Engineering solutions for the reinforced concrete structures’
reinforcement of a multi-storey administrative amenity buildings

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Abstract. The paper considers the reinforced concrete structures’ reinforcement of an administrative industrial amenity building facility that received damage during their operation. The main results of the technical survey of the facility are described with a description of the structural damages’ possible causes. The proposed atypical reinforcement of the load-bearing structures contains the changes in some design solutions in two versions, which ensure the facility’s further safe operation. Based on the performed analytical calculation, the design solutions to restore local damage and deformation, as well as to ensure the overall spatial rigidity of the structure have been developed. The technology for performing restoration work is described in detail.

Introduction
The object considered in this article is the administrative and household amenity building of an industrial enterprise, erected in the 60s of the XX century and continuously operated for its intended purpose from the moment of its construction to the present. The object is a three-story building with an incomplete longitudinal connection frame. The overlap is made of prefabricated reinforced concrete slabs. The floor of the first storey is arranged on a soil base. On the first and second floors of the right wing of the building there are shower rooms.

The technical inspection of the facility showed that the technical condition of the supporting structures depends on their location. The supporting structures of the shower rooms (beams, columns and floor slabs) have destruction dangerous for normal operation. The lack of corrosion protection led to significant plate corrosion of the reinforcement. In some places, the cross section of the working fittings decreased by 60%. The transverse reinforcement of the beams is torn off from the longitudinal working and does not fulfill its functional purpose. Systematic waterlogging of the soil as a result of the sewer collectors’ integrity violation led to its significant deformations and uneven foundations’ precipitation. The concrete floor construction on the first floor was designed with the soil backfill support. As a result of the production technology violation, the soil under the floor remained in a loose state and, when soaked, started being compacted. Because of this, the characteristic cracks and deflections have been formed in the floor structure.

The results of the technical examination showed that the structures’ reinforcement exposed to moisture is required. The remaining structures of the building are in satisfactory condition.

In this case, typical reinforcement with metal clips [1] is not effective, due to several reasons:
1. Metal reinforcement structures in showers will quickly become in emergency condition due to constant temperature and humidity exposure;
   2. The reinforcing column elements will not immediately be included in the work, since free space is formed between the base plate and the beam. Therefore, it is required to additionally perform a wedging system.

Also, typical restoration of a cracked floor structure is not suitable [2]. Due to the incomplete compaction of the soil in a fairly short period of time, the restored floor will be destroyed, and the repairs will need to be carried out again.

**Design and reinforcement of the structures**

After studying the design and operational documentation, as well as analyzing the results of the survey, the following solution was proposed: restoring the serviceability of structures by increasing the sections and constructing reinforced concrete “shirts”. It was decided to organize a new monolithic ceiling of the first floor in the reconstructed part of the domestic premises [3]. The main difficulty of this work was the correct organization of the device technology for overlapping the first floor due to the lack of a basement and technical underground. In addition, due to insufficient rigidity in the longitudinal direction, as well as the presence of subsidence soils in the base and their intensive soaking [4], the need for an additional device for stiffness diaphragms [5].

1.1. **Design and installation of a monolithic ceiling on the first floor**

The designed ceiling is a system of monolithic slabs, based on the contour on monolithic reinforced concrete beams. Two reconstruction options were proposed, due to the fact that according to the initial project, the level of clean floor corresponds to +0.085.

The first option involves supporting the beam on the foundations’ edge with the conclusion of the clean floor level at around +0.185.

The second option is proposed in order to comply with the design level. The trimming of the monolithic reinforced concrete beams to a height of 100 mm was performed in the area of its support.

The monolithic plates and beams’ layout in the reconstructed part of the domestic premises is shown in Figure 1.

![Figure 1. The floor designed structures’ location.](image)

An analytical calculation and design of the slabs and beams was performed for both options. The plate was considered as loosely supported along the contour and loaded with a uniformly distributed load. The beams were considered as articulated and loaded with a uniformly distributed load [6-7]. The beams’ type and their reinforcement schemes are shown in Figure 2.
Figure 2. Type of beams and reinforcement schemes in two reconstruction options

1.2. The device of monolithic beams at elev. -0.05 m
Before the start of the main work on the monolithic beams’ installation, the following was recommended:
- to disassemble the existing water supply and sanitation systems;
- to disassemble the internal partitions;
- to open old floors with reinforced concrete slab;
- to remove building debris from the premises;
- to install a new drainage system;
- to clean the upper edges of the foundations from soil, dirt and rinse with water. To level and seal the upper foundation;
- to fill the reconstructed area with sand to the level of 0.50 m with layer-by-layer compaction. To spill each layer after compaction with water.

After the last layer has been dried, it is necessary to start carrying out the basic work on the installation of monolithic reinforced concrete beams. For this it is necessary:
- to install the beam formwork;
- to assemble the spatial welded beam frames;
- to install spatial frames in the formwork of beams in compliance with the protective layer of concrete for reinforcement;
- to lay concrete in the formwork, compact it with vibrators, avoiding delamination of the concrete mixture. The upper edges of the beams should correspond to the mark -0.05m;
- when gaining strength of concrete, beams should not be allowed to dry. It is necessary to moisten the concrete periodically by sprinkling 2-3 days after its laying;
- it is not recommended to remove the formwork before 5-6 days from the day of concreting. The monolithic slabs’ installation on the beams should be started no earlier than they set 70% of the concrete strength of the design, that is, 10-12 days after the concrete beams are concreted.

1.3. Installation of monolithic slabs at +0.06 m
Before installing the monolithic slabs, it was recommended to fill them with sand from the level of 0.40 m to the upper face of the beams with its layer-by-layer compaction and spill each layer after compaction with water. After the last layer has been dried, the basic work should be proceeded in the following sequence:
- on compacted sand preparation, lay two layers of roofing material;
- lay welded wire mesh in compliance with the protective layer of concrete for reinforcement in two directions;
- at the locations of columns, gangways and risers, cut the grid rods in place, with the frame of the holes;
- in the middle of the width of the upper faces of the beams, install on the cement mortar strips of steel 5 mm thick and 110 mm wide, that is, the monolithic plates’ thickness;
- lay concrete with a thickness of 110 mm, compact it with vibrators, avoiding delamination of the concrete mixture. The top of the plates should correspond to the mark + 0.06m.

Work on the columns’ strengthening, the stiffness diaphragms’ installation, should start no earlier than 10-12 days after concrete slabs.

1.4. Column reinforcement on the first and second floors with stiffness diaphragms
In the process of developing a gain scheme, an analytical calculation and design of stiffness diaphragms was carried out, justified by this calculation [8-9]. The diaphragm reinforcement schemes and column reinforcement are shown in Figure 3.

![Figure 3. Reinforcement of columns with reinforced concrete cage with simultaneous stiffness diaphragm](image)

Before reinforcing the columns and stiffness diaphragm device, it is necessary to perform the following types of work:
- to destroy flaking and peeling concrete;
- to clean the fittings from rust to metallic luster with brushes;
- to remove the paintwork and plaster from the surface of the column;
- to make notches on concrete columns;
- to install the fittings in the design position by welding it to the existing working fittings;
- to tie the column with transverse reinforcement;
- to combine the diaphragm grid with the working reinforcement of the frame of the opening;
- to combine grid elements into a spatial frame in the design position;
- to install the formwork and concreted with concrete. Rinse the surface of old concrete columns with water.

1.5. Reinforcement of floor slabs and crossbars above the first and second floors
The work on reinforcing floor slabs and crossbars on the first and second floors can start immediately after the columns’ reinforcement and the stiffness diaphragms’ installation on these floors.
Reinforcement schemes for the floor slabs and crossbars are shown in Figure 4.5. Reinforcement is proposed to be carried out by the extension method [10-11].

Figure 4. Floor slab reinforcement

To do this, it is recommended to carry out the following preparatory work:
- to disassemble the existing water supply, sewage and ventilation systems located at the locations of reinforced structures;
- to disassemble all the internal partitions that interfere with the repair work;
- to remove the remaining loose concrete from all surfaces of the reinforced structure;
- to clear the concrete surfaces from paint and varnish coating, and exposed reinforcement of various functional purposes - from plate and surface corrosion;
- to notch on non-collapsible structural surfaces;
- to wash the reinforced structures’ surfaces with water.

Figure 5. Reinforcement of the crossbar lower reinforcement

Strengthening of crossbars and plates is carried out by welding a new additional working reinforcement with a subsequent layer-by-layer closing with shotcrete. The work should be carried out in the following sequence:
- to chop off the protective layer of concrete for the lower working reinforcement. To expose the longitudinal and transverse rods at the locations of the short rods; to weld short rods with intermittent seam to longitudinal and transverse reinforcement;
- to weld additional reinforcement in girders and mesh in plates to short rods;
- to moisten the surfaces of the reinforced structure with water immediately before spraying the concrete;
- to produce the layer-by-layer gunning of the reinforced structure’s surfaces with shotcrete to design dimensions;
- to smooth the surface of the structure and wipe it with a thin layer of cement mortar after setting the last layer of shotcrete.

All other repair and restoration work (restoration of partitions; installation of a new water supply, sanitation, ventilation system; installation of floors in showers and walk-in closets) should be carried out in the above-mentioned sequence in accordance with their projects. The repair work on the second floor of the building should begin after the completion of work to strengthen the columns, crossbars and floor slabs above the first floor.

**Summary**

As a result of the comprehensive analytical and design work, an engineering solution to the problem of restoring the operational suitability of an operating facility was obtained. The customer was offered two options for performing the work to strengthen the structures, ensuring further safe operation. The proposed amplification schemes contain the detailed guidance on the technology for performing the work.

The developed proposals allowed the customer to carry out all the necessary types of work by the organization forces, and the reconstruction object, after performing these works, has been in operation for more than 10 years.

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