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Analysis of seepage in the conditions of increased reservoir capacity by raising the spillway level(Case study: Kamal-Saleh earth dam)

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ABSTRACT: Seepage is one of the main threats to the stability of the earth dam, which can weaken the dam structure and cause piping, washing the earth dam materials inside the body or foundation and eventually its failure. In this study, seepage analysis of Kamal-Saleh earth dam was performed using Seep/W software under three conditions of steady-state, rapid drawdown and end of construction for the current dam as well as for increased spillway level in stable seepage condition. The effect of increasing the height of spillway on the seepage rate inside the body and foundation of the dam, hydraulic gradient and phreatic surface was investigated. To evaluate the dam behavior in the conditions of increasing reservoir capacity, seepage analysis was performed for the current level and increased levels of spillway by one-meter intervals. According to the software results, the dam was safe against seepage in the current spillway level in every three conditions and provided the required factors of safety. In the conditions of increased spillway level, the amounts of seepage and the hydraulic gradients increased and the factors of safety against boiling decreased in a way that by increasing the dam spillway level equal to 4 meters, the seepage through the dam body and foundation increased 85% and the safety factor against boiling decreased 4.5% but in all these conditions, the dam was safe against boiling. In the current and increased levels of the spillway, there are the appropriate similarity of phreatic lines produced by the selected analytical method and Seep/W. The most similarity is seen in the upstream shell and core and the maximum difference is seen in the phreatic line intersection with the downstream slope of the dam.

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1- Introduction

The dam is an impermeable barrier in front of the water flow that is mainly used to store or divert the flow direction [1]. Some reasons for increasing the capacity of the reservoir include technical problems and limitations during the construction of the dam, reducing the useful storage of the reservoir with the entry of large volumes of sediments over time, increasing the need to store more water over time due to the increase in population and the low cost of increasing the capacity of the current reservoir compared to the construction of a new one [2]. In order to increase the capacity of the dam, methods such as installing gates or fuse gates on the spillways, installing rubber dam along the entire dam crest, raising the level of spillway crest by concreting on it, raising the top of the non-overflow section of the dam are used [3-5].

The aim of this study was to analyze the seepage of the Kamal-Saleh rockfill dam using the Seep/W module of GeoStudio software for the current dam and increased spillway levels.

2- Methodology

2- 1- Calculation of phreatic surface

In the present study, two analytical methods, Stello [6] and Rezk and Senoon [7], that have been less seen in Persian references have been used to estimate the phreatic surface of the dam. Full details of these methods can be found in the references [6] and [7].

3- Kamal-Saleh rockfill dam

Kamal-Saleh dam is a rockfill dam with a capacity of 110 million cubic meters, a height of 76 meters from the riverbed and 80 meters from the foundation, a crest length of 765 meters and a crest width of 12 meters located 74 km southwest of Arak. Figure 1 shows the typical cross-section of Kamal-Saleh Dam [8].

4- Results and Discussion

4.1. Seep/W verification in seepage calculation

The results of seepage simulation with SEEP/W software compared with the seepage monitored data from the instrumentation system installed in the dam body and foundation. The average error between the estimated seepage discharge values and the actual values was 6.4% and the coefficient of determination was R2=0.98, which indicates the appropriate match between the results of the software Seep/W and the instrument and therefore, software results can be considered acceptable.

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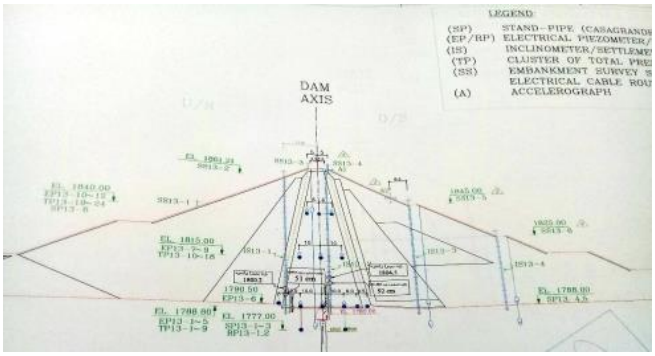

Fig. 1. Typical cross-section of Kamal-Saleh rockfill dam [8]

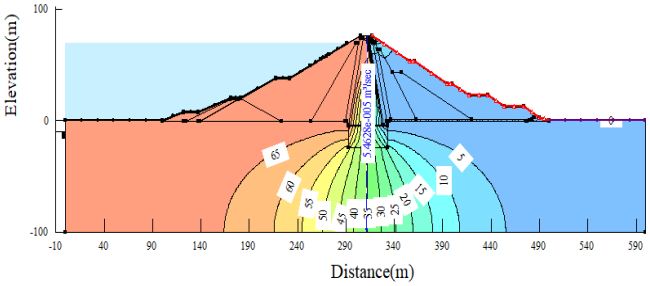

Fig. 2. Total head contour (m) and the amount of seepage discharge for the current level of Kamal-Saleh dam overflow spillway (water height of 69.1 m)

4- 1- Seepage analysis of Kamal-Saleh Dam

Initially, in order to determine the size and type of optimal mesh, the amount of discharge from the analysis for different types of mesh and their size per unit width was investigated. The results showed that the effect of mesh and type size on the rate of seepage is negligible, which is consistent with the findings of many studies, including [9]. Finally, 3-meter mesh was selected as the optimal mesh.

4- 1- 1- Seepage analysis of Kamal-Saleh Dam in current level of the spillway

Seepage analysis of Kamal-Saleh earth dam was analyzed using Seep/W software under three conditions of steady-state, rapid drawdown and end of construction for the current level of the spillway. As an instance, total head contour (m) and the amount of seepage discharge for the current level of Kamal-Saleh dam spillway under steady state are shown in Figure 2.

During rapid drawdown of water in the reservoir, in all parts of the dam body, the pore water pressure decreased almost linearly, indicating that steady-state flow takes place. Water level fluctuations affected the upstream of the dam more rapidly and reduction of pressure occurred at a higher rate. Due to the low velocity of water drainage inside the clay core materials, the least change in the amount of pore water pressure occurred within the core. At the upstream slope, the pore water pressure became negative, which indicates that the water level becomes below the evaluated selected points. The obtained results were consistent with the studies of Fattah et al. [10]. At all points in the upstream slope, the exit hydraulic gradient was smaller than one and therefore, the factor of safety against boiling was greater than one and the dam was stable.

4- 1- 2- Seepage analysis of Kamal-Saleh Dam for increased spillway levels

Seepage analysis was performed under steady-state condition for the current spillway level (water height of 69.1 m). Then, with the increase in the spillway level at one-meter intervals up to a height of 73.1 meters, the seepage was analyzed for each step. The results showed that the highest rate of discharge from the body and foundation would happen in the condition of raising spillway level by four meters which is equal to 85% increase. In order to check whether this seepage increase causes boiling at the dam downstream, the factor of safety against boiling was calculated for each increased level. This consideration showed that although the factor of safety decreases with raising the spillway level, still its value is more than 3 in all cases and therefore, the dam is safe against boiling.

For up to 4 meters increase in the level of the spillway, the phreatic surface was still at a lower level of the core crest, but by considering the capillary rise, the phreatic surface would be very close to the core crest and so from this point of view, it is not recommended to increase the spillway level by 4 meters. By increasing the spillway level by 5 meters, the phreatic surface passed over the core according to the analytical and numerical methods.

4- 2- Determining the phreatic line within the dam

Comparing the phreatic lines obtained from these two analytical methods, Stello [6] and Rezk and Senoon [7], with the corresponding results in the Seep/W software would specify whether the analytical method can be used like the Seep/W software in drawing the phreatic line and analyzing the permeability of Kamal-Saleh study dam or not.

For the same hypothetical dam, which was used in original references ([6 and 7]), the phreatic line obtained in Seep/W software and the results of analytical and numerical methods were compared. The results showed that among the two analytical methods, the method of Rezk and Senoon is more accurate in drawing the phreatic surface and therefore, it used to determine the phreatic surface of the Kamal-Saleh dam. At the current level of the Kamal-Saleh spillway and in the conditions of raising its levels, there was a good match between the phreatic line that can be drawn from the variables obtained from Rezk and Senoon analytical methods [7] and the Seep/W numerical method.

5- Conclusions

Increasing the probability of occurrence of high precipitation amounts and floods in the Kamal-Saleh dam basin due to climate change which can endanger downstream areas and also increasing the need for storing the water of the dam in low water conditions, led to the investigation of the possibility of increasing the dam storage capacity in this study. The plan of raising the spillway level is investigated in this research. The results showed that raising the spillway level up to a height of 4 meters is possible. Of course, it should be noted that the efficiency of this action is controlled from the seepage point of view, and the static and dynamic stability of the slopes should also be examined.

References

[1] H. Rahimi, Embankment Dams, Tehran University, Iran, 2013 (in Persian).

[2] H. Karimian Aliabad, Explaining the Elevation Method in Dam Cure, A Case Study of the Fusegate System in Zarrineh Rood Dam, M.Sc. Thesis in hydraulic structures, Shahid Chamran Ahvaz university, Iran, 2010 (in persian).

[3] M. Yazdanian, H.R. Afshoon, S. Ghasemi, V. Afshoon, F. Fahim, Effect of Height on the Static Stability of Heterogeneous Embankment Dams, Journal of Engineering, Science and Technology, 5(3) (2017) 274-282.

[4] X.G. Song, Z.D. Zhou, H.B. Zhang, H.Y. Yue, Study on the Capacity Increasing and Dam Heighten of Plain Reservoirs, Journal of Applied Mechanics and Materials, 353-356 (2013) 2531-2536.

[5] A. Abdulsattar, M. Faris, A. Zedan, Seepage Analysis through an Earth Dam (KHASA-CHAI Dam) as a Case Study, Journal of Engineering and Technology, 35(2) (2017) 172-181.

[6] M.W. Stello, Seepage charts for homogeneous and zoned embankments, Journal of geotechnical engineering, 113(9) (1987) 996-1012.

[7] M.A.E.-R.M. Rezk, A.E.-A.A.A. Senoon, Analytical solution of seepage through earth dam with an internal core, Journal of Alexandria Engineering, 50(1) (2011) 111-115.

[8] L.C.E. Company, Geotechnical reports of Kamal Saleh Dam, Regional Water Authority of Markazi-Arak Province, 2010 (in Persian).

[9] H. Hasani, J. Mamizadeh, H. Karimi, Stability of slope and seepage analysis in earth fills dams using numerical models (Case Study: Ilam Dam-Iran), Journal of World Applied Sciences, 21(9) (2013) 1398-1402.

[10] M.Y. Fattah, H.A. Omran, M.A. Hassan, Behavior of an Earth Dam during Rapid Drawdown of Water in Reservoir–Case Study, International Journal of Advanced Research (2015), 3(10) (2015) 110-122.

[11] stand-alone wind turbine-generator systems, Electrical Engineering in Japan, 150(4) (2005) 13-22.

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