Application of a Software and Hardware Complex to Improve the Operational Reliability of Water Pipelines

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Abstract. This article discusses the issues of using a software and hardware complex to improve the operational reliability of water supply pipelines. The use of a software and hardware complex allows us to automate operational monitoring, and most importantly, significantly speed up the inspection of water supply pipelines for defects and damage by non-destructive testing methods, detect decompression and subsidence of soil around them. With its help, it is possible to characterize various parameters of defects and damages, as well as calculate the predicted residual life of their elements, and the geometric parameters of each defect, namely, the location, depth, width, height, as well as the operational assessment of the residual life, which consists in predicting the total number of freezing and thawing cycles that have passed during the period of operation and remained until the loss of bearing capacity of reinforced concrete elements of water pipelines.

1. Introduction

Water supply pipelines have a large margin of safety, but a number of negative factors, such as non-compliance with construction technology, a lack of geological and hydrological features of the route of the water supply channel during the design, as well as improper operation during the operation of the channel, to some extent reduces the effectiveness of water-permeable properties of the reinforced concrete lining of main channels. The problem of long-term operation of such structures is the lack of knowledge of processes occurring during its time, which makes it necessary to monitor the waterproofness of such structures in case of possible violations of the integrity of concrete coating and formation, various decompressions and voids [1].

2. Materials and methods

The software and hardware complex for improving the operational reliability of water supply pipelines is designed to determine various parameters of defects and damages, as well as calculate the predicted residual life of their elements. The software and hardware complex for improving the operational reliability of water supply pipelines [2] is used for operational monitoring of the technical condition of reinforced concrete water supply pipelines located in the ground, identifying dangerous defects and damage, as well as evaluating and predicting their technical condition and further suitability for operation [3].

Fig. 1 shows the technical part of the software and hardware complex for improving the operational reliability of water supply pipelines, including a stop 6, which is attached to the walls of the water...
supply pipeline 7 with the help of fixing screws and moves the frame 3 with rubber wheels 1 inside the pipeline 7 located in the ground 8 with the help of a telescopic rail 5 [4]. Data from the motion sensor 4 and antenna blocks 2 are sent to the processing unit, where data processing takes place, and an assessment of the technical condition of elements for defects and damage, as well as the surrounding soils 8 for the formation of decompression and subsidence, and a detailed decoding of the data obtained from the antenna blocks and positioning of the location of defects and damage using the GLONASS navigation system [5] takes place.

**Figure 1.** The technical part of the software and hardware complex for improving the operational reliability of water supply pipelines: 1-rubber wheels; 2-antenna blocks; 3-frame; 4-motion sensor; 5-telescopic rail; 6-stop; 7-water supply pipeline; 8-ground base.

The survey zones include [6]: zone 1 – is examined for defects and damage to the destruction of the bottom part of the water supply pipeline and subsidence of the underlying soil base; zone 2 – is examined for the formation of longitudinal and oblique cracks; zone 3 – is examined for the formation of transverse cracks and soil decompression, zones are assigned along the entire length of the water supply pipeline, each with a width equal to 30 % of the perimeter [7].

The use of the software and hardware complex to improve the operational reliability of water supply pipelines allows us to automate operational monitoring, and most importantly, significantly speed up (up to 5 times) the inspection of water supply pipelines for defects and damage by non-destructive testing methods, detect decompression and subsidence of the soil around them. Together, all this allows us to reliably assess the technical condition of water supply pipelines [8].

A comparative analysis of monitoring of various main channels showed that during construction, the slopes in some cases were not properly aligned and compacted, and therefore, due to subsidence of the soil base, voids of various shapes were formed under individual slabs, which can easily be determined by tapping. In such cases, the plates hung up and, due to their loose fit to each other, filtration through damage significantly increased [9, 10, 11].

During the inspection of right and left slopes of water supply channels, it was found that the sealing of joints between the reinforced concrete slabs was of poor quality. Cracks were formed on each longitudinal construction seam along its entire length, and they were found every 10-15 cm on the transverse seams. During the visual inspection, a number of other violations in the concrete lining were also detected, namely, the opening of the reinforcement, cracks in the plates, violation of the shape of plates, bulge and their displacement.

Based on the survey, the main types of possible violations of protective concrete coatings, destruction of the deformation seam, formation of straight, oblique, smooth and rough cracks in the coating plate, in combination with damage to the solid polyethylene screen, holes, punctures and cracks were identified [12].
In the future, geo-radar sounding and measurement of the concrete strength of water supply pipelines in normal and unsatisfactory operational conditions were performed using a software and hardware complex to increase the operational reliability of water supply pipelines [13, 14]. Fig. 2 shows the profile No. 51 passing along the bottom of the water supply pipeline, which is in an unsatisfactory condition, including 6 reinforced concrete rings, where voids have formed under rings No.1 and 4 and where water seeps due to the destruction of the joint between the rings, which can lead to subsidence of the hydraulic structure. The destruction of the joint is clearly visible between rings No.1 and 2.

![Figure 2. Profile No. 51 at the bottom of the water supply pipeline.](image)

In Fig. 3, the voids formed on top of ring No.9 are visible, the ring No.11 on the contrary is in a satisfactory condition, the reinforcement mesh is clearly visible, there are no sinks and cracks in the concrete surrounding it. Profile No. 52 passing along the top through the entire water supply pipeline, including 16 reinforced concrete rings, demonstrates its technical condition [15, 16]. The destruction of the joint between the rings, rings No.1 and 2, No.2 and 3, No.5 and 6, etc., is clearly visible, the destruction occurs, and the protective layer of concrete is loosened, shells and concrete corrosion are formed in the places where the rings come into contact with the base of the channel.

![Figure 3. Profile No. 52 on the top of the water supply pipeline including 16 reinforced concrete rings.](image)

Next, Figure 4 shows the profile No.53, which runs along the top of the water supply pipeline including 16 reinforced concrete rings [17]. The resulting voids and violations of the butt joints between the rings were isolated. It can be seen that shells have formed at the junction between No.9 and 10 rings and concrete corrosion occurs, and rings No. 4,5 and 12 have formed voids and the reinforcement mesh is exposed and corroded.
3. Conclusion

Automation of monitoring of the technical condition of reinforced concrete rings of the water supply pipeline produced by the software and hardware complex has shown that it is possible to identify characteristic defects and damages that are not visible during visual inspection of the elements of the structure. So, using the example of profile No. 53, rings that are in unsatisfactory condition are identified - No. 5, 10 and 12 require repair, and No. 3, 7 and 13 are in normal operational condition. On the ring No. 10, the reference points of the reinforcement are visible, as they are displaced or absent. Voids were formed under the ring No. 12, as well as the detachment of the concrete protective layer and its corrosion.

The presence of these damages after a long service life of the water supply pipeline is due to the imperfect technology of production and construction and installation works.

4. References

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