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Leakage Analysis of Embankment Dams Using SEEP/W, 3D SEEP Software

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ABSTRACT

Leakage in civil engineering including dams and especially in embankment dams is considered as one of the main issues. The wide valleys in the basin prioritize implementation of embankment dams. Iran location is in the Seismic zone of the world and this is also one of the reasons for the implementation of the embankment dams because flexibility of these kinds of dams against the incoming forces can show significance of these Geotechnical structures. Leakage analysis in embankment dams is one of the most important issues, and in case of insufficient attention, the dam safety can be threatened by devastating factors such as seepage forces or pore water pressure. In the present paper, different models were prepared using SEEP 3D, SEEP/W software from the software system of GEO-SLOPE. In the models preparation, it was tried to use most of Leakage control and reduce methods (clay trench, cutoff curtain, drains, etc.), and the dam physical and geometric factors such as permeability, upstream and downstream slope of the dam slopes were considered. The results show that the two-dimensional analysis of its nature was problematic, and the three dimensional model should be applied for the detailed analysis of leakage. Also through checking the results, it was found that if the cutoff curtain is located near the toe of dam (rather than picking it under the core), the hydraulic gradient in addition to control of leakage discharge ddecreases at the water withdrawal place from the body.

KEYWORDS: Leakage– Piping phenomenon– discharge leak– SEEP/W, SEEP 3D software-Feriatik line

INTRODUCTION

Embankment dams are as one of the largest embankment structures, and like many of the important structures forms parts of the modern society that economically, politically, and socially are of high importance. Therefore, one of the most essential analyses that are important in the many of the dam parts design is leakage analysis. Through leakage analysis of an embankment dam, the content of discharge leakage, pore water pressure at any point of the body and dam footing, amount of Hydraulic gradient in different parts of the dam such as core and the exit points of water from the body, etc. will be determined. The water that will be store d behind the embankment dams is always looking for a way to escape and this subject proves the importance of controlling infiltration phenomenon that is accounted as a destructive factor in the earth dams. With respect to the particular geometry of each embankment dam, a lot of parameters can be affecting body of these embankment dams. One of the most important factors is the same leakage phenomenon that should be controlled appropriately in order not to cause problems such as leakage force and ultimately the dam destruction. Due to the importance of embankment dams, special attention should be paid to their major issues including leakage from the dam body.

The precise calculation of the content of discharge leakage from the dam body and foundation is of great importance technically and economically. Leakage analysis in the design of an embankment dam is also important in terms of the dam safety because the water flow in the dam body and foundation creates pore pressure and the leakage forces. If these forces content will not be at the clearance limit, sustainability of the dam body and Foundation materials may face major problems such as boil and water scour which finally can result in the dam failure. Statistics show that more than 30 percent dam failure is due to lack of leakage accurate estimates, and as well, the lack of control procedures use or leakage reduces. Ignoring the water escape from dam body and foundation, besides creating damage and slowing down the construction process of a building, will cause wasting water resources as well. Also, this phenomenon at the earthquake time can face the dam stability with serious problems. Hence, leakage control stabilization is before the crisis management.

Leakage and the variety of its analysis methods

The embankment dam is composed of discontinuous physical dirt particles in different sizes that is required to be opposite the water flow and save it. Through saving water behind the dam and increasing its level, the potential energy of water particles increase and began to move due to the porous nature of the soil. According to the hydrodynamics rules, a drop of water when penetrates into the soil chooses the most

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comfortable route with a minimum of friction to be move, a phenomenon which is called infiltration. The leakage in embankment dams is unavoidable, but, if appropriate conditions are provided for soil erosion, it leads to its leaching in suitable locations. If in the beginning of soil erosion the required measures are not done, it can lead to destruction of the dam. This phenomenon has some undesirable effects as follows:
-Waste of the stored water in the back of the embankment structures;
- Creation of pore pressure in the porous environment and decrease of the effective stress between the soil particles and following decrease of its shear strength;
- Lift pressure exerting on impervious structures (such as concrete and steel structures)…in the environment;
- Movement of the soil particles and the creation of internal erosion phenomena in the environment;
- Exerting leakage force on the soil mass in the direction of the flow;
Therefore, the importance of a detailed leakage analysis in dam designing becomes more bold with regard to the mentioned issues.

Failure mechanisms of embankment dams
Internal erosion mechanisms and supercharge are specific matters and, the causes of the most serious injuries or failure occurred for dams are these two factors.

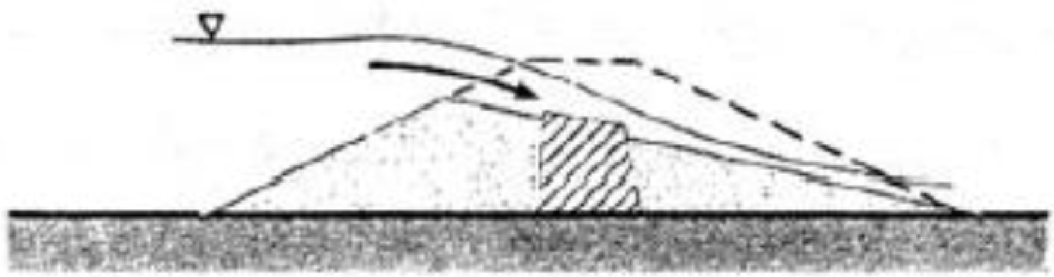


Figure 1: Overflow from the dam body (bankfull)

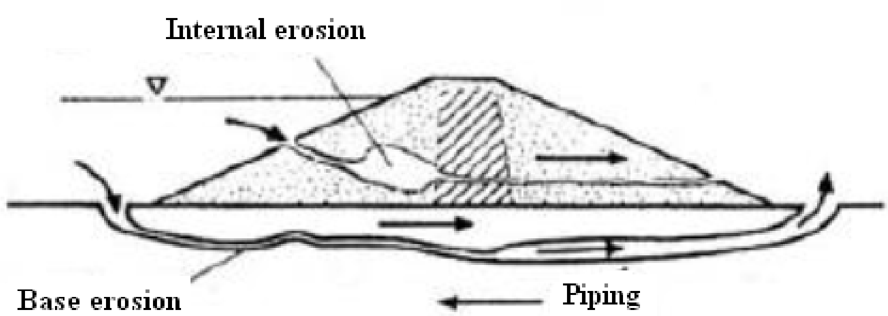


Figure 2: Internal erosion

Infiltration control (leakage)
In order to prevent erosion due to piping phenomenon, migration of fine materials from the impermeable cores, and downstream becoming marshy, the water infiltration out of the dam body and foundation should be controlled. So, the hydraulic slope pressure and speed of infiltration should be kept to the clearance limit for the selected materials.

The ways to prevent infiltration
Among the important characteristic of the infiltration process are water loss and leak erosion that is caused by foundation permeability, imperfect sealing, and internal cracks that can be avoided using the solutions offered above:
1- Creating a cutoff curtain and taking care in core design and injection, 2- internal drainage, 3-filters, 4-correct segmentation of earth embankment, 5-using sealing rings.

Piping phenomenon of leakage creating
In designing an embankment dam, the soil type if possible should be selected so that the detrimental effect of infiltration will be eliminated or reduced. In sights where the hydraulic gradients are abundant, infiltration

may lead to erosion and the creating channels within the dam. This erosion in cases where the soil is not well knocked is higher and may be causing dam failure, due to this reason; a central impermeable core is used to reduce the infiltration rate. Virtually, the entire hydraulic load is disappeared in the core. If the case that the core is slim, the hydraulic gradient will be created remarkably. If the output hydraulic gradient from the dam central core is large, there will be significant erosion risk of in the common part of the adjacent soil. For protection against this risk, a drainage layer posited between the central core and the soil layer in the downstream can be used. In fact, it can be said that if the hydraulic gradient increases in the part of water leakage from the dam body slope in the downstream, it may lead to soil elutriating, especially if the compression operation is not done well. This action is a progressive phenomenon. Initially, the finest particles will be elutriated. After the particles being elutriated, the soil resistance decreases against flow and the hydraulic gradient is increased. With the increase of the hydraulic gradient, more coarse particles are elutriated and gradually erosion operation happens more quickly and thereby leads to forming a tunnel within the dam. This internal tunnel is called pipe and the phenomenon is piping or internal erosion. When the said tunnel reaches the upstream with its progress, the water enters into it directly and flows too fast. The water flow leads to the tunnel loosening. In this step, the tunnel roof collapses and the complete dam failure occurs.

The piping phenomenon is a progressive phenomenon. It can be arranged in a timely manner through regular inspection of the dam. This phenomenon may happen after the dam being constructed on the condition that a factor leads to significant increase of the hydraulic gradient in the exit part.

On the embankment dams, if it is possible to choose the proper soil, the dam design will be done in the order that the destructive effects of leakage will be minimized. To cut on leakage, the dam is constructed from the two parts of the dam core or core and crust. Virtually, all of the energy loss takes place in the core that has very little penetration as compared to the crust. Therefore, if the core thickness is low, great hydraulic gradient will be created. The critical location of the border is between the core and the crust because water with higher hydraulic gradient exits of that.

The leakage theory in embankment dams

The foundations of analysis leakage traced back to the principle of Darcy in the year 1856. Darcy's experiment showed that the leakage flow of a quiet passing kind from one instance depends to its cross section and the hydraulic gradient difference section imposed on it.

$$q = k \times i \qquad (1)$$

Where k: leakage coefficient of soil, i: total hydraulic gradient, q: leakage per unit area

Laplace's equation that takes the following form of partial differential equation for water leakage in a porous layer, and for leakage in non-homogeneous soil, saturated-unsaturated conditions of soil is resulted through meeting equation of mass conservation of in the partial volume.The equation dominating the two-dimensional flow of water in soil is:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial H}{\partial y}\right) + Q = \frac{\partial \Theta}{\partial t} \qquad (2)$$

Where H: total head, ky & kx: hydraulic conductivity in the order of x, y, θ, applied border discharge, Q: volume moisture percent, t: time.

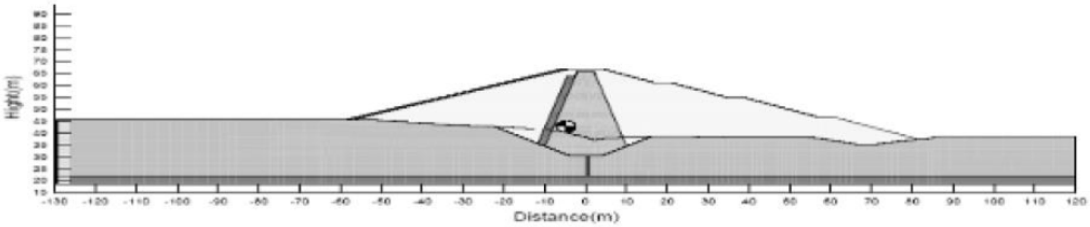
Software Introduction

One of the powerful software systems in the field of water leakage estimation in saturated and unsaturated soils is GeoStudio software, and modeling of the problems of water leakage in soil is conducted by the numerical software, in particular the SEEP/W subprogram. Numerical analysis in this program is carried out based on the limited components. The scope of the analysis in the software in addition to saturated soils also includes the unsaturated soils is, that is on the most important differences with other leakage analysis software. The given input to this software includes the permeability coefficients of all the dam materials, different points coordinates, the materials definition, the elasticity coefficients, and the dam upstream and downstream water level. The desired output in the present research is discharge of the specified section.

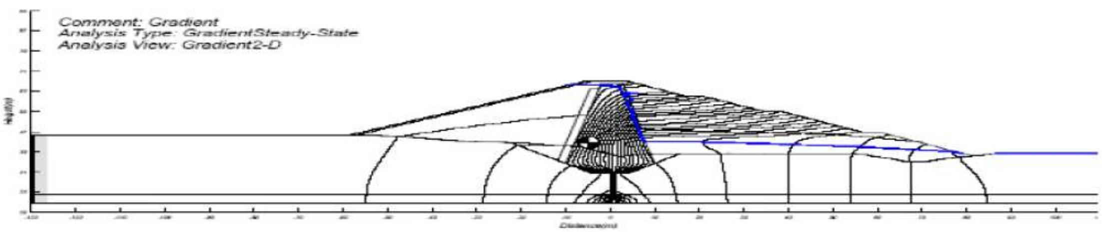
Leakage analysis of body and foundation of the examples dam along with presentation of the results

Technical specifications and scope of materials aggregation has been provided for various components of any part of the dam body such as the core, filters, drainages, and crust based on the results of the geotechnical tests selected samples selected from the identification borrow and available materials in the area. At the end when the values are obtained with taking into consideration the above parameters, twenty-five models of the dam in different scenarios will be analyzed with SEEP/W software. From among the results of maximum leakage discharge of core, leakage of foundation, and the daily leakage of the dam body and foundation, two optimized models were selected and analyzed by SEEP3D. The models selection was based on the variety of leakage control methods, and the drainage force and critical hydraulic gradient were investigated in all versions.

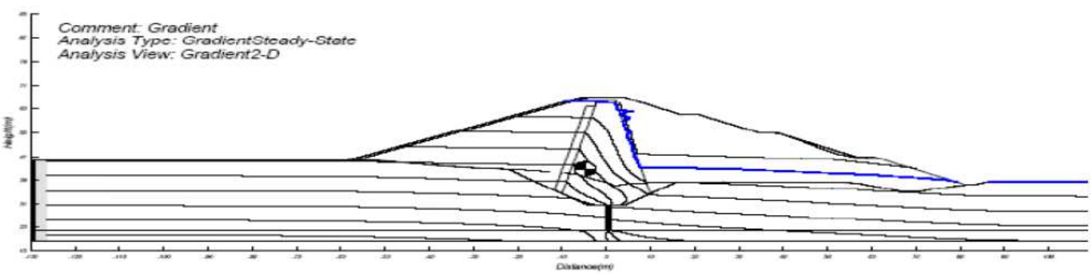
As can be observed in figure 3 in any one of these versions, the plan overview, equi-potential lines, isobar, and hydraulic gradient were drawn. In all models, the hydraulic gradient was examined on the output points of the core and body and compared with the critical hydraulic gradient.



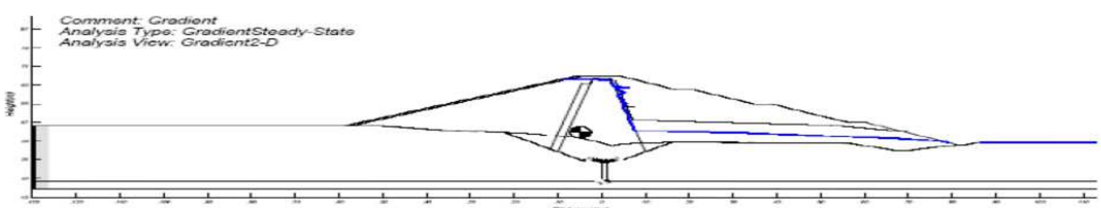
A. Overview



C. Isobar

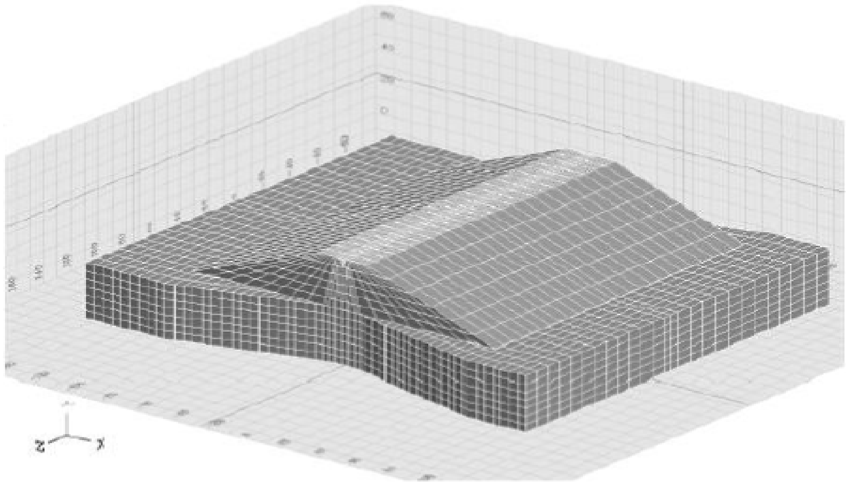


B. Equipotential lines

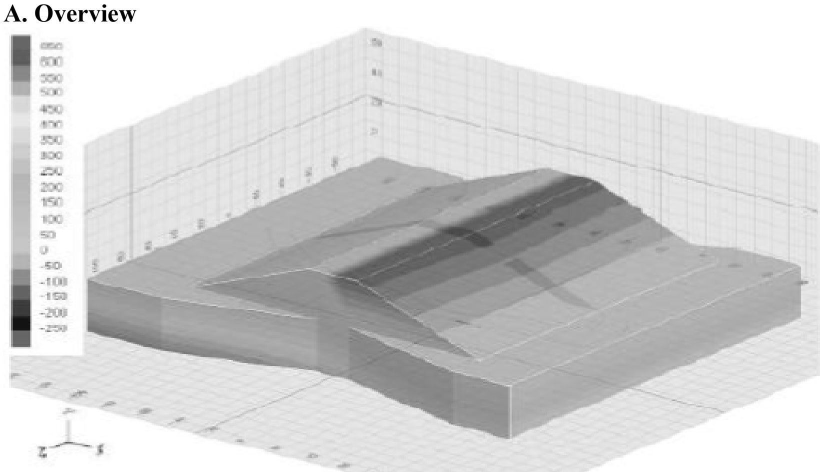


D. Hydraulic gradient

Figure 3: the two-dimensional model of the selected optimal model



A. Overview



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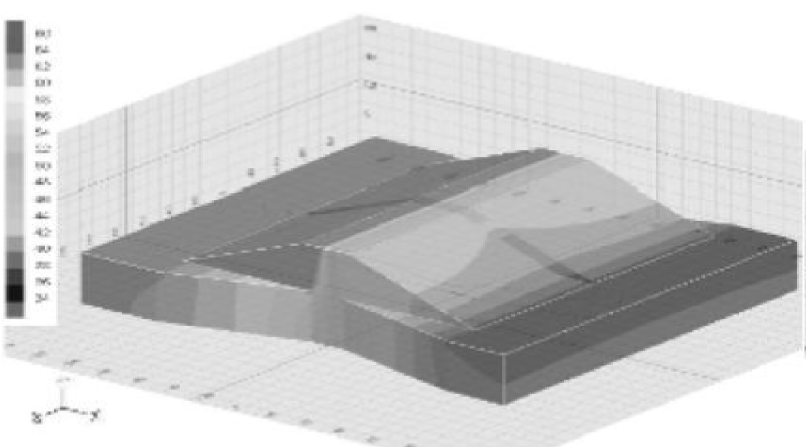

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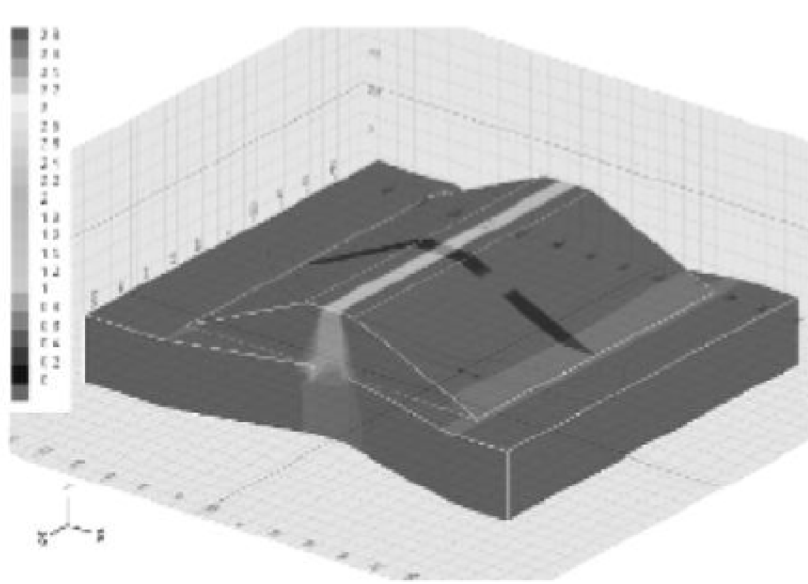

D. Hydraulic gradient
Figure 4: the three-dimensional model of the selected optimal model

In Figure 5, two optimal models were considered of the samples, and in every model a comparison was made between the results of discharge leakage in the two-dimensional and three-dimensional modeling status.

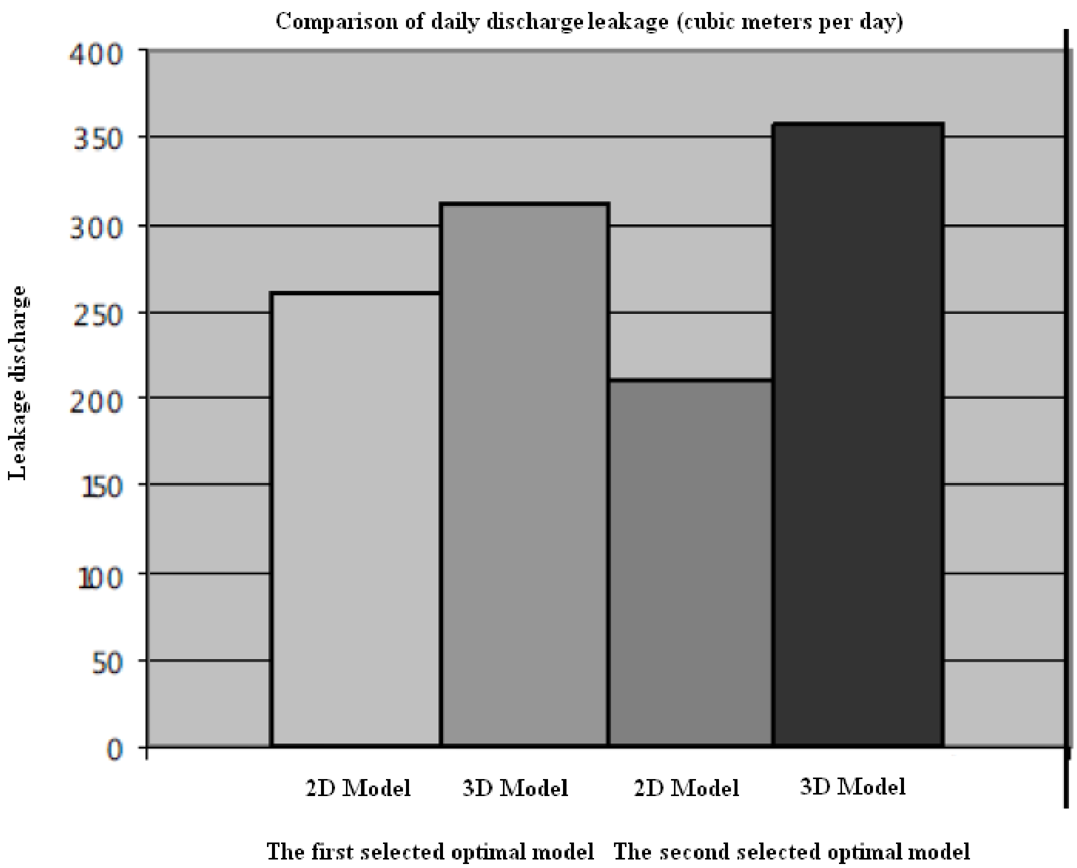

Figure 5: Comparison of daily discharge leakage between two-dimensional and three-dimensional models

Conclusion

1- Because there are a lot of problems in solving the infiltration equation or modeling equation in 3D form (especially in the time it is on), modeling is usually conducted in two dimensional forms in one or more sections. In tight canyons or valleys where their profiles are very variable, this assumption will be accompanied with significant error or maybe unacceptable due to the complex pattern of infiltration. Since in two-dimensional leakage analysis only the water flow in the plate is considered, so the water content flowing in a section of the dam is the flow which passes the previous section. Therefore, the water flow content can be controlled with the section which has the lowest permeability, that is, the sections act as series. However, all directions will be considered in three dimensional analyses. So, this water will flow through paths with the least drop of energy; as the result, the main part of the flow will pass through sections with high permeability while the flow path is slightly more than the shortest possible path. Thus, the two dimensional analysis is problematic in nature.

2- In analyzing the designed two-dimensional and three-dimensional models, it was observed that the discharge rate in the three-dimensional pattern of a model was about1.21times of its two-dimensional pattern. In another model, the three-dimensional pattern was about 1.70 times of the two-dimensional pattern; so, the three-dimensional pattern should be applied for more detailed.

3- The hydraulic gradient in both two-dimensional and three-dimensional patterns in place of the water exit from the dam body was equal to 0.5 which was less than the critical hydraulic gradient.

4- Because of time consuming designing of the three-dimensional models, the author initially decided to choose the most optimal two-dimensional model then change it to a three-dimensional model; however, during the work it was realized that if the model leakage in two-dimensional pattern is less than other model, it was not true about the three-dimensional model. So, in case that several optimal two-dimensional patterns are chosen, the three-dimensional pattern is better to be controlled for all of them.

5- With regard to the permeability coefficients of dam materials and to that core permeability coefficient is considerably less than that of the alluvium and its lower layer; it could have been predicted from the beginning that the measures are more effective for controlling leakage that are in the foundation and under the core. Therefore, the use of cutoff curtain and trenches are more effective which is also confirmed by the models results (almost in all models the leakage content from the body was less than that from the foundation).

6- Results of the models study showed that if the cutoff certain is selected near the dam toe (rather than its place under the core), it can be more effective in the control of leakage discharge and also the hydraulic gradient is less in the place of water exit from the body

(the hydraulic gradient is approximately three quarters).

7- Feryatic line (the highest leakage line) was placed in the higher elevation in the three-dimensional model which itself represented increase of pore pressure in the dam body.

8- Given that the shape of the valley and it's actual topography was not considered accurately in the 3D model, the responses may be considered a little conservatively.

REFERENCES

[1]: Nooranee, V., Fatehi Nobarian, B. (2002), The impact of the permeability changes of the earth dam body in numerical modeling of leakage phenomenon in zenouz earth dam, the Fifth Congress of the civil engineering, Ferdowsi University of Mashhad.

[2]: Saleh Fard, H., Sanaee RAD, A., Saba, h. (2009), Review and analysis of Hashian Earth Dam leakage in Shazand, The sixth Conference of the engineering and environmental geology, Tarbiat Modares University, Iran.

[3]: Jamal, A. R., Nico, M., Rohanee, A. (), "The effect of the clay core slope on the unstable phenomenon of leakage in the Earth dams.

[4]: Hedayatee Far, B., Rahimi, L., Tamanaaee, H. (2014), The leakage analysis in Sahand dam and comparing the results with data Survey of behavior, the first National Conference on soil mechanics and foundation engineering, University of Shahid Rajaee, Secretary education, Tehran.

[5]: Anjam Shoa, N., Soltani, F. (2014), Numerical analysis of water leakage in the heterogeneous earth dam taking into account the various sealing conditions, The First National Conference on soil mechanics and foundation engineering, University of Shahid Rajaee, Secretary education, Tehran.