A study of the soil base of water canals of reclamation systems

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Abstract. The article discusses the issues of improving the methods of studying the soil base of long-term operating water-conducting canals of reclamation systems. The observation system involved the profile shooting. In order to determine the actual state, the soil base was examined using the shock pulse method, an electronic strength meter. The measurement sites were linked to GPR surveys to determine the strength of each structure at the characteristic points of the profiles. In the field studies, defects and damage to the soil base of the water-conducting canals of the reclamation systems were revealed. In the study of the soil base, non-destructive testing devices are used to assess the technical condition of water canals objectively without additional damage, to identify defects and damage and determine geometric parameters. The soil base study can make short-term, medium-term and long-term forecasts of the state of the structure and reduce the likelihood of emergencies. When using this approach, it becomes possible to substantiate the parameters of defects and damage to the subgrade, which cannot be established by visual inspection.

1. Introduction

Rostov region is one of the ten Russian leaders by the volume of fresh water consumption. In 2015-2020, the annual water intake was 2.2 billion m³ (537.9 m³/person, the Russian average was 415 m³/person) [1]. The volume of discharge of polluted wastewater into surface natural water bodies is quite high. In 2015-2020, it varied from 255 million m³ to 282 million m³ per year (11-12 % of the water intake) [2].

There are 1806 potentially hazardous hydraulic facilities in Rostov region. Many hydraulic facilities lack maintenance services. Over the past 20 years, the technical condition of hydraulic facilities has degraded. As of January 1, 2010, 278 hydraulic facilities were included in the Russian register [3], of which only 20 hydraulic ones (7.2 %) had an approved safety declaration. An analysis of the safety level for a sample of 391 hydraulic facilities showed that the normal safety level was 26.9 %, the reduced one - 31.5 %, the unsatisfactory one - 24.8 %, and the dangerous one - 7.4 % [4].

In 2021, the Rostovmeliiovodkhoz company owned 228.5 thousand hectares of irrigated land on which 2500 hydraulic facilities were located. None of the potentially dangerous hydraulic facilities had operation certificates [5].

This year, the hydraulic facility installed on the watering and irrigation systems of the Don Main Canal marks the 65th anniversary. In the 1950s, it was planned that the irrigated areas of Rostov region on the basis of the Tsimlyansk reservoir, would reach 600 thousand hectares, of which 170
thousand hectares were to be irrigated by gravity, and 430 thousand hectares - with the help of a machine water lift. The area of lands watered by the Don river was supposed to be 2 million hectares [6].

The most important hydrotechnical facilities in Rostov region include hydraulic facilities of the Tsimlyansk reservoir, the Rostov nuclear power plant, the Konstantinov, Kochetov, Nikolaev, Proletarsk, and Veselov hydrosystems [7], navigational locks 14 and 15 of the Tsimlyansk hydroelectric complex, hydroelectric stations 1-7 of the Severo-Don lock systems, hydraulic facilities of the Salsk, Rostov, Remontensk, Krasnopartizansk, Sokolov, Voloshin, Efremov, Glinsk reservoirs, hydraulic facilities of the Don canal, structures for engineering protection of cities and populated areas.

On the Temernik river with a total length of 35.5 km, 23 hydraulic facilities are located (Verkhovoe, Nizovoe reservoirs, Rostov Sea, etc.) [8].

The number of ownerless hydraulic structures located is high (946), 89.7 thousand inhabitants of the region live on the territory exposed to the negative impact of water [9].

The problems of safety of hydraulic facilities are due to their long service life (more than 40-50 years) and a low residual resource. Investment into the hydraulic facilities is insufficient. Reservoirs and ponds on small rivers are located in a cascade, which increases the risk of accidents. Other problems are low-skilled personnel, a high number of orphaned hydraulic structures.

Currently, insufficient and reluctant funds are invested to improve the safety level of federal hydraulic facilities - Rostov nuclear power plant (owned by Rosatom), Rostovmeliovodkhoz "(owned by the Ministry of Agriculture of Russia), Azov-Don state basin management waterways and shipping, Volga-Don State Basin Administration of Waterways and Shipping, etc. [10].

In 1997, Federal Law No. 117-FZ "On safety of hydraulic facilities" was adopted. In European countries, these laws were adopted 100 years ago. Federal Law No. 117 had a positive impact on the protection of economic facilities and the population, but the risk of accidents is significantly higher than the world average. The Government of the Russian Federation aimed to reduce the share of hydraulic facilities with an unsatisfactory and dangerous level of safety by 5.5 times.

To assess the soil base of long-term operating water supply canals in Rostov region, the protection of the population and economic facilities, it is necessary to prioritize the implementation of monitoring systems for water facilities at the design, construction, reconstruction and operation stages.

2. Materials and methods

In studying the soil base of water canals, the non-destructive testing methods combined with the ultrasonic and shock pulse methods were used [11].

During the survey of the soil base, the degree of physical wear and and its causes, performance of the elements, measures aimed to improve various operational parameters and technical conditions are studied.

In the visual inspection, one should pay attention to external features of the soil base of water canals. At this stage, it is possible to classify the degree of destruction by external features of a structure element. To determine the actual state of the structure, namely the size of defects, the degree of losses of bearing capacity cased by the freezing and thawing cycles is studied [12].

The durability of reinforced concrete elements of water canals is affected by the size of the protective layer of concrete and its defects - cavities, pores, cracks, etc. The protective layer protects the reinforcement from moisture, oxygen, corrosive substances and gases. Reinforcing rods with a small protective layer or significant defects cause corrosion [13].

The results processing are presented in the figures. Figures 1 and 2 show a fragment of the GPR sounding along the axis of the soil base of the water canal [14], which includes 7 reinforced concrete linings, where the canal section was examined for characteristic defects and damage. Figure 1 shows cavities and concrete delamination on slabs 4, 5 and 7 cracks at the joint between slabs 4 and 5 [15].
We have developed a survey system for the soil base of main canals of irrigation systems saturated with siphons, aqueducts, hydraulic tunnels, flumes, pipes, and varius regulators [16]. The system includes the following subsystems: instrumental information collection [17]; assessment of the subgrade, stress-strain state of elements made of concrete, reinforced concrete, metal, wood and composite materials; hydraulic, hydrodynamic and filtration modules; assessment of the residual resource of the bearing capacity of structures; issuance and accumulation of information in time [18].

Figure 1. Profile 1 along the soil base axis for the water canal, including seven reinforced concrete linings

Figure 2. Profile 1 along the soil base axis for the water canal, including seven reinforced concrete linings

Figure 3 shows profile 2 along the canal axis, which includes five reinforced concrete linings; slabs 2 and 4 are in a satisfactory condition, the reinforcing mesh is visible, there are no cavities and cracks in the concrete surrounding it. Slab 3 is in an unsatisfactory condition, the destruction occurred [19], and as a result of decompaction of the protective layer of concrete, pits and concrete corrosion develop at the points of contact between the slab and the subsoil.

Figure 3. Profile 2 along the soil base axis for the water canal, including five reinforced concrete linings with an reinforcement
To obtain complete data, georadar sounding was performed along the width of the soil base of the water canal, namely, along its walls as elements that are the most susceptible to destruction. Figure 4 shows profile 3 along the width of the soil base of the water canal, which includes four reinforced concrete linings [20]. The mixing of the dielectric capacity layers in the profile middle is visible, where the protective concrete layer degrades both from the outside and from the place of support of the slab on the base due to the penetration of water and reinforcement corrosion.

![Figure 4. Profile 3 along the width of the soil base of the water canal, including four reinforced concrete linings](image)

Figure 5 shows profile 4 along the width of the soil base of the water canal, which includes 5 reinforced concrete linings. Slabs 3 and 4 contacting with water are out of order and require immediate replacement. One can see reflections from the reinforcement, which is displaced and the reinforcement mesh is broken [21]. The profile runs along the root base of the water canal at the point of contact with water. There are voids and broken butt joints between the slabs. At the junction of slabs 3 and 4, there are cavities and concrete corrosion, and slab 6 has a longitudinal crack due to the base subsidence. The reinforcement mesh is exposed and corroded.

![Figure 5. Profile No. 4 along the width of the soil base of the water canal, including five reinforced concrete linings](image)

The soil base of the water canal is assessed by the non-destructive methods. The assessment showed that it is possible to identify defects and damage that are not visible during the visual inspection of structure elements. Using profile 4, slabs 2 and 3 that were in an unsatisfactory condition required immediate replacement, and slabs 1 and 4 were in a normal operating condition [22].

Timely detected defects and damage to the soil base contribute to the normal operation of the structure.

After conducting the visual technical inspection of the soil base and using the non-destructive control devices, the observation materials were analyzed, causes of defects were identified, and their impact on the technical condition of the structure was assessed.
3. Conclusion
Some Russian regions have already adopted targeted programs for monitoring water facilities. This program has been adopted in Krasnodar region. In 2021, 43.76 million rubles were allocated to implement this program. In 2022, 38.16 million rubles will be allocated, and in 2023 - 53.76 million rubles. Rostov region needs this program as well.

The conclusion based on the soil base survey results should include a textual part, survey diagrams, drawings, and applications.

The textual part should contain:
1) an introduction, which indicates an object, a purpose, execution time, a basis for conducting surveys, general information about the structure, history of construction and operation;
2) a brief description of the design solutions of the object surveyed;
3) information about the soil base, defects and damage and their causes, and technical conditions;
4) conclusion about the state of elements of the soil basis, their possible applications, recommendations for eliminating defects, ensuring the durability of facilities and observing their state [3].

The survey should include the following stages:
- preparation of the soil base survey;
- visual inspection of the soil base;
- soil base inspection with non-destructive testing devices;
- analysis of survey materials

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