



ANALYSIS OF THE PERFORMANCE OF REINFORCED CONCRETE STRUCTURES IN ULTIMATE STATES

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Abstract

This article is devoted to the analysis of reinforced concrete structures in ultimate states. Building structures are often subjected to unexpected extreme impacts, which can lead to so-called progressive collapse. To date, specific approaches and methods for assessing the potential for progressive collapse, as well as methods for protecting buildings and structures, have been developed. One method for improving the operational safety of a facility can be ensuring its survivability. Calculating the survivability of reinforced concrete structures and structural systems is fully consistent with the principles of the limit state method. The article outlines basic strategies for mitigating the risk of progressive collapse, increasing survivability, and reducing the structural vulnerability of reinforced concrete buildings.

Keywords: Reinforced concrete structures, building survivability, structural vulnerability, progressive collapse, extreme impacts.

Introduction

Building structures are often exposed to unexpected extreme events, such as gas explosions, vehicle accidents, terrorist attacks, fires, accidental overloading, improper storage of hazardous materials, design and construction errors, and foundation collapses [1]. Such extreme loads typically cause localized damage to building structures, which can lead to disproportionate collapse or progressive collapse of the structure. Because progressive collapse is a high-consequence event, it is necessary to evaluate the resistance to progressive collapse and the protective performance of key buildings and infrastructure.

Assessing the inelastic response of reinforced concrete (RC) structures is essential for assessing the strength and damage of structures under extreme loads, such as earthquakes, impacts, and blasts. In recent years, predicting large deformations of reinforced concrete structures has become more practical thanks to the development



of modern numerical algorithms and computing power. In recent decades, the feasibility of numerical methods for predicting the nonlinear behavior of reinforced concrete structures has been assessed through numerous test campaigns conducted on reinforced concrete walls, columns, and buildings.

To date, specific approaches and methods for assessing the potential for progressive collapse, as well as methods for protecting buildings and structures, have been developed [5]. A general methodology for reducing the risks of progressive destruction of buildings and structures has been formulated [4], the main provisions of which are as follows:

- prevention or complete elimination of the possibility of emergency impact by organizational methods;
- reduction of the volume of destruction of an object by constructive methods;
- prevention of progressive collapse.

One method for improving the operational safety of a facility is to ensure its survivability. According to current regulations, the calculation of the structural safety and survivability of reinforced concrete structures is based on the limit state method. Particularly important in survivability calculations is the consideration of potential impacts not foreseen in the design.

The most comprehensive definition of the concept of "survivability" is the ability of a statically indeterminate structural system to resist destruction in the event of failure of one of its most heavily loaded elements due to a sudden, beyond-design-basis impact [2]. The level of survivability of reinforced concrete structures is characterized by the number of local failures of the structural system. In accordance with current regulations, the calculation of the structural safety and survivability of reinforced concrete structures is based on the limit state method. Particularly important in survivability calculations is the consideration of possible impacts not foreseen by the design.

Failures can be caused by impacts not anticipated by normal structural operation (including those arising during emergency situations) or by gross human error. With the introduction of new technological solutions and the increasing scope of reconstruction, an increase in these and other types of beyond-design-basis impacts is inevitable. Therefore, to minimize damage from beyond-design-basis impacts, it is important to develop approaches to predicting the condition of reinforced concrete structures and buildings in general that will maximize their safety.

When assessing survivability, the possibility of the immediate removal of a single load-bearing element of the building's structural system is considered. This situation is possible as a result of explosions, terrorist attacks, accidental impacts, or transport accidents. When considering this design scenario, it should be noted that the primary consideration in ensuring survivability is not technical and structural measures, but organizational ones aimed at preventing these types of accidents. The possibility of disabling the element damaged by corrosion is considered, but this assumption appears unlikely.

Since corrosion damage to reinforced concrete structures develops over time and is easily diagnosed, a mandatory requirement for the operation of buildings and structures is an established system of maintenance and repair. This is confirmed by experience in inspecting reinforced concrete structures of buildings and structures [6]. The extent of progressive damage can be reduced by localizing it.

The building's frame is "divided" into separate volumes, preventing damage from extending beyond these volumes: The building is divided horizontally by expansion joints, while vertically, braced floors or strong beams are installed between floors. Another approach to reducing the volume of damage is the introduction of additional bracing into the structural design. [7] recommends implementing bracing along external columns, vertical bracing, contour bracing, and internal bracing in load-bearing frames.

The diagram of the reinforced concrete frame of a multi-story building (a) and a fragment in the vicinity of the disabled column A-2 (b) is shown in the figure. 1.

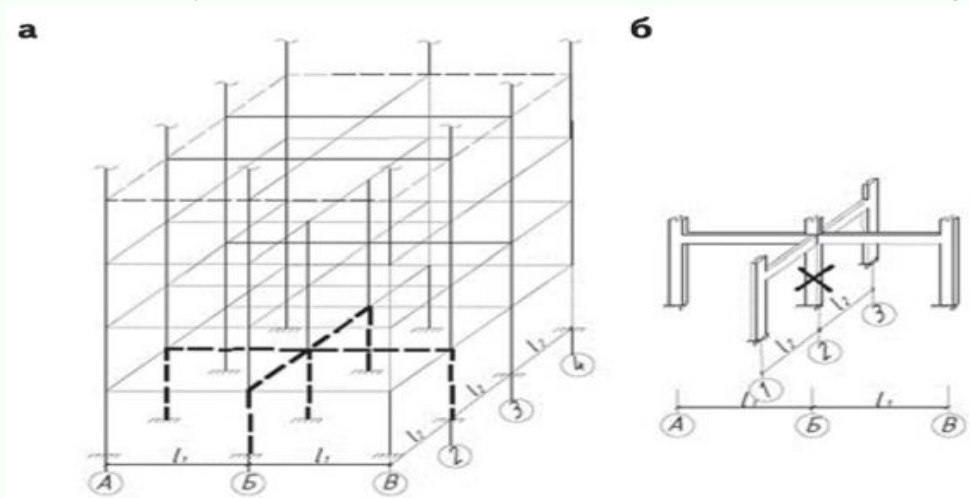


Fig. 1. Diagram of the reinforced concrete frame of a multi-story building (a) and a fragment in the vicinity of the disabled column A-2 (b)

The survivability of a building can be ensured if, to prevent progressive collapse, the load-bearing capacity of all system elements is sufficient to withstand the initial emergency impacts. This solution significantly increases the material consumption of the structural solution. As shown in [3], the reinforcement required to withstand emergency impacts and applied loads exceeds by 3 to 3.5 times the amount of reinforcement required to ensure the load-bearing capacity of the structure under design loads. Thus, the survivability of a reinforced concrete structure should be considered as its ability to resist brittle failure.

The viability of structural systems can be defined as the system's ability to resist progressive collapse under emergency loads and impacts. The viability calculation of reinforced concrete structures and structural systems is fully consistent with the principles of the limit state method. The calculation using the first group of limit states should protect the structure from failure of any type, taking into account the structural deformation state where necessary, and the structural system from localized and progressive collapse. The loading diagram for a structural system fragment is shown in Figure 2 (a — design diagram; b, c — beam sections; 6 — disconnected column).

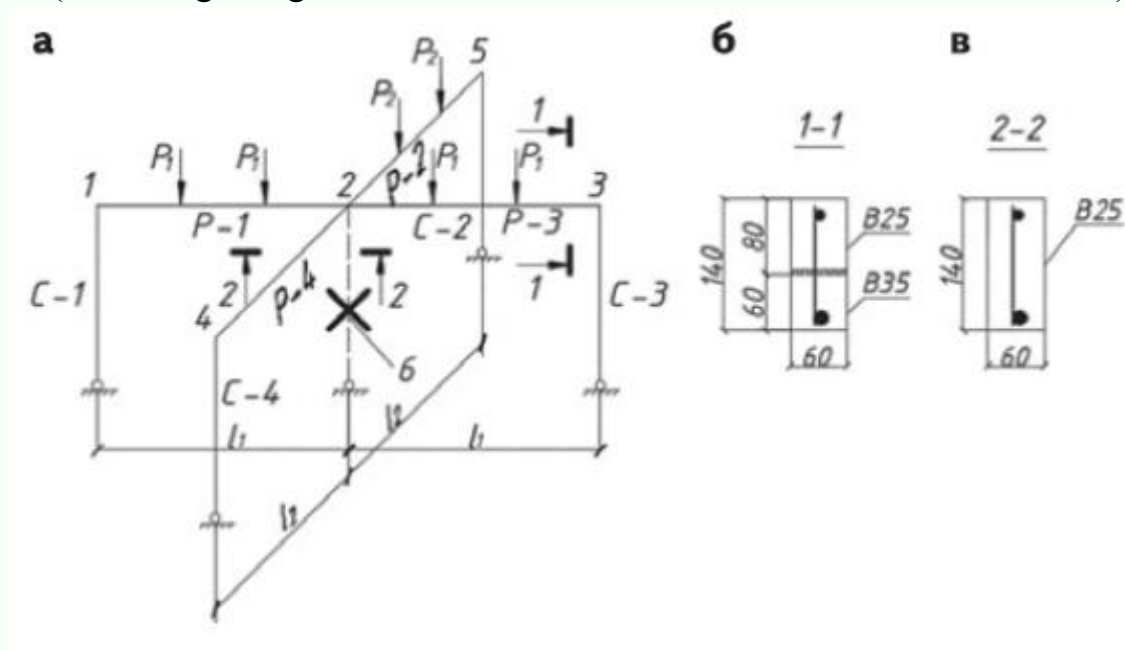


Fig. 2. Loading diagram of a fragment of a structural system

a — calculation scheme; b, c — cross-sections of the beam; 6 — switchable rack

The resistance of a structural system to such an impact characterizes its survivability and is determined by a special limit state, the excess of which can lead to further structural reconstruction or destruction of the structural system [8]. Research into the



survivability of rod structural systems with elements operating under simple stress states was examined in the works of G.A. Geniev , V.I. Kolchunova and N.V. Fedorova [6].

Designing a building to resist progressive collapse may require analytical approaches not used in conventional design. Most building structures are susceptible to progressive collapse to varying degrees, developing due to localized damage. It is estimated that approximately 15-20% of building collapses occur in this location. While all buildings are at risk, certain properties can make a building particularly vulnerable to progressive collapse. Some of these attributes are inherent to the building's structural system. Others are determined by the nature of the building's use or its interaction with other structures.

Vulnerability is defined for buildings as the degree of loss resulting from a hazard of a given severity level and depends on the reduction in resistance and the degree of damage to structures as a result of continuous exposure to environmental factors (e.g. seismic effects).

Perhaps the most important factor contributing to structural vulnerability is the lack of continuity within the system and the lack of ductility in structural materials, elements, and connections. During an earthquake, for example, the top and bottom of a column are most vulnerable to shear forces. If these forces are strong, the column may lose much of its strength and tilt under seismic and vertical loads.

On the other hand, redundancy (a large number of load-bearing walls and shorter spans) in such systems can to some extent compensate for the reduced ductility. Flat slabs and flat structures can be vulnerable to column/slab connections, which can be addressed through careful design. Load-bearing unreinforced masonry walls are poor at resisting structural loads that are not subject to compression.

To summarize the above, the following can be summarized: engineers and other members of the design team must determine which hazardous events and damage scenarios to consider and what the acceptable probabilities and consequences are.

Basic strategies to reduce the risk of progressive collapse should target three main levels:

— preventing the occurrence of deliberate abnormal loads by social or political means;

- to prevent the occurrence of localized significant structural damage that could lead to progressive collapse;

— prevent structural system failure and loss of life through structural design, separation, development of alternative loading paths, alternative exits, and other active and passive measures.

References:

1. Vetrova O. A. Experimental studies of the deformability of concrete beams reinforced with composite reinforcement // Bulletin of the South-West State University. - 2020. - Vol. 24. - No. 1. - P. 103-114.
2. Merkulov S. I. On the development of the theory of structural safety of operated buildings and structures // RAASN. Bulletin of the Department of Construction Sciences. 2014. No. 18. pp. 43–46.
3. Feng FF et al . Multilinear model for progressive collapse response of reinforced concrete frames under penultimate column removal scenario // Journal of Building Engineering. — 2022. — T. 47. - S. 103850.
4. Lim, H.-K.; Kang, J. W.; Pak, H.; Chi, H.-S.; Lee, Y.-G.; Kim, J. Seismic Response of a Three-Dimensional Asymmetric Multi- Storey Reinforced Concrete Structure. Appl . Sci . 2018, 8, 479. <https://doi.org/10.3390/app8040479>
5. Klyueva N. V., Korenkov P. A. Methodology for experimental determination of survivability parameters of reinforced concrete frame-and-rod structural systems // Industrial and civil engineering. 2016. No. 2. pp. 44–48.
6. Fedorova N. V., Korenkov P. A., Wu N. T. Methodology of experimental studies of deformation of monolithic reinforced concrete building frames under emergency impacts. // Construction and reconstruction. 2018. No. 4 (78). P. 42–52
7. Kolchunov V. I., Osovskikh E. V., Filatova S. A. Method for experimental determination of dynamic additional loads in frame-and-rod structural systems and a device implementing it. [Experimental determination of dynamic additional load in frame-and-rod structural systems and a device implementing it]. Patent for invention RU 2622496 C dated 15.06.2017. Application No. 2016128903 dated 15.07.2016.
8. Alkadi S. A., Osovskikh O. E., Fedorova N. V. Calculation of deformation of reinforced concrete spatial frames with elements of composite sections // In the collection: Series of conferences IOP: Materials Science and Engineering. Novosibirsk, 2018. P. 012033.