International Journal of Scientific & Engineering Research, Volume 8, Issue 11, November-2017
ISSN 2229-5518

The Significance of Grout Curtain in Rock Fill Dams

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Abstract

Dams are built due to increasing drinking and irrigation water and energy requirements. The objective of the dams is to hold water. Thus, the seepage volume is required to be minimum in a constructed dam. Water retention is reduced when no seepage analysis is conducted for the dams. Seepage causes both loss of water and damages to the dam structure. Thus, it is necessary to perform seepage analyses in the pre-construction project phase. The basic principle in seepage analysis is Darcy's law. Often, seepage analysis can be conducted with software that utilizes the finite element method, can process the water flow and accept geological parameters. The phreatic line is very important in calculation of seepage. The highest the intersection of the phreatic line and the downstream slope, greater the damage it causes. Therefore, the phreatic line needs to be determined during the profile design phase of the waterline profile and thus, measures can be taken against the said damage.

In the present study, the analyses of the seepage that could occur at Tokat Turhal Dam body and closing dike floor that was constructed by State Hydraulic Works, Dams and Hydroelectric Power Plants Department were investigated using the "Slide 5.0" software. The seepage amounts in the dam body floor in the presence and absence of a grout curtain were compared. It was observed that the seepage amount in the case where the grout curtain is present decreased significantly.

Index Terms: Seepage, rock fill dam, phreatic line

Introduction

Dams are built to meet our increasing requirement for water and energy as a result of global population growth and economic developments. Humans are not the only builders of dams in the world. The beavers are the first dam engineers. Dams that are built by beavers across rivers and streams change the original water flow. In time, these dams could alter the upstream and downstream environment and create an impact on the ecosystem through direct or indirect influences on the wildlife. This is the reason why beavers are also called "ecosystem engineers" [1].

Figure 1 Beaver dam on Smiliga

The first dam ever built in Turkey was the "Topuz Bend" or the "Osman 2nd" dam built by Ottoman Sultan Osman 2nd. The height of this dam that was constructed with soil and rock filling is 9 meters and 91 centimeters [2].

Figure 2 Topuz Bend Dam

Due to the increasing water and energy demand, it became imperative to build large dams with larger water reservoirs.

The first dam constructed during the Republican era was the Çubuk Dam. It was 33 meters high and completed in 1936 in Ankara.

Several important dams were built in Turkey, especially after the 1950s. The first major dam was the Keban Dam that was built in Eastern Anatolian region. Keban Dam, which is 207 m high and concrete weight and rock fill type, ranks 18th in the world in terms of dam height. Atatürk Dam, which is located within the Southeastern Anatolian Project (GAP), is the largest dam in our country. There are several dams that are being built in Turkey. Analyzes conducted in these newly built dams are very important. Seepage analyzes are quite important since seepage on the dam body affects dam stability. Thus, researchers conduct seepage analysis.

E. Kesgin conducted a seepage analysis with a new mathematical model formed by the finite differences in landfill type dams [3].

D. Alkaya and B. Yeşil examined the geotechnical properties of the foundation rock, utilized material and grouting pressures in Cindere dam. As a result of the study, it was found that when the dam would start to hold water, seepage is not expected through the foundation rock along the dam axis [4].

Seepage is briefly defined as the flow of the water from the dam upstream to dam downstream. Examination of the seepage problem is very important in terms of the safety and longevity of the dam. Thus, seepage calculations should be conducted in all phases such as project planning, construction, initial water retention and operation.

Generally, seepage analysis can be conducted with software that utilize the finite elements method, can process the water flow method, and where geological parameters can be entered. The basic principle utilized in seepage analysis is the Darcy's law.

$Q=A\times k\times i$

Q=Seepage

A=Seepage area

i=Hydraulic slope

The phreatic line is quite important in seepage calculation. The highest the intersection of the phreatic line and the downstream slope, greater the damage it causes. Therefore, the phreatic line needs to be determined during the profile design phase of the waterline profile and thus, measures can be taken against the said damage.

In the present study, the seepage on Turhal Dam body, which is clay core rock fill dam, was investigated. It is necessary to minimize the seepage in the dams. The dams are built to retain water. Water retention in the dams is reduced when no seepage analysis is conducted. Seepage causes both water loss and damages the dam structure. Thus, it is necessary to perform seepage analyzes during the pre-construction project planning phase.

In the present study, the analyses of the seepage that could occur at Tokat Turhal Dam body and closing dike floor that was constructed by State Hydraulic Works, Dams and Hydroelectric Power Plants Department were investigated using the "Slide 5.0" software. The seepage amounts in the dam body floor in the presence and absence of a grout curtain were compared.

Turhal Dam

Figure 3 Turhal Dam

Turhal Dam is being built on the Gülüt Brook, a tributary of Yeşilırmak, at 3 km distance from Yazıtepe village, with an height of 121 meters from the base and in clay core rock fill.

Turhal Dam is being built for drinking and irrigation water supply and protection against floods and energy generation and when completed, it would supply 14.84 million cubic meters of drinking and utility water to the center of Turhal district center by 2050.

The dam that would supply irrigation water to 43,660 decares of agricultural land and also would possess a power plant with 0,79 MW capacity and protect the district of Turhal from flood damages.

It is targeted that the dam would be completed by 2018 by completing the remaining work such as derivation-sluice outlets, upstream coffer dam, and closing dike in the dam, where body stripping excavations, spillway excavations and slope support work are already completed.

Sixty percent of the Turhal dam construction is physically complete. With the operation of the irrigation project, an additional revenue increase of 405 liras per decare will be acquired in the irrigation lands, contributing 17 million 680 liras annually to the national economy. It is targeted to provide employment to 2 thousand 183 individuals when the dam is complete with an investment of approximately 100 million TL.

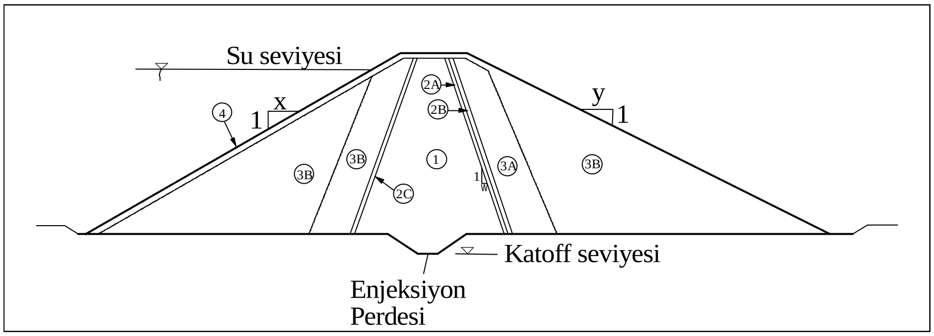

Figure 4 Turhal Dam Body Section

In dam body seepage analyses, the maximum body cross-section was used. The studies conducted on the project site demonstrated that under the dam body, it was proposed to open the grout holes vertically and at 3 m intervals for the grout curtain and to place the grout lids at a depth of 5 m at 2.5 m upstream and 2.5 m downstream of the grout curtain. The depth of the curtain for the analyzed section is 27m from the body bed (The grout depth is between 30-80m. Since the water load is lower in the cross section where maximum grout section is located, the section with the highest water load was analyzed). Analysis parameters are presented in Table 1.

Table 1 Dam Body Material Permeability Coefficients

Material Type	Material Code	k (m/s)
Impermeable	1	3.50E-10
Permeable	Fk	1.00E-05
	Fç	3.00E-05
	Ku	5.00E-05
Rock	4	5.00E-05
Loss	Z	5.00E-05
Alluvion	Al	1.00E-05
Grout Curtain	EP	1.00E-10
Main rock (Kot: 766 – 736 m.)	Main rock 1	5.00E-06
Main rock (Kot: 736 – 716 m.)	Main rock 2	1.00E-08

Analysis Results

Body Sections without Grout Curtain and Finite Elements Network Used in Analyzes

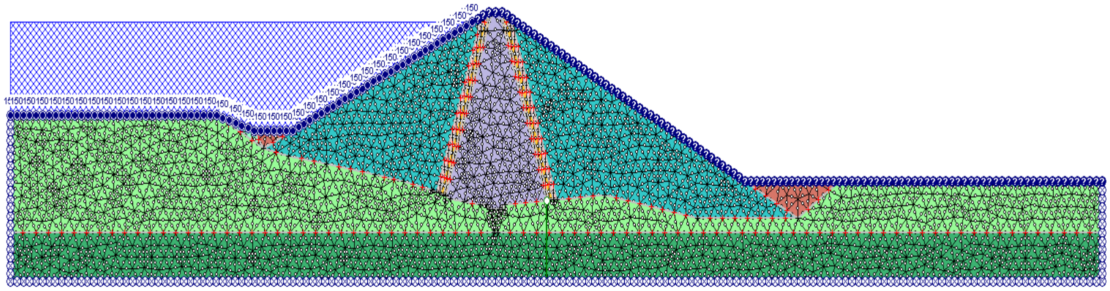

Figure 5 Body Sections without Grout Curtain and Finite Elements Network

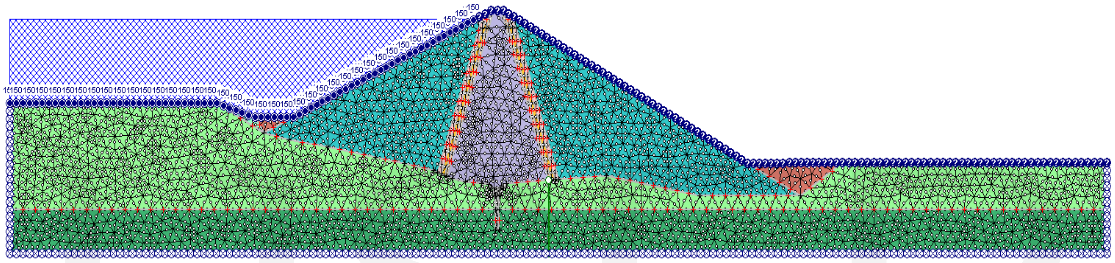

Figure 6 Body Sections with Grout Curtain and Finite Elements Network

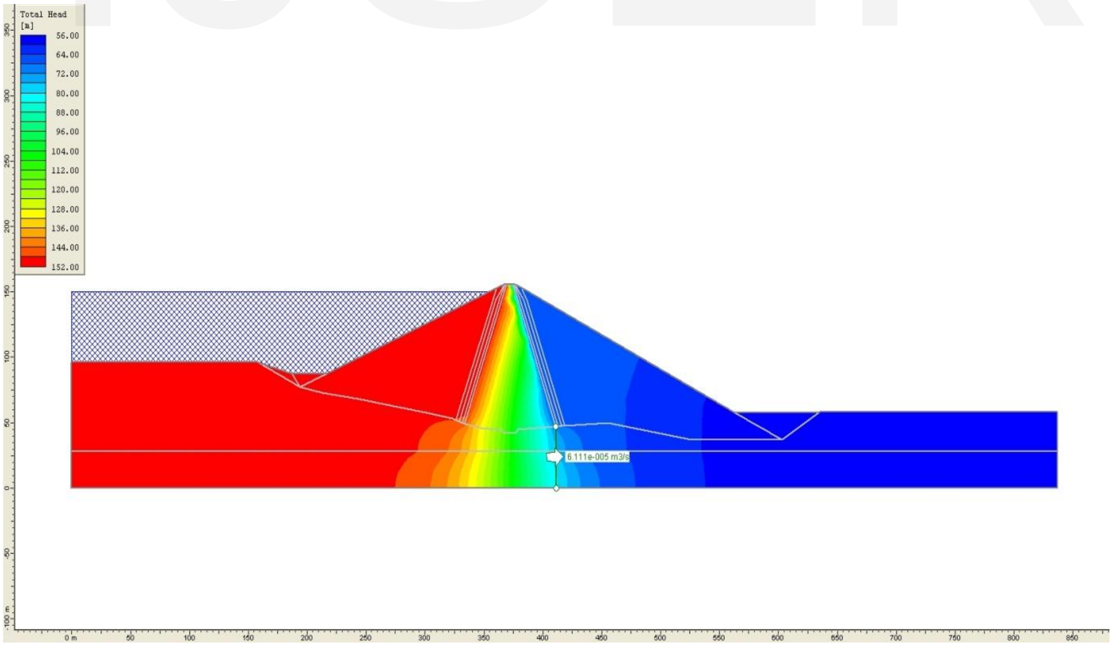

Figure 7 Body Seepage Analysis without Grout Curtain

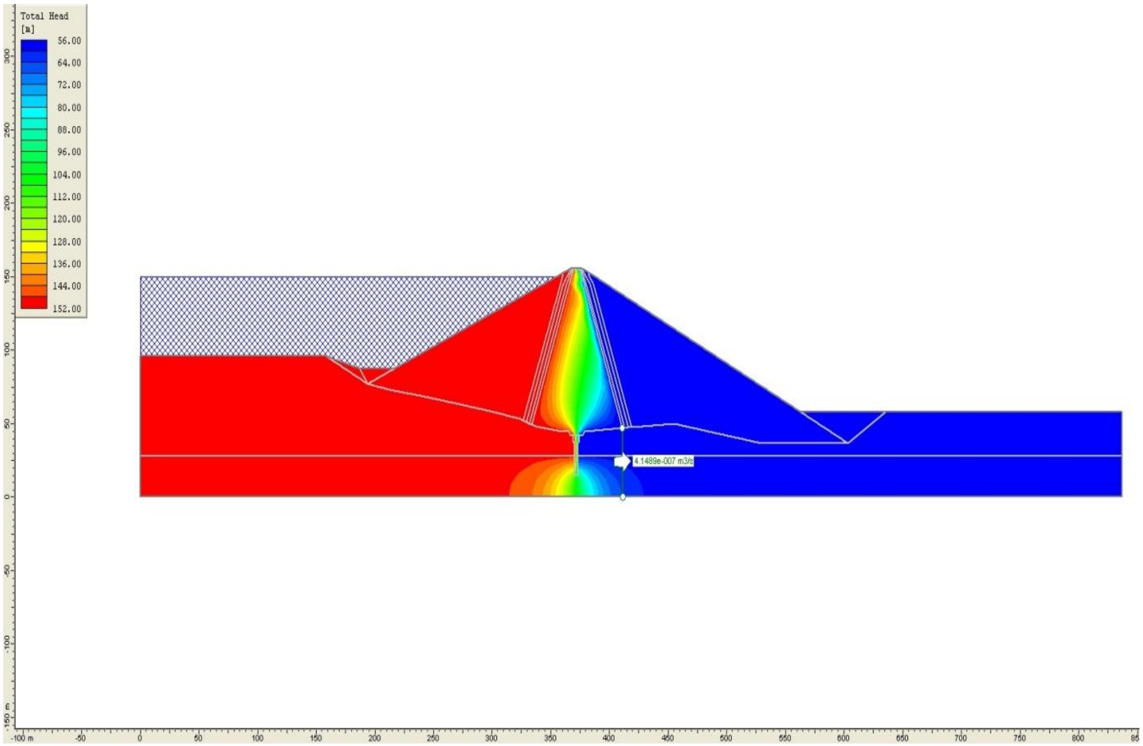

Figure 8 Body Seepage Analysis with Grout Curtain

Bases on the analysis results, the seepage under the dam body was q = 6.11E-5 m^3/s/m (Fig. 7) when grout curtain is not built on the maximum cross-section and q = 4.15E-7 m^3/s/m (Fig. 8) when the grout curtain is built.

Thus, when the seepage obtained for the maximum cross-section is multiplied by the crest length (574m) to remain on the safe side, the seepage was calculated as q = 35 lt/s when grout curtain is not built on the maximum cross-section and q = 0.24 lt/s when the grout curtain is built. The findings demonstrated that the grout curtain reduced the seepage under the dam body by 99%.

Closing Dike

In the seepage analyzes conducted on the Turhal dam closing dike, the maximum cross-section that would constitute the most critical condition was utilized. A large part of the closing dike would sit on the thick clay layer encountered in the drills conducted in the area (KSK-1,2,3,4,5,7). The permeability of the clay layer is accepted as k = 1E-6 m/s, taking into account the high gravel ratio and field test results. Due to the low permeability of the clay layer, no grout curtain is recommended in this area and it was decided to build only a lid grout at 5m depth. Analysis parameters are summarized in Table 2.

Tablo 2 Closing Dike Material Permeability Coefficients

Material Type	Material Code	k (m/s)
Impermeable	1	3.50E-10
Permeable	Fk	1.00E-05
	Fç	3.00E-05
	Ku	5.00E-05
Rock	4	5.00E-05
Alluvion	Al	1.00E-05
Grout Curtain	EP	1.00E-10
Main rock	Clay	1.00E-06

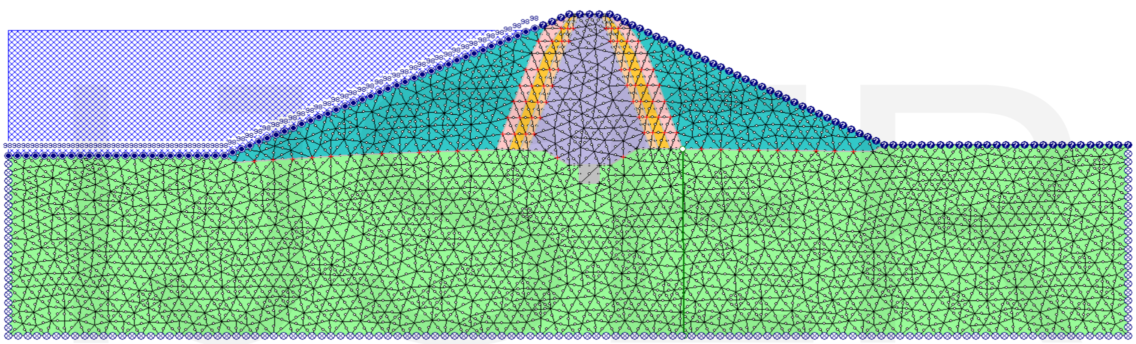

Figure 9 Closing Dike Analysis Cross-Section and Seepage Analysis

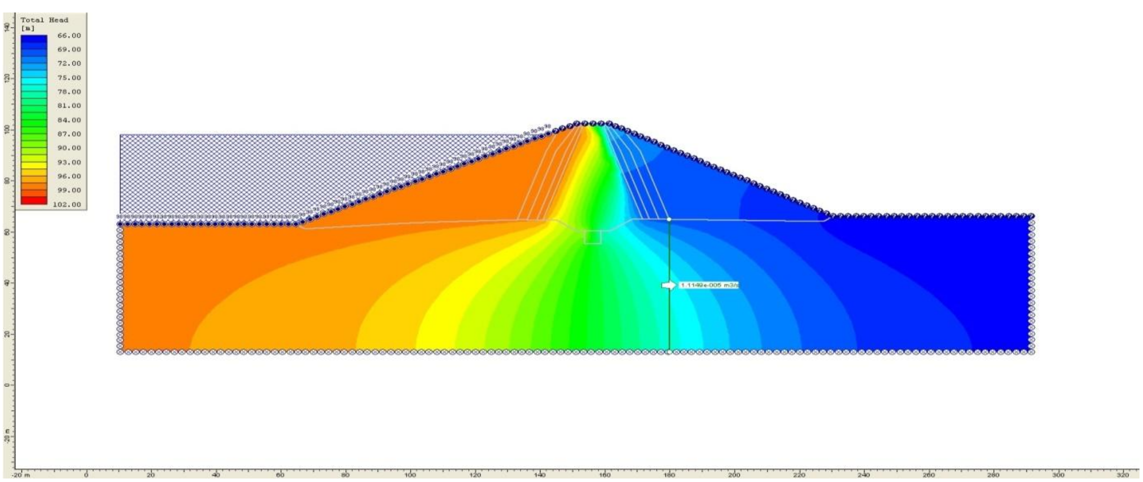

Figure 10 Closing Dike Analysis Cross-Section and Seepage Analysis

It was calculated that the seepage would be q = 35 lt/s at the dam body floor if grout curtain is not constructed and q = 0.24 lt/s if grout curtain is built. The findings demonstrated that the grout curtain reduced the seepage under the dam body by 99%. The seepage that would occur at the bottom of the closing dike bottom was found as q ≈ 5.3 l / s as a result of the analysis.

Conclusion

The seepage volumes calculated under both the dam body and the closing dike were within acceptable limits. As a result, problems due to seepage from the dam structure are not expected.

It was aimed to provide an example with the present study by emphasizing the significance of grout curtain in the ground seepage analysis.

Acknowledgements

We would like to thank the General Directorate of State Water Works for providing the data used in the present article and for their assistance in on-site examinations.

Resources

[1] https://commons.wikimedia.org/wiki/File:Beaver_dam_on_Smilga.JPG

[2] http://www.tarihteilkler.com/ilk/iLK_BARAJ_(Su_bendi)/135/

[3] Erdal Kesgin. Kil Çekirdekli Toprak Dolgu Atık Barajlarında Sızmanın Nümerik Metotlarla Araştırılması. Yüksek Lisans Tezi Ocak, 2015 İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü.

[4] Devrim ALKAYA, Burak YEŞİL. Grouting Applications in Cindere Dam. Pamukkale Üniversitesi, Mühendislik Fakültesi, İnşaat Mühendisliği Bölümü, 20070, Denizli

[5] Turhal Barajı Planlama Raporu (DSİ)