ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 7 , July 2019

The Calculation of Unsteady Filtration in Uniform Ground Dams Taking into Account Filtration Animotropic Grounds

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ABSTRACT: This article presents the results of calculation of unsteady filtration in homogeneous earth dams taking into account anisotropic permeability of the soil. The effect of the anisotropic soil on the position of depression curve syrup filtration.

KEY WORDS: soil dams, filtration, unsteady filtration, rapid decrease in water level in the upstream, rate of decrease in water level, finite difference method, Filtration anisotropy of soils, reservoir drainage.

I.INTRODUCTION

When the design of earth dams in practice is increasingly considered an isotropic filtering is characterized by the same conductive material in all directions. At the same time, there are frequent cases of damage or destruction of earth dams, including with catastrophic consequences and loss of life. The main causes of damage and damage to or destruction of ground dams are the filtration deformations of the soils of the body and the bases of the dams, in many cases caused by their anisotropic water permeability.

Neglecting anisotropy in the design of a subsurface dam can lead to an emergency situation. For example, this circumstance was one of the main causes of the accident at the earth's dam in the ash dump of the Novak (Czech Republic) hydropower station in 1965. Due to anisotropy in the earth dam of the Orto-Tokoy hydroelectric complex on the Chu River, the level of seepage increased almost to the level of the headwater, which created a serious threat to the safety of the structure and required costly repairs [1].

The developed methods for calculating unsteady filtration and constructive measures that increase the stability of the slopes do not take into account the anisotropic water permeability of the soils of the dam body.

The mathematical formulation of the considered boundary value problem of anisotropic filtering in the general case has the following form with the following initial and boundary conditions.

$$A_0 \frac{\partial U}{\partial t} = A_1 \frac{\partial}{\partial x}\left(A_2 \frac{\partial U}{\partial x} \right) + A_3 \frac{\partial}{\partial y}\left(A_4 \frac{\partial U}{\partial y} \right) + A_5 \frac{\partial U}{\partial x} + A_6 \frac{\partial U}{\partial y} + F, \tag{1}$$

Under boundary conditions

$$g_{11} \frac{\partial U}{\partial x}\bigg|_{x=a} + g_{12} U(a,y,t) = \varphi_1(y,t), \qquad c \le y \le d, \tag{2}$$

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$$g_{21}\frac{\partial U}{\partial x}\bigg|_{x=b}+g_{22}U(b,y,t)=\varphi_2(y,t)\,, \qquad c\le y\le d, \tag{3}$$

$$g_{13}\frac{\partial U}{\partial y}\bigg|_{y=c}+g_{14}U(x,c,t)=\varphi_3(x,t), \qquad a\le x\le b, \tag{4}$$

$$g_{23}\frac{\partial U}{\partial y}\bigg|_{y=d}+g_{24}U(x,d,t)=\varphi_4(x,t), \qquad a\le x\le b, \tag{5}$$

and the initial condition

$$U(x,y,t)\big|_{t=0}=\psi(x,y)\,, \tag{6}$$

Equations (1) with reduced initial and boundary conditions (2-6) were solved by the finite difference method [2]. A program for calculating unsteady filtering in earth dams has been compiled and a certificate has been obtained of the official registration of the program at the Agency for Intellectual Property in the Republic of Uzbekistan.

The possibilities of the developed methodology, the program for calculating unsteady filtering and the assessment of the reliability of the results obtained are illustrated below using the example of filtration problems.
In the given areas we consider the equations describing the filtration process

$$\mu\frac{\partial H}{\partial t}=K_x\frac{\partial}{\partial x}\left(H\frac{\partial H}{\partial x}\right)+K_y\frac{\partial}{\partial y}\left(H\frac{\partial H}{\partial y}\right) \tag{7}$$

Equations (7) are solved in the following:
Initial

$$H(x,y,t)\big|_{t=0}=f(x,y), \tag{8}$$

and boundary conditions

$$\begin{aligned}&H(x,y,t)\big|_{x=0}=\varphi_1(y,t),\;\; H(x,y,t)\big|_{x=L}=\varphi_2(y,t),\\ &H(x,y,t)\big|_{y=0}=\psi_1(x,t),\; H(x,y,t)\big|_{y=B}=\psi_2(x,t),\end{aligned} \tag{9}$$

Find the values of the function satisfying conditions (8) and (9)

II. SIGNIFICANCE OF THE SYSTEM

A homogeneous earth dam was considered on a bed with a drainage prism in the downstream. The initial headwater depth is 20 m; laying the upper slope m = 3; laying the bottom slope m2 = 2. The problem was solved for Kx / Ku = 2.0; 4.0; 8.0, the soil water return coefficient of the dam body is μ = 0.1; the rate of water level processing in the reservoir 1,0 = 1.0 m / day, the level of the downstream was assumed unchanged and equal to H2 = 3m. As the initial condition, the solution of the filtration problem for the steady state was taken at the depths of the upper and lower pools, respectively 20 and 3 m, taking into account the anisotropy of soils [3]. The design scheme is shown in Fig. one

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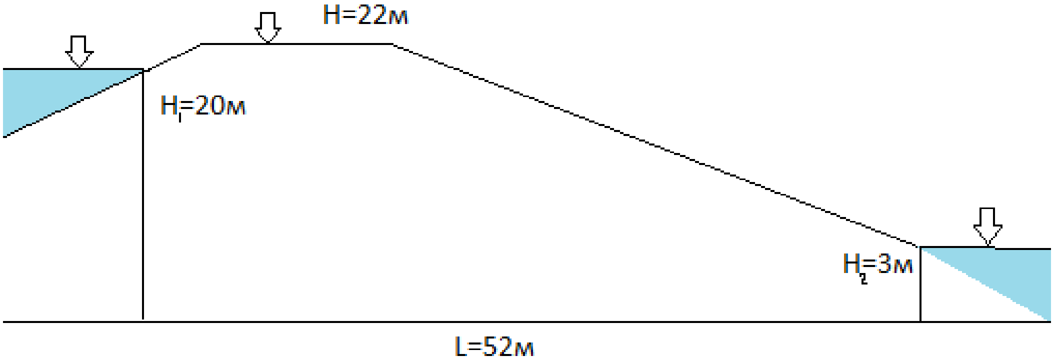

Fig. 1 Calculated filtering scheme

III. ANALITICS AND RESULTS

The performed calculations allow us to trace the dynamics of changes in the position of the depressed surface, gradients and velocities of the filtration flow occurring during the drawdown of the reservoir. With non-stationary anisotropic filtering during the run-down to the 4.0-meter mark from speeds ϑ = 0.5 m / day with K_x/K_y=2, a rather gradual decrease in the depression curve occurs. For the first 2 days after the start of the drawdown, the depression curve on the uphill slope is mated with the headwater mark with a near zero slope. With K_x/K_y=4 and 8 (Fig. 2) in all cases of water movement, it is almost always directed towards the downstream (Table 1). Unlike isotropic filtering at the same rate of drawdown, a greater outflow of water in the horizontal direction leads to the fact that the depression curve for all the calculated time points has a gentle form with a slope towards the downstream. The rate of decline of the depression curve near the surface of the upper slope is almost equal (with a slight delay) the rate of decrease in the level of the upstream. Compared with isotropic filtration, we have a more uniform change in the filtration head in the computational domain, smaller gradients and smaller magnitudes of filtration hydrodynamic forces directed towards the surface of the upper slope. Obviously, this is more favourable from the point of view of the stability of the upper slope of the picture than in the case of isotropic filtering. Then the inclusion of anisotropic non-stationary filtration in the calculations of the stability of the uphill slopes of the ground dams during the drawdown of the reservoir creates more favourable conditions in terms of the stability of the uphill slope.

However, at high rates of water drawdown in the upstream (3-5m / day or more), a significant lag in the depression curve from the upstream water level and the appearance of dangerous hydrodynamic pressure of water directed towards the upper slope may occur. However, in reservoir dams, there is practically no decrease in water at such speeds (except for emergency cases). Water reductions at such speeds are possible on the dams of the GAES operating in peak mode, where there is a decrease and filling of the water level in the headwater per day.

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ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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Table 1. The calculation results of determining the position of the depression curve at

H1	H2	Lx	V1	V2	myu	Kx	Ky	Kx/Ky	Ky/Kx
22	3	118	1	0	0,02	15,36	1,92	8	0,125

	-66	-55	-44	-33	-22	-11	0	11	22	33	44
t=22	0	0,93	1,48	1,86	2,15	2,37	2,54	2,67	2,78	2,87	2,95
t=20		2,19	2,53	2,78	2,96	3,07	3,15	3,18	3,18	3,14	3,09
t=18			4,13	4,21	4,24	4,23	4,17	4,07	3,93	3,75	3,52
t=16			5,99	5,93	5,83	5,69	5,5	5,27	4,99	4,66	4,27
t=14				7,85	7,63	7,37	7,07	6,72	6,31	5,85	5,31
t=12				9,92	9,59	9,23	8,81	8,35	7,84	7,26	6,59
t=10					11,69	11,22	10,71	10,15	9,54	8,85	8,08
t=8					13,9	13,35	12,75	12,1	11,38	10,6	9,73
t=6						15,59	14,9	14,17	13,37	12,5	11,54
t=4						17,93	17,17	16,35	15,47	14,52	13,48
t=2							19,54	18,64	17,69	16,66	15,55
t=0							22	20,97	19,89	18,74	17,52

ISSN: 2350-0328
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Figure 2. The calculated position of the depression curve at K_x/K_y=8