures. Through the continuous improvement of construction materials, we can create buildings that are not only more effective but also environmentally friendly and, most importantly, safe for occupancy.

Considerations of safety and durability are crucial for every construction project and building structure, as they are subject to various influences throughout their operational lifecycle. It is important to recognize that these influences can lead to the emergence of defects and damages, which, in turn, affect the safe functioning of these elements (Czajkowska & Ingaldi, 2021; Kopiika et al., 2021). Hence, the quality of materials used in construction is of paramount importance. Many experts emphasize that the quality of materials employed in the construction process can have the most significant impact on the final outcome and the durability of the structures (Bacharz et al., 2022; Kraus et al., 2018; Krynke et al., 2022; Kucharikova et al., 2019).

The advancement of technology, including in the construction sector, leads to a constant search for new solutions and the improvement of existing ones. Modern civil engineering is evolving rapidly, resulting in the creation of advanced materials capable of performing multiple functions simultaneously. Consequently, it is essential to emphasize the need for a continuous pursuit of innovation and the improvement of currently utilized materials (Fidlerova et al., 2022; Pachura, 2012; Szajnar et al., 2013).

Every day, businesses face various risks that have the potential to impact the smooth operation of their activities. This is why risk management represents an effective approach that can mitigate or limit the adverse effects of these risks (Ennouri, 2015). An essential aspect of effective risk management is its integration with the overall management systems within the company. Such integration fosters efficient collaboration among different areas of the business and creates a cohesive approach throughout the organization. Risk management not only aids in risk identification and assessment but also assists in developing action plans to address and mitigate these risks. As a result, risk management adds value to companies by enhancing operational efficiency and effectiveness (Kovácsné Mozsár & Michelberger, 2018).

The advancement of construction methods and principles is inherently linked to the conduct of experimental research. In the current stage of scientific and technological development, modern materials find widespread application in the design and reinforcement of structures (Blikharskyy et al., 2017; Khmil et al., 2023).

The design and implementation of various construction projects are associated with diverse unwanted situations, which may stem from natural phenomena, socio-political factors, technical issues, and errors made by inexperienced workers (Anthopoulos et al., 2013). Such situations can also arise during the use of a building. Each of these circumstances carries the potential for significant damage, leading to construction delays, cost overruns, and potentially having adverse impacts on the environment and the health of individuals, including construction workers and building users.

Phenomena of this nature, commonly referred to as disasters, crises, or failures, require comprehensive analysis using various available techniques. There is a need to promote actions aimed at controlling uncertainty and minimizing the risk of a construction disaster that could pose a threat to a particular building structure.

As our knowledge and ability to predict and manage risks continue to grow, there are better chances of minimizing potential adverse consequences arising from unwanted situations in construction. Simultaneously, the development and implementation of modern materials and technologies are a key factor in preventing and managing such situations.

Every building structure is exposed to various factors, such as weather conditions, mechanical loads, material degradation, or aging processes. These factors can lead to damage, corrosion, cracking, or other defects that have the potential to jeopardize both the safety of users and the durability of the structure itself. Therefore, it is essential to systematically monitor the technical condition of buildings and infrastructure and take preventive actions to avert potential damages. This includes regular technical inspections, maintenance, as well as necessary repairs or upgrades to ensure that building structures remain safe and functional throughout their operational lifespan. It is worth emphasizing that the care for the safety and durability of construction projects is of paramount importance to maintain the integrity of infrastructure and ensure the protection of users and the environment. Above all, it plays a critical role in preventing construction disasters.

The analysis of the causes of construction accidents plays a pivotal role in the overall framework of building safety management. Understanding the factors that contribute to construction disasters is essential for implementing effective safety measures and preventing potential disasters.

Effective safety management in construction is paramount due to its critical role in safeguarding human lives, preserving property, and ensuring the successful completion of projects. The construction industry inherently involves complex and hazardous activities, making the proactive identification and mitigation of risks essential. Safety management not only prevents accidents and injuries but also contributes to increased productivity, reduced project delays, and improved overall project quality. Furthermore, a robust safety management system fosters a positive work culture, enhancing employee morale and satisfaction. The commitment to safety not only aligns with legal and regulatory requirements but also reflects an organization's dedication to its workforce and the communities it serves. In essence, prioritizing safety management is an integral aspect of responsible and sustainable construction practices.

By definition, a construction disaster is characterized as an unintentional, sudden destruction of a building or its components, as well as structural elements of scaffolding, formwork elements, retaining walls, and excavation enclosures (Act of 7 July 1994 – Construction Act).

A construction disaster results in material costs and significantly larger intangible costs, including threats to life and health. Unfortunately, in most cases, human influence on construction disasters is limited, as they often arise from natural phenomena. However, this doesn't mean that we are entirely powerless. By understanding the sources of construction disasters, people can take preventive measures. Knowing the vulnerabilities of a structure allows for the identification of materials, methods, and solutions to mitigate construction disasters.

The analysis of the causes of construction disasters aims to limit their occurrence. The goal of this analysis is to understand the primary causes of construction disasters and their locations.

Construction disasters have been categorized into two groups:

a) Category I – disasters not resulting from random events,
b) Category II – disasters resulting from random causes.

The causes of non-random construction disasters resulting from human errors have been analyzed in (Czajkowska & Ingaldi, 2017). Much information is provided by the causes attributable to human fault, as they shed light on mistakes made by participants in the construction process. Managing safety during construction and operation helps mitigate construction disasters.

However, the analysis of causes resulting from random events is also of great importance. It serves as a source of knowledge about regions where construction disasters most frequently occur and the types of events that trigger them. Based on these analyses, the following determinations are made (Szymczak-Graczyk, 2011):

– division of Poland into wind load zones,
– new characteristic values of wind velocity and pressure,
– corrections to the exposure coefficient and an increase in the load coefficient values.

Building roofs, in addition to supporting their own weight, must withstand snow loads, wind forces, and technological loads. The roof structure and its covering must be designed to meet the first limit state – load-bearing capacity and serviceability.

The aim of the conducted research was to analyze the causes of construction disasters with a view to their elimination or reduction and to enhance the safety of using building structures in the future. The article examined construction disasters that occurred in Poland in the years 2020-2021, and two main groups were identified:

– causes resulting from random events,
– causes induced by human error at various stages of the construction process and during operation.

The data from the analysis will enable the proposal of actions aimed at reducing the occurrence of construction disasters in the future.

1. Materials and methods

The source of data for the analysis were reports from the General Office of Building Control (GUNB).

Construction disasters were analyzed in terms of:
- their locations on the map of Poland,
- the pattern of occurrences over the years 2015-2021,
- the type of building structure that suffered disaster.

The analysis revealed that construction disasters in 2020 (Fig. 1) occurred in all voivodeships. The highest number of disasters were recorded in the following voivodeships: Masovian – 72 (26%), Opole – 30 (11%), Greater Poland – 27 (10%), Lublin – 26 (9.5%). The fewest disasters occurred in the following voivodeships: Podkarpackie and Warmian-Masurian – 1 each (0.4%), Pomeranian – 2 (0.7%), Podlaskie – 3 (1.1%).

Construction disasters in 2021 occurred in all voivodeships. The highest number of disasters were recorded in the following voivodeships: Łódź – 175 (37%), Lublin – 75 (16%), Masovian – 37 (8%), Greater Poland – 31 (7%). The fewest disasters occurred in the following voivodeships: Pomeranian, Warmian-Masurian, and West Pomeranian – 3 each (0.6%), Lubuskie – 4 (0.8%), Podkarpackie – 8 (1.7%).

By understanding the causes of construction disasters in different voivodeships, it is possible to update the map of Poland's wind load zones, new characteristic wind speed and pressure values, exposure coefficient corrections, and an increase in the load factor values. From the data analysis in Figure 1, it is evident that the most construction disasters occurred in the voivodeships of Greater Poland, Masovian, Lublin, and Łódź. Conversely, the fewest disasters occurred in Podkarpackie and Lubuskie in both of the studied periods.

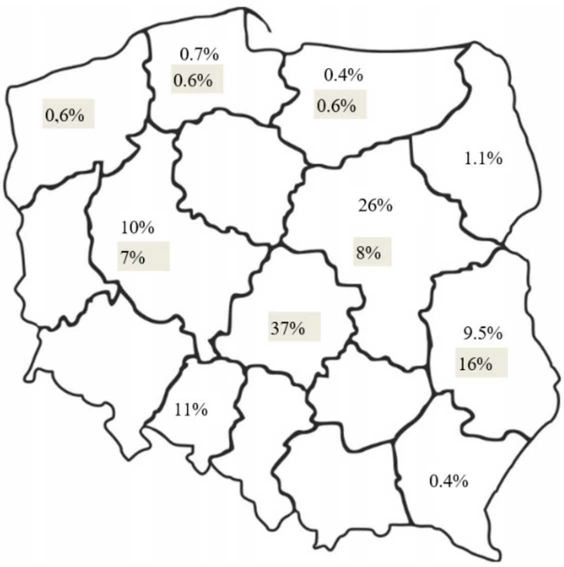

Fig. 1. Percentage distribution of construction disasters by voivodeships in 2020 and 2021 (2021 is highlighted in gray) (*own elaboration based on General Office of Building Control (GUNB), https://www.gunb.gov.pl*)

2. Results and discussion

The most common causes of construction disasters are random factors, errors during the maintenance of a building, and mistakes during the construction of a new facility or the execution of other construction work within an existing structure (Fig. 2). These results are based on data concerning construction disasters in Poland from the years 2020 to 2021.

The analysis indicates that in 2021, there were more construction disasters in each of the analyzed areas compared to 2020. There were 143 more random events in 2021 than in 2020. Throughout the analyzed years, disasters caused by random events accounted for 70 to 83% of all incidents (Czajkowska & Ingaldi, 2021).

In Figure 3, the percentage breakdown of construction disasters by the type of building for two research periods, 2020 and 2021, is presented. The analysis reveals that residential buildings are most frequently affected by construction disasters (42.6% in 2021 and 41.9% in 2020), as well as farm or livestock buildings (44.1% in 2020 and 40.9% in 2021).

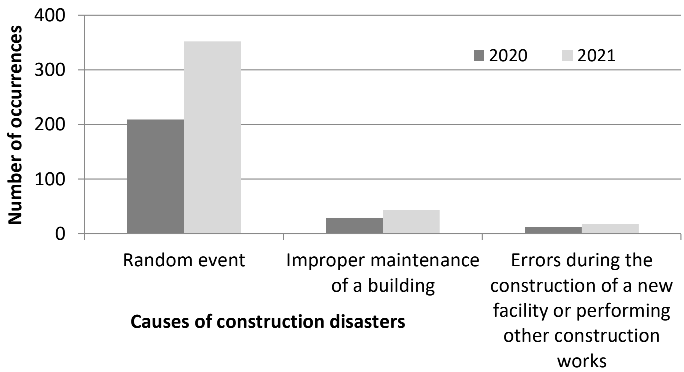

Fig. 2. Causes of construction disasters in 2020 and 2021 (*own elaboration based on General Office of Building Control (GUNB), https://www.gunb.gov.pl*)

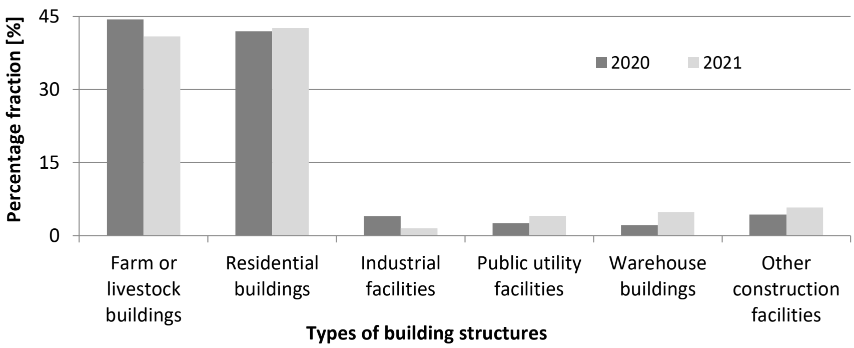

Fig. 3. The type of buildings affected by a construction disaster (*own elaboration based on General Office of Building Control (GUNB), https://www.gunb.gov.pl*)

In 209 cases, a sequence of random events was identified as the primary cause of the construction disaster. Often, the disaster's cause consisted of multiple events, such as strong gusty winds occurring simultaneously with heavy precipitation or storms, or explosions along with fires. The causes of random disasters are presented in Figure 4. However, most commonly, strong winds and fires are the primary random causes.

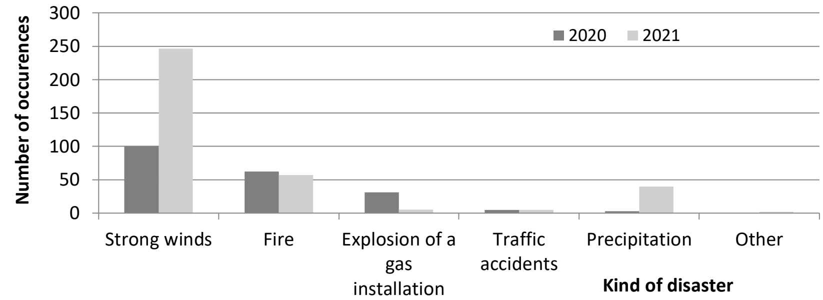

Fig. 4. Causes of construction disasters in 2020 and 2021 (*own elaboration based on General Office of Building Control (GUNB), https://www.gunb.gov.pl*)

According to GUNB data, the elements of a building affected by disasters (average based on data from 2015-2021) are as follows:
– roof structure: 84%
– other building elements: 31.2%
– floor structure: 33.2%
– vertical structural elements: 92%

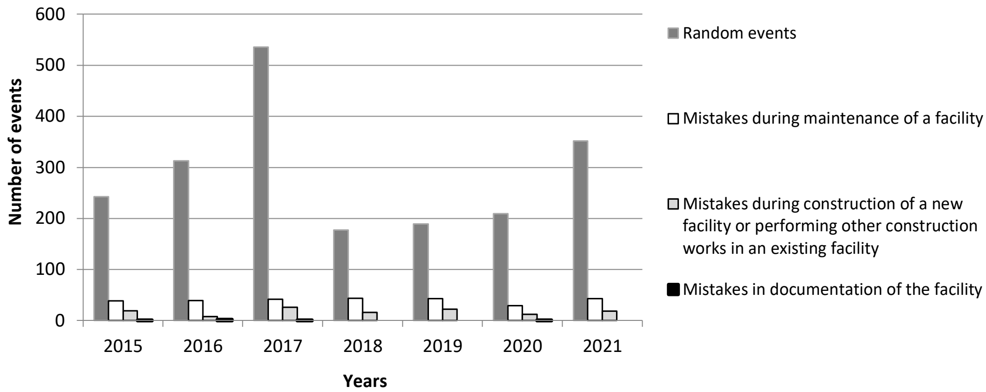

Fig. 5. Structure of the causes of construction disasters in the years 2015-2021 (*own elaboration based on General Office of Building Control (GUNB), https://www.gunb.gov.pl*)

The results were based on data regarding construction disasters in Poland from 2020 to 2021, but they were also compared with an analysis for the years 2015-2019 (Fig. 5), where the causes of construction disasters resulting from human errors were analyzed in detail (Czajkowska & Ingaldi, 2021). From the analysis in the figure, it can be observed that, similar to the years 2015-2019, the second most frequent cause of construction disasters is errors during the maintenance of a building. Furthermore, the analysis indicates that there are greater fluctuations in the number of disasters caused by random factors than those resulting from human error.

It is important to monitor the number and causes of construction disasters because both the regions exposed to disasters caused by random factors and the structural elements of buildings change. The analysis of the causes of disasters is the starting point for taking actions to reduce the number of disasters in the future, thereby improving user safety. Presenting the structure of causes over several years, analyzing the causes resulting from human error and random factors, and identifying the most vulnerable regions is information that can serve as a starting point for further research by the authors and for actions to be taken by the relevant authorities.

Table 1. Proposals for preventive actions for both groups of causes of construction disasters (*own elaboration*)

Recommendations for both groups of causes	
Category I – disasters not resulting from random events	**Category II – disasters resulting from random causes**
– Careful planning and design. – Risk assessments during construction and operation of construction objects. – Legal regulations preventing unprofessional actions by all participants in the investment process. – Inspections during the construction of a new building. – Increased on-site control by construction supervisory authorities. – Update of Building Law regulations. – Inspections during the construction phase. – Conducting inspections and adhering to inspection schedules at every stage of the building's use. – Regular technical condition inspections and maintenance. – Clearly defined regulations regarding periodic inspections. – Sanctions for failing to conduct technical condition inspections and maintenance. – Regulations specifying the minimum parameters that materials must meet.	– Enforcing the recommendations of Regulation (EU) 305/2011 by the European Parliament. – Regulations specifying the minimum parameters that materials must meet. – Updating the map dividing Poland into zones in accordance with standard PN-77/B-02011. – Careful choice of locations for new buildings and infrastructur – An analysis of natural hazards specific to the region.

However, after analysis, the authors decided to initially indicate preventive measures in this area. These recommendations were based on:

– the European standard PN-EN 1991-1-4:2008 and changes introduced to the PN-77/B-02011/Az1:2009 standard, which tightened requirements for the design of buildings subjected to wind loads,

– changes to the PN-77/B-02011 standard (Az1 amendment), involving the introduction of a new map dividing Poland into wind load zones, new characteristic wind speed values, and pressure values for this speed, exposure factor corrections, and an increase in the load factor values,
– European Parliament Regulation 305/2011.

Proposed actions for both groups of causes are presented in Table 1.

Proposals for preventive actions targeting both groups of causes of construction disasters are instrumental in establishing a proactive safety culture within the construction industry. The synergy of these preventive actions not only addresses specific causes but also creates a comprehensive safety net, mitigating the overall risk of construction disasters. Emphasizing a preventive approach underscores the industry's commitment to continuous improvement, fostering a safer working environment for all stakeholders involved in construction projects.

Conclusions

Construction disasters caused by external factors, such as random events and extreme weather conditions, pose significant challenges in the field of construction. These inevitable forces of nature, including earthquakes, hurricanes, floods, or avalanches, can have catastrophic effects on buildings and infrastructure.

In the face of such events, engineers and risk management specialists must focus on creating more resilient and resistant structures to withstand these phenomena. Additionally, proper emergency plans and recovery procedures become crucial to minimize losses and ensure a swift return to normal functioning after such disasters occur. Despite the lack of control over these natural forces, investments in research, the development of new technologies, and preventive actions are essential to mitigate the impact of these disasters on construction and society.

The analysis of the conducted research, the results of which are presented in the article, has allowed us to demonstrate that:

– The most threatened regions, both in terms of random and human-dependent causes, are the Łódź and Masovian voivodeships.
– The most frequent causes of disasters categorized as Class II in Poland are strong winds and fires. Due to the significant number of disasters caused by strong winds in recent years, the Chief Inspector of Construction Supervision deemed it expedient to accelerate the adoption of the Eurocode 1 package into the regulations in force in Poland.
– In 2021, there were more construction disasters in each of the analyzed areas than in 2020.
– From the conducted analysis, it is evident that the majority of construction disasters pertain to residential buildings (41.9 and 42.6%) and farm or livestock buildings (44.4 and 40.9%). In 2020, in comparison to 2021, there was a higher proportion of disasters in economic and agricultural buildings and industrial buildings, while the share in public utility buildings, warehouse buildings, and other structures decreased.

The causes of construction disasters presented in the article, taking into account their frequency over several years, their spatial distribution, and the identification of the least resilient elements, serve as a valuable source of knowledge and guidance for securing buildings against their destruction, whether due to human errors or random factors.

The results presented in the article are part of a broader study on building disasters, which was conducted for the purpose of analyzing the risk of their occurrence. The article focuses on the first two stages of this analysis, namely risk identification in the form of individual causes of building disasters and risk classification in the form of numerical risk assessment, both of which were carried out using GUNB materials. The authors have completed the third stage, namely risk assessment and measurement, but the study is not yet complete. Therefore, they have decided not to incorporate the results of this stage in the development. The fourth stage, which is risk monitoring and response method, is planned for the near future.

In conclusion, the analysis of the causes of construction disasters serves as a crucial foundation for the overarching goal of effective safety management in the construction industry. Understanding the intricate interplay of human factors, structural vulnerabilities, and technical elements provides valuable insights for formulating targeted preventive measures. By implementing these measures, ranging from enhanced training programs to rigorous quality control, the industry can significantly reduce the occurrence of construction disasters.

Furthermore, the holistic approach to safety management not only focuses on mitigating risks but also encompasses a broader commitment to fostering a culture of safety. This cultural shift involves continuous improvement, technological advancements, and a steadfast dedication to the well-being of both workers and the communities impacted by construction projects.

In essence, the prevention of construction disasters is not solely a regulatory necessity but a moral and professional obligation. The construction industry's commitment to proactive risk mitigation and safety management ensures not only the success of individual projects but, more importantly, the preservation of human lives and the sustainable development of infrastructure for generations to come.

Information

Publication financed from statutory research of the Czestochowa University of Technology.

Bibliography

Act of 7 July 1994 *on Construction Act*. OJ 2010, No. 243, item1623 with further amendments.

Anthopoulos, L.G., Kostavara, E. & Pantouvakis, J.-P. (2013) An effective disaster recovery model for construction projects. *Procedia – Social and Behavioral Sciences*, 74, 21-30.

Bacharz, M., Bacharz, K. & Raczkiewicz, W. (2022) Szacowanie odkształceń skurczowych w fibrobetonie w świetle wybranych norm. *Inżynieria i Budownictwo*, 11-12/22, 558-563.

Blikharskyy, Z., Khmil, R. & Vegera, P. (2017) Shear strength of reinforced concrete beams strengthened by PBO fiber mesh under loading. *MATECweb of Conferences*, 116, 02006.

Boadu, E.F., Wang, C.C. & Sunindijo, R.Y. (2020) Characteristics of the construction industry in developing countries and its implications for healthand safety: An exploratory study in Ghana. *International Journal of Environmental Research and Public Health*, 17, 4110.

Czajkowska, A. & Ingaldi, M. (2017) Analysis of the impact of individual phases in the building process cycle on the environment with respect to the principles of sustainable development. *IOP Conference Series Earth and Environmental Science*, 214,012012.

Czajkowska, A. & Ingaldi, M. (2021) Structural failures risk analysis as a tool supporting corporate responsibility. *Journal of Risk and Financial Management*, 14(4), 187.

Ennouri, W. (2015) Risk management applying fmea-steg case study. *Polish Journal of Management Studies*, 11(1), 56-67.

Fidlerova, H., Poplawski, L. & Surowka, M. (2022) Replacement of the expanded polystyrene with polyethylene in the packaging. *Przemysł Chemiczny*, 100(5), 432-435.

https://www.gunb.gov.pl

Khmil, R., Blikharskyy, Z., Vegera, P. & Kopiika, N. (2023) Bearing capacity of reinforced concrete beams with and without damages of rebar. *Production Engineering Archives*, 29(3), 298-303.

Kopiika, N., Vegera, P., Vashkevych, R. & Blikharskyy, Z. (2021) Stress-strain state of damaged reinforced concrete bended elements at operational load level. *Production Engineering Archives*, 27(4), 242-247.

Kovácsné Mozsár, A.L. & Michelberger, P. (2018) IT risk management and application portfolio management. *Polish Journal of Management Studies*, 17(2), 112-122.

Kraus, P., Náprstková, N., Jirounková, K., Cais, J. & Svobodová, J. (2018) Effect of heat treatment on the microstructure of the alloy AlSi7CrMnCu2.5. *Manufacturing Technology*, 18(6), 935-942.

Krynke, M., Ivanova, T.N. & Revenko, N.F. (2022) Factors, increasing the efficiency of work of maintenance, repair and operation units of industrial enterprises. *Management Systems in Production Engineering*, 30(1), 91-97.

Kucharikova, L., Mazur, M., Tillova, E., Chalupova, M., Zavodska, D. & Vasko, A. (2019) Fracture surfaces of the secondary A226 cast alloy with 0.9% Fe. *Engineering Failure Analysis*, 105, 688-698.

Kumor-Sulerz, A. & Michta, D. (2022) Intellectual innovation in the manufacturing enterprise – case study. *International Business Information Management*, 1-10.

Michałowska-Maziejuk, D. & Goszczyńska, B. (2023) Effectiveness of strengthening RC beams using composite materials – An accelerated strengthening method. *Materials*, 16(13), 4847.

Pachura, A. (2012) Innovation theory – an epistemological aspect. *Polish Journal of Management Studies*, 5, 128-135.

Szajnar, J., Walasek, A. & Baron, C. (2013) Tribological and corrosive properties of the parts of machines with surface alloy layer. *Archives of Metallurgy and Materials*, 58(3), 931-936.

Szymczak-Graczyk, A. (2011) Obciążenie wiatrem budynków. *Architectura*, 10(4), 25-32.