Supporting structures of machine-building enterprises of 1920-1930

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Abstract. The article provides an analysis of the design solutions of industrial buildings of the engineering industry, that were built in 1920-1930. This period is characterized by the use of monolithic and precast concrete elements as the supporting structures of the frames of industrial buildings, because of the need for super-efficient use of steel. Low-carbon steel of low grades was used as reinforcement. Space-planning and constructive solutions of buildings of this period are not peculiar to later periods of construction. The purpose of research is to identify and describe the characteristic features of the frameworks, its inherent defects and damage of the supporting elements, and ways to eliminate them. As a rule, the considered buildings are characterized by increased spatial rigidity and stability, provided by the rigid coupling of columns with foundations, monolithic transverse elements and longitudinal crossbars. This explains the safety of supporting structures during long periods of operation, low sensitivity to the sediments of the supports during deformations of the soil base. Enclosing structures, self-supporting walls on almost all the objects surveyed have become inoperable. To continue the exploitation of such buildings, almost complete replacement of envelopes, repair and strengthening of local damage of supporting reinforced structures is required.

1. Introduction
In the Russian Federation there are more than 2,000 large and medium-sized enterprises of mechanical engineering. About 3.5 million people are employed in these enterprises. Some of these enterprises operate industrial buildings, that were built in the 1920-1930. To assess the technical condition of the supporting structures of such industrial buildings, it is necessary to study the features of their structural solutions that are not inherent in the later periods of construction, to identify and describe the characteristic damage to the supporting elements and how to eliminate them.

The purpose of this study is to analyze the design solutions of industrial buildings with a reinforced concrete frame, analyze the influence of design features on the technical condition of the supporting and enclosing elements of the frame, taking into account operating conditions, analyze defects and damage typical for this type of buildings, and suggest options for strengthening the elements to ensure the guaranteed period trouble-free operation of the facility after the reconstruction or overhaul.

2. The supporting structures of engineering enterprises
The supporting structures of engineering enterprises built during the first five-year periods of the Soviet power (1920–30) were mainly made of reinforced concrete, and both prefabricated and
monolithic reinforced concrete structures were used (Figure 1). For single-storey industrial buildings built during this period, a large length in plan in both directions, relatively small spans and a small height are typical, cranes were usually absent or had a small carrying capacity [1]. The weight of individual precast concrete elements was small and in most cases did not exceed 3–3.5 tons. The typical dimensions are $6 \times 12$ m (between the axes of the columns), but there are also $5 \times 10$ cells; $7 \times 10$; $7 \times 8.5$ m. The bottom mark of the trusses of such buildings is usually 4.5–6 m and only in some cases reaches 9–10 m.

![Figure 1. Precast concrete construction single-storey building (dimensions in meters).](image1)

At many enterprises of mechanical engineering, schemes with T-shaped columns of the middle row and L-shaped columns of the extreme rows were applied. For the construction of the Moscow Automobile Plant, for most workshops, a grid of $6 \times 12$ m columns with monolithic reinforced T-shaped and L-shaped columns and metal trusses was adopted. The longitudinal rigidity of the frame was provided by ribbed plates of the coating. If it was necessary to increase the longitudinal stiffness of the frame, along the columns in the direction parallel to the direction of the lanterns, longitudinal reinforced concrete stiffeners were inserted, stacked over the columns along their axes [2].

The walls of industrial buildings were erected everywhere by self-supporting brick, slag concrete, and sometimes natural stones. For some industrial buildings and structures were used half-timbered brick or asbestos cement sheets of the wall along the metal frame.

In cases where bridge cranes were required by technology, the columns were arranged with consoles (Figure 2), onto which crane girders were laid.

![Figure 2. Multi-span reinforced concrete frame with bridge cranes (dimensions in centimeters).](image2)
3. Inspection of the industrial building of the machine-building plant in Rostov-on-Don

Many buildings of industrial enterprises, which were not destroyed during the Patriotic War of 1941–1945, are still in use [3,4]. Since nearly a hundred years have passed since the construction of some of them, the technical condition of buildings requires assessment, and buildings need reconstruction and modernization [5,6]. A typical example of an industrial building built during the first five-year plans is the iron processing shop of a machine-building enterprise in Rostov-on-Don (Fig. 3). Transverse monolithic reinforced concrete frames, consisting of columns and roof beams, are rigidly interconnected by monolithic reinforced concrete longitudinal girders and crane girders for supporting cranes with a lifting capacity of up to 5 tons.

![Figure 3. General view of the workshop with monolithic reinforced concrete crane beams.](image)

Spatial rigidity and stability of the building is provided by rigid mating of columns with foundations, monolithic transverse beams, crane girders and longitudinal girders. On the end rows, reinforced concrete beams and crane girders rest on bearing walls 510 mm thick made of ceramic bricks. In one of the spans, lanterns with reinforced concrete structures supported on reinforced concrete beams are provided. In the other span, lanterns with steel bearing structures are built, which also rely on reinforced concrete trusses. The peculiarity of this solution (Fig. 4) is that the lights are not designed to be solid along the length of the building, as is usually the case, but staggered through one span both in the transverse and in the longitudinal direction of the building.

Enclosing structures of the building are self-supporting walls 380 mm thick along the longitudinal axes and load-bearing walls 510 mm thick along the end rows of ceramic bricks on a lime mortar. The foundations of the building are monolithic, concrete columns under the pillars of the frame and the concrete under the supporting and self-supporting walls.

Monolithic reinforced concrete structures of the frame are made of concrete, whose class of compressive strength corresponds to the classes - B15 - B25. Testing of concrete is performed by the direct method of non-destructive testing - separation with chipping [7].
In general, the space-planning and constructive solutions of the building ensure its bearing capacity, rigidity and overall stability. Loss of stability, roll, deflections in the main supporting structures of the frame (columns, roof beams and cover plates) was not detected. This is due to the rigidity of the structural scheme of the building, broken down into temperature blocks.

During the operation, the bearing and enclosing structures of the building received defects in local areas, reducing their bearing capacity and operational reliability [8]. Characteristic structural damage is the destruction of a protective layer of concrete with lamellar corrosion of reinforcement in monolithic reinforced concrete structures of the framework, through cracks opening up to 12 mm and weathered masonry in load-bearing and self-supporting exterior brick walls due to the absence of reinforcement of masonry, deformation of foundations, systematic soaking.

Based on the data obtained when leveling the above-ground structures, it was revealed that the surveyed building received vertical deformations up to 190 mm along one of the end axes. Significant differences in elevations indicate uneven deformations of the soil base [9,10]. This is due to the soaking of soils in the process of long-term operation, caused by the periodic rise of the groundwater level, violation of the drainage of surface water from the walls of the building, the absence of a blind area around the building's perimeter. Significant damage (cracks in the upper zone), caused by uneven deformations of the soil base, were obtained by continuous crane beams in the end steps. The place of occurrence of cracks (in a quarter of the span from the extreme column of the frame) corresponds to the place where the upper reinforcement breaks above the support. The technical condition of the crane girders is assessed as limited and efficient, it is required to take measures to restore and strengthen weakened and defective building structures.

### 4. Analysis of the technical condition

Analysis of the technical condition of industrial buildings built in 1920-1930, calibration calculations of load-bearing structures lead to the conclusion that the supporting elements of the frame, made of monolithic reinforced concrete structures, have, in general, sufficient bearing capacity, if they were not subjected to mechanical and significant corrosion damage. The reinforcement of the monolithic elements of the frame is made, as a rule, of reinforcing rods of large diameter (20–32 mm) with
durability corresponding to class A240. To preserve the bearing capacity of columns, crossbars, coating beams, it is sufficient to restore the protective layer of concrete, inject the cracks. Precast concrete crane girders, on many of the objects surveyed, were replaced with metal ones. The surviving monolithic reinforced concrete crane girders over the years of operation were significantly damaged, repeatedly repaired, strengthened, but can be used after the repair work has been completed. Enclosing structures (for example, coating on a corrugated sheet with a reed mat insulation), self-supporting brick walls have become inoperable or partially operational and require repair and replacement.

References
[1] Kuznetsova G F(ed.) 1935 Reference Designer industrial structures, vol. IV, Reinforced concrete structures (Moscow-Leningrad) p 796
[2] Serk L A 1939 The course of architecture. Civil and industrial buildings. Vol. II. Structural schemes and elements of civil construction (Moscow: Gosstroyizdat) p 440
[3] Subbotin A I, Shmatkov V V, Pavlyushchik S A, Skibin M G 2007 Inspection of the technical condition of the instrumental building of LLC "PC" NEVZ "in Novocherkassk Information technologies in the survey of buildings and structures in use: materials of the VII International scientific-practical conference (Novocherkassk: SRSTU) p 69–75
[4] Rak V I, Yakimenko I V, Gontarenko I V 2013 Strengthening of crane girders in the span of the bonneting section in the axes of L-M JSC "Combine plant "Rostselmash" in the city of Rostov-on-don. Defects of buildings and structures. Strengthening of building structures: materials scientific.-method. Conf. VITU (SPb) pp 136–142
[5] Rak V I, Kozhikhov A G, Yakimenko I V 2014 Typical defects and damages of reinforced concrete structures of frame industrial buildings "Construction-2014" Modern problems of industrial and civil construction: materials international. science.-prakt. Conf. (Rostov n/D: RGSU) pp 45–47 http://www/rgsu.ru/upload/medialibrary/f99
[6] Morgunov V N, Galashev Y V, Skibin G M 2014 Al Kabir Khaki Hadi Abd. Inspection of a technical condition of buildings of loading small concentrate processing factory in the city of Zverevo of the Rostov region Information technology in the inspection of buildings and structures: proceedings of the XIV Intern. science.-prakt. Conf. (Novocherkassk: URGPU) pp 112–118
[7] Rak V I, Kozhikhov A G, Yakimenko I V 2014 Typical defects and damages of reinforced concrete structures of frame industrial buildings "Construction-2014" Modern problems of industrial and civil construction: materials international. science.-prakt. Conf. (Rostov n/D: RGSU) pp 45–47 http://www/rgsu.ru/upload/medialibrary/f99
[8] Manual on the inspection of building structures 1997 JSC "CRI OF INDUSTRIES" (Moscow)
[9] Recommendations for assessing the reliability of building structures on external signs 2001 AO "CRI OF INDUSTRIES" (Moscow)
[10] GOST 31937-2011 Buildings and structures. Rules of inspection and monitoring of technical condition
[11] GOST R 54257-2010 Reliability of building structures and bases. Fundamentals