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Ensuring the Safety of Buildings and Structures Damaged as a Result of Military Man-Made Actions

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Abstract: A significant number of destroyed buildings and structures during the military aggression of the Russian Federation in Ukraine make it necessary for scientific organizations to solve new problems in the restoration of residential and public buildings. After explosive devices have hit the building, the first task is to identify the possibility of its further operation. Technical assessment of the damage level should be justified by using experimental data on changes in the physical and mechanical parameters of construction materials and structures, which are strength, deformability, crack resistance, etc., as a result of the blast waves and fires that accompany explosions in the premises. An urgent task is to develop a methodology that takes into account the impact of explosions and fires caused by them so that structures can be calculated and their residual life estimated. For many decades, the State Research Institute of Building Constructions has been solving problems of assessing the technical condition of damaged buildings and structures as a result of man-made disasters and actions, followed by the development of technical solutions that ensure the necessary operational characteristics of these objects can be restored.

Keywords: buildings, damage, explosions, fires, military action

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1. Introduction

Inspection of buildings is the first procedure that should be carried out in a building or structure damaged as a result of man-made, natural or military operations. Inspection organizational issues, the efficiency of the inspection methodology, the adequacy of the inspection outcomes, the thoroughness of conclusions and technical solutions for strengthening structures identify the safety of life and health of residents or personnel serving the structure and employees of construction organizations that have to carry out emergency recovery operations. Technical inspection is a process that involves testing, analyzing, and evaluating the condition of buildings and structures. The purpose of the technical inspection is to identify the current technical condition of structures and engineering systems of buildings and structures, identify their damage degree, and defects incurred due to the destruction of the building, assess the possibility of further operation of the building based on forecasting their behavior in the future. Tasks that should be solved during a technical inspection include: - diagnostics of the technical condition of structures, engineering systems, and the object as a whole based on the results of visual inspection and instrumental research, - modelling of building stability based on the results of instrumental measurements; - confirmation of the possibility of further safe operation of the object; - identification

of the scope and timing of urgent emergency response, mothballing; - justification of the decision to terminate operation, perform work on dismantling (liquidation) the object; - identification of the type and scope of work on the restoration of the object.

The military aggression of the Russian Federation in Ukraine has led to the destruction of buildings and structures on a scale that civilized countries have not experienced in the 21st century. Only more than 158 thousand residential buildings were damaged and destroyed, including about 20 thousand high-rise multi-family houses. Ukraine has had to face a big social problem of providing housing for the residents of damaged and destroyed buildings. The main result of the technical inspection of such buildings should provide an answer to the possibility of restoration and repair and the safe stay of residents in the part of the building that remained undamaged. The article offers a list of challenges that scientists and expert engineers should solve when destroyed buildings and structures undergo technical inspections, with the results of the inspections and studies to be analysed.

2. Legislative and regulatory framework for inspections

Legislative and regulatory framework for inspections is stipulated by the laws of Ukraine and state building codes, which entities of activity must apply, and national standards, which include international and European standards harmonized under the established procedure (Figure 1).

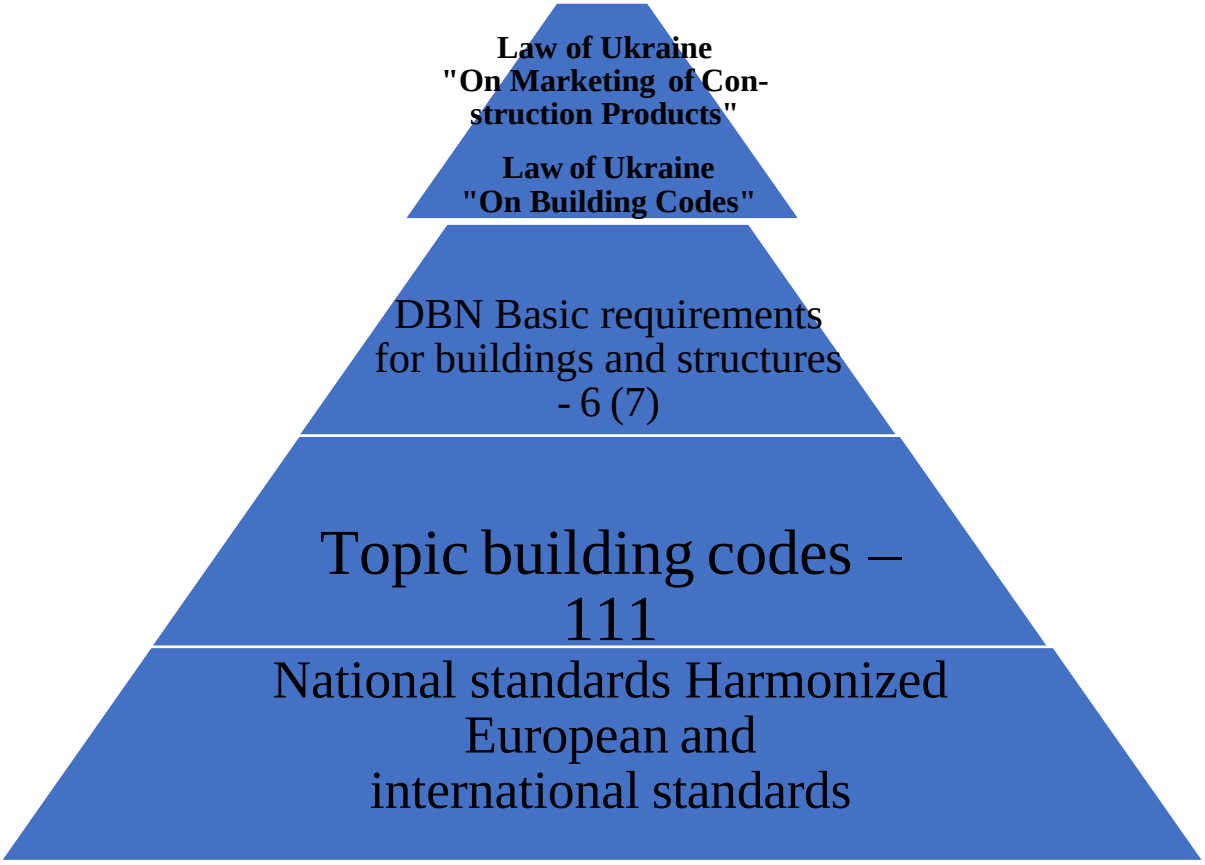

Fig. 1. Structure of the legislative and regulatory framework

The basic requirements for the safety of buildings and structures are identified by the Laws of Ukraine "On marketing of Construction Products" and "On Building Codes".

The condition of buildings and structures should be assessed according to seven basic requirements:

- Mechanical resistance and stability;
- Fire safety;
- Human health hygiene and environmental protection;
- Safety and accessibility during operation;
- Noise and vibration protection;
- Energy saving and energy efficiency;
- Sustainable use of natural resources.

The regulations and methodology for evaluating the first six requirements are established by State Building Codes. The new generation of state building codes was developed by the State Enterprise NIISK in 2021: [1-6]. The seventh basic requirement remains uncovered in the national regulatory environment.

3. Specifics of evaluating buildings damaged as a result of military operations

Assessment of the technical condition of buildings damaged as a result of military operations solely using the measurement of the area of damaged structures does not allow identifying the actual properties of structures and establishing the possibility of further safe operation of the building. Figure 2 shows an example of a residential three-section building that an aerial bomb hit. The section where the bomb exploded was completely destroyed. In the other two sections all window and door external structures were knocked out, and internal structures were partially damaged. The total area of damaged structures exceeds 60%. With external inspection alone, the conclusion can be made that the building should be classified as destroyed and is subject to complete dismantling. Detailed instrumental inspections have shown that damage to structures in the undamaged sections can be eliminated by strengthening them, with the destroyed section to be dismantled and restored using a groundwork, whose structures have retained their mechanical properties.

Fig. 2. View of a residential building damaged due to an aerial bomb explosion

Complex engineering tasks include cases of buildings destroyed by powerful explosions inside of the buildings. Figure 3 shows a view of the building and the consequences of structural destruction from a rocket explosion on the 17th floor of a 26-storey residential building. Based on the assessment of the properties of structures on the lower floors and the construction of a mathematical model of the building as a whole [7], experts of the Research Institute of Building Constructions (NIISK) developed technological solutions for building restoration and implemented them within 3 months, which had the residents returned to their homes (Figure 4).

Fig. 3. View of the facade and destruction of structures after a rocket explosion

Fig. 4. View of the building that underwent restoration as of 19 August 2022, 8 September 2022, and 27 October 2022

Based the statistical data of NIISK's own research during 2022-2023, every third explosion in residential buildings as a result of artillery and tank shelling was followed by a fire (Figure 5), which makes it difficult to assess the technical characteristics of damaged structures. Therefore, among the challenges of ensuring safety there is the need to develop methods that cover the impact of explosions and fires caused by them when calculating structures and estimating their residual life.

Fig. 5. Consequences of a Russian rocket hitting a residential building

The explosion is characterized by the appearance of a shock wave propagating at a high speed in the compression - rarefaction area. The wave parameters depend on the source of the explosion and the environment (air, groundwork, water), the distance to the explosion source, and other factors [8]. Blast waves impact the structure as short-term (episodic) actions that can significantly exceed the operational static loads. Construction objects are subject to requirements for the perception of dynamic load without collapse. To assess the degree of damage to buildings and structures, one should use experimental data and the results of analysis of past accidents, which facilitate identifying the degree of risk of destruction, material damage and damage to people. The results of the impact of explosions on structures are shown in Figure 6.

Fig. 6. Consequences of artillery shell explosions in residential buildings

It should be taken into account that most residential multi-apartment multi-storey buildings in Ukraine are built under serial technical and planning documentation, which stipulates that standard technical solutions can be employed to strengthen damaged buildings and ensure their further safe operation within a short timeframe of restoration operations. Over 2022-2023, a large number of residential buildings in the cities of Ukraine were restored using the technical solutions and design documentation elaborated by the NIISK, with one of the examples shown in Figure 7.

Fig. 7. General view of a frame-monolithic residential building in April 2022 and after its restoration

The patterns of changes in the properties of concrete and brick structures, which are the most common in housing construction, have not yet been sufficiently studied. Unfortunately for the Ukrainian people and all civilized peoples, nowadays, Ukraine is a unique testing ground for studying such patterns and Ukrainian scientists are willing to cooperate with European institutes in performing systematic research, the results of which can be used in predicting the consequences of possible man-made accidents that constantly accompany the history of human development.

Successful experience in eliminating accidents of global significance includes the works by experts from Ukraine, the United States, France, and other European countries on creating a new Shelter Facility for the Chornobyl Nuclear Power Plant. Scientists and engineers of the Research Institute of Building Constructions provided scientific and technical support for the development, design and construction of a new confinement (Figure 8), which was put into operation in 2018. (Figure 9).

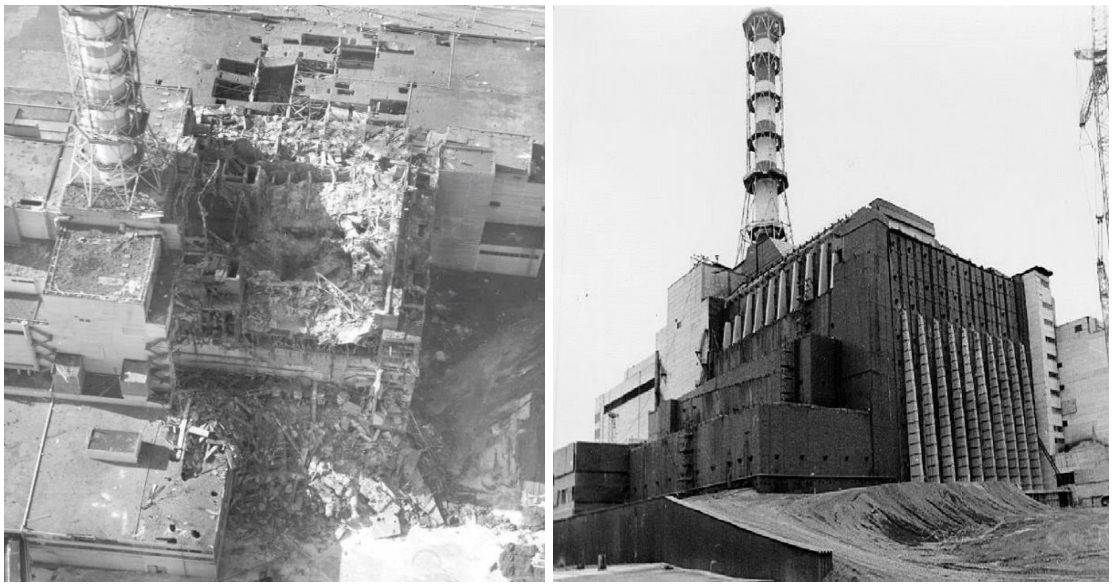

Fig. 8. General view of Unit 4 of the Chornobyl Nuclear Power Plant after the accident occurred on April 26, 1986, and view of the Shelter Facility after completion, November 1986

Fig. 9. Construction of the Shelter Facility in the "safe" area of the construction site and general view of the Shelter Facility after construction operations were completed

As a result of military operations in the cities of Ukraine, a huge number of construction debris have formed, which requires recycling (Figure 10). To solve this problem, modern technologies for secondary use of construction debris should be utilized, taking into account the specifics of its composition formed during the destruction of buildings, which are different mineralogy of components, different sizes of pieces, the impossibility of preliminary technological preparation, and so on. Therefore, the study of concretes based on processing should be performed and a class of structures based on them should be identified, with regulatory documentation on the field of their use to be developed. Solving these issues will necessitate combined efforts of European companies that successfully apply modern technologies for processing construction waste, and Ukrainian institutions such as the NIISK, working in the field of rationing and standardization of efficient structures.

Fig. 10. Construction debris that requires recycling for secondary use

The war in Ukraine has terrible consequences for the complete destruction of entire cities – Bakhmut, Soledar, and Mariupol (Figure 11). To restore these cities, the challenges of developing a concept and methodology for their new construction must be addressed.

Completely destroyed cities should be planned and designed using modern rules and practices of sustainable development and efficient urban life management systems.

Fig. 11. Large-scale destruction of buildings in Ukrainian cities as a result of Russian shelling and bombing

4. Conclusions

The mass destruction of buildings and structures as a result of Russia's military aggression in Ukraine makes it necessary to conduct inspections of the technical condition of structures so that the possibility of their restoration can be identifies. The safety of further operation of buildings depends on the assessment level of changes in the properties of structures and materials from the effect of blast waves and fires, followed by their extinguishing. Solving these problems will necessitate a set of special research to study the patterns of changes in the physical and mechanical parameters of construction materials and structures, namely their strength, deformability, and crack resistance due to the effect of non-standard loads that occur during military operations or man-made disasters.

The emergence of huge volumes of construction debris due to the mass destruction of buildings and structures requires that modern technologies for the secondary use of construction debris should be applied, taking into account the specifics of its composition during the destruction of buildings, as well as a class of structures based on them should be identified, with regulatory documentation on the field of their use to be developed.

Most of the destroyed and damaged multi-storey residential buildings were built using standard serial technical solutions, therefore, the search and testing of modern technologies for their restoration and repair will significantly reduce the time to get the safe operation of buildings back on track.

Completely destroyed cities should be planned and designed using modern rules and practices of sustainable development and efficient urban life management systems.

Bibliography

[1] DBN V. 1.2-6:2021. (2022). *Basic requirements for buildings and structures. Mechanical resistance and stability.* [1] Kyiv: Ministry of Development of Communities and Territories of Ukraine.

[2] DBN V. 1.2-7:2021. (2022). *Basic requirements for buildings and structures. Fire safety.* Kyiv: Ministry of Development of Communities and Territories of Ukraine.

[3] DBN V. 1.2-8:2021. (2022). *Basic requirements for buildings and structures. Hygiene, health, and environmental protection.* Kyiv: Ministry of Development of Communities and Territories of Ukraine.

[4] DBN V. 1.2-9:2021. (2022). *Basic requirements for buildings and structures. Safety and accessibility during operation.* Kyiv: Ministry of Development of Communities and Territories of Ukraine.

[5] DBN V. 1.2-10:2021. (2022). *Basic requirements for buildings and structures. Noise and vibration protection.* Kyiv: Ministry of Development of Communities and Territories of Ukraine.

[6] DBN V. 1.2-11:2021. (2022). *Basic requirements for buildings and structures. Energy saving and energy efficiency.* Kyiv: Ministry of Development of Communities and Territories of Ukraine.

[7] Farenyuk, G., Belokon, O., Nemchynov, Y., Marienkov, M., Bogdan, D., Babik, K., & Baytala, K. (2022). *Assessment of the condition of buildings and structures using vibrodynamic method after damages caused by military actions.* Science and Construction, 32 (2).