Measures to improve the performance of concrete of reinforced concrete supports of technological overpasses

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Abstract. The paper presents the process of assessing the technical condition of reinforced concrete supports of existing technological overpasses, gives their characteristics, shows the defects found in the process of assessing the technical condition. The article describes the monitoring of concrete strength by the non-destructive method of elastic rebound using the Digi Shmidt 2000 device and the determination of the thickness of the concrete cover and the location of reinforcement by the magnetic method using the Profometer-5S device. We determined the layout of the working reinforcement in the reinforced concrete supports of the overpasses’ sections. We present the results of verification calculations of the structures of the technological overpasses, taking into account the revealed defects and damages, the strength of materials and the specified actual loads. We give recommendations for improving the performance of the concrete of the reinforced concrete supports of the overpasses.

1. Introduction
Technological overpasses are modern engineering structures with many identical spans and columns. Such overpasses are installed with the aim of placing technical communications above the ground, bypassing already occupied territories in a settlement or existing traffic flows. Over time, in the course of operation, it becomes necessary to lay new pipelines and, accordingly, to assess the technical condition of the overpasses.

The purpose of the work is to assess the technical condition of reinforced concrete supports of existing technological overpasses of an industrial enterprise for further reliable operation, taking into account their bearing capacity with new technological pipelines.

2. Characteristics of the overpasses
The general view of the overpass under study is shown in figure 1. The intermediate supports of the technological overpass section are made free-standing, reinforced concrete. The posts of the supports are made of rectangular section 400×500 mm. Supports No. 2852, No.123, No.124 and No.125 are reinforced with steel rings. The rings are made of equilateral angles 90×8 mm and plates –...
Anchor supports No. 123, No. 126, No. 131, No. 135-136 and No. 138-139 of the second section of the overpass are spatial structures. The posts of the anchor supports are interconnected by means of cross bracings and distance bars [1, 2, 3, 4]. The bars of the anchor supports are made of paired steel angles ∟100×10 mm, ∟110×8 mm, and the bracings are made of paired equilateral angles ∟75×6 mm and ∟90×8 mm.

The structure has socket-type footing made of monolithic reinforced concrete for the reinforced concrete stand-alone supports. The foundation at the base has a size of 3.2×6.45 m. The foundations are made with two steps. The height of the steps is 400 and 500 mm, respectively. The socket-type footings have a rectangular cross-section of 1.2×4.25 m. The depth of the footing base from the ground surface is 2.600 m and 3.000 m, respectively [5, 6, 7, 8].

The upper and lower chords, diagonals and vertical web members of the steel girders are made of paired steel angles. The connection of the girder elements is carried out by welding, gussets and inserts. On the upper and lower chords of the girders, cross-shaped bracings are made of equilateral angles ∟63×6 mm. Spans of the second tier are made in the form of transverse frames. The frame ties are made of steel equilateral angles ∟125×10 mm. On the top of the frames, cross bracings are made of equilateral angles ∟63×6 mm. The support of the ties is carried out in the joints onto the upper chord of the girders of the lower tier [9, 10, 11, 12].

3. Reinforced concrete supports of the overpasses

The assessment of the technical condition of load-bearing reinforced concrete structures based on external features was carried out according to the method [13, 14, 15, 16].

The main destruction and damage detected visually was the destruction of the protective layer of concrete, exposure and surface corrosion of reinforcement (figures 2, 3).

Indicators of strength and homogeneity of the concrete of the reinforced concrete structures of the overpasses were controlled by the non-destructive method of elastic rebound using a Digi Shmidt 2000 device according to [17, 18, 19, 20]. The coefficient of variation of strength, determined to assess the homogeneity of concrete, was calculated by the method [21, 22, 23, 24].

The concrete strength and homogeneity were monitored with a Digi Shmidt 2000 device for the reinforced concrete foundations and overpass supports. The number of tests at each site, the distance between the test sites was taken 10, in accordance with the requirements of clause 4.4 [17]. The concrete strength values are given in table 1. Based on the results of the concrete tests, we established that the class of concrete for determining the compressive strength of a reinforced concrete foundation is B12.5, and the class of concrete for determining the compressive strength in prefabricated reinforced concrete supports corresponds to B20.

Magneto metric studies were carried out to determine the thickness of the concrete cover and the scheme of reinforcement of the load-bearing reinforced concrete structures of the overpasses.

To determine the location of reinforcement made of steel rods and the thickness of the concrete cover, we used the Profometer-5S device and the magnetic method according to the method described in [25, 26, 27, 28]. Also, we carried out control openings of working reinforcement in the reinforced concrete structures of the overpasses. The layout of the working reinforcement in the reinforced concrete supports of the overpass section is shown in figure 4. We performed all verification calculations by certified software products "Lira-Sap 2013 PRO". We carried out the calculation according to the requirements [29, 30, 31, 32]. One of the ways to repair supports is to strengthen them with cases (figure 5).

We carried out verification calculations of the structures taking into account the identified defects and damages, the strength of materials and the specified actual loads. For load-bearing elements with corrosive wear, the calculated cross-section is taken from the results of measurements in places free of corrosion products.

In accordance with section 8.3.11 [33, 34, 35, 36], it is assumed that the standard load from the weight of working personnel and repair materials on platforms, bridges and ladders is 750 Pa and is assumed to be uniformly distributed.
Table 1. Strength of the concrete of the reinforced concrete supports of the overpasses.

| No | Sclerometer reports | Mean square deviation | Average strength of the concrete, MPa | Actual coefficient of variation | Concrete class, B |
|----|---------------------|-----------------------|--------------------------------------|---------------------------------|------------------|
|    |                     |                       |                                      |                                 |                  |
| 1  | 18.0                |                       |                                      |                                 |                  |
| 2  | 28.0                | 1.49                  | 28.0                                 | 0.05                            | 19.7             |
| 3  | 28.0                | 1.65                  | 28.4                                 | 0.06                            | 19.8             |
| 4  | 27.0                |                       |                                      |                                 |                  |
| 5  | 29.0                |                       |                                      |                                 |                  |
| 6  | 30.0                |                       |                                      |                                 |                  |
| 7  | 26.0                |                       |                                      |                                 |                  |
| 8  | 26.0                |                       |                                      |                                 |                  |
| 9  | 29.0                |                       |                                      |                                 |                  |
| 10 | 28.0                |                       |                                      |                                 |                  |

Reinforced concrete foundations of the supports

| No | Sclerometer reports | Mean square deviation | Average strength of the concrete, MPa | Actual coefficient of variation | Concrete class, B |
|----|---------------------|-----------------------|--------------------------------------|---------------------------------|------------------|
| 1  | 18.0                |                       |                                      |                                 |                  |
| 2  | 20.0                |                       |                                      |                                 |                  |
| 3  | 20.0                |                       |                                      |                                 |                  |
| 4  | 20.0                |                       |                                      |                                 |                  |
| 5  | 24.0                | 2.87                  | 20.7                                 | 0.14                            | 12.1             |
| 6  | 25.0                |                       |                                      |                                 |                  |
| 7  | 22.0                |                       |                                      |                                 |                  |
| 8  | 22.0                |                       |                                      |                                 |                  |
| 9  | 21.0                |                       |                                      |                                 |                  |
| 10 | 15.0                |                       |                                      |                                 |                  |

Reinforced concrete supports

| No | Sclerometer reports | Mean square deviation | Average strength of the concrete, MPa | Actual coefficient of variation | Concrete class, B |
|----|---------------------|-----------------------|--------------------------------------|---------------------------------|------------------|
| 1  | 18.0                |                       |                                      |                                 |                  |
| 2  | 20.0                |                       |                                      |                                 |                  |
| 3  | 20.0                |                       |                                      |                                 |                  |
| 4  | 20.0                |                       |                                      |                                 |                  |
| 5  | 22.0                |                       |                                      |                                 |                  |
| 6  | 20.0                |                       |                                      |                                 |                  |
| 7  | 21.0                |                       |                                      |                                 |                  |
| 8  | 20.0                |                       |                                      |                                 |                  |
| 9  | 20.0                |                       |                                      |                                 |                  |
| 10 | 20.0                |                       |                                      |                                 |                  |

Reinforced concrete supports
Table 2. Continues. Strength of the concrete of the reinforced concrete supports of the overpasses.

| No | Sclerometer reports | Mean square deviation | Average strength of the concrete, MPa | Actual coefficient of variation | Concrete class, B |
|----|---------------------|-----------------------|---------------------------------------|---------------------------------|------------------|
|    |                     |                       |                                       |                                 |                  |
|    | Reinforced concrete supports                                  |                       |                                       |                                 |                  |
| 1  | 25.0                |                       |                                       |                                 |                  |
| 2  | 32.0                |                       |                                       |                                 |                  |
| 3  | 30.0                |                       |                                       |                                 |                  |
| 4  | 30.0                |                       |                                       |                                 |                  |
| 5  | 26.0                | 2.46                  | 29.5                                  | 0.08                            | 19.5             |
| 6  | 32.0                |                       |                                       |                                 |                  |
| 7  | 28.0                |                       |                                       |                                 |                  |
| 8  | 30.0                |                       |                                       |                                 |                  |
| 9  | 30.0                |                       |                                       |                                 |                  |
| 10 | 32.0                |                       |                                       |                                 |                  |

Figure 1. General view of the surveyed overpass.

Figure 2. Type of damage to the concrete cover, exposure and corrosion of the reinforcement in the posts of the reinforced concrete supports.

Figure 3. View of damage to the concrete cover, exposure and surface corrosion of the reinforcement of the posts of the reinforced concrete supports.
Figure 4. Layout of the working reinforcement in the reinforced concrete supports of the overpass section.

When calculating external influences on the supports of overpasses, the temperature difference is taken into account, considering the climatic effect, wind loads, loads from the branch of pipelines, vertical load from the dead weight of the pipeline as a structure, and snow.

When entering the initial data, we specified the design loads. In this case, the loads are divided, depending on the type of loads and safety factors for loads.

The building responsibility level according to [37, 38, 39, 40] is II - normal. Figure 6 shows a general view (diagram) of the overpass. The general condition of the overpass structures was assessed in accordance with [41, 42, 43, 44]. Some calculation results are shown in figure 7. When performing the work, we used research materials [45, 46, 47, 48] on the example of the use of information technologies for solving technical problems [49, 50, 51, 52, 53].

Figure 5. View of the cases of the reinforced concrete supports.

Figure 6. General view of a fragment of the overpass.
4. Conclusion

Based on the results of the verification calculations, we found that the elements of the girders of the span structures do not have a deficit in the bearing capacity in the first group of limiting states. Calculation of the supports of the technological overpasses in all sections did not reveal any deficiencies in the bearing capacity.

The results of the reliability calculation showed that it is necessary to carry out an overhaul of the building structures of the overpasses in the shortest possible time.

Dispersed reinforcement can be recommended to improve the performance of the concrete of the reinforced concrete supports of the overpasses.

Taking into account the unfavorable factors that are present during the operation of the overpass supports (high humidity, high temperature, vibration loads, the aggressiveness of the working environment), the use of dispersed reinforcement will make it possible to more effectively resist these factors [45].

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