ASSESSMENT OF VERTICAL DEFORMATIONS OF WATER OUTLET HYDRAULIC STRUCTURES

Feruza Rustembaevna Aitbaeva
Research Institute of Irrigation and Water Problems
Republic of Uzbekistan, Tashkent
E-mail: aytbaeva.feruza1@gmail.com

Abstract. This article examines the assessment of vertical deformations of water outlet hydraulic structures operating in the challenging geotechnical and climatic conditions of the Republic of Karakalpakstan. Factors influencing structure settlement are analyzed, and the main geodetic methods for monitoring vertical deformations are presented. A layer-by-layer summation method was used to determine the foundation settlement of the structure in accordance with the requirements of KMK 2.02.01–98. Calculations revealed that the total foundation settlement is 125 mm, which corresponds to permissible regulatory values and confirms the safe operation of the structure. The need for systematic monitoring of the technical condition of hydraulic structures is substantiated as one of the key factors in improving their operational reliability and extending their service life.

Keywords: Water outlet structure, hydraulic structure, vertical deformation, foundation settlement, geometric leveling, geodetic monitoring, foundation soil, operational reliability, technical condition, engineering and geological conditions.

Introduction. In many countries around the world, water outlet structures on irrigation canals have been in operation for a long time, necessitating scientific research aimed at assessing their operational condition, maintenance level, and operational efficiency, as well as developing modern technological solutions to extend the standard service life of these structures. Particular attention is paid to improving methods for assessing and calculating the operational reliability of hydraulic structures, increasing their operational efficiency, and developing scientifically based maintenance requirements.

In this area, the key tasks include improving existing calculation methods to account for changes in the physical and mechanical properties of the foundation soils of water outlet structures located in complex engineering and geological conditions, developing effective technologies for the operation and maintenance of hydraulic structures, and implementing the obtained scientific results into water management practices.

Main Section. Currently, over 2,000 different hydraulic structures are in operation in the Republic of Karakalpakstan. These facilities are essential for providing water to large consumers in such sectors of the economy as agriculture, drinking water supply, fish farming, and other economic activities. Therefore, ensuring the reliable, uninterrupted, and safe operation of these structures is a priority (Fig. 1).

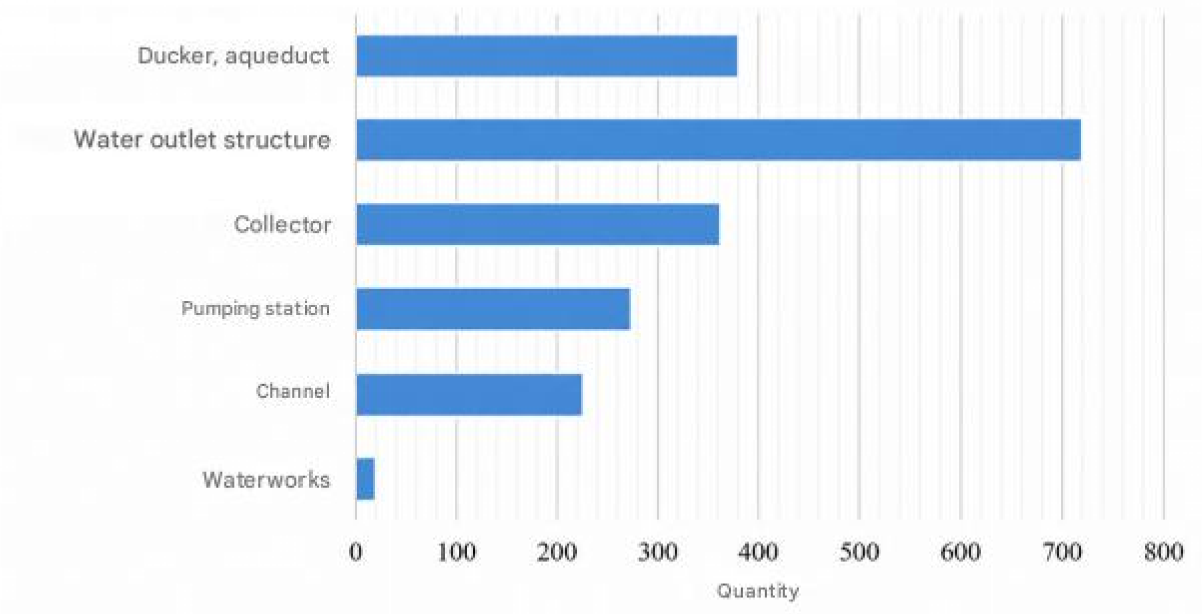

Figure 1. Distribution of hydraulic structures

Hydraulic structures located in the Republic of Karakalpakstan operate in challenging climatic, geological, and hydrogeological conditions. Therefore, continuous monitoring of their technical condition and timely detection and assessment of deformation processes are of great practical importance.

The region's geographic location facilitates the free penetration of northern Arctic air masses. This results in harsh winters, a short growing season, and a relatively low sum of effective temperatures necessary for the growth and development of agricultural crops. The climate of the Republic of Karakalpakstan is characterized by sharply continental features: summers are characterized by high air temperatures, and winters by severe cold. Furthermore, under the influence of the Karakum and Kyzylkum deserts, summer temperatures in some areas can reach 47°C.

To ensure the safe operation of hydraulic structures, in-situ observations are regularly conducted. The composition and scope of such observations are determined depending on the structure's class, engineering and geological conditions, the environmental situation, and the requirements of current regulations. Monitoring programs developed at the design stage are subsequently adapted to the operating conditions of the structures.

Deviations from construction technology, non-compliance with design solutions, or violation of operating regulations can lead to horizontal and vertical deformations of hydraulic structures. Therefore, timely detection and assessment of deformations are particularly important to ensure their reliable operation.

In hydraulic engineering, the main geodetic methods for assessing deformations are geometric and hydrostatic leveling. These methods allow for determining vertical displacements of structures, while angular and horizontal measurements are used to assess horizontal displacements.

Vertical deformations of structures in most cases manifest themselves as settlement. To monitor the settlement process, special settlement markers are installed in the areas of the structure most susceptible to deformation. The elevations of the markers are determined relative to foundation benchmarks and monitored through regular leveling measurements.

Foundation benchmarks are typically located no more than 1 km from the structure and are grouped to enable mutual monitoring. During operation, settlement marks are leveled annually until settlement stabilizes at 1–2 mm per year.

The leveling results are processed by aligning the leveling lines and comparing elevations obtained during different observation periods. Compliance of existing deformations with permissible standard values is determined by comparing actual and design deformation values.

Since the height of the structure in question is 5 m, its vertical settlement is assessed in accordance with the requirements of KMK 2.02.01–98. Using the layer-by-layer summation method, based on the linearly deformable half-space model, the settlement of the structure's foundation is determined by the following formula:

$$S=\beta\sum\frac{\sigma_{zp}\cdot\ h_i}{E_i}$$

Where:

β – dimensionless coefficient (β = 0,8);

σzp –the average value of vertical normal stress arising under the influence of an external load;

hi – thickness of the i-th soil layer;

Ei – deformation modulus of the i-th soil layer.

According to calculation results, the concrete density of the structure's body is 2.4 t/m³, and the vertical pressure transmitted to the foundation is 78 kPa. Taking into account the deformation characteristics of the sandy loam, loam, and silty sand layers, it was determined that the total settlement of the structure's foundation is 125 mm. This value complies with regulatory requirements established for most hydraulic structures and indicates the possibility of their safe operation.

Conclusion. This study examined the theoretical and practical aspects of assessing the vertical deformations of hydraulic structures' outlets. The results confirmed that long-term operation of structures is accompanied by changes in the physical and mechanical properties of the foundation soils, which significantly affects their settlement.

It was established that the use of geometric leveling in combination with the layer-by-layer summation method allows for reliably assessing the vertical deformations of structures. According to the calculations, the total settlement of the foundation of the studied structure was 125 mm. The obtained value complies with the requirements of the current building codes KMK 2.02.01–98, indicating the possibility of safe operation of the structure.

Furthermore, it has been proven that systematic monitoring of the technical condition of hydraulic structures, regular geodetic surveys, and comprehensive analysis of measurement results are important conditions for ensuring operational reliability, improving safety, and extending the service life of water outlet structures.

Proposals. Based on the results of the study, the following is proposed:

1. Organize systematic geodetic monitoring of vertical deformations of water outlet structures and create a unified digital database of observation results.

2. When assessing the technical condition of hydraulic structures, in addition to traditional leveling methods, use modern geodetic technologies, including GNSS measurements, digital levels, and automated monitoring systems.

3. When designing, reconstructing, and overhauling structures, consider changes in the physical and mechanical properties of foundation soils during long-term operation and utilize advanced engineering calculation methods.

4. If permissible vertical settlement values are exceeded, conduct timely, unscheduled technical inspections of structures and implement engineering measures to strengthen the foundation and improve structural stability.

5. To improve the operational reliability and safety of hydraulic structures, it is recommended to gradually implement digital monitoring technologies, intelligent data processing systems, and artificial intelligence elements to predict the development of deformation processes.

6. The obtained research results can be used to improve regulatory and technical documentation, as well as in the practical activities of organizations engaged in the operation and maintenance of hydraulic structures.

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