# CHAPTER 4
# BUILDINGS FROM VOLUME BLOCKS

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## 4.1 Structural schemes of buildings from volume blocks

Volumetric blocks are large reinforced concrete spatial boxes that represent separate rooms or apartments and are manufactured in a factory [61; 84]. During the production of blocks in the factory, all work on finishing and equipping the premises is often also performed. Volumetric elements are used for the construction of residential buildings, hotels, boarding houses and other buildings with the same room structure. The volumetric blocks manufactured at the factory, fully prepared for operation, are delivered by special vehicles to the construction site, where they are mounted side by side and one on top of the other (see Figure 4.1). The experience of building buildings from volumetric blocks shows that it is possible to achieve a significant improvement in the quality of construction work, reduce construction costs and material consumption, increase labor productivity and reduce installation times at the construction site compared to large-panel ones by approximately 5...6 times [6]. At the same time, about 85% of all construction work is transferred to factory conditions.

*According to the manufacturing method*, volumetric blocks are assembled from separate panels and monolithic. Assembled blocks are made from large-sized panels and are categorised into frame and frameless types. Frame blocks consist of a frame (posts and crossbars), hinged panels and floor slabs. Frameless blocks are assembled from separate panels and connected by welding embedded parts [13].

*According to the structural scheme*, houses made of volumetric blocks are conventionally divided into three types:

– block, while the houses consist of separate blocks, which are installed side by side and one on top of the other. This scheme is the most industrial, as it allows most of the work to be transferred to factory conditions. The disadvantage of this scheme is the presence of double internal walls and ceilings, that is, to some extent, an unjustified consumption of materials;

– panel-block, when wall panels are used alongside blocks. This scheme is characterized by the need to produce more than half of the finishing work at the construction site;

– frame-block, which is a combination of a frame of posts and crossbars and volumetric blocks resting on the frame. Given that each block perceives insignificant loads, they can be made of lightweight materials. However, buildings with this scheme are characterized by an increase in the number of mounting elements, and they differ sharply in their mass and dimensions. Considering the above, the best are block schemes.

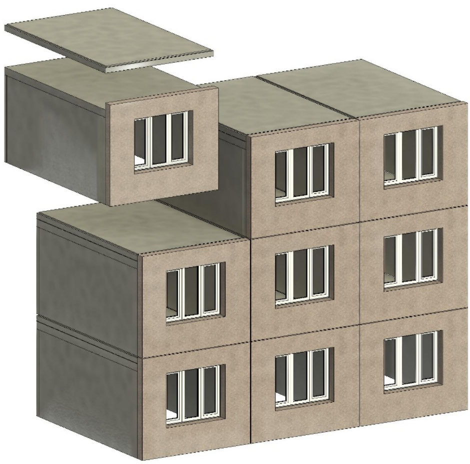
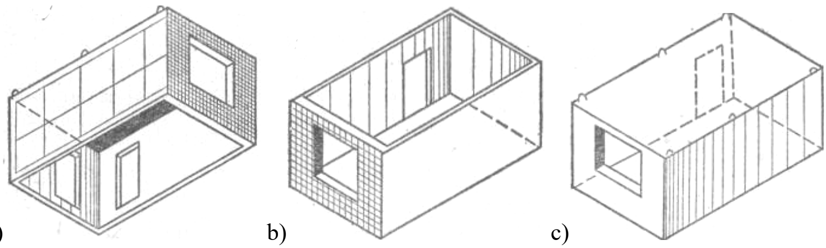


**Figure 4.1 – Example of assembling residential buildings from volumetric spatial blocks**

*Spatial blocks* can be monolithic and prefabricated from rolled panels assembled at the factory. In monolithic blocks, one of the six faces of the block is formed separately, which is why the blocks have received conventional names: such as "cap", "glass" and "pipe" (Figure 4.2). In the "glass" type blocks, four walls are monolithically connected to the floor slab, but without a ceiling. In the "cap" type blocks, four walls are monolithically connected to the ceiling, but without a floor slab. The floor panel in the "cap" type bulk elements is connected with reinforced concrete dowels and welding of embedded metal parts.



a) b) c)

**Figure 4.2 – Types of monolithic volumetric blocks:**
**a) "cap"; b) (glass); c) "pipe"**

In prefabricated volume elements, all six faces of the block are made mainly of ribbed panels manufactured in factories. The panels are joined by welding embedded parts.

*Depending on the conditions of supporting* the volumetric blocks one on one (load transfer conditions), a distinction is made between load transfer along the perimeter, on two sides and only on four corners. When assembling buildings, insulating elastic gaskets are placed on the lower blocks in the places of support. The blocks are connected by welding embedded parts [45].

The most critical point in a building made of large volume blocks is the external seam at the joint, a poor solution or execution of which can cause blowing and leakage of walls. In addition, the disadvantages of volume-block construction include the need to develop a new structural scheme; a certain complexity of production, transportation and installation of volume blocks; limited architectural and planning solutions for buildings [30; 32]. The general view of the building made of volumetric blocks is shown in the Figure 4.3.

## 4.2 Analysis of damage to buildings made of volumetric blocks caused by off-design impacts

The analysis of damage to buildings made of volumetric blocks caused by off-design impacts was performed using the example of a 9-story residential building, in *which a two-room apartment located on the 3rd floor exploded due to gas* accumulating in the premises due to a malfunction of a gas cylinder [5; 29]. The location of the 2nd apartment on the building plan is shown in Figure 4.4.

**Figure 4.3 – General view of a residential building made of volumetric blocks**

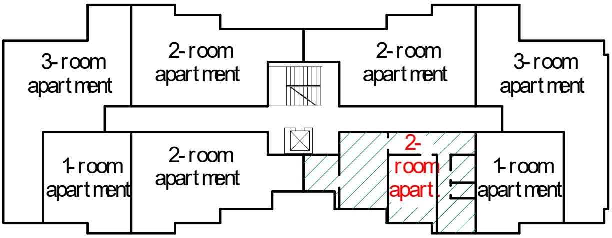



**Figure 4.4 – Layout of the 3rd floor of a two-room apartment where an explosion of gas accumulated in the premises occurred**

According to the architectural and structural solution, the multi-storey residential building is made of volumetric blocks the size of a room. The block system is a “cap”, which represents a room immediately made in the formwork with external dimensions of 3.4×5.4 $m^2$ or 2.8×5.4 $m^2$ with a height of 2.8 m, including walls 40-50 mm thick and a flat floor slab 40 mm thick.

The floor slab was manufactured together with the walls, so it is supported along the contour. The corners of the block rooms (vertical and horizontal) are made with a rounded inner corner, which increases the bearing capacity of the corner elements of the block room. The cross-sectional area of the corners of the internal load-bearing walls is about 500 $cm^2$. A 180 mm high floor panel with transverse ribs 130-140 mm high was installed on the block room floor, which serves as a bearing element of the floor of the living rooms.

The longitudinal walls in block rooms are self-supporting. The load from floor to floor is transferred through the transverse walls of the block rooms and their corner elements, which create a load-bearing spatial frame supported by wall and floor slabs.


**Figure 4.5 – Location of damage to reinforced concrete structures: a) fragment of the facade; b) cross-section of the building**

During the post-emergency inspection, a number of defects and damage to the building's load-bearing and enclosing structures were discovered. The determination of the technical condition of the load-bearing and enclosing structures of a multi-storey residential building was carried out taking into account the instructions of Appendix B "Determination and assessment of the condition of foundations and technical condition of structures of objects" (in particular Appendix B.2 "Concrete and reinforced concrete structures") and Section 5 "Categories of the technical condition of building structures and objects" of DSTU 9273:2024 "Guidelines for the inspection of buildings and structures to determine and assess their technical condition" [24]. The identified defects and damages are presented in the damage location diagram (see Figure 4.5) and damage photographs (see Figure 4.6 – 4.13). The identified damages to building structures occurred both during the gas explosion (in the vast majority) and accumulated during the operation of the building.

**Figure 4.6 (a-c) – Formation of through and surface cracks, fragmentation, peeling of reinforced concrete structures and destruction of the filling of the joints between them within the 1st and 5th floors in the rooms above and below the apartment in which the explosion occurred**

During the inspection of reinforced concrete structures, it was found that the geometric dimensions of the structures correspond to the typical dimensions of the corresponding series of structures, and their connection nodes, except for damaged structures (geometric parameters of the support areas, dimensions of embedded parts, etc.), correspond to typical connection nodes of prefabricated reinforced concrete structures. The physical and mechanical characteristics of concrete correspond to those used for the manufacture of typical reinforced concrete structures. The main damage to reinforced concrete structures after a gas explosion (dynamic non-project load) is:

– formation of through and surface cracks, fragmentation, peeling of reinforced concrete structures and destruction of the filling of the joints between them within the 1st and 5th floors in the rooms above and below the apartment in which the explosion occurred (see Figure 4.6);

– destruction of 100 mm thick reinforced concrete partitions between apartments on the 3rd floor around the apartment where the explosion occurred (see Figure 4.7);

– cracks in the body of the 320 mm thick reinforced concrete exterior wall panels on the 3rd floor around the apartment where the explosion occurred (see Figure 4.8);

– deformation, departure from the design position of the reinforced concrete block of the doorway of the apartments, which opens onto the landing of the apartment in which the explosion occurred (see Figure 4.9);

– cracking and excessive deflection of the balcony slab of the apartment on the 3rd floor where the explosion occurred (see Figure 4.10);

– complete destruction of inter-storey reinforced concrete slabs of floors under and above the apartment in which the explosion occurred (between the 2nd and 3rd and 3rd and 4th floors) with exposure, bulging, displacement, loss of adhesion to concrete, reaching the yield point and rupture of reinforcing bars (see Figure 4.11);

– departure from the design position of the internal partition of the bathroom of the apartment on the 3rd floor, where the explosion occurred (see Figure 4.12);

– destruction of the bathroom floor slab above the apartment in which the explosion occurred (see Figure 4.13).

a) b)

**Figure 4.7 (a-b) – Destruction of 100 mm thick reinforced concrete partitions between apartments on the 3rd floor around the apartment where the explosion occurred**

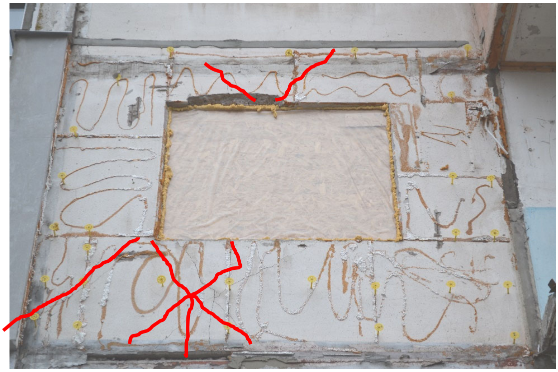


**Figure 4.8 – Cracks in the body of the 320 mm thick reinforced concrete exterior wall panels on the 3rd floor around the apartment where the explosion occurred**

a)  b) 

**Figure 4.9 (a, b) – Deformation, departure from the design position of the reinforced concrete block of the doorway of the apartments, which overlook the staircase of the apartment in which the explosion occurred**

**Figure 4.10 – Cracking and excessive deflection of the balcony slab of the apartment on the 3rd floor, where the explosion occurred**

a)

b)

c)

**Figure 4.11 – Complete destruction of interfloor ceilings below and above the apartment in which the explosion occurred (between the 2nd and 3rd and 3rd and 4th floors) with exposure, bulging, displacement, loss of adhesion to concrete, reaching the yield point and rupture of reinforcing bars**

**Figure 4.12 – Exit from the design position of the internal partition of the bathroom of the apartment on the 3rd floor, where the explosion occurred**

**Figure 4.13 – Destruction of the bathroom floor slab above the apartment where the explosion occurred**

Technical condition of load-bearing reinforced concrete structures of apartments No. 84, 92, 100, located in the area of the explosion, according to the characteristic full-scale classification features of the technical condition of reinforced concrete structures (Table B.2.1 DSTU 9273:2024 [24]) is assessed as emergency (technical condition category 4) and requires urgent reinforcement of vertical load-bearing reinforced concrete elements and restoration of two interfloor ceilings under and above the apartment in which the explosion occurred (between the 2nd and 3rd floors and the 3rd and 4th floors) (see Figure 4.5).

### 4.3 Summary of damage and brief recommendations for the restoration and reinforcement of damaged elements of reinforced concrete volumetric blocks of the building

The structural scheme of the building, made of room-sized, room-sized, reinforced concrete blocks of the "cap" system, in which self-supporting wall structures and a 40…60 mm thick floor slab are combined into a room-sized block room by rounded corner posts, prevented the complete destruction of half of the entrance during a fairly powerful spatial explosion of gas that accumulated in the rooms due to a malfunction of a gas cylinder. The identified damage and defects of the reinforced concrete volume block elements of the building caused by the gas explosion can be classified as follows:

– complete destruction of inter-storey reinforced concrete slabs of floors under and above the apartment in which the explosion occurred, with exposure, loss of adhesion to the concrete, reaching the yield point and rupture of reinforcing bars;

– destruction of 100 mm-thick reinforced concrete partitions between apartments on the 3rd floor around the apartment where the explosion occurred;

– cracks in the body of the 320 mm thick reinforced concrete exterior wall panels on the 3rd floor around the apartment where the explosion occurred;

– deformation of the reinforced concrete block of the doorway of the apartments that overlook the landing of the apartment in which the explosion occurred;

– departure from the design position of the internal partition of the bathroom of the apartment on the 3rd floor, where the explosion occurred.

The detected structural damage after the explosion significantly affects the possibility of the building operating trouble-free. Based on the results of verification calculations of individual structures, foundations and foundations of the building, it can be concluded that the detected structural damage after the explosion leads to the lack of stability of part of the building and requires urgent repair and restoration work. The spatial rigidity of the building after the emergency explosion is partially ensured, there are structural elements with responsibility categories A and B with technical condition category "4" (emergency) - these are ceilings, walls and partitions in apartments on the 2nd, 3rd and 4th floors, located in the area of the explosion. In addition, there are structures with liability category C with technical condition category "3" (unsuitable for normal operation) – these are blind areas in places, destroyed doors and windows. The general technical condition of the building is emergency (technical condition category "4"). Therefore, the structures require urgent major repairs (partial dismantling, reinforcement and restoration), and further operation of the building is possible only under limited conditions for the period until the completion of measures to restore its operational suitability.

Based on the above, for the possibility of further accident-free and safe operation of the analyzed multi-storey residential building made of volumetric blocks, part of which was damaged as a result of a non-projectile impact (accidental gas explosion), the following **recommendations** can be provided:

1. Perform urgent repair and restoration (emergency) work:

1.1 Urgently prohibit access of residents or other persons to the emergency fragments of the building; by the end of the work, clear the premises on the 1st and 2nd floors under the areas of future repair work of any belongings.

1.2 Before completing the work on the floor of the premises on the 2nd floor, under the areas of repair work (under the apartment where the explosion occurred), lay out plank boards with a thickness of at least 40…50 mm to prevent the penetration of the undamaged ceiling by fragments of reinforced concrete structures that may fall during the dismantling of sections of the damaged ceiling from the 3rd and 4th floors;

before starting the work, install scaffolding from outside the building within the facade of the apartment where the explosion occurred, up to the top of the fourth floor.

1.3 Dismantle fragments of destroyed reinforced concrete floor slabs. Dismantle from top to bottom using a diamond cutting tool to minimize impact (dynamic) loads. Dismantle destroyed reinforced concrete fragments, at the choice of the contractor, may be carried out through windows by hanging (slinging) the dismantled fragments to a suspension system or along the existing stairs of the building, cutting the destroyed reinforced concrete slab into hand-weight fragments. Cutting of destroyed floor fragments should be performed along the letter axes (across the cracks) to prevent uncontrolled instantaneous (catastrophic) collapse of large fragments of floor slabs.

1.4 To install steel elements to reinforce wall structures and restore interfloor ceiling structures made of prefabricated steel structures and monolithic reinforced concrete floor slabs.

2. Until the completion of measures to repair and restore the operational suitability of emergency load-bearing and enclosing structures (see paragraph 1 of the recommendations above), part of the undamaged residential building may be used for its main purpose, but taking into account the recommendations of the program for its limited operation.

3. All major building repairs (with partial dismantling, reinforcement and restoration of emergency building structures) should be carried out in accordance with specially developed design documentation, including a work execution project. This documentation, in the section of the construction organization project, should specify the deadlines for the work execution, which are given in paragraph 1 of these recommendations. The schemes for strengthening and restoring damaged building structures developed in the design documentation should achieve the following main goals:

3.1 Ensure the interoperability of damaged block rooms to prevent possible further destruction of the building.

3.2 Ensure safe dismantling of damaged ceiling elements and their subsequent restoration in the form of steel-reinforced concrete systems.

3.3 The ability to perform top-down work with diamond drilling with minimal possible impact.

3.4 Damaged corridor panels should be reinforced after installing steel posts at the welding points of the panels (especially on the 3rd floor).

3.5 After reinforcement, external structures should be insulated with rigid mineral wool insulation boards to prevent cold bridges and corrosion of the reinforcement connecting rods.