Organizational and technological approaches to assessing the safety of buildings affected by emergencies

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Abstract. This article is devoted to the problem of assessing the safety of buildings affected by natural disasters and man-made accidents. The work describes stages of assessing the safety of buildings affected by natural disasters and man-made accidents; proposes technical and organizational measures for improving the quality of the assessment of technical condition and safety of capital construction projects; reviews main directions for solving the problem of timely organization of the process of assessing the technical condition and safety of buildings affected by natural and man-made emergencies.

1 Introduction

The assessment of safety of buildings affected by natural and man-made accidents and disasters focuses on the structural integrity and safety of buildings [1]. At the same time, it is important to understand whether the disaster made the building less safe than it was before the event in order to determine the restrictions on its further use.

The purpose of assessing a building damaged as a result of emergency situations (hereinafter referred to as ES) of natural and man-made nature is to determine its safety and facilitate its recovery [2]. Building safety assessment is the first step in the restoration of the facility after an ES.

If the structural component of the building is not disrupted and there are no significant damages, it can be deemed unsafe, because its usability for its intended purpose may be restricted by other negative characteristics, such as environmental hazards, leakage of toxic chemicals, spillage of sewage, or lack of necessary utility and civil engineering systems (water supply, sewerage, electricity supply, fire extinguishing systems) [3, 4].

2 Research materials and methods

The main criteria for assessing the safety of buildings are universal in most types of emergency situations. Within the scope of building safety assessment, qualified
professionals inspect damaged or potentially damaged facilities to assess their safety and suitability for further use, and determine if their use should be restricted [5].

After a disaster of a natural and man-made nature, initial information is collected on the severity of the damage, as well as information about the territory subject to destruction. Employees of the Ministry of Emergency Situations carry out an initial assessment of the degree of destruction, fence off areas with broken power lines and other dangerous elements, and also provide the victims with appropriate medical care. Building services and local authorities inspect damaged buildings to further assess the severity of the damage. Search and rescue teams locate and rescue victims from the rubble of damaged buildings. Utility service providers inspect and repair damage to engineering equipment, restore power lines, etc.

Utility service providers inspect and repair broken power lines, gas leaks and other damage to engineering equipment.

The post-disaster assessment is carried out by experts authorized for assessing the safety of buildings affected by natural and man-made accidents and disasters [6]. In the event of a major disaster, the assistance of additional assessors outside the affected area is requested.

Building safety assessors also perform limited initial reconnaissance of environmental hazards and alert appropriate authorities if toxic chemical spills, power line outages, gas leaks, etc. are observed.

During a safety assessment, a specific building or entire area affected by a disaster is fenced off to limit the entry of unauthorized persons and prevent accidents. The assessment of the safety of buildings affected by natural and man-made disasters may also include a re-assessment if there is a risk of possible subsequent negative events, such as aftershocks, which may occur for a long time after a major earthquake [7].

The assessment is carried out in several stages. During the first stage, a preliminary inspection of the site (express assessment) is carried out by emergency services before sending assessment teams to the site. It is carried out both from the ground and from the air to determine the nature and extent of damage to buildings in the area, as well as to determine the capital construction projects that should be assessed first.

The express assessment involves an external inspection of buildings, however, there are situations when it is necessary to enter the building, for example, when internal damage is suspected or when internal damage is visible from the outside, and also when part of the structure is not visible from the outside. Such an assessment is usually of limited scope and of short duration.

During the second stage assessment teams perform a rapid assessment (average 30 minutes per building) of the initial overall degree of damage and safety, as well as to quickly identify structures that present a hazard and to identify buildings that require a detailed assessment or to determine the necessary restrictions on the use of facilities.

During the third stage a detailed assessment requiring on average from one to four hours to complete is carried out for each individual facility. During the detailed assessment a thorough visual inspection of the building and its structural elements is carried out. Such measures are applicable to assessment of buildings that carry a potential danger and the possibility of collapse, as well as to determine the necessary restrictions on its use and determine the need for an engineering assessment [8]. A detailed assessment should be carried out with the participation of civil engineers, professional engineers specializing in structural design, and architects. In some situations, geotechnical engineers or hydrological engineers may be involved (depending on site conditions and type of emergency). Highly hazardous and technically complex buildings may require more than four hours to assess, and the assessment is carried out using specialized equipment, including non-destructive testing devices [9].
During the fourth stage an engineering assessment is carried out, which includes a detailed engineering survey of damaged buildings using construction drawings, damage data and calculations. Used to assess potentially dangerous buildings in order to determine the degree of damage and develop a work plan for the restoration and repair of the capital construction project [10].

3 Results and discussion

The adoption of appropriate and timely response measures during and after natural and man-made emergencies plays a crucial role in minimizing negative socio-economic consequences. Large-scale damage to infrastructure and housing is accompanied by injuries and loss of life, reversal or stagnation of the local economy [11]. Disasters occur at uncertain times and with unknown consequences. In addition, persons authorized to make decisions on the restoration of territories after ES face various ES factors at the same time, which requires an appropriate response in a stressful situation.

Restoration of buildings and structures after natural and man-made emergencies is a dynamic, complex work that is chaotic in nature and contains many issues associated with uncertainty [12].

Building information modeling (BIM), which is an intelligent tool used in construction projects to manage design information and in digital design of buildings, may become one of the tools for analyzing and visualizing the expected, as well as already effected consequences of disasters at capital construction sites in the near future. This approach ensures the exchange of information and interaction between parties. Information Modeling is a platform for improving collaboration and communication, and its scope has expanded from 3D modeling to attachment the time factor (4D), costs (5D), environmental sustainability (6D), and facility management (7D) thereto [13]. Despite the presented advantages of information modeling, its implementation in the field of assessing the scale of destruction and the technical condition of buildings and structures after natural and man-made emergencies has not yet received due attention.

However, in the near future, BIM technologies should obtain a center spot in disaster management at all stages. BIM can help prepare such responses by using augmented reality to simulate multiple scenarios of natural and man-made disasters and then determine the best way to deal with them or their consequences.

It is possible to use BIM technologies during ES to track key data about the building for technical inspection and to prevent the failure of the facility in the event of a natural disaster. In addition, a parametric model can help decision makers understand the broader picture of ES impacts and speed up assessment of damage to buildings, as well as to more effectively organize a construction site to restore a damaged facility [14].

When considering possibilities of implementing BIM technologies in the formation of evacuation routes, it is important to note that they should not only be short, but also safe and free from obstacles. These evacuation routes are subject to change during the evacuation depending on emergency conditions. Therefore, evacuation routes must be determined dynamically. In such case a building information model, combined with neural networks and a search algorithm, will help provide fire evacuation guidance. The choice of the route by the system in such case will be carried out based on the analysis of distance by the neural network, the risk of exposure to ES factors, possible crowding, as well as smoke in certain areas using sensors. A building's integrated Internet of Things (IoT) and BIM technology system can be used to control LED signs, thus helping evacuees find safe routes in real time [15, 16].

BIM technologies can also be used to assess the seismic vulnerability of existing buildings. Assessment of structural elements of a building after an earthquake requires
accurate geometric characteristics of the building elements, and this information can be obtained from the information model of the facility being evaluated. BIM-based seismic analysis can provide important information about structures (including reinforcement for concrete buildings and connections for steel structures) leading to more detailed and improved analysis results. The information model can also be exported from the BIM software package to the calculation software package for seismic analysis [17].

BIM technologies can be combined with structural monitoring using sensors to protect and monitor critical assets [18]. This will enable rapid acquisition of structural data, post-quake inspection, reduce expert labor costs for inspection of the damaged area, and effective aftershock assessment, minimizing the number of inspections required and therefore reducing inspection risks and time [19]. It will also allow acquisition of timely and up-to-date information about the technical condition of the building. It is important to note that because some structures and building elements are hidden, the assessment of object deformations after earthquakes is complex and expensive, however, sensors can solve this problem and provide up-to-date information about deformations, which can then be visualized in BIM software systems. In addition, BIM can pave the way for information exchange during accidents to make effective decisions in identification and management of risks. During search and rescue activities, the information model will help employees of the Ministry of Emergency Situations to determine priority locations with the possible presence of people.

The combination of BIM technologies and geographic information systems (GIS) is a promising tool for assessing the risk of ES and assessing its damage, given the fact that most of GIS are associated with geographical objects, and BIM with an information database about buildings [20]. For example, modeling the spread of a flood or underflooding based on high-resolution topographic data. The proposed assessment method can provide detailed information on the estimated magnitude of the disaster, the speed of the flow to downstream settlements, and also can create a parametric model of the impact of rising water on a building, while legacy approaches use 2D graphical models to assess flood or underflooding hazards. BIM combined with smart sensors located in storm drains can be used to monitor flood hazards in real time.

After the destruction of a building due to natural and man-made disasters, it is not always possible to determine the amount of damage quickly and completely. In order to effectively organize the disaster recovery of buildings, experts of the assessment commissions determine the condition of structural elements. Remote sensing technologies (i.e., airborne or ground laser scanning) with point cloud generation are a promising tool for collecting information on damaged structures. The degree of structural damage can be characterized by comparing the parametric model of the building created in BIM software systems with the scan data.

However, there is a problem of implementing such concepts in practice, which consists in the complexity of organizing communication between software systems developed by different companies, and which will require the development of a link in the form of scripts or the unity of the program code arranged through the cooperation of developers. Despite such issues, it is important to note that the use of BIM technologies during the next decade can qualitatively change the procedure for surveying and organizing the process of restoring buildings and structures affected by disasters.

4 Conclusion

It is important to note the problem associated with the timeliness of assessing the safety of buildings affected by natural and man-made accidents and disasters, the solution of which can be the creation of specialized emergency assessment centers in places of possible
emergency situations, as well as the improvement of the legislative framework and the development of simplified guidelines for assessing the safety of buildings by visual inspection for volunteers.

The assessment should begin immediately after the initial response, search and rescue of people in order to proceed quickly to the restoration and reconstruction of buildings affected by natural and man-made disasters. Emergency services managers and those responsible for assessing the safety of buildings affected by natural and man-made ES should determine the resources necessary to complete the safety assessment of facilities within the specified timeframe.

Improving the quality of assessing the safety of buildings affected by natural and man-made accidents and disasters is possible with the use of geographic information systems and satellite systems; the use of computers using machine learning, artificial intelligence to extract information from a large number of photographs or videos in order to improve the assessment of the safety of a building and its elements; introduction of a system of autonomous remote seismic monitoring devices for facilities located in potentially hazardous areas; the use of unmanned aerial vehicles with specialized sensors (thermal, gas control) that provide more extensive and accurate information than a conventional visual inspection. Such devices can be used in areas where additional equipment is required, for example, in areas with high temperatures, gas-polluted locations.

In order to competently implement a building safety assessment, it is necessary that before the onset of a possible emergency, training and certification of specialists and their managers be organized. After an emergency, it is necessary to organize a safe accommodation; determination of priority among all objects of assessment, taking into account the scale of the incident; effective collection of data obtained during the evaluation process, as well as the supervision of experienced and qualified specialists to ensure the quality of the work performed.

References


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