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The study results of the filtration process in the ground dams body and its chemical effect on piezometers

Asror Yangiev*, *Galiya* Omarova[2], Farida Yunusova[1], *Dilmurat* Adjimuratov[1], and *Aliya* Risalieva[2]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
[2]Taraz regional university named after M.Kh.Dulaty, Taraz, Kazakhstan

Abstract. The article describes the definition of filtration flow gradients in the dam's body on the example of the Kattakurgan reservoir, the analysis of the reasons for their change in cross-section. Evaluation of the aggressiveness of the filtration flow in the dam's body plays an important role in ensuring the stability of the reservoir dam and its parts. To assess the aggressiveness of the filtration flow in the dam's body, it is necessary to know the action pattern of the filtration water in the reservoir dam and its effect on the elements of the dam. In addition, the chemical composition of the water in the piezometers was analyzed in the laboratory to determine the aggressive effect of sulfate elements on the piezometers and their corrosion. Measures on the observations of systemic piezometers were also mentioned.

1 Introduction

The research aims to determine filtration flow gradients in the dam body, analyze the reasons for their change by cross-section, estimate water filtration effect on structure elements at the example of Kattakurgan reservoir dam. To estimate the aggressiveness of filtration flow in the dam body, it is necessary to know the movement pattern of filtration water in the reservoir dam and its effect on the dam elements. The results of the analysis gain importance in providing the stability of the reservoir dam and its parts [1-6].
Filtration water in the reservoir dam body usually moves in chaotic flow. In particular, filtration flow is non-pressure flow. In non-pressure flow, filtration flow has an open surface and moves towards the side from the upper part of the dam to its lower part. The head difference is

$$\Delta H = H_1 - H_2$$

Filtration flow gradient (J) is the ratio of the head difference of filtration flow in the dam body ($\Delta H = H1 - H2$) to the length of the filtration path:

*Corresponding author: yangiev_asror_63@mail.ru

$$J = \frac{\Delta H}{l}$$

Filtration flow in the dam body follows the Darcy's law. Such movement can be thoroughly observed in the base soils and in the dam body, including sands, loams, and sandy loams [7, 8].

Filtration flow discharge in the dam body can be determined by the following equation according to the law of the French scientist Darcy:

$$Q = K_f F \frac{\Delta H}{l} = K_{\Phi} F J$$

where: Q is filtration flow discharge, i.e., amount of filtrated water through soil in a unit of time, m^3/day; K_f is filtration coefficient, i.e., the amount, expressing the ability of the dam soil pass water through itself, m/day; F is filtration flow zone cross-section area, m^2; l is filtration flow path length, m; ΔH is head difference of the head race and the tail race, m;

By dividing both sides of the equation by (F), we can determine filtration velocity $\nu = K_f J$.

Thus, by Darcy's law, it is considered that the velocity (v) of filtration or water movement in the soil composing the dam body is proportionate to filtration head gradient (*J)* and filtration coefficient. In cases when head gradient $J = \frac{\Delta H}{l} = 1$, the equation $\nu = K\,J$ becomes $\nu = K$, i.e., filtration coefficient will be equal to filtration velocity concerning numerical value [9]. While estimating the filtration stability of the earth-fill dam and its antifiltration elements, the following conditions must be met:

$$J_{est,m} = \frac{\Delta H}{t_2} \leq J_{cr,m} = J_{dop} or \qquad J_{est,m} \leq \frac{1}{\gamma_n} J_{cr} \qquad (3)$$

Were: $J_{est,m}$ is mean gradient of the dam design element; γ_n is dam rehabilitee coefficient (I-class-1.25; II-class-1, 2; III-class-1.15; IV-class-1.1); J_{cr} is mean filtration gradient allowable for earth fill dams.

2 Methods

Collection of data from hydro-meteorological stations and reservoir operation. Mathematical processing of statistical data and comparison of the obtained data with field observations [10-18].

3 Results and Discussion

The soil of the Kattakurgan Reservoir dam consists of homogeneous local soil, and there is cover drainage in the lower partThe average gradient of filtration pressure for such reservoirs is calculated by the following formula.

$$J_{est,m} = \text{tg}\alpha = \frac{H}{L_n} (4)$$

Here: α is the angle of the depression curve relative to the horizontal line; H is pressure affecting the dam ($H = H_1 - H_2$); L_n is the distance between the calculated sections.

Based on field research, gradients have been calculated between piezometers 1, 2, 3, 4, and 5, located at section № 9 (ПК 20+00) of Kattakurgan reservoir dam and the results are shown in Table 1 and Figure 2 [13, 14]. Tashkent reservoir dam cross-section is shown in Figure 1.

Table 1. Design gradients between the piezometers in the Kattakurgan reservoir dam

Piezometers	MSL	Years							
		2010	2011	2012	2013	2014	2015	2016	2017
P15-P16	0.75	0.10	0.74	0.67	0.13	0.13	0.09	0.11	0.20
P16-P17	0.55	0.36	0	0	0.34	0.34	0.33	0.35	0.36
P17-P18	0.024	0.14	0.25	0.19	0.17	0.16	0.16	0.12	0.15
P18-P19	0.031	0.015	0	0.02	0.015	0.005	0.02	0.01	0.02

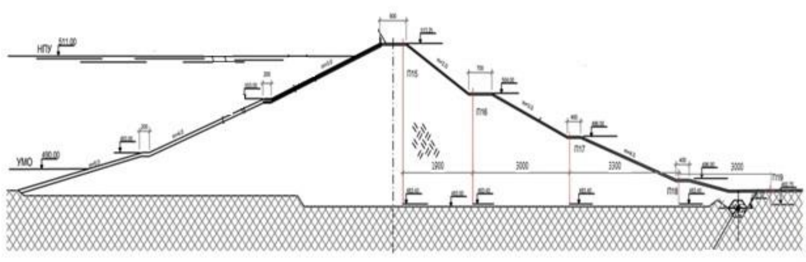

Fig. 1. Kattakurgan reservoir dam cross-section

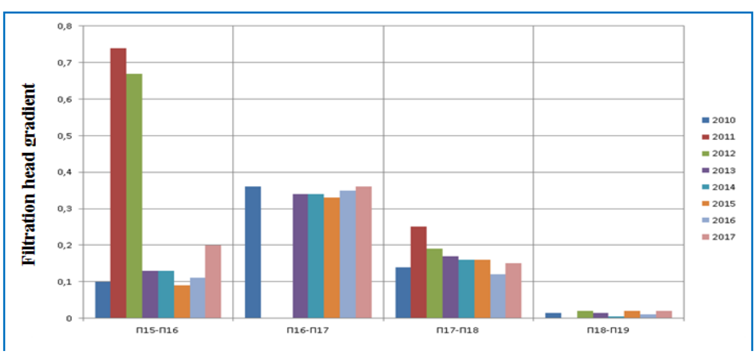

Fig. 2. Gradient change between piezometers in section (PK 20+00) of the dam

The analysis shows that filtration water movement velocity and head differences are large according to the design results, and the filtration path is short in the section between piezometers 15 and 2. Still, in the section between piezometers 17, 18, and 19, filtration water movement velocity and head differences are low and filtration path is long. As a result, in the section between piezometers 17, 18, and 19 head gradient sharply decreases. Water stability is observed in the piezometers if the amount of gradient is very low [19-25].

On the results of the research, it is considered that the movement of soil filtration is unsteady. The unsteadiness depends on the amount of gradient between piezometers located in the dam, i.e., if the gradient is at a normal level, then the change of filtration movement will comply with the pattern, and if the amount of gradient is too low, then water level stability is observed in piezometers.

Quality change analysis was conducted for the water samples taken from the

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Kattakurgan water reservoir basin and tail race drainage to determine the state of changes mentioned above within the research and estimation of water filtration effect on the structure elements (Table 2 and figures 3 and 4).

Table 2. Chemical analysis of the quality of water, taken from Kattakurgan water reservoir basin

Water sample point	pH	Hard residual, mg/l	Amount of the basic ions dissolved in water, mg/l					
			HCO'3	Cl'	SO''4	Ca	Mg	Na'+K -
Water reservoir basin	8.3	800	48	80	422	40	60	113

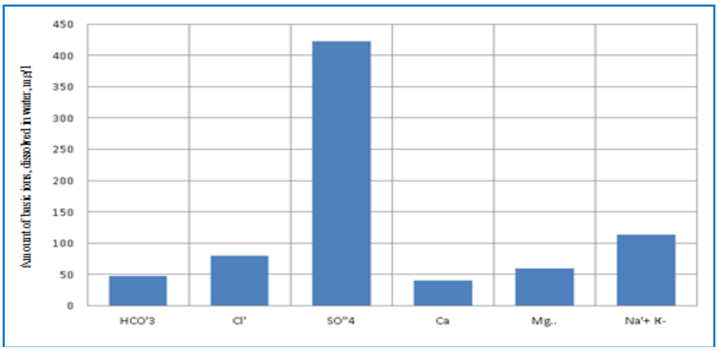

Fig. 3. Diagram of the chemical analysis of the quality of water, taken from Kattakurgan water reservoir basin

Table 3. Water aggressiveness for concrete structures in the head race of Kattakurgan water reservoir basin

№	Data description	Results of laboratory analysis	Non-pressure structure		Results of determining aggressiveness regarding concrete structures
			Portland cement original and sulfate resistant	Pupallan and Portland cement with slag original and sulfate resistant	
1	2	3	4	5	6
1	Type of structure	Nonpressure			
2	Size of structure, m	Above 2.5			
3	Kf, m/day	0.1<Kf<10			
4	Ca^{2+}, mg/l	48.8			
5	pH	8.3	5.2	5.5	Water has no general acidic aggressiveness
6	HCO_3^-, mg/l	0.7872	0.4	not regulated	Water has no alkaline aggressiveness
7	Carbon acid CO_2, mg/l	not defined			Water has no carbon acid aggressiveness
8	Chloride, Cl^-,mg	80			
9	SulphateSO_4^{2-}, mg/l	422	422>350	422>350	Has sulphate aggressiveness for ordinary cement structures
10	Mg^{2+},mg/l	60	60<1000	60<1000	water has no magnesium aggressiveness

In estimating the filtration water aggressiveness stability of the dam elements in the reservoir, it is necessary to consider the soil filtration coefficient. The aggressive effect of water on the elements located in soils, where the filtration coefficient is large, can also be high. Based on this, water aggressiveness has also been estimated for concrete structures in the head race of the Kattakurgan water reservoir basin (Table 3). Also, the aggressiveness of water has been specified for concrete structures and piezometers located in the body of the dam (Table 4) [26-31].

Table 4. Piezometers and water quality from downstream drainage

Water sample taken point	pH	Dry residue, mg/l	Amount of basic ions dissolved in water, mg / l					
			HCO'_3	Cl'	SO''_4	Ca..	Mg..	Na'+ K-
piezometer 15	6.2	4 510	36	40	2 989	560	276	303
piezometer 16	8.6	4 330	24	40	2 929	260	288	593
piezometer 17	6.8	6 030	98	32 0	3 858	120	288	1 406
piezometer 18	8.1	5 890	305	30 0	3 741	40	648	827
piezometer 19	8.1	2 260	84	10 0	1 478	80	252	235
Drainage	7.9	2 390	146	10 0	1 555	260	168	247

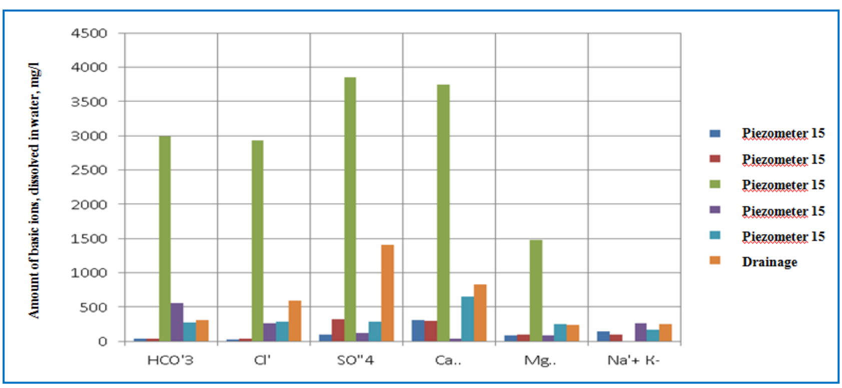

Fig. 4. Diagram of change in water quality obtained from piezometers and tail race drainage.

Table 5. Aggressive effect on concrete structures and piezometers of filtration water, located in the body of Kattakurgan water reservoir dam

№	Data description	Results of laboratory analysis	No pressure structure		Results of determining aggressiveness regarding concrete structures
			Portland cement original and sulfate resistant	Pupallan and Portland cement with slag original and sulfate resistant	
1	2	3	4	5	6
1	Typeof structure	Non pressure			
2	Size of structure, m	Above 2.5			
3	Kf, m/day	$0.1<K_f<10$			
4	Ca2+, mg/l	560			
5	pH	8.3	5.2	5.5	Water has no general acidic aggressiveness
6	HCO_3, mg·/l	from 0.4 to 5.0	0.4	Not standardized	At the point where the 16 piezometers are located, there is alkaline aggressiveness of filtration water
7	Carbon Acid CO_2, mg/l	not defined			Water has no carbon acid aggressiveness
8	Chloride Cl^-, mg	from 40 to 320	320<1000	320<1000	Accelerates corrosion of metal structures
9	Sulphate SO42-, mg/l	from1478 to 3858	3858>250	3858>250	Has sulfate aggressiveness for ordinary cement structures and metal structures
10	Mg^{2+}, mg/l	648	648<1000	648<1000	water has no magnesium aggressiveness

4 Conclusions

Filtration flow in the body of the Kattakurgan water reservoir dam is sulfate aggressive about concrete and metal structures; it accelerates the corrosion of piezometers in the dam. It requires taking measures to process the concrete surfaces and joints on the headrace of the Kattakurgan water reservoir dam with hydroisolation materials and providing good operation of drainage in the tailrace of the dam. The sensitivity of piezometers in the water reservoir dam must be checked; during the process of checking, the sensibility piezometers must be filled with water and then emptied, thus providing the process of water replacement in them. As a result, filtration flow water aggressiveness will decrease concerning piezometers.

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