Scenario modeling of groundwater filtration in a enclosing tailings dam of a mining enterprise

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Abstract. Scenario hydrogeomechanical 3D modeling of groundwater filtration through the body of the enclosing tailings dam of a mining enterprise was carried out. A hydrogeomechanical 3D model of the tailings dam was created and modeling of filtration-deformation processes was carried out according to three scenarios for the position of the depressed surface of groundwater: the actual state, the limit according to the project, and the maximum filling with water. The calculated values of the rate of water filtration through the body of the enclosing dam are determined for the simulated scenarios of the position of the depression surface. A graphical dependence of the filtration rate on the position of the depression surface of groundwater is revealed, and an analytical expression approximating it is found.

1 Introduction

The tailings dam of a mining enterprise is a complex hydrotechnical system (HTS), the industrial and environmental safety of which is largely determined by the strength and filtration stability of the enclosing dam [1-6].

Much attention is paid to the study of filtration-deformation processes occurring in the enclosing tailings dam and determining its reliability [2, 7-9]. At the same time, one of the main tasks of research in order to ensure the filtration stability of the enclosing tailings dam is to assess the degree of water filtration through its body at different positions of the depression surface of groundwater in the tailings dam HTS [10-15].

The purpose of this work was to identify patterns of changes in the rate of water filtration through the body of the enclosing tailing dam of a mining enterprise based on scenario hydrogeomechanical 3D modeling of the position of the depression surface of groundwater.

2 Methods and materials

The main methods in the work were to build a hydrogeomechanical 3D model of the tailings dam HTS and scenario modeling of the emerging filtration-deformation processes at different positions of the depression surface of groundwater.

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To build the model, data from reconnaissance and visual surveys, geological data, and the results of engineering-geological, hydrological and geophysical surveys carried out at the tailing dam of one of the mining enterprises of the Kola Peninsula were used. The parameters of the physical and mechanical characteristics of soils used in the model and for modeling are shown in Table 1. The location of soil types on the model is shown in Figure 1 with inscriptions, in accordance with Table 1.

Table 1. Parameters of physical and mechanical characteristics of soils of the tailing dam HTS used for scenario modeling.

Parameters			Soils, rocks				
Name	Symbols	Unit	Rocky soil (diabase)	Blocky-crushed stone soil	Soils of the starter dam	Filled soils of the enclosing dam	Alluvial tailing deposits
			1	2	3	4	5
Specific weight of unsaturated soil	γ_{unsat}	[kN/m³]	23.0	20.2	17	19.82	16.9
Specific weight of saturated soil	γ_{sat}	[kN/m³]	23.5	20.5	21	22.1	20.6
Filtration coefficient	k_f	[m/day]	0.01	0.001	0.1	1.0	0.1
Deformation model	E_{ref}	[kN/m²]	500 000	17 000	10000	40000	8 000
Poisson's ratio	ν	[-]	0.25	0.33	0.35	0.3	0.32
Coupling	c_{ref}	[kN/m²]	8	7.0	2	4.0	0.1
Angle of internal friction	φ	[°]	60	29	28	34.0	33.0
Dilatancy angle	ψ	[°]	25	--	--	--	--

In the created model, the following mechanisms of soil behavior under load were used: for foundation rocks - MohrCoulomb, for alluvial deposits - HardeningSoilSmall, for other soils - HardeningSoil. The type of drainage for all soils and rocks was set by Drained [10].

Computer hydrogeomechanical 3D modeling was performed according to three scenarios of the position of the depression surface of groundwater in the tailings dam: I - actual (according to piezometric measurements); II - limit (according to the project); III - off-design (maximum (floods, showers, industrial water discharge) filling of the tailings dam basin with water (Figure 1b).

The geometric dimensions of the created model and the position of the depression surface of groundwater according to the accepted scenarios are shown in Figure1. It should be noted that for scenario I (Figure 1b), the water on the surface is in the ditch that outlines the tailings dam, which corresponds to the actual state.

For the model, two finite element meshing modes were used: Fine and Veryfine, including: the number of elements (176141), the number of nodes (252776), the average size of the elements (10.13m), the maximum (57, 03m) and minimum (0.29m) dimensions.

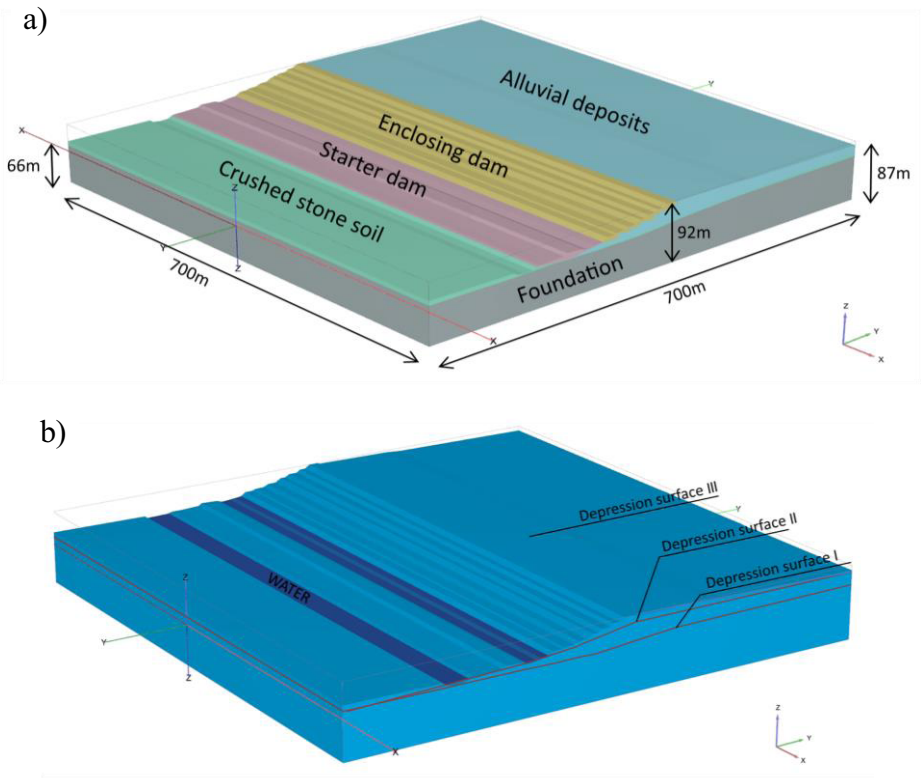

Fig. 1. 3D model of the tailing dam HTS: a) geometric scheme; b) the scheme of positions of the depression surface of groundwater.

3 Results

As a result of scenario computer simulation using a specialized licensed program PLAXIS 3D, calculated values were obtained that characterize the state of the investigated HTS for the conditions under consideration. In particular, Fig. 2 shows a picture of the degree of filtration Saturation for the scenario of the actual position of the depression surface of groundwater in the tailings dam.

Similar patterns were obtained for all simulated scenarios.

According to the results of the calculations for the scenario of the actual position of the depression surface of groundwater, it was determined that the rate of water filtration through the body of the enclosing dam will be *0.029m/day*.

For the scenario of the limiting position of the depressed groundwater surface, it is determined that the rate of water filtration through the body of the enclosing dam will increase and reach 0.118*m/day*.

For the scenario of maximum filling of the tailings dam with water, it is determined that the rate of water filtration through the body of the enclosing dam will increase sharply and may amount to 0.49*m/day*.

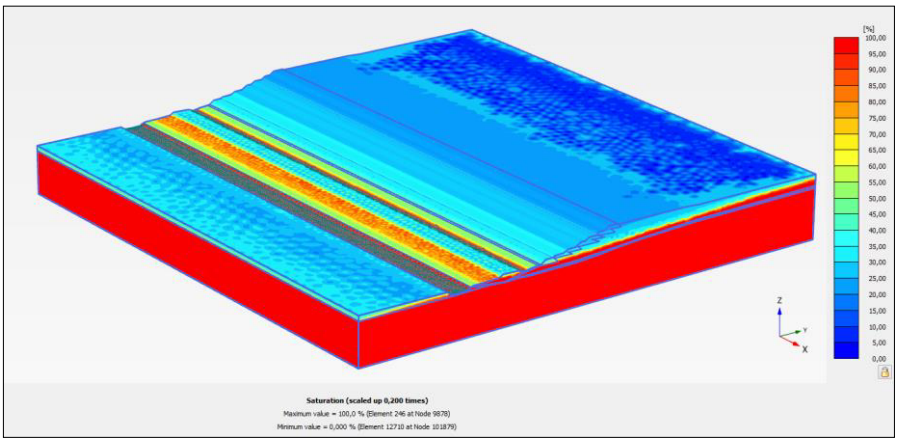

Fig. 2. Picture of the degree of filtration Saturation for the scenario of the actual position of the depression surface of groundwater in the tailings dam.

The dependence of the calculated values of the rate of water filtration through the body of the enclosing dam on the position of the depression surface (according to the accepted scenarios) is shown in Figure 3. The position marks of the depression surface for each scenario are taken in accordance with the geometric dimensions shown in Figure 1.

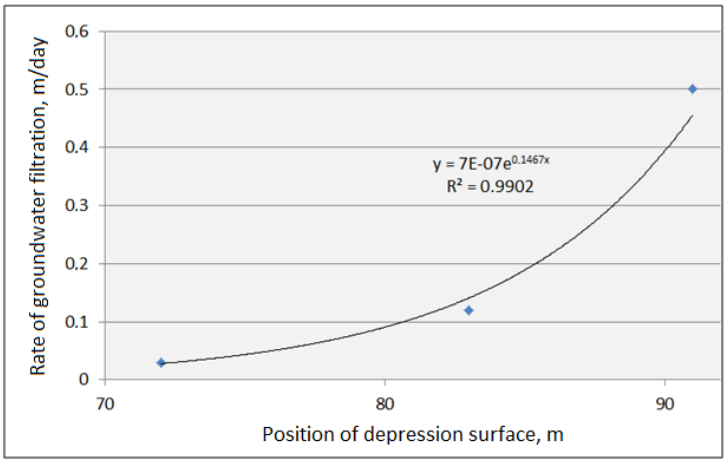

Fig. 3. Dependence of the rate of water filtration through the body of the enclosing dam on the position of the depression surface.

As follows from Figure 3, an increase in the depression surface from the actual state (a little more than 70 m) to the limiting one (a mark of about 83 m) will lead to an increase in the values of the filtration rate by 4 times. The maximum filling of the tailings dam basin with water (a little less than 92 m) will lead to a sharp increase in the filtration rate (almost 17 times), which will cause a significant change in the hydrogeomechanical state of the soil.

4 Discussion of results

It has been established that changes in the rate of water filtration through the body of the enclosing dam on the position of the depression surface (according to scenarios) with a high

degree of reliability (R^2=0.9902) is approximated by the exponential dependence y=7E-07$e^{0.1467x}$. This provides a scientific and technical basis for obtaining the values of the rate of the filtering water through the body of the enclosing dam, both according to the constructed graph, and through calculations using the obtained analytical dependence. The starting point for this will be the position mark of the depression surface of groundwater in relation to the crest of the enclosing dam.

It should be noted that the rate of water filtration through the body of the enclosing dam largely determines the state and movement of its soils, and thus their filtration stability.

The analysis of the obtained results of the scenario computer modeling of the tailings dam HTS with the section of the enclosing dam showed that, both for the actual and for the limiting position of the depression surface, potentially dangerous filtration-deformation processes, both in the body of the dam and at its interface with the underlying foundation, are not formed. The maximum filling of the storage basin with water due to unscheduled discharges of industrial waters, heavy rainfall and floods will lead to a sharp increase in the filtration rate through the body of the enclosing dam, a change in the state, movement and overconsolidation of the soils that make it up. This gives reasons to predict the formation of conditions under which the enclosing dam may lose its filtration stability.

5 Conclusion

On the example of the tailing dam of one of the mining enterprises of the Kola region, scenario modeling of groundwater filtration through the body of the enclosing dam was performed. A hydrogeomechanical 3D model of the tailing dam was created and modeling of filtration-deformation processes was carried out according to three scenarios for the position of the depressed groundwater surface in the tailing dam: the actual state, the design limit and the maximum filling with water. It was revealed that an increase in the depression surface of groundwater from the actual to the limit position will lead to a 2-fold, and to the maximum - to a 17-fold increase in the rate of water filtration through the body of the enclosing dam. A graphical dependence of the filtration rate on the position of the depression surface of groundwater has been established, which is approximated with high reliability by an exponential analytical expression. This provides a scientific and technical basis for obtaining the values of the speed of the filtering water through the body of the enclosing dam, both according to the constructed graph, and through calculations using the obtained analytical dependence.

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