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Development of Erosion Scenarios for Earth Dams During Environmental Protection

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Keywords: earth dams, erosion, water reservoir, water resources, hydraulic structures, hydraulic tray, overflow of water, similarity criterion, hydrodynamic accidents, deformation, model.

Abstract: The methodology for assessing the level regime in the reservoir basin shows the trend of hydrodynamic accidents and the dependence of the water level rise (fall) rate on the supplied flow. Research on the process of water overflow through the earth dam was conducted based on the developed calculation program using the example of the Langar mudflow reservoir. This mudflow reservoir was built to collect and regulate the mudflow flows of the Langar River. Similarity criteria for directly transferring the obtained results to natural conditions were fulfilled. Scenarios for the erosion of an earth dam at different water discharge values were obtained. The research results showed that the upper prism of the earth dam was preserved, while erosion occurred in the lower prism. The obtained scenario allows for consideration of hydrodynamic accidents and is recommended for assessing reservoir level regimes.

1 INTRODUCTION

Earth dams are important not only for the efficient use of water resources but also for assessing safety, environmental protection, and preventing hydrodynamic accidents. During mudflows in reservoirs, by maneuvering shutters, the water levels in the upper and lower reaches are regulated, which leads to flooding of territories and prevents flooding. Timely malfunction of mechanical equipment in reservoirs, insufficient capacity of water discharge structures due to excessive water volume, excessive settlement of the earth dam body lead to water overflow through earth dams in practice (Makhmudov, Sadiev, Lapasov, Ernazarov, Rustamov, 2022; Rasskazov, 2008; Rozanov, 1985; Paluanov, Gapparov, 2020). At the same time, the qualifications of operating personnel also play an important role in the operation process, as they must be able to eliminate problems in a timely manner, effectively operate structures, identify defects, and implement measures aimed at solving problems during operation.

The methodology of the water overflow process through earth dams is based on the scenario of hydrodynamic accidents occurring in reservoirs (Duncan, 2000; Phoon, Ching, 2015; Mukhammadiev, Dzuraev, Abduaziz Uulu, Murodov, 2022; Paluanov, Makhmudov, 2022). Scenarios are developed based on field studies of the condition of reservoir hydraulic structures, which allows for the identification of possible causes of earth dam destruction (Xie, Liu, Zhang, 2007; Sun, Huang, 2005; Paluanov, 2022; Makhmudov, Sadiev, Rustamov, 2022; Paluanov, Mamatkulov, Gadaev, Saidov, 2021; Bagratuni, Bolgov, Velichko, 1969; Paluanov, Kulanov, Gadaev, Saidov, 2019; Paluanov, Mamatkulov, Gadaev, Saidov, 2021).

The occurrence of excessive water runoff can be caused by heavy rains, a sharp rise in temperature and accelerated melting of snow cover, shortcomings in emergency water discharge, or the destruction of the above-ground structure.

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2 MATERIALS AND METHODS

The purpose of the research is to develop a scenario for water overflow through earth dams as a result of rising water levels in the reservoir basin and to determine its dependence on time. To describe the process of water overflow through earth dams, an electronic computing program was developed. Based on this program, a research model was adopted (Figure 1). The object of the research is the earth dam of the Langar mudflow reservoir. The Langar Reservoir is located on the Langar River, 15.0 km from the center of the Qamashi District, Qashqadaryo Region. The mudflow reservoir was built to collect the mudflow flows of the Langar River and was accepted for permanent operation in December 1973. The water from this village-reservoir irrigates 2.4 thousand hectares of agricultural land. Hydraulic structures include a mudflow-reservoir basin, earth dams, water discharge structures with a diversion channel, and catastrophic water discharges.

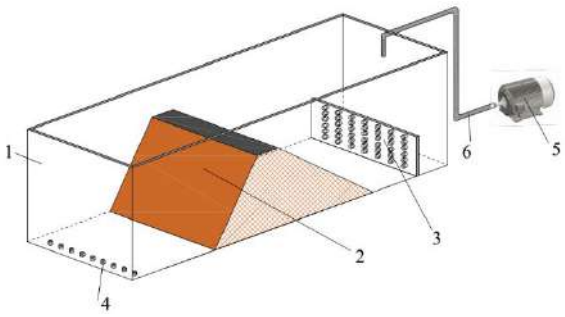

Figure 1: Type of model installation 1-hydraulic tray; 2-earth dam; 3-wall with holes; 4 holes for water drainage; 5-pump; 6-pressure pipeline.

In the research model, all geometric parameters of the Langar mudflow reservoir were adopted based on similarity criteria. The model consists of a plastic glass hydraulic tray (1) with a width of 1.0 m, a length of 3.5 m, and a height of 0.5 m. In the center of the trough, a clay earth dam (2) with a height of 0.34 m and a length of 2.16 m along the bottom is designed, and a perforated wall (3) with a height of 15 cm is installed in the upper beef of the trough to form a steady uniform water flow. The lower pool of the trough is equipped with holes (4) that perform the function of diverting water to prevent water from leaking. A small pump (5) was used to supply water to the model.

The coefficients of the upper and lower slopes of the earth dam are taken as m=2.5. With generally accepted methods, it is permissible to remove individual elements of the structure that do not affect the research processes. In our study, the berms in the upper and lower reaches of the earth dam, the roofs in the upper reach, were not taken into account in the model of the dam body. The listed elements do not have significant importance in studying the process of water overflow through the structure.

When studying water movement, the model of the dam body should be prepared in such a way that it is geometrically and dynamically similar to the actual structure. If this condition is met, the model can be transferred to life without changing the quantities determined as a result of the tests.

Two hydraulic systems are geometrically similar if there is a constant relationship between the respective dimensions of these systems:

$$\frac{l_н}{l_м} = \alpha_i = const \tag{1}$$

where: $l_н$ - dimensions of the natural structure (in nature); $l_м$ - dimensions of the corresponding model; α_i - length scale.

The scale of the dam body model was adopted in accordance with the “Unified System of Construction Documentation” and was 1:100. The geometric parameters of the dam and the flow values are given in Table 1, respectively.

Table 1: Parameters of the earth dam (in nature and model).

Name of the structure	Length along the bottom of the structure	Height of earthen dam	Top slope coefficient	Down slope coefficient	Water flow generated by floods
			In nature (meter)		
Lyangar reservoir	216	34	2,5	2,5	10-15 (m^3/s)
			In model (centimeter)		
	216	34	2,5	2,5	100-150 (cm^3/s)

Considering that the motion under consideration is mainly determined by gravity forces without taking into account viscous forces, only one similarity criterion was used (Froude criterion).

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$$\frac{\vartheta_н^2}{l_н g} = \frac{\vartheta_м^2}{l_м g} = idem \quad (2)$$

where: ϑ - flow rate; l - length along the bottom of the structure; g - acceleration of gravity; the indices "m" and "n" refer to the model and the natural model, respectively.

A calculated value of the Froude criterion of less than 1 represents a uniform flow of water both in the model and in nature.

The earth dam on the model is equipped with a grid with a side wall of 1 cm (see Figure 1). This grid was used to monitor the amount and level of water supplied to the trough, control the overflow of water through the structure, and change the profile of the dam body. Filling the hydraulic trough with water was carried out through a pressure pipe connected to the pump. The amount of water supplied by the pump was controlled by the flow meter.

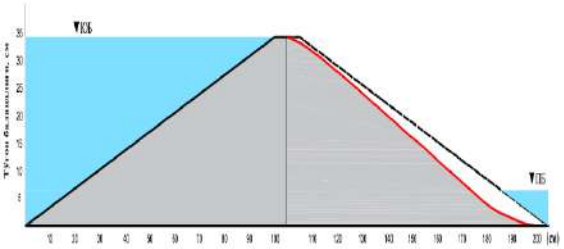
After the water flow supplied by the pump stabilized, the water level in the upper pool was regularly monitored every 10 seconds with an average water flow rate of 100-150 cm3/s.

3 RESULTS AND DISCUSSION

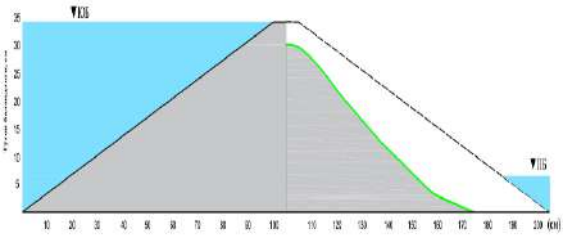
The general picture of earth dam erosion in all cases was the same. With the onset of flooding from the upper reach, a slight subsidence of the dam body began. With an increase in the water level in the upper reach, the pressure before the water overflow through the body of the structure was considered insignificant.

The erosion of the earth dam occurred in the following sequence. The increase in water pressure in the upper reach of the dam led to a rapid increase in water discharge exceeding it. During the research process, the hydraulic parameters of the flow change with the change in the shape of the earth dam.

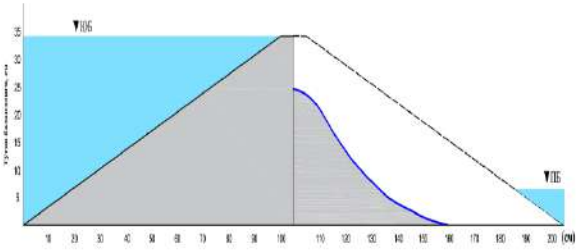
A slightly different situation was observed when studying deformations in the upper part of the earth dam, where the velocities were higher than the permissible velocities. In the studies, the intensity of the lowering of the upper part of the earth dam was significantly greater (Figure 2).



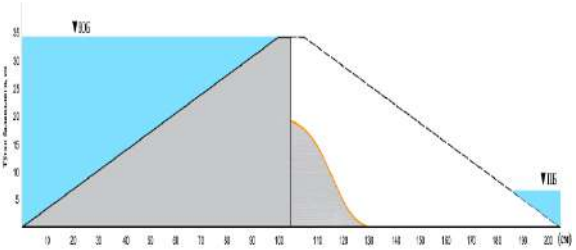
a) state of erosion in the first 10 seconds



b) state of erosion after 40 seconds



c) state of erosion after 90 seconds



d) state of erosion after 140 seconds

Figure 2: The process of erosion of the earth dam.

The earth dam profile initially had a trapezoidal shape, and during the first 10 seconds of the study, no significant changes occurred in the dam profile due to erosion. The reason for this is presumably the properties of the loam and the fact that it belongs to the category of soils where deformation occurs rarely (Fig. 2, a). In subsequent minutes, sharp changes occurred in the earth dam profile, but the profile of the upper reach slope was somewhat preserved (Figure 2, b, c, d).

At all stages of the study, the degree of erosion of the upper pool prism remained in a triangular shape, and it can be seen that erosion occurred more often in the lower pool prism. Based on the research results, the erosion process of an earth dam constructed from loam was described, and the research results were achieved.

4 CONCLUSIONS

The presented methodology for assessing the level regime in reservoir basins demonstrated a trend in the development of hydrodynamic accidents and the dependence of the water level rise (fall) rate on the supplied flow. Scenarios for the erosion of an earth dam at different water discharge values were obtained. At the same time, it is shown that the upper prism of the earth dam has been preserved, and erosion has occurred in the lower prism. The proposed methodology allows for consideration of cases of hydrodynamic accidents and is recommended for assessing the reservoir level regime at the stage of earth dam operation.

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