A Case Study - Installation of Cut-Off Wall In Seyrantepe Dam Project

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ABSTRACT: Due to high energy demand, recently dams are one of the most encouraged projects by the state in Turkey. Dam locations are determined in order to obtain maximum energy output and minimum cost to attract the private investors. On streams alluvial and permeable areas possess special problems for controlling groundwater seepage under the dam. For this purpose cut-off walls are well known relatively impermeable groundwater barriers that have been used for decades in various sizes and types. This paper examines a cut-off wall case study beneath Seyrantepe Dam Project in Elazig, Turkey. Seyrantepe Dam is planned to be constructed on alluvial deposits of Peri Stream which discharges into Munzur River. Maximum 30 meters deep alluvial and slope debris layers exist under the Seyrantepe Dam site. A slope failure has occurred during the initial stage of the construction that added great difficulty and complexity in construction of seepage barrier. To avoid the groundwater seepage in the alluvial and slope debris layers, a cut-off wall with 800 mm thickness was planned to be constructed penetrating two meters into relatively impermeable marl base rock. Mechanical grab and hydrofreze cutter diaphragm wall machine was used to construct the cut-off wall considering very unfavorable subsoil conditions given by slope debris containing irregular large size basalt boulders. In addition systematic grouting of limestone formations was planned in order to control permeability within of the dam settlement area. The plastic concrete which used in the cut-off wall was determined based on the hydraulic conductivity tested in the laboratory. Special permeability tests are also implemented after construction in order to verify the impermeability of the cut-off. Construction method and encountered difficulties with special emphasis are discussed in the scope of this case study.

INTRODUCTION

The number of dam projects which serving for multiple purposes is now increasing rapidly in Turkey. Dam locations are determined in order to obtain maximum energy output and minimum cost to attract the private investors and engineers are compelled
to locate dam projects on unfavorable soil condition. Controlling the groundwater seepage is one of the challenging problem which encountered during design and construction phase. It is well known that effects of the uncontrolled groundwater seepage are very important for the dam stability and as well for seepage loss. Groundwater seepage may cause catastrophic results if they are not handled properly. Results of the uncontrolled ground water seepage can be indicated as economical problems due to water loss. More seriously, if the velocity of seepage water where it emerges on the downstream is large, particles of foundation material can be carried away by the water and thus decrease the resistance to seepage, resulting in an increase in velocity and greater erosion, ultimately causing the formation of a channel underneath the dam in the pervious material which may enlarge rapidly and cause the failure of the structure, namely piping phenomenon (Tanaka and Yahagi, 1956). Impermeable curtains are most common solutions to eliminate these serious problems in pervious soil conditions under dams. For this purpose, cut-off walls are well known relatively impermeable groundwater barriers that have been used in the past in various sizes and types in dam projects. In this manner, dam safety can be satisfied and water loss could be limited.

Since dam is located on pervious soil profile in this case study, it is compulsory to build impervious slurry-trench curtain to eliminate seepage problems. Beside the seepage problems also slope stability failures were encountered in the site during the initial stage of construction (Vardar and Sans, 2006). Seyrantepe Dam is planned to be constructed on alluvial deposits of Peri Stream which discharges into Munzur River. General view of the Seyrantepe Dam Project site is given in Figure 1.

![FIG. 1. General View of The Seyrantepe Dam](image)

The cut-off (800 mm thickness) wall is designed to be constructed within the originally failed slope described by Vardar and Sans, 2006. Failed slope contained erratic large size magmatic origin boulders, creating a great difficulty during excavation of segments in case of using bentonite slurry and cutter technology. Special emphasis is given to encountered problems and their consequences during excavation of cut-off walls segments.
Plastic concrete is designed based on its hydraulic conductivity measured in the laboratory. Special permeability tests of the core samples taken from the plastic concrete of cut-off wall are tested in the laboratory to verify the acceptable limits.

**SUBSOIL CONDITIONS**

Soil profile under the proposed dam site is determined according to the results of soil investigation works. According to borehole logs, there is slope debris (partly failed slope due to initial phase excavation) which includes various size large basalt and agglomerate boulders to a depth of approx. 38 m and base rock is located under this layer which consists of sandstone and marls. Typical soil profile where the problems are encountered in excavation cut-off segments is given in Figure 2. Ground water table is approximately 10 m below the surface.

![FIG. 2. Soil Profile](image)

Existance of the soil debris is also emphasized by Vardar and Sans (2006) in the soil profile of the cut-off wall area due to previous slope failure the area. Slope failure mechanism and typical section of the dam shoulder is illustrated in Figure 3.

![FIG. 3. Failure Mechanism on the Dam Shoulder, Vardar and Sans (2006)](image)

**CUT-OFF WALL**

Because of the existence of pervious soil layers alluvial and limestone directly under the dam site and failed pervious slope debris containing large boulders at the left side of dam long cut-off wall is planned to be constructed both beneath the alluvial, limestone and slope debris to eliminate the excessive groundwater seepage.
Cut-off curtain wall depth is determined based on 2.0 m minimum socketing into the relatively impermeable underlying bedrock marl formation.

It is well determined that the limestone formation beneath the dam is heterogeneous. Water pressure – Lugeon values determined during soil investigations often yield excess Lugeon values. Therefore systematic cement grouting was planned to be implemented based on observed Lugeon values within the limestone. Further, systematic cement grouting is also planned to be implemented prior to cut-off wall construction up to 90.0 m under dam foundation including the west side. Dam and cut-off wall section is illustrated in Figure 4.

**FIG. 4. Cut-Off Wall and Cement Grouting Section**

**CONSTRUCTION OF CUT-OFF WALL**

Because of the heterogenous and difficult subsoil conditions, as explained previously, it is planned to construct the cut-off wall using both mechanical grab and hydro-freze cutter diaphragm wall machine. Cut-off wall is constructed in debris with the mechanical grab wherever possible and hydro-freze cutter (81 kNm max. Torque per gear box, 30 rpm max. revolution, max cutting depth 53m) was used where large basalt and agglomerates boulders encountered within slope debris and for the socketing of cut-off in bedrock. Typical equipment used in this project is shown in Figure 5. Due to urgency and tight construction schedule, continuous two shifts were employed throughout regardless of the weather conditions as shown in Figure 6.

**FIG. 5. Hydro-Freze Cutter and Mechanical Grab During Operation**

**FIG. 6. Construction under Unfavorable Climate Conditions**
Cut-off wall panels are constructed as primary and secondary units as illustrated in the Figure 7. Panels are constructed with providing minimum 200mm - 400 mm overcutting between them.

![FIG. 7. Primary and Secondary Panels](image)

**PROBLEMS ENCOUNTERED**

In the construction phase, large size basalt originated boulders within slope debris are encountered. Unfortunately, the size of boulders at the cut-off locations were larger than the sizes reported during design stage and large cavities are encountered during diaphragm wall excavation. Boulder size diameter as large as 2.0 m - 3.0 m at various elevations of the walls are observed. A boulder which extracted with excavator from the top elevations of the slope debris within a cutoff trench is shown as an example in the Figure 8.

![FIGS. 8 Encountered Boulders](image)

Cut-off wall construction with grab was not possible in these areas because of the existence of large size boulders. In this case hydro-freze machine took over the operation but with special difficulties due to the large size of boulders compared to the width of the cut-off wall. Also, basaltic nature of the boulder lithology caused a significant decrease in the production rate.

During the operation, because of the large cavities between boulders, bentonite slurry level decreased rapidly and as a result of this situation, segment of trench collapsed while hydro-freze cutter machine was working at 18.5 m depth from the working platform. As a result, trench was partly filled with boulders and debris up to 8.0 m depth. Due to presence of high groundwater level, a special rescue mission had to be implemented. To rescue the hydro-freze machine, a new neighbouring caisson trench as shown in the Figure 9 is excavated up to the elevation which hydro-freze cutter machine was stucked. Because of the high water level, caisson trench could be excavated together with dewatering using high capacity pumps. It was a challenging mission ended up pleasantly so that
hydro-freze cutter machine could be rescued after seven days of struggle without a major breakdown (Figure 10).

As faced in this case study, the excavation of cut-offs in loose slope debris containing large boulders under ground water is one of the most difficult and unpredictable task to be performed in foundation construction.

DESIGN OF PLASTIC CONCRETE

In the scope of the design of plastic concrete, hydraulic conductivity tests are conducted in the laboratory on the core samples taken from the plastic concrete from initial cut-off wall as reported by Altun and Mihcakan (2007). Permeability tests are conducted on the samples under various pressures. Pressure is increased from 1 bar to 5 bar and it is noted that permeability decreased respectively with the increasing pressure. Permeability values $10^{-4}$ and $10^{-6}$ cm/sec are obtained for the design mixture of plastic concrete and found to be acceptable. Test results are given in the Figure 11.
CONCLUSIONS

A cut-off wall using mechanical grab and cutter is constructed in order to prevent seepage under the dam described in this case study. Since bedrock stratum where the cut-off wall is socketed is heterogeneous, systematic cement grouting is also implemented based on observed Lugeon values in excess of unity within the bedrock. Cut-off wall is constructed within slope debris with the mechanical grab and hydro-freze cutter where very large basalt and agglomerate boulders were presented. Boulder sizes encountered during construction were larger than the ones anticipated in the design stage. It is demonstrated that loose slope debris containing large size boulders under groundwater as in this case study is one of the most difficult and detrimental condition to be faced in cut-off wall construction using cutters. High groundwater conditions and very high strength of boulders having basaltic and agglomerate lithology within the failed slope added greatly to the complexity of the problems. During the operation, one of the segment of trench collapsed while hydro-freze cutter machine was at a depth of 18.5 m from the working platform due to presence of large size boulders and loose slope debris. Hydro-freze cutter machine have been rescued in seven days of struggle without a major breakdown by implementing special rescue operation employing construction of a special dewatered rectangular caisson shaft. The construction of the cut-off wall has been completed with success, finally and giving the possibility to learn great deal and never to forget to ask the critical question of “what could go wrong in such challenging foundation engineering problems”.

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REFERENCES


Altun G., Mihcakan I.M., (2007), (In Turkish) Seyrantepe Barajı ve HES İnşaatı ZETAŞ Plastik Beton Karışmaları Geçirgenlik Deneyleri Ön Deney Çalışmaları, Dahili Rapor