Problems and prospects of using mobile devices when performing operational monitoring of water supply structures

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Abstract. This article presents the results of work on a mobile device for conducting operational monitoring of the technical condition of water supply structures, designed to determine various parameters of defects and damages, as well as calculate the projected remaining life of their elements. The modern development of mobile devices, network computer technologies, cellular communication and mathematical methods opens up new prospects in the automation of operational monitoring of water supply structures. The technical part of the mobile device for conducting operational monitoring includes various technical schemes of frames for each water supply structure separately. It can be used for conducting operational monitoring of the technical condition and determining the remaining life of the protective coating of water supply channels and soils under them, identifying dangerous defects and damages, as well as evaluating and predicting its technical condition and further suitability for operation. The technical result achieved by this mobile device is to identify the influence of defects and damages, both of the protective coating itself and the condition of the soil located under it, on the formation of decompressions and subsidence at an early stage of their formation. The mobile device is developed using the Data Mining database management system and Microsoft Access. The use of a mobile device makes it possible to improve the quality of operational monitoring of water supply channels due to the fact that the survey is carried out over the entire cross-section of the water supply channel for defects, damages, decompression and subsidence of the soil under the structure by non-destructive testing methods. And the presence of a vehicle that transports the complex allows you to speed up significantly the survey of water supply channels.

1. Introduction
The modern development of mobile devices, network computer technologies, cellular communication and mathematical methods opens up new prospects in automation of operational monitoring of water supply structures [1]. Until now, Russia has not had an operational, reliable, cheap universal digital technology for effective operational monitoring of water supply structures. The proposed mobile device for carrying out operational monitoring of the technical condition of water supply structures is designed to determine various parameters of defects and damages, as well as calculate the projected remaining life of elements of hydraulic structures [2]. Your mobile device allows you to assess the
geometric parameters of each defect, an operational residual life assessment (prediction of the total number of cycles of freezing and thawing as the past operating period, and remaining until the loss of bearing capacity of reinforced concrete elements of water conveyance structures) and the complex influence of several factors on the reliability of structures [3], the most characteristic ones of which are abrasion, leaching, wear in areas with different hydraulic characteristics.

Here are a number of new features of modern mobile devices [4–6]: collecting and transmitting data from sensors without a computer using mobile communication media that has access to the global Internet;

– collecting data on the state of water supply structures using web cameras to analyze differences between the current image and previously taken images [7];

– placement of data analysis and management programs on a computer network server outside of water supply facilities;

– data analysis using Data Mining and Microsoft Access (DBMS) methods [8], a method of group accounting of arguments that allows you to identify behavior patterns and create models of property change dynamics;

– creating virtual models of water supply structures, organizing continuous monitoring of measurement results and modeling results, using models to predict the state of structures.

The results of visual observations and field studies were used as initial data when creating a complex of operational monitoring of the technical condition of water supply structures [9]:

– results of visual inspection of water supply structures with identification of characteristic damage to individual elements;

– geometric parameters of damage obtained using non-destructive monitoring devices [10].

2. Materials and methods

As a result of numerical experiments there were identified zones of hydraulic structures that may contain the same types of characteristic damage, which makes it possible to streamline the process of laying GPR profiles, determining the points where it is necessary to measure the strength of concrete during field surveys.

To perform the necessary calculations of the technical condition, the mobile device has an information and reference database on hydraulic structures operated on the territory of Russia [11].

The technical part of the mobile device of operational monitoring includes various technical schemes of frames of each hydraulic structure separately and can be used for operational monitoring of the technical condition and determining the remaining life of the protective coating of water supply channels and soils under them, identifying dangerous defects and damages, as well as evaluating and predicting its technical condition and further suitability to operation.

3. Results

The technical result achieved by the mobile device is the detection of defects and damages, both of the protective coating itself and the condition of the ground base located under it, for the formation of decompressions and subsidence at an early stage of their formation [12]. This technical result is achieved by the fact that the mobile device for conducting operational monitoring contains a mover for free movement along the bottom of the water supply channel with an operator with a processing module located in it, and the frame consists of rods and consists of three parts connected by hinges [13].

Figure 1 shows the technical part of a mobile device for conducting operational monitoring in an axonometric projection, which includes a frame 1 consisting of rods that repeat the shape of the water supply channel and consists of three parts connected by hinges 2 with rubber wheels 3, a processing module that includes the GLONASS system 4, a motion sensor 5, and antenna blocks 6 located along the perimeter of the frame 1 [14].
Figure 1. Mobile device for performing operational monitoring and determining the remaining service life for channels

For operational monitoring, the technical part of the mobile device is placed in the water supply channel in the absence of water, after which power is supplied to the processing module 4, which confirms the readiness of all systems for operation. With the help of the mover 7, the frame 1 moves along the water supply channel and data from the motion sensor 5 and antenna blocks 6 are sent to the processing module 4, where the data received from the antenna blocks is detailed and the location of defects and damages is positioned using the GLONASS system [15]. Using classical solutions of the theory of elasticity, according to the known angular displacement can be calculated from the spatial displacement. Moreover, the recalculation program can be located on a remote server of a computer network and serve any number of sensors located even on several objects [16].

The use of a mobile device makes it possible to improve the quality of operational monitoring of water supply channels due to the fact that the survey is carried out over the entire cross-sectional area of the water supply channel (the entire area of the structure is covered) for defects, damage, decompression and subsidence of the soil under the structure by non-destructive testing methods, and the presence of a vehicle that transports the complex can significantly speed up the survey of water supply channels [17].

The technical part of the mobile device can be used to conduct operational monitoring and determine the remaining life of the protective coating of water supply pipelines, storm drains and soils under them, as well as to conduct operational monitoring of reinforced concrete pipelines located in the ground, identify dangerous defects and damage, assess and predict their technical condition and further suitability for operation.

Before starting work at the entrance to the water supply pipeline, the operator attaches the stop 6 with fixing screws to the walls of the pipeline 7, and then, using a telescopic rail 5, moves the frame 3 with rubber wheels 1 inside the pipeline 7, located in the ground 8 (Fig. 2). Data from the motion sensor 4 and antenna blocks 2 are sent to the processing unit, where data is processed, the technical condition of the elements is evaluated for defects and damage, as well as the surrounding soil 8 to the formation of decompression and subsidence, 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 [18].
Figure 2. Mobile devices for operational monitoring and determination of the remaining life of the robot capacity of rainwater drainage structures

Software of the mobile device is based on natural research of a technical condition of hydraulic structures, data obtained by testing the water resistance of concrete and data of concrete abrasion, as well as information obtained during the testing of structural properties of concrete samples to cyclic freezing and thawing.

A generalization and analysis of the results of studies of the state of long-term water supply structures in order to determine their residual resource of their working capacity is performed. Reinforced concrete water supply structures are most often destroyed by leaching. The relatively high filtration coefficient, high porosity, and flow pressure determined the filtration of water through concrete. To calculate the time of safe lime leaching during water filtration through the concrete lining there were studied the filtration conditions, the thickness of the structure and the filtration coefficient of the concrete lining were determined [19].

The filtration coefficient of concrete of monolithic linings of water supply channels is determined. Water resistance of concrete is estimated by reducing the strength under water saturation and is characterized by a softening coefficient that expresses the ratio of the strength of water-saturated concrete to the strength of dry concrete. But such studies were not conducted, since the reduction in the strength of concrete is insignificant and will not affect the load-bearing capacity of the structure.

A generalized analysis of the results of studies of the state of long-term water supply structures is performed to determine their residual resource of resistance to cyclic freezing and thawing. On the basis of local empirical dependences of the loss of strength characteristics of structural structures on the cycles of freezing and thawing, the mathematical support of a mobile device was formed in the format of a calculation model of the structure as a whole. This allows calculating the behaviour of defects and damage to water supply structures under the further influence of cyclic freezing and thawing [20].

The degree of accident risk of elements of water supply structures (small – k≤0.15; obtained using non-destructive testing devices) was also evaluated, moderate – k=0.16...0.30; large – k=0.31...0.50; emergency – k>0.51).

Information about the state of the water supply system is evaluated by a variety of criteria. If the quantitative value of each local criterion falls within a certain range of values, we can make a conclusion about the state of the structure. Taking into account the multiplicity of criteria, it is advisable to "collapse" them into a single integral criterion, for which close ranges of values are preferred, which is achieved by normalizing the latter [21].

A priority direction of future improvement of mobile device software may be the creation of a virtual model of a hydraulic structure, which will increase the efficiency of monitoring and forecasting the state of hydraulic structures. Each update of information about the state of the structure is accompanied by a comparison with the forecast on the model, if the mismatch is higher than a certain value, the forecast on the model is recalculated, if the mismatch is growing at a rate higher than a certain set, then the model needs to be refined.
4. Conclusion

Modern trends in the modernization of the system of operation of the reclamation water management complex are associated with automation and digitalization of monitoring the technical condition of hydraulic structures. The development of mobile devices for monitoring water supply structures, performed as a part of these studies, solves the actual problem of technical operation - the formation of a high-tech and effective system of monitoring, accounting and evaluating the performance of GTS resources and is very timely.

To determine the residual life of the protective coating of water supply channels and soils under them, identify dangerous defects and damages, as well as assess and predict its technical condition and further suitability of operation, technical devices differentiated by types of hydraulic structures are proposed as a part of a mobile device: open channels, tubular hydraulic structures.

As initial data for the operation of the mobile device software environment, we used the results of the conducted research, which include:

– visual inspections of water supply structures with identification of characteristic damage to individual elements;
– quantitative parameters of damage to elements of water supply structures obtained using non-destructive testing devices (width, depth and length of damage, etc.);
– quantitative assessment of damage to elements of water supply structures.

The software package of the mobile device is developed using the Data Mining and Microsoft Access database management systems.

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