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The Most Efficient Sealing Factors with Attention to the Effective Factors in Classified Earth Dams

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Abstract: *Water molecules flow through the porous soil environment due to potential energy. Leaking is always one of the important topics in dam design. Due to the presence of cavities among the soil grain solids, it is possible to move water in the soil mass that may endanger the stability of the dam, so the effects of this movement should be considered. In this research, which uses a nonlinear permeability function, the water escaping dimming elements include a seal wall in the core axis; a seal wall in heel; a seal wall in heel and paw; a clay blanket with variable thickness and length; the combination of two seal walls, one on the axis and the other on the heel, the combination of clay blanket with variable thickness and length along with a seal wall in the core axis, which is compared to the non-sealing state due to the most important effective factors in leaking, including Debi, velocity, and gradient in Bashar's zoned dam. The Geo-Studio software is used and hydraulic tilt changes are also considered at the core of the dam.*

Keywords: Hydraulic Tilt, Dam, Leaking, Seal Wall, Permeability Function

INTRODUCTION

In order to reduce and control the negative effects of leakage in soil grain solids, it is necessary to reduce the potential energy of water molecules by applying suitable methods, which will reduce leaking in soil grain solids. Since soil leakage cannot be practically reduced to zero, it is necessary to use methods for controlling leaking in the soil environment.

Due to the fact that the leakage inside the body and the foundation of the earth dam creates problems, the amount of it should minimize by preventing the leakage flow and reducing the energy (Rahimi, 2013).

One of the most important issues in earth dam studies is the problem of water leaking movement in the body and its foundation. This movement is important in order to calculate the amount of water loss, the stability of the dam, the calculation of the active pressure, the thickness and length of the drains, the grout curtain and the design of the seal wall (Vafaeian, 2012).

Feng et al. (2006) carried out the flow characteristics in dams with a variable width of the fam floor, multilayer foundation and the variable depth of sheet-pile wall, and presented the results as dimensionless curves (Feng et al., 2006).

In 2007, El Liban worked on the seal curtain effect of the Adhaim Al dam by Seep/w software. He concludes that the presence of a sealing curtain is not very effective when the membrane permeability is greater than the foundation (Al-Labban, 2007).

Griffiths and Fenton, in 1997, combined the techniques of the production of random fields and finite element, modeled the three-dimensional leakage, and concluded that the combination of these two methods could yield certainty results (Griffiths et al., 1997).

Materials and Methods

Introduction of the studied dam

Bashar Reservoir Dam is located at 51 degrees, 44 minutes 53 seconds longitude, 30 degrees, 12 minutes and 14 seconds north latitude. Access to the position of the Bashar Reservoir Dam is through the old road of Shiraz-Yasouj and within 35 km of Yasouj through a one-way road of sub-soil road. The site of Bashar Dam in located on the Bashar River in the Kherson river basin.

Bashar River is one of the main basins of the Karoon River, which originates from the western slopes of the Zagros Mountains. After passing through the city of Yasouj, this river joins the Kabkian River along the south to the northwest, and accepts frequent and seasonal flows along 115 km of the route, and after passing the Patwa station, located in 70 km from the Yasouj-Samirm road, goes on its way and with 25 km of another distance, in a place called Dezak, joins to Marbor River, and then is called Khersan and by receiving the Bazoft river, which originates from Chaharmahal and Bakhtiari Province, called Karoon enters to Khuzestan plain.

The area of the Bashar River basin is 2738 km^2 in Patwa location. Also, its annual yield in this situation is estimated at 1500 million cubic meters (Abfan Consulting Engineers Co., 2004).

Scheme Objectives

The supply of long-term drinking water and industry in Yasuj, as well as the agricultural use of the surrounding plains, along with the provision of part of the needs and uses of drinking water in Shiraz, is one of the main goals defined for the construction of the Bashar reservoir. Table 1 shows the permeability coefficients, different elements of the body and the dam foundation have been introduced (Abfan Consulting Engineers Co., 2004).

Table 1: Permeability coefficients of different elements of the body and the dam foundation (Ministry of Energy, 2012)

Permeability coefficient ratio / $K_y K_x$	Permeability coefficient value (cm/s)K_y	elements of the body and the foundation
9	1.1*10-7	Impermeable core
3	2.6*10-3	membrane
1	4.5*10-2	filter
1	5	drain
1	4*10-2	foundation
1	4*10-5	grout curtain

Research Method

In this study, the sealing reservoir options of the dam include a seal wall under the core, a seal wall in heel, a seal wall in heel and paw, a clay blanket with variable thickness and length, a combination of two seal walls, one is in axis and the other is in heel, the combination of clay blanket with variable thickness and length along with a seal wall in the core axis, which is considered as non-sealing mode. It should be noted that the height of the sealing wall is variable. Also, in each of these methods, the water level in the reservoir is different and in 3 levels, including normal level (reservoir with 46 m water), level with 30 m water and the level with 20 m water. The results have been analyzed and the height of the seal wall is considered variable.

In this study, we evaluated the effect of mesh variation on leaking for different sizes and maximum water gradient and its change in dam height using Geo-Studio software.

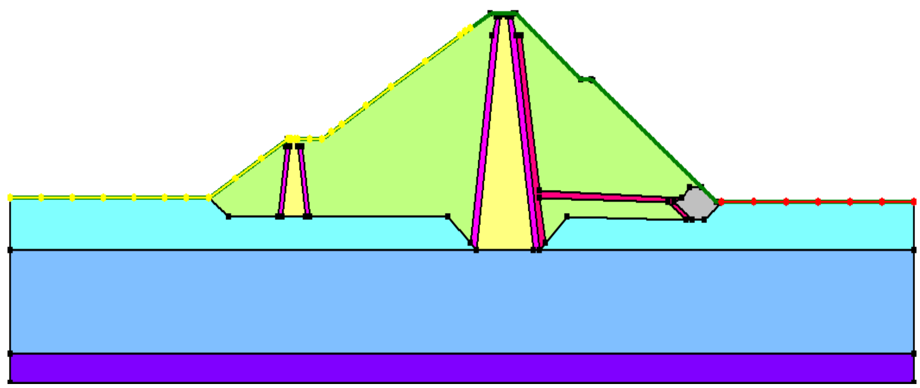

Figure 1: Cross section of earth dam in the non-sealing mode

Results and Discussion

The most suitable dam mesh

Due to the fact that Geo-Studio uses finite element technology, it is necessary to consider elements in small sizes so as not to enter damage in the analysis. It is clear that the smaller the meshes are considered, the accuracy of the results will increase (Javaheri et al., 2012).

Therefore, the meshes should be fined and not to change the results or the change in the small results is small and avoidable. In the modeling of the mentioned dam, a combination of square and triangular elements is considered. By solving the models with different mesh sizes, it was determined that using 2 m mesh, the change in the results of Debi flow through the foundation at the dam section in the case of a non-sealing viewpoint are small and avoidable (Biswas 2005).

As you see in Fig. 2, with a smaller mesh size of less than 2 meters, there is no change in the Debi flow through the dam cross-section. Also, Fig. 3 shows the built-in model of the dam with a dimension of 2 m in non-sealing mode.

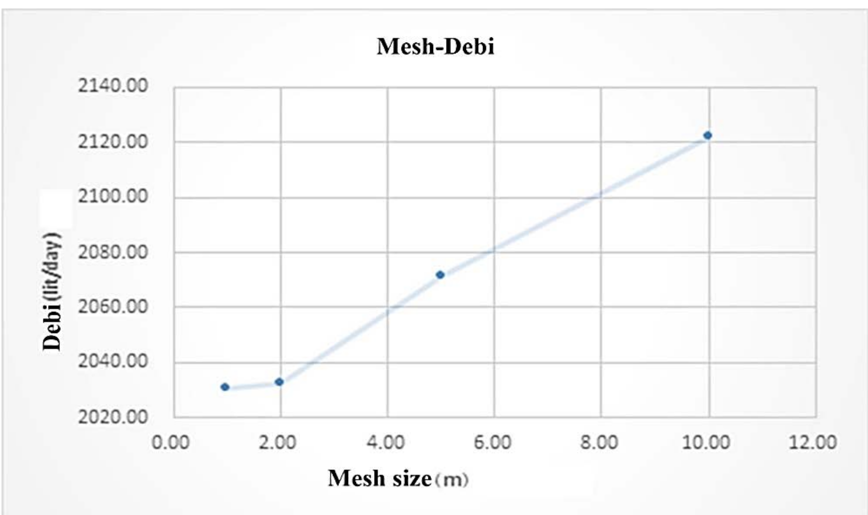

Figure 2: Effect of the mesh on foundation's Debi

Checking the maximum hydraulic tilt in the dam

Fig. 3 shows the maximum hydraulic gradient contour and the region with the highest hydraulic gradient in the x-direction. It is seen that the maximum value is at the core and at the boundary with the downstream filter.

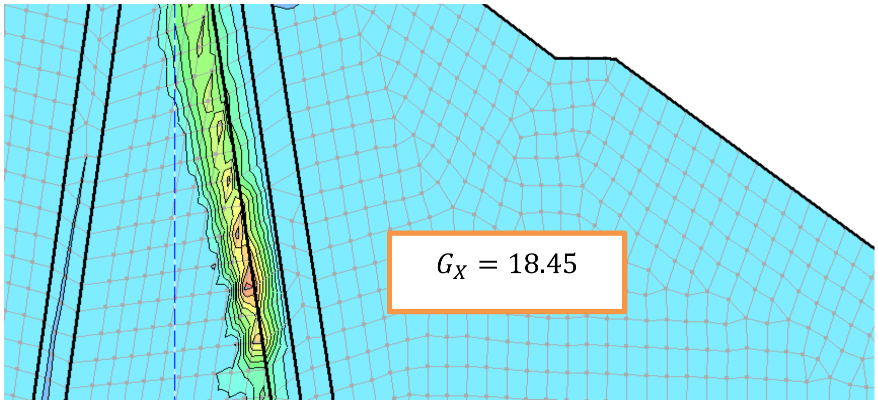

Figure 3: Maximum hydraulic tilt in the dam

Fig. 4 shows the hydraulic gradient changes in the x-direction at the dam height and at the core boundary. Also, a maximum value of 18.45 at 65.5 m height from the bed rock is deep, which should be considered (in the case of non-sealing)

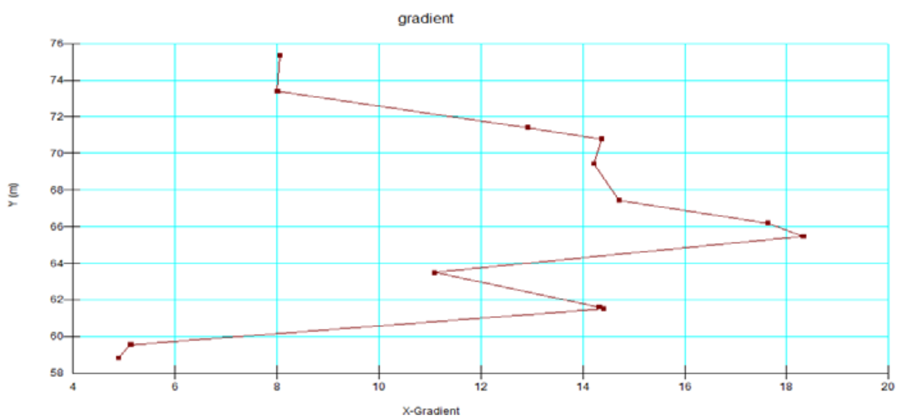

Figure 4: Hydraulic gradient in x-direction at the core

Effect of the seal wall on the core axis of the dam relative to the non-sealing mode

- By comparing the total Debi flow in the non-sealing state of the reservoir at normal level, which is 2134.75 liters per day, it is determined that the use of this option has been effective in reducing the total Debi flow. The total Debi flow reduction in this case is 50.84 liters per day which represents a 2.38% decrease.
- By comparing the hydraulic gradient in the x-direction in the non-sealing mode which is equal to (2.34e-4) and the lowest value in this state (2.29e-4), it is indicated that the use of this option in reducing the hydraulic gradient of the output in the x-direction is effective. The amount of reduction is equal to 5.5e-6.
- In reducing the hydraulic gradient, the output on the xy plane also affects. In the case of non-sealing, its value is equal to 2.35e-4 and in this case, it is equal to 2.3e-4, which indicates the difference (5.5e-6) in reducing the hydraulic gradient of the output on the xy plane.
- In the hydraulic gradient reduction, the output in the y-direction has not been effective only in the seal wall with a depth of 10 meters, which is equal to 9.6e-6. In the case of non-sealing, the value is 9.7e-6 which indicates a decrease 1e-7 at a depth of 10 meters.
- It has a positive effect on decreasing the flow rate of water in the x-direction. In non-sealing mode, this value is 6,263 m/day and the lowest value in this case is 6.103 m/day, which has a decrease of 0.16, which is 2.381% decrease.

- It has also been helpful in reducing the flow rate of water on the xy plane. In non-sealing mode, it is equal to 6.28 and the lowest value in this case is 6.14 m/day, which shows a decrease of 0.14.
- If we use a seal curtain, 10 m reduction in flow rate of the water in the y-direction is slightly affected that in this case is 0.502 m/day and in non-sealing case is 0.506 m/day. Reduction (4e-3) is considered, but it has a negative effect on the other depths and increases it.

Effect of the seal wall in the heel of dam towards the non-sealing state

- The use of seal walls at this section up to 24 m and 29 m depth, not only does not reduce the total Debi flow, but also increases it. But in this depths, the seal wall has been affected and it has reduced the Debi flow rate. The amount of Debi flow reduction in this case is 1.23 liters per day.
- The hydraulic gradient output in the x-direction in the seal walls with depths of 9, 14 and 19 m is greater than the hydraulic gradient output in the x-direction in non-sealing state. If we use a seal wall, we have 5 m decrease (6.82e-7) towards the to the non-sealing mode.
- The hydraulic gradient output in y-direction from depths 5 to 19 m is more than the hydraulic gradient output in y-direction in non-sealing mode. If we use a seal wall, we have 5 m decrease (1.26e-6) towards the to the non-sealing mode.
- At depths of 9, 14 and 19 m, the flow rate of water in the x-direction is higher than the non-sealing mode. But in other depths it has been reduced and the seal wall is more effective in other depths. If we use a 5 m seal wall, we have 5 m decrease (6.7e-3) towards the non-sealing mode.
- The flow rate of water at the xy plane is 9 to 24 m depth, the hydraulic gradient output at the xy plane is more than non-sealing mode. If we use a seal wall, we will have 5 m decrease (7.3e-5) towards the non-sealing mode.
- At depths of 5, 9, 14 and 19 m, the flow rate of water in the y-direction in heel is higher than the non-sealing mode. But in other depths it has been reduced and the most decrease is 5e-4 m/day. it is seen that it has no effect on decrease.

Fig. 5 shows the built-in model of a dam with a seal wall in heel.

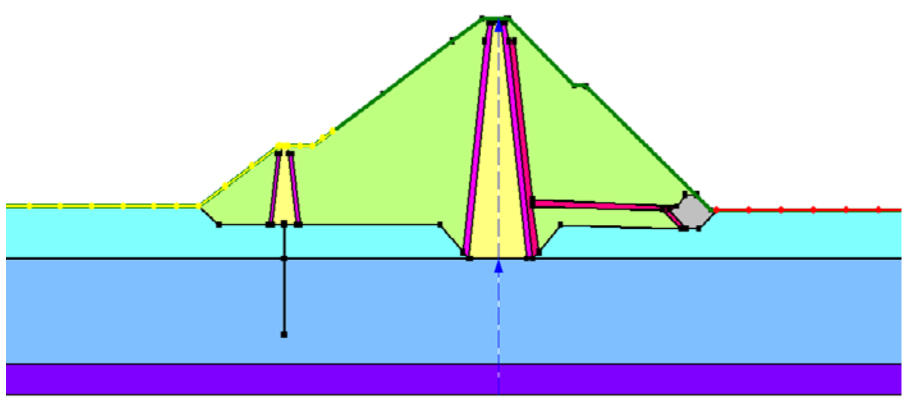

Figure 5: A built-up model of a dam with a seal wall in heel

The effect of the seal walls with the same height and simultaneously in the paw and heel of the dam relative to the non-sealing mode

- The total Debi flow through the section below the dam axis, in the case of using the paw and heel seal wall, only has a greater total Debi flow than the non-sealing mode using the 5 m wall, but with increasing depth of the seal wall, the amount of the total Debi flow decreases. In the best case, the use of a 29 m seal wall in this case means a total Debi reduction of 198.51 liters per day which indicates the effectiveness of this mode in reducing total Debi flow.

- As the depth of the wall increases, the hydraulic gradient of the output decreases in the x-direction. In the best case, using a 9 m seal wall, the reduction value of this parameter is (5.06e-7).
- The process of changing the output hydraulic gradient on the xy plane is like the trend of the hydraulic gradient output in x-direction. Using a seal wall, it will be 9 m decrease (4.53e-7).
- The use of a seal wall in the paw and heel is effective in controlling the flow rate of water in the x-direction and reduces it. Only in the case of a wall depth of 14 and 19 meters, the flow rate of water in the x-direction in this case is greater than non-sealing mode. In the seal wall of 9 meters, its decrease will be 2.46e-2.
- The process of changing the flow rate on the xy plane, in the most appropriate case, means that the use of a 9 m seal wall, will result in a decrease of 4.6e-3 liters per day.
- The variations of the flow rate in the y-direction relative to the non-sealing mode when the 45 m seal wall is used, has the amount of decrease that is equal to (3e-3) liters per day.

The effect of clay blanket on the bottom of the reservoir upstream of the dam towards non-sealing mode

- By comparing the total flow rate through the section with each of the clay blanket lengths and thicknesses, this option is suitable for reducing the total flow rate through the cross-section.

This process exists at different levels of the reservoir, but there is no clear relationship between them.

- In comparison to the hydraulic gradient of the output in the x-direction with the non-sealing mode, all the conditions for the implementation of clay blanket have been effective in reducing this value and this trend is seen in different reservoir levels.
- The implementation of a different clay blanket has had a positive effect on reducing the output hydraulic gradient on the xy plane.

As the length of the clay blanket increases, the output of the hydraulic gradient decreases on the xy plane.

- Comparing these two situations, it is determined that the implementation of clay blanket with different dimensions increases the output hydraulic gradient in the y-direction, due to the change in the direction of the flow lines that are affected by the clay blanket.
- The use of clay blanket with different dimensions has a positive effect on reducing the flow rate of water in the x-direction.
- In checking the water flow rate on the xy plane, the performance of the clay blanket reduces the water flow rate in the xy plane relative to the non-sealing mode.
- The process of changing the flow rate of the water in the y-direction is the same as the changes of the output hydraulic gradient in the y-direction, i.e., by applying the clay blanket, the flow rate of the water in y-direction is increased.

According to the analysis of the results in each of the sealing options in the dam, the best of each option is selected. These are: - seal wall with 20 m in axis (c20c[1]) - seal wall with 29 m in heel (c29l[2]) - Seal wall with 29 m in heel and paw (c29lr[3]) - Clay blanket with thickness and length of 1 and 90 m, respectively (b190) - The combination of two seal walls that one is 20 m in axis and another is 29 m in heel (clc) - A combination of clay blanket with 1 m thickness and 30 m length with a seal wall of 20 m in the core axis (bcc) – Non-sealing mode.

Conclusion

- The maximum output hydraulic gradient occurs at the core of the dam in the x, y, and xy directions that the sealing options are used in foundation, are not effective in changing its location.
- Due to the increased length of the clay blanket, the amount of the leakage passing through the body, and the entire body is reduced because of the fact that the seepage line will be reversed.

[1] cut off 29(m) left & cut off 20(m) right
[2] blanket width 1(m) & length 30(m) & cut off 20(m) center
[3] free

- Due to the increased thickness of the clay blanket, the water leakage rate of the foundation, body and total decreases because the low permeable factor of the seepage line will be prolonged.
- Whether the thickness of the clay blanket or its length is more effective to reduce leakage or not, the function of the flow conditions is how the flow lines are affected by clay blankets.
- In some sections, with different sealing options, there is a connection between the Debi flow rate through the foundation and the body, and in others there is no connection.
- As the depth of the seal curtain increases, the leaking of the foundation decrease leakage, and it should be in the exact position because the permeability of the layers is different, and the permeability flow range changes.
- Creating the sealing elements in some cases, reduces the flow rate of the water and the output hydraulic gradients in the x, y and xy directions, and in some cases increases these values.
- At intervals with a seal curtain, due to their low permeability, the pore pressure of water increases in the upstream which should be considered.
- Creating a combination of sealing elements can produce a better result if they are positioned properly, otherwise they cannot do the sealing with only a single element.
- Although the seal wall is effective in reducing the amount of leakage, but its high length will increase the pore pressure of the water, which should be considered at critical points.
- Because of the decrease or increase in the thickness of the foundation, hydraulic gradients change due to the approaching, and keeping out the flow lines.
- Due to the limitation of the permeability flow, for example under the seal curtain, the flow speed and Debi flow increase.

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