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Permeability, groutability and protected clayey blanket appraisal of the Qadrony Zarand dam site in Iran

Perméabilité, injectabilité et protégé l'évaluation générale argileuse du site du barrage Qadrony Zarand en Iran

Mehdi Momeni

Department of civil engineering, Islamic Azad University, kerman Branch, Kerman, Iran, zimaraz.pars@gmail.com

Mohsen Amiri, Seyyed Mohammad Kalvandi

Ph.D. student, Department of civil engineering, Islamic Azad University, kerman Branch, Kerman, Iran

ABSTRACT: Seepage from the body and foundations of dams is one of the most important design parameters highly influenced by permeability. Also, permeability is one of the basic parameters for designing grout curtains, preventing water from escaping from the foundation and avoiding negative seepage pressures in borrow materials used for grouting. In this work, rock mass classification of a rock foundation dam site was carried out using the rock mass rating (RMR) and geological strength index (GSI) systems. This study was mainly conducted to evaluate permeability and groutability at the left side of Qadroni Zarand dam in Iran using Lugeon tests and insitu grouting. Also, the dam foundation was evaluated by pressure tests (WPTs) that indicated the need for a grout curtain below the dam foundation. The rock mass quality of the samples obtained via the SPI in conjunction with the drill core jointing degree acts as a useful reference for ground treatment design. The dam foundation groutability was zoned according to an SPI classification point view. At the left side zone, a blanket of two - layer of soil cement with a layer of clay (protected clayey blanket) were select for foundation improvement from permeability view point. Technical and economical choice reasons are discussed. The concluded "combined sandwich blanket connected to natural reservoir clayey blanket and grout curtain" is presented.

RÉSUMÉ : L'infiltration du corps et des fondations des barrages est l'un des paramètres de conception les plus importants fortement influencé par la perméabilité. En outre, la perméabilité est l'un des paramètres de base pour concevoir des rideaux de coulis, empêchant l'eau de s'échapper de la fondation et d'éviter les pressions d'infiltration négatives dans les matériaux d'emprunt utilisés pour les injections. Dans ce travail, le classement des masses rocheuses d'un site de retenue de fondation rocheuse a été effectué à l'aide des systèmes d'indice de masse rocheuse (RMR) et d'indice de résistance géologique (GSI). Cette étude a principalement été menée pour évaluer la perméabilité et la groutabilité du côté gauche du barrage de Qadroni Zarand en Iran à l'aide de tests de Lugeon et d'injection in situ. De plus, la fondation du barrage a été évaluée par des essais de pression (WPT) qui indiquaient la nécessité d'un rideau de coulis en dessous de la fondation du barrage. La qualité de la masse rocheuse des échantillons obtenus par l'intermédiaire du SPI en liaison avec le degré d'assemblage du noyau de forage sert de référence utile pour la conception du traitement au sol. Le groupement des fondations du barrage a été divisé en zones selon une vue de point de classification SPI. Dans la zone du côté gauche, une couche de ciment de terre à deux couches avec une couche d'argile (couverture argileuse protégée) a été sélectionnée pour l'amélioration des fondations du point de vue de la perméabilité. Les raisons du choix technique et économique sont discutées. On présente la «couverture sandwich combinée reliée à la couverture argileuse du réservoir naturel et au rideau de coulis».

KEYWORDS: Rock mass classification, Permeability and groutability, Qadroni Zarand dam site, protected clayey blanket.

1 INTRODUCTION

The sealing of dam foundations and abutments requires considering the geological conditions of the rock masses in question, including lithology, rock strength, hydrothermal veins as primary discontinuities, main joint sets as secondary discontinuities, distribution of the discontinuities, quality and strength of the joint-filling material and their permeability conditions (Sadeghiyeh et al. [2012](#)). The decision to construct a grout curtain depends largely on the results of water pressure tests (WPTs), as introduced by Lugeon (Ewert [1997c](#)). Hedayati analysed the engineering properties of rocks in the site Qordanlu dam (Hedayati 2012). Turkmen ([2003](#)) evaluated the seepage problem at the Kalecik Dam in Turkey. In this regard, similar studies were also conducted at the Nargesi Dam in Iran by Azimian and Ajalloeiian ([2015](#)). Tan and Chen have an experimental study on cohesive sediments and their consolidation behavior which causes remarkable changes in the stress field and seepage field of dams and reservoirs, due to variations in the dry density (Guangming and Yiming 2016).

Geological and permeability conditions of a rock mass can be evaluated based on laboratory, field and office studies. This paper discusses the Qadroni Dam under construction in the Zarand province. The river bed is at a level of 1675 m and has a total storage capacity of about 42 million m³. The dam will be built on the Qadroni River about 35 km south of Ravar southeast Iran; its geographical coordinates are 30N and 56E. The formations in the foundation of the dam consist of Sangestan and Taft formations. The main problem of this dam is that faults in the riverbed are parallel to the flow direction and groutability of left side is very high in deep crush layers. On the other hand, there is a deep layer of impermeable clay at the reservoir bed. Thus, to deal with this problem a grouting project was initiated. In this regard, the permeability of rocks was determined and analyzed using WPTs in boreholes excavated in the dam axis. The dam foundation groutability was zoned according to an SPI classification point view. At the left side zone, a blanket of two - layer of soil cement with a layer of clay (protected clayey blanket) were select for foundation improvement from permeability view point.

This paper provides technical and economical foundation improvement choice reasons. The concluded "combined

sandwich blanket connected to natural reservoir clayey blanket and grout curtain" is discusses the ability to control water seepage from the foundation and abutments.

2 METHODOLOGY

2.1 SITE LOCATION

Qadrony dam are 135 km north of the city of Kerman in longitude 56 degrees, 50 minutes and 16 seconds latitude 30 degrees, 57 minutes and 38 seconds Qadrony two kilometers north of the East Village is located on the Htkan and Qadrony river.

2.2 SITE GEOLOGY

Geologically, the Qadrony dam site is located in the folded Zagros basin on quaternary deposits and sedimentary formations. The sedimentary formations in the dam site are Sangistan and Taft formations.

Sangistan Formation: This formation consists of marl - Fvrsh red rock (siltstone) where the layers of sandstone and conglomerate are also seen.

Taft Formation: stratigraphic unit composed of limestone that Sangestan the manufacturer and the marl and limestone marl where also there is (Figure 1).

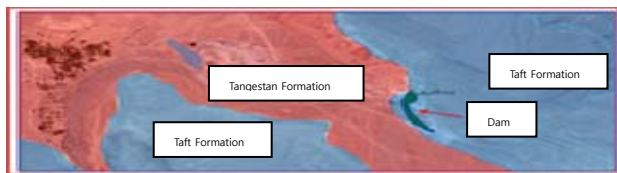


Figure 1 - geological conditions of dam site.

2.3 SITE PERMABILITY

The results of the drilling and injection test panel on the left side of the reservoir are:

The results of the pilot injection operation on a 24-meter panel on how the reservoir rock, cement absorption charts CT (Figure 2 and 3) is significant. As can be seen in the holes of the first series, the second, third, and to a depth of 75 meters, drilling and injection were take place. To access the LU <5 and CT <50 additional boreholes (fourth series) with a distance of 75 meters by a depth of 55 meters in order to result comparison to the adjacent borehole drilling and grouting was done, the result was not satisfactory.

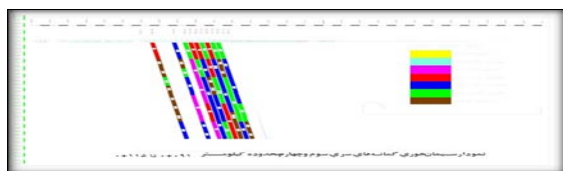


Figure 2. First and second d series borehole groutability.



Figure 3. Third and fourth series borehole groutability.

2.4 SITE FAULTS (TECTONIC)

Whole fault, F-3, F-2 F-K's in the middle part of the three fault, a wedge is being raised by fragmentation (Figure 4).

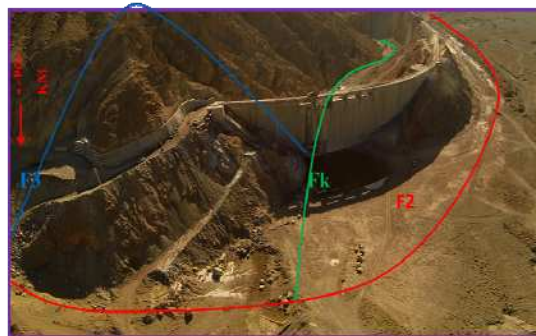


Figure 4. faults in the site of Qadrony dam

Groups fault F-3:

Fault F-3 and F-3, which plugs F'-3 intake system downstream of range passes. Between the two branches of the F-3 is also a sharp stone fragmentation.

Groups fault F-2:

The performance of the fault that has caused the left, between Taft limestone and marl and stones Sangestan Fvrsh remain as a pop-up and That the cutoff for the implementation of this water will escape The necessity of the measures to close it came to normal level of action taken.

Groups fault F-K:

This is the fault of the downstream dam axis perpendicular to the slope 65 to 70 F-2 goes into the tank to fault. Due to the absence of groundwater level in the range mentioned, and because of steep faults that extends deep into the earth and As well as extending them into the tank, the seepage of shear zone between faults outside of the cutoff was inevitable. Field surveys conducted in rock cavities left in the tank and the tank showed that there are several tectonic fractures and To check the hydraulic conductivity of the Left Bank close the bottom outlet valve to collect flood to 1685 levels (about 450 thousand cubic meters of tank volume) were measured. The hydraulic conductivity of about 440 liters per second from the left that the tests need to run the Surface coatings on the left to be more visible (Figure 1).

3 LEFT AND RIIGHT ABUTMENT SEALING OF QADRONY DAM

Sealing front of rocky wall of the left bank:

A. Run for cover due to the steep staircase Stays

Implementation of structural concrete with cement content 340 kg with the largest aggregate of 38 mm and use the network armature 16 to prevent heat cracks and thick (5/1 -1) m and the concrete cover on slopes by a series of bolts to 22 mm diameter in the rock wall a meter network is inhibited.

B.Implementation of soil and cement

Cement grade 180-160 kg per cubic meter of river materials with a maximum aggregate of 50 mm mixed layer with a thickness of 30 cm and width of 5.3 meters and just stepped run as stone veneer.

In comparing the two methods technically, stepped concrete method is easier and safer and from an economic standpoint stepped concrete implementation cost estimate was about 20% cheaper then was used to cover the left bank of reinforced concrete staircase (Figure 5).



Figure 5. Grout curtain proof test for right hand sealing technic (water level decline from 2015/02/22 to 2015/05/21)



Figure 6. Bottom of the reservoir improvement and concrete lining for walls of the left side.

4 BOTOM OF THE RESERVOIR SEALING FOR QADRONY DAM

Technic for sealing of the bottom of the reservoir is shown in Figure 6 and 7. For sealing the area at the bottom of the tank, a cover seal surrounded by a protective layer was used. The sealing covers at the bottom of the trench inflow, on the one hand by the seal into impermeable layers sewn Sangestan and the other at the foot of the dam has been connected to the concrete body. The seal between the cover and the concrete dam of the water stop bentonite was used.

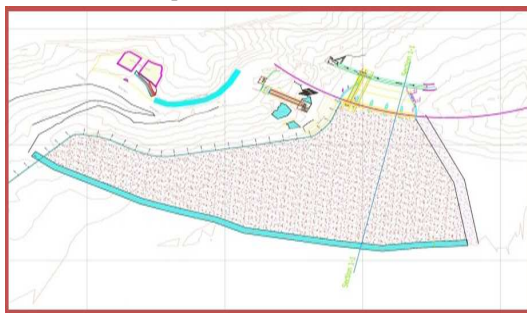


Figure 7 – Bottom of the reservoir sealing

Options for sealing of the bottom of the reservoir were:

1. Consisting of two layers of conductive materials of river materials in the soil layer thickness of each layer 25 cm and 30 cm and a thickness of each layer of cement to the concrete slab 20 cm thick reinforced.
2. Consisting of two layers of materials river transport materials to the thickness of each layer 25 cm and two layers of geotextile underside with Hrlayh grammage 500 g and a geomembrane layer with a thickness of 2 mm and a geotextile layer on it with the grammage 500 g and a layer of thick reinforced concrete slab 20 cm.
3. Consists of two layers of conductive materials of river materials, Hrlayh 25 cm and two layers of fine-grained sand filter each layer with a thickness of 25 cm and 4 meters of clay (in layers 17 cm) and a thickness of 40 cm layer of soil and cement.

4. Contains two layers of materials river transport materials to the thickness of each layer and dual-layer 25 cm of soil and cement thickness of each layer 30 cm and Three layers of clay seal each 17 cm thick and 30 cm thick layer of cement dust and moisture protection for hydraulic and clay (figure 8).

With regard to duration, operating costs and technical advantages and disadvantages fourth option was selected:

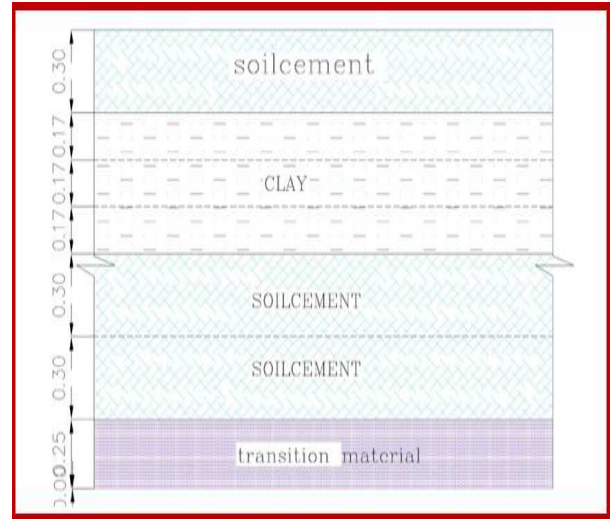


Figure 8 – sandwich blanket for bottom of the reservoir sealing

In this type of combination of clay and cement is used as a sandwich filling. This approach has technical advantages clay soil and cement, and placed them side by side, reduces the disadvantages of each of them separately and and between a layer of clay soil and cement to repair cracks might be more effective (Table 1).

Table 1: Comparison of options from technical and economical view point

explained	Option 1	Option 2	Option 3	Option 4
The thickness of the sealing element	Soil and cement 60 cm	Geomembrane 2 mm	Blanket t clay 4m	Soil and cement 60 cm and Blunkett clay 50 cm
Permeability factor	10^{-6} cm/s	10^{-12} cm/s	10^{-6} cm/s	10^{-6} cm/s
Duration (days)	75	60	250	90
Ensure the quality of execution	Control moisture content, density, connectivity layers, soil texture, homogeneous mixture	Welding control	Control moisture content, density, connectivity layers, soil texture, homogeneous mixture	Control moisture content, density, connectivity layers, soil texture, homogeneous mixture
subsidence	Subsidence with probability	high	Good	Subsidence with probability

	leave		leave	
Building Supplies	Local materials	Factory materials	Local materials	Local materials
Punch resistance	Good	Good	Good	Good
Strength and durability	Good	Good	Good	Good
Perhaps scour	Does not exist	Does not exist	Existence	Does not exist
Shield	Reinforced concrete slab 20 cm	Reinforced concrete slab 20 cm	Soil and cement 30 cm	Soil and cement 30 cm
Estimate Cost (millions of dollars) (total wall and floor)	1.35	1.35	1.19	1.08
The cost of adjustment (millions of dollars)	0.4	0.4	0.39	0.32
Total value (millions of dollars)	1.76	1.76	1.58	1.41

5 CONCLUSIONS

Due to the complexity of rock masses in Qadruny dam site, rock mass permeability and groutability are very different at left and right abutment. The main objective of the present study is to illustrate different choice methods for dam foundation improvement from permeability view point. The results and conclusions of this work can be listed as follows:

- In the bottom of the reservoir of dam foundation, "sandwich blanket" is the best choice and will be connected to natural deep layer of clayey soil.
- In the right abutment, grout curtain is the best choice.
- In the left abutment, concrete lining for walls which is connected to deep layer of clayey soil at the base is the best choice.

Further evaluation of connection behaviors of different choice methods for sealing of dam foundation is undertaken using 3D modeling in GEOSTUDIO.

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