UDC 69.059.3 **doi:10.31650/2707-3068-2023-27-5-12**

STRENGTHENING OF REINFORCED CONCRETE ROOF WITH STEEL FRAME

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Abstract. Strengthening methods of reinforced concrete roofs are known and developed in sufficient detail. They are classified according to the constructions: strengthening of simply supported and continuous beams, cantilever beams, panels, girders, trusses, arches, etc. But all the proposed ways have common disadvantages – they require open space for work, provide for preliminary unloading, and under certain circumstances, partial dismantling of significantly damaged structures, and cannot consider the features of a specific technical situation naturally. We offer the strengthening method of not a single beam, but the entire roof block, with limited time period and the need to restart the production process in the shortest possible time, which has got critical damage, during the situation that excludes temporary unloading, and the dismantling of damaged areas or structures is impossible. The additional technical problem is that the supporting vertical structures of the emergency shutdown – the columns are also in a critical technical condition. Therefore, the attempt to dismantle any load-bearing element will lead to the complete destruction of a large part of the industrial building and the cessation of production for a considerable time period. The use of a spatial steel frame simplifies the strengthening work, speeds up the return to production and does not increase the material costs

Keywords: strengthening of reinforced concrete structures with rolled steel profiles, steel reinforcement beams, steel reinforcement casing.

Introduction. In the following years we will need to carry out the significant restoration work on the reconstruction of industrial enterprises damaged by artillery attack. The determination of the possibility and expediency of reinforcement, as well as the choice of ways and scheme of the reinforcement are conducted in each individual case, considering the actual technical condition of the structure and the building in general, the application severity and fire safety, the reinforcement possibility without the suspension of production, the live load capability and the conditions of performance of reinforcement works. Any reconstruction is accompanied, as a rule, by the change of the loads for the building structures and the change of their initial structural schemes, which leads to the need to increase the bearing capacity and, therefore, their strengthening. Especially if this reconstruction is caused by the damage that led to poor technical condition of the load-bearing structures or even to the emergency state. Due to the fact that among the building structures that have been in use for many years as the industrial buildings, the reinforced concrete ones prevail. The generalization and analysis of existing proposals and the development of effective and reliable strengthening ways of such structures are the relevant task. In this scientific work the existing technical solutions for beams strengthening are analyzed and another complex solution for strengthening of the whole block of load-bearing structures of the industrial building is proposed.

Analysis of existing ways of beam strengthening. Strengthening of reinforced concrete structures is achieved by two ways: the arrangement of the unloading elements or the increasing of the cross-sections of the structures. At the same time the rigid unloading elements and flexible ones with the elastic compliance are distinguished. The first ones include the strengthening elements, the rigidity of which differs little from the rigidity of the strengthened structures. The second ones are the elements which rigidity is much less. The involving of strengthening structures into the

continuous work with the strengthened structures is accompanied by changing of the initial design scheme of the structure and its stress state. Strengthening with concrete or reinforced concrete when increasing the cross-section does not cause the change of the structural scheme and its stress state. The rigid unloading elements are used in those cases when significant load increasing is required after strengthening of the structure and when there is no possibility to carry out their pre-stressing, flexible for the structures that take mainly dead load and the strengthening is conducted when the structure is fully loaded. The way and type of strengthening of the structures working for bending and eccentric compression are chosen depending on the strength degree and the damage of the compressed and tension cross-sectional areas.

Rigid unloading elements, the use of which is followed by increasing of the statical indeterminacy degree of the strengthened structure, are used in the form of steel and reinforced concrete poles, knees, portal frames, etc. Such strengthening elements are recommended to be used in such a way as to provide their timely involving into the work. The degree of prestressing can be insignificant, in other words it provides the shimming between the strengthened structure and the unloading elements. Rigid unloading elements, the including of which is followed by changing the place of load transfer, are used in the form of steel or reinforced concrete beams located on the top or bottom of the strengthened structure. Flexible unloading elements are used in the form of cross bracing and hangers made of reinforcement steel and rolled profiles, beams made of rolled profiles, braced beams, prefabricated and monolithic reinforced concrete beams, brackets and knees made of rolled profiles, truss rods made of reinforcement steel, rolled profiles or sheet steel, hinged-rod systems made of reinforcement steel, rolled profiles, ropes, horizontal and inclined cables and clamps made of reinforcement steel, cases and attachment racks made of rolled profiles and sheet steel. In most cases, flexible unloading elements are prestressed.

In the following paragraphs we will consider several common ways to strengthen the reinforced concrete beams.

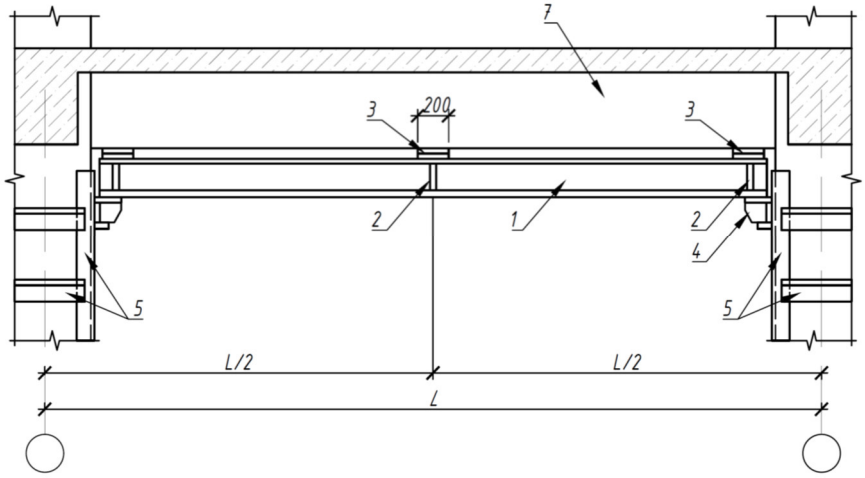

Fig. 1. Strengthening of the reinforced concrete beam with the steel beam resting on the piers

Strengthening is the method based on the prestressing of strengthening structures and is used to increase the load-bearing capacity of the beam in connection with increasing of the load on the roof or floor. The support bracket 4 is welded to the column, which at the previous stage of the work should be strengthened with the case 5. The rolled I-beam or channel 1 is installed on the brackets. The stiffening ribs 2 are welded near the supports and in the middle of the span. With such strengthening, the compulsory condition is the development of the strengthening with reactive force required to take the calculated element loads. The calculated value of the reactive force can be controlled by the deflection of the steel beam 1, which is formed as a result of the installation of the wedges 3 in the gap. The installed wedges must be welded to the steel beam 1. When strengthening, the steel beam is included in the cooperation of reinforced concrete by generation of steel beam stress using a jack, which is installed between reinforced concrete and steel beams. The jack pulls

the strengthening beam 1 away from the reinforced concrete beam 6 and develops the calculated value of prestress in the steel beam. The stress value is controlled by the manometer. The given stress value is fixed with the help of the wedges 3.

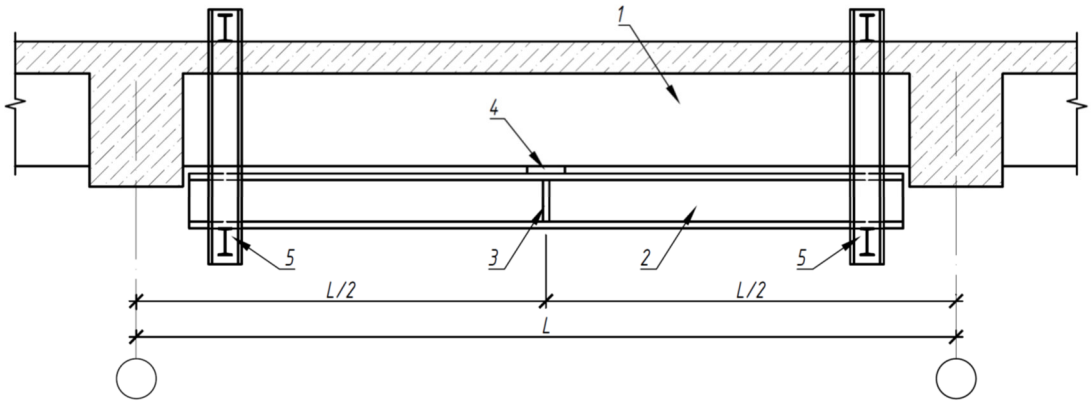

Fig. 2. Strengthening of the reinforced concrete beam of the monolithic floor slab with the prestressed steel beam on the clamps

At first, four holes are made in the floor slab corresponding to the sizes of the channels 5. Then the channels 5 are inserted into the holes and fixed to the floor slab by welding the stirrups 6. The steel beam 2 is installed on the stirrups 6. The beam 2 is wedged with the wedges 4 with the step 1.5-2 m to the calculated value of deflection. The stiffeners are welded under the wedges 4.

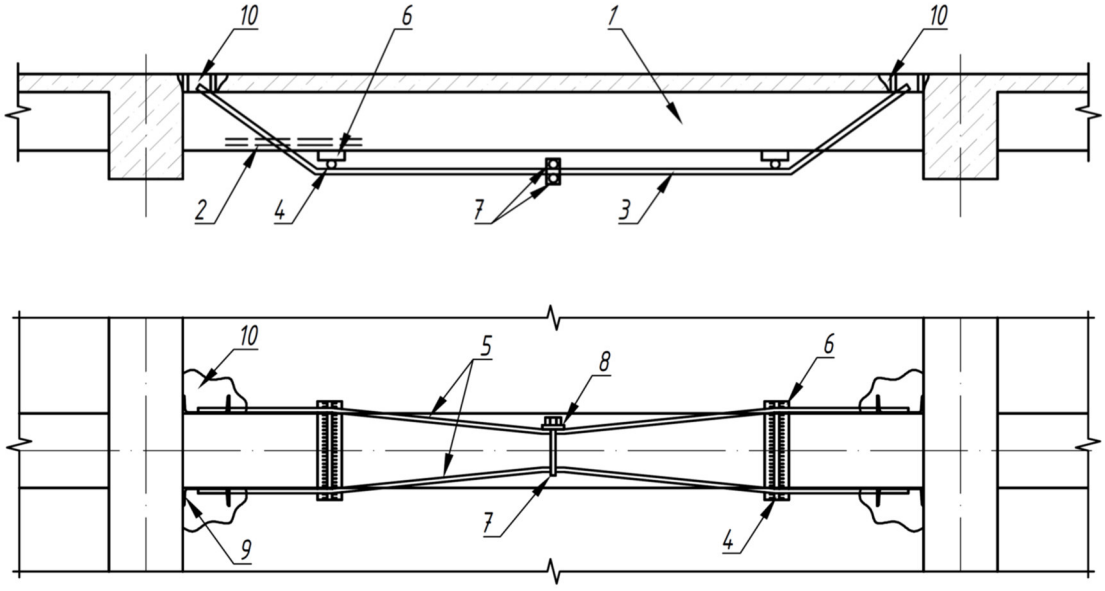

Fig. 3. Strengthening of the beam of the monolithic reinforced concrete floor slab with the trussing rod

The holes 10 are made in the floor slab and the reinforcement is opened. The anchors 9 in the form of the channel scraps are welded to it. The tie 5 is performed with the diameter 16-36 mm. The ends of the tie 5 are welded to the anchors 9. In the bent points of the rods, from the horizontal section to an inclined one, between the ties and the bottom edge of the strengthened element, the strip steel stirrup 6 is installed, to which the wedges 4 are welded. The ties 5 are involved in the tension state by inter tightening of both legs with the tightening bolts 7, which are the stirrup with two threaded ends and a common washer 8. After tightening, the locknuts are fixed on the tightening bolts, which are then welded together with the bolts.

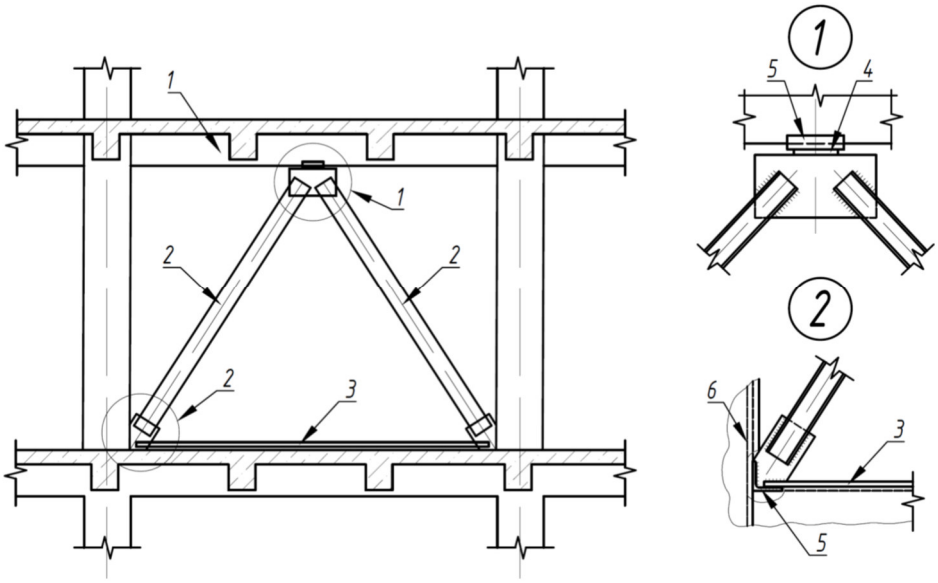

Fig. 4. Strengthening of the floor beam with the additional rigid support

When strengthening the frame 1 with the steel knees 2, the base angles 5 are welded to the reinforcement 6 of the top and bottom floor slabs. After fixing the knees 2, the wedge inserts 4 are used to wedge the reinforcement structure in the top joint tightly.

Research object. One-story industrial building. The structural scheme is mixed, with the internal framework: the interior load-bearing elements are monolithic reinforced concrete framework with the columns 300x300 mm and the beams 400x300, 300x300 mm, the external ones are load-bearing walls made of shell stone and brick. Monolithic reinforced concrete foundations.

The structural scheme of the roof is reinforced concrete beam grillage made of monolithic reinforced concrete, overlapped with the prefabricated box panels. The survey revealed the significant damage of the columns and beams: the cracks in the tensioned zone of the beams, the deflection of the columns from the vertical. The customer defined the special conditions for the restoration of the building: the impossibility of dismantling the damaged structures and limited time period for the strengthening of the structure.

Fig. 5. Research object

The aim of the research. Determine the technical condition of the research object. Develop the procedure and make the working drawings for strengthening the damaged load-bearing structures of the research object.

Research methods. The configuration, measurements, position in the plan and vertically of the load-bearing roof structures, the sites of defect and damage were carried out according to the

diagrammatic plan and the measurements of the structures at the construction site. The main height marks of the bottom of the beams and slabs were determined. The cross-sections of the framework elements, their damage and defects were measured. The survey of the open surfaces of the structures revealed their damaged areas. In order to determine the construction of the foundations and the depth of foot laying, two exploratory shafts were made: next to the column and the external wall.

Research results. During the survey the following damages were registered in the building structures:

- the cracks in the tension zone of monolithic reinforced concrete beams with the opening width up to 10 mm. It was not possible to establish the full-scale deflection in the middle of the beam span because it is unfastened by a temporary post (Fig. 5). The measured deflection was 28 mm;
- the deflection of the columns from the vertical – up to 15-18 mm.

The general technical condition of the building is defined as emergency.

Considering the strengthening principles of reinforced concrete elements, we decided to refuse the strengthening of individual damaged beams and columns and offer a comprehensive solution for the entire block of building structures. The reinforced concrete roof with load-bearing box panels and monolithic beams of rectangular cross-section is strengthened by the steel framework made of rolled profiles resting on the individual columns and strengthened foundations. The steel spatial skeleton is a backup load-bearing structure for the entire building block, which allows to avoid determining the load-bearing capacity of individual damaged reinforced concrete structures, which requires painstaking work regarding the strength of concrete and reinforcement, the degree of physical depreciation and the development of individual strengthening of each element. This approach is guaranteed to speed up the return to production and does not increase the material costs, as opposed to the traditional way of complex searches for a considerable time period with the involvement of the relevant specialists.

Based on the analysis of the technical situation at the construction site, the technical capabilities of the enterprise, and the special conditions of building restoration, the following strengthening method of load-bearing structures of reinforced concrete roof without dismantling the damaged elements was proposed:

1. before starting the work, jack up the reinforced concrete beams of the roof;
2. strengthen the foundations in accordance with the layout of new steel columns;
3. install the steel columns with 2[24;
4. strengthen the reinforced concrete columns by connecting them with the columns strengthened with the steel welded casing;
5. make the support brackets on the columns for further installation of steel strengthening beams;
6. strengthen the main reinforced concrete beams of the roof with the channels № 30, and the secondary ones with I-beams 24;
7. the channels № 30 should be installed on the support brackets on both sides relative to the main reinforced concrete beams;
8. jack up and raise the main reinforced concrete beams to the original design position;
9. install the tie bars (packing blocks) [14 (according to the scheme of strengthening) between the channels № 30;
10. weld the tie bars (packing blocks) [14 to the channels № 30 with the help of the angles on both sides;
11. fasten the strengthening steel beams from the channels № 30 to the main reinforced concrete beams with the expansion bolts. The anchoring of the channels on both sides should be done in the criss-cross pattern;

12. install the secondary steel reinforced I-beams № 24 under the secondary reinforced concrete beams;
13. weld the secondary steel reinforced I-beams № 24 to the main 2[30 steel beams and steel columns;
14. install the horizontal bracing between the erected steel beams;
15. dismantle the jacks.

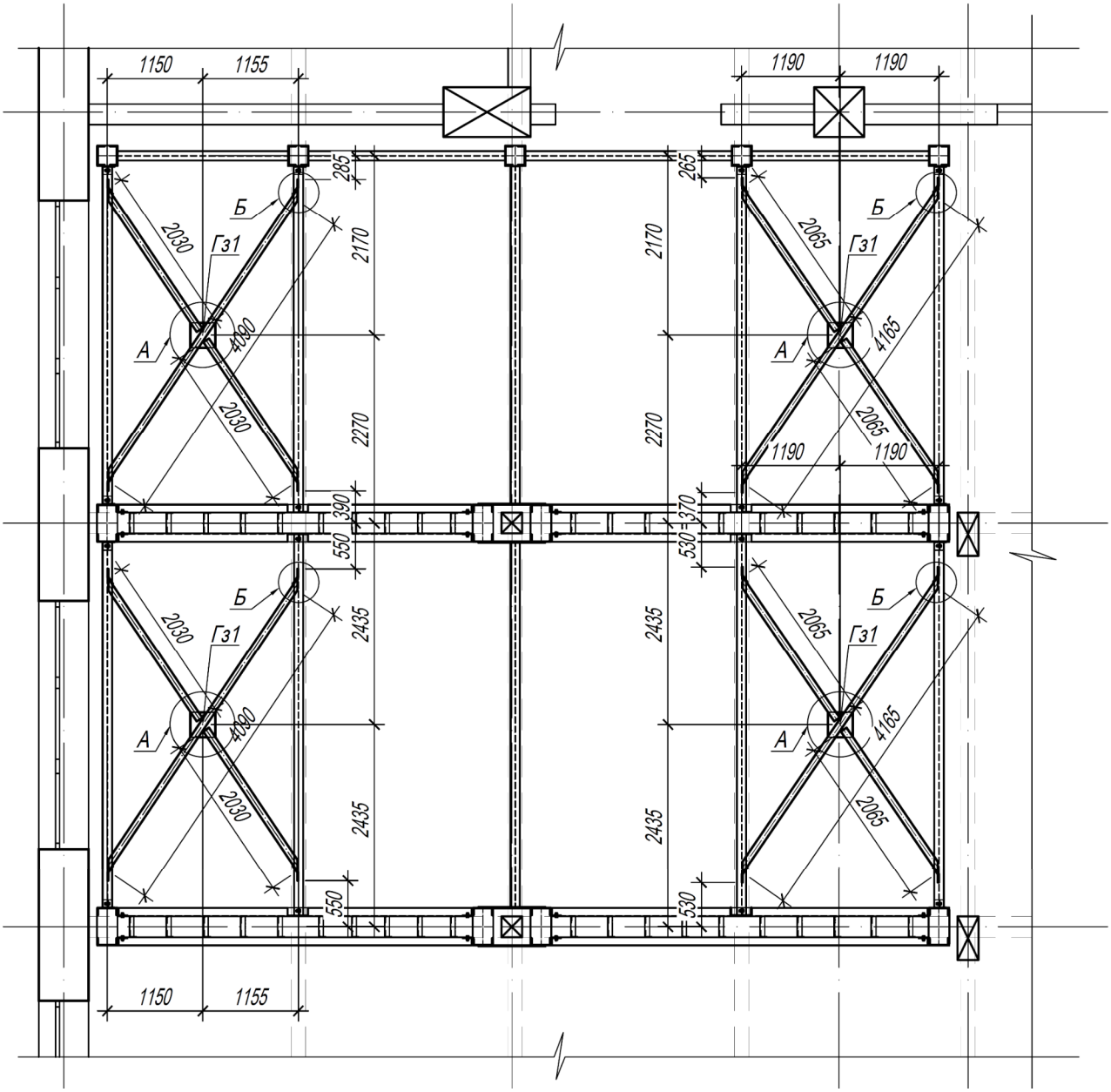

Fig. 6. Strengthening scheme of the reinforced concrete roof

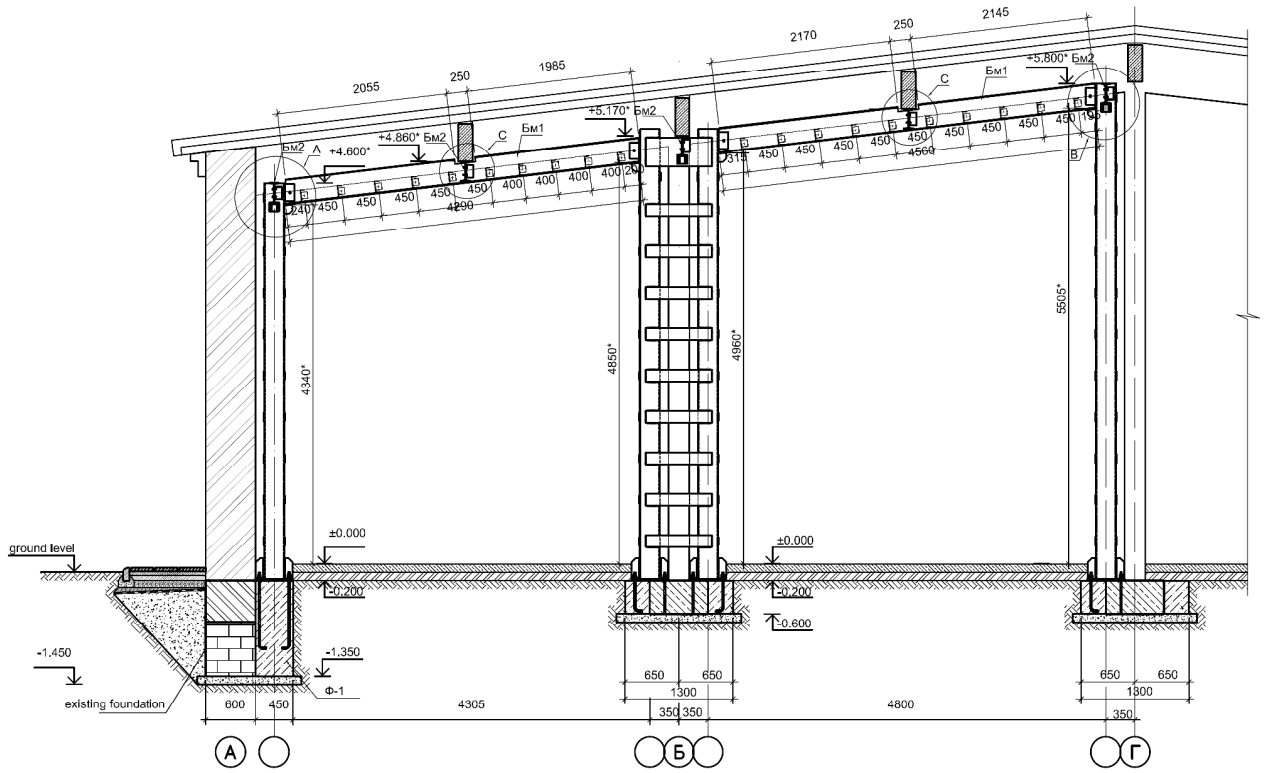

Fig. 7. Cross-section

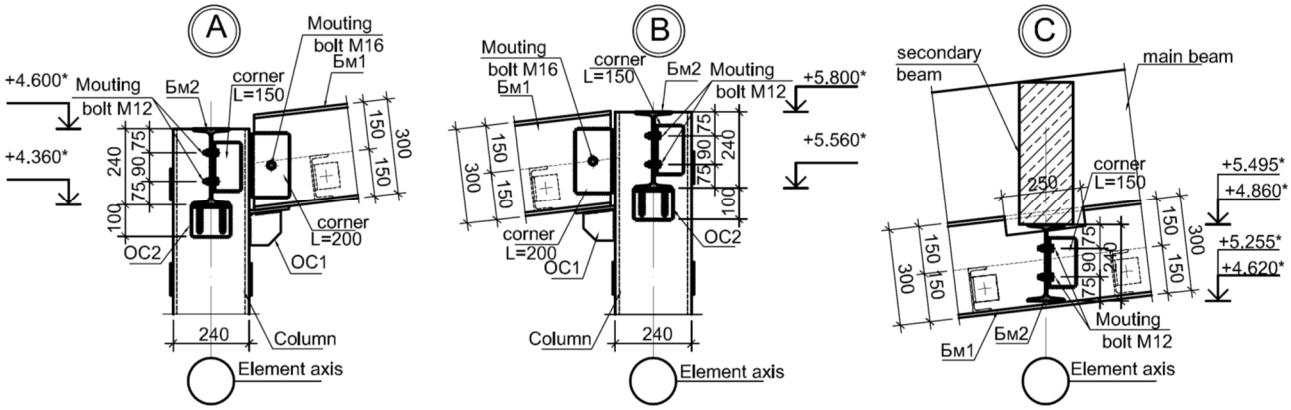

Fig. 8. Joints A, B, C

Conclusions:

1. The research object is the one-story industrial building with a mixed structural scheme, with an internal monolithic reinforced concrete framework and external load-bearing walls made of the shell stone.
2. The inspection detected the significant damage of the roof. The technical condition of the building is defined as emergency.
3. The customer defined special conditions for the restoration of the building: the impossibility of dismantling the damaged structures and a limited time period for the strengthening of the structure.
4. The complex solution for a whole block of building structures was proposed. The reinforced concrete roof with load-bearing box panels and monolithic beams with the rectangular cross-

section is strengthened by a steel spatial framework made of rolled profiles resting on the separate columns and strengthened foundations.

5. The use of a spatial steel framework simplifies the strengthening work, speeds up the return to production and does not increase the material costs.
6. The proposed structural strengthening solution can be used reliably in the case of the need to strengthen roof reinforced concrete structures under similar technical conditions.

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ПІДСИЛЕННЯ СТАЛЕВИМ КАРКАСОМ ЗАЛІЗОБЕТОННОГО ПОКРИТТЯ

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Одеська державна академія будівництва та архітектури

Методи підсилення залізобетонних покриттів відомі і розроблені достатньо детально. Вони класифікуються відповідно до конструкцій: підсилення розрізних і нерозрізних балок, консольних балок, панелей, ригелей, ферм, арок і т. п. Але всі пропоновані засоби мають загальні недоліки - вимагають вільного простору для роботи, передбачають попереднє розвантаження, а при певних обставинах частковий демонтаж суттєво пошкоджених конструкцій, не можуть, що природньо, враховувати особливості конкретної технічної ситуації. Ми пропонуємо метод підсилення не окремої балки, а цілого блоку покриття, при обмеженому часі і необхідності відновити виробничий процес в найкоротші терміни, що зазнав критичних пошкоджень, у ситуації, що виключає тимчасове розвантаження, а демонтаж аварійних ділянок або конструкцій неможливий. Додатковою технічною проблемою є те, що несучі вертикальні конструкції аварійного покриття – колони, теж знаходяться в аварійному технічному стані. Тому спроба демонтажу будь-якого несучого елемента призведе до повного руйнування значної частини промислової будівлі і припинення виробництва на значний період часу. Застосування просторового сталевого каркасу спрощує роботи з підсилення, прискорює відновлення виробництва і не збільшує матеріальні затрати.

Ключові слова: підсилення сталевими прокатними профілями залізобетонних конструкцій, сталеві балки підсилення, сталеві обойми підсилення.