



**International Journal of Biology, Pharmacy
and Allied Sciences (IJBPAS)**

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

**STUDYING AND NUMERICAL ANALYZING OF WATERWORN IN FOUNDATION
OF KOCHEREE EARTHEN DAM IN GOLPAYEGAN CITY BY SEEP/W SOFTWARE**

REZA NAGHMEKHAN DAHANDE

Master of hydro-civil Engineering, Islamic Azad University of Islamshahr branch,

Naghmekhan.reza@gmail.com

ABSTRACT

One of the important and considerable factors, in the design and construction of earthen dams, is investigation of leakage of water from the body and foundation in order to secure stability and waste water. In this paper, the foundation waterworn of Kochery earthen dam has been examined. The studying area is geographically located within Golpayegan city in Isfahan province. For numerical analyzing of water leakage Seep/w software has been used in which the numerical analysis of leakage done by finite element method. According to that the annual leakage rate is not acceptable from an economic standpoint and safety coefficients are less than the maximum allowable amount in 2,3,8,9,11,12 segment and waterworning phenomena occurs at the above mentioned segments. Therefore in order to waterproofing of the dam foundation, two method of trench and walls waterproofing have been used. After waterproofing of foundation by trenches of sealer, the amount of water leakage from foundation will be reach to allowable level and it is acceptable. But safety coefficients are acceptable to prevent from piping phenomenon, except 2, 11 segments. Waterworn matter is an important problem in technical and engineering perspective that has been solved after building a waterproofing wall and water leakage reduced and reach to 1.63 percentage of storage measure.

Keywords: Hydraulic gradient, piping, finite element, waterworning, Seep/w software

INTRODUCTION

Waterworning, in term of engineering, backrest. Among the factors that could put considered the stability of foundation and hydraulic structures is unallowable leak of

water. In the other word, in designing of dam foundation waterproofing, Suppose is allowable water leakage from dam foundation. When Water passing through the dam (water leaks) so that it is not including movement and transportation of earth materials of foundation, or in other words, piping does not occur, can be said that the dam foundation is stable. In this plan, the most thickness alluvial deposits located on the left side of built. To evaluate the potential of piping, calculation of hydraulic gradient is required.

1 .The existing hydraulic gradient i (exit):

To obtain it that must be calculated the leakage of each segment then the rate of leakage. By dividing the flow ratio of leakage (Q), on the cross-sectional area (A) in permeability coefficient (k), hydraulic gradient (i_{exit}) of segment is obtained.

$$Q = k.i.A \quad (1-1)$$

2 .The critical hydraulic gradient i_{cr} :

Critical hydraulic gradient (i_{cr}) is obtained from afloat density ratio (γ_r) of materials to density of water (γ_w).

$$i_{cr} = \frac{\gamma_r}{\gamma_w} \quad (1-2)$$

If the critical hydraulic gradient ratio to the hydraulic gradient is more than 2-3 (safety index), then surly can be stated no event of piping associated to the safety index [8].

$$F_s = \frac{i_{cr}}{i_{exit}} \geq 3-2 \quad (1-3)$$

Exudation analysis can be considered by using various methods such as analytical methods (Darcy's Law) Similar Electric method (Palofsky) and numerical methods. Nowadays numerical methods have been used more because of computer development and good accuracy mathematical models, ease of use, cost reduction and investigation of the phenomenon.

In this study, finite element numerical method due to more accurate answers almost applying any boundary conditions for any geometric shape of body and bedrock to solve the equations in the saturated and unsaturated soil have been used.

Also the potentials pore pressure and speed and water flow through the foundation and body of dam can be obtained. By solving the equations and get the hydraulic head of water can be examined passing discharge in terms of with waterproofing act and without waterproofing act with high accuracy [1].

This leakage may occurs from geological formation of dam built or the dam body. Although leakage is inevitable, for various reasons, such as meetings of non-uniform subsidence or earthquakes, etc., during operation of storage but dams that are built correctly, it is effected less by subsidence.

According to Nonvieller (1989) water leakage from foundation (increase of groundwater flow from foundation) leads to the following consequences:

-Increase the rising pressure into the foundation surface which may be caused to damaged and instability in structure.

-Drainage flow at the seams and holes in the foundation materials could have been made erosion, increased natural permeability of stone and granular soil lead to hydraulic break. [5].

2. Geographical position and specifications of the Kocheree dam:

Structure of Kocheree dam located in Isfahan province and within Golpayegan city limit. Access way to the site is the asphalted road which begins from Golpayegan and continues to Aligodarz. The 5th kilometer of mentioned road has a diversion road to the dam. The road length is about 3 km and lead to the left abutment of the dam and access to other parts of the site is possible through local access path. The location of the project is shown in Figure 1.



Figure 1: geographical location of Kocheree earthen dam

Kocheree dam characteristics can be summarized as follows:

Dam height from the bottom of the river: 33 m

The dam's crest length: 150m

Dam crest balance: 1205

Free height of dam: 3 m

Normal level of water in the storage (overflow level): 1202 m

Storage level in normal balance: 207,959 sq.m.

Adjusted volume of the dam: 2967252 cubic meters

The minimum operating balance (intake balance): 1181 m

3. MATERIALS AND METHODS

3.1 Kocheree dam site status

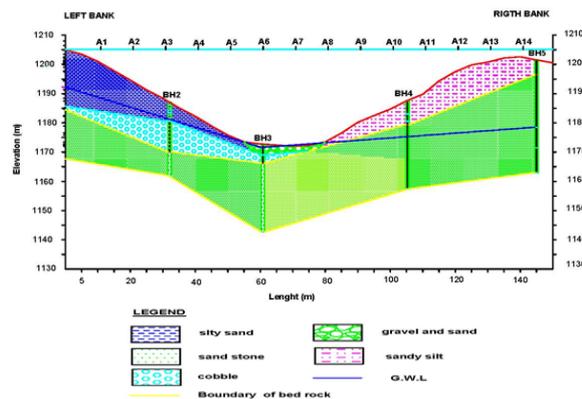
Kocheree dam has a foundation composed of soil and rock that alluvial materials have been on the rocks below. The thickness of alluvial materials are different in the left and right bents of the dam axis so that the thickness of the average of alluvial deposits in the left and right bents are 17 and 8 meters respectively. Stratigraphic sections of the dam axis presented in Figure 2.

As observed in Figure 2, the stone part of foundation composed of sandstone and in the bottom of river are alluvial material, coarse material and is made of gravel, the left bent

composed of silt and sand and right bent is made up of sandy silt.

To provide the segment permeability, at first drilling machine boreholes of location has been implemented (in rotatory form) on the axle section of dam and the establishment of permeability coefficient values in the tested

grades each borehole, a permeability column was defined. Also, distance between the boreholes have been used to identify permeability zones by interpolation method. Permeability section of foundation is given in Figure 2 .



3.2. Alluvial foundation

Alluvial foundation divided into two parts of permeable and impermeable in which the separation base of permeable part from impermeable part is permeability coefficient, so that the boundary index of impermeability is 1×10^{-5} cm per second. Thickness of permeable part in the left bent is greater than its thickness in the right bent. In general, the thickness of the alluvial materials in the left bent is greater than right bent. Alluvial foundation of dam axis has different permeability in different parts, the permeability coefficient of the materials of the permeable alluvial part are swinging between 2.5×10^{-5} to 4.9×10^{-2} . With regard to

the distribution of different permeability zones in different locations of foundation and also their different coverage percentage, the average permeability coefficient equals to 7.23×10^{-3} cm. The thickness of alluvial deposits in the river bed below the dam upstream and downstream due to lack of adequate information is considered equally.

3.3. Stony foundation

Bedrock of Kocheree dam is made of sandstone which according to Lozhan's experiments that have been conducted in different boreholes, stony foundation has low permeability coefficient. Here impermeable border index is considered Lvzhan's stone 3. The average depth of stony foundation is

between 6.5 to 20.5 m in the left bent and average depth of the right bent is between 6.5 to 11.5 meters. In all sections except sections A6 and A7 and A8, stony part is impermeable and requires to waterproofing, so the foundation rocks in the left and right bent is impermeable and has only been permeability in the river bed. The greatest depth of the stony foundation is observed in the borehole BH1 and its lowest depth is observed in BH3. The value of Lozhan's number for all segments tested values obtained under one Lozhan, index of impermeable border at the axel of dam is three Lozhan based on the permeability of rocks and alluvium by 1×10^{-5} cm per second.

3-4-The amount of water leakage from foundation

In calculating of Kocheree earthen dam leakage, three assumptions are considered as follows:

First hypothesis:

To calculate the leakage, permeable border has been considered under the dam foundation is less than 1×10^{-5} cm per second for permeability coefficient of the alluvial area and it is less than 3 Lozhan for stone area of permeability coefficient.

Second hypothesis:

It is related to the usage of finite element method in order to numerical analyze of

leakage in stone part. Considering that all performed analyzes in rock mass, including stress-strain, rupture, leak and etc. are done based on numerical analysis by using discrete components in modeling section. In this section, according to the low thickness of stony layer and also lack of using to analytical methods examine leakage by limited component in the stony section in a software with regarding to safety coefficient.

Third hypothesis:

For modeling permeability coefficient between the soil and rocky section, based on Barton and Koadros (2003) a Lozhan was assumed equals to 10^{-5} cm/s.

Before calculating the leakage, first drawing the permeability segment of dam foundation, in 14 sections (number of sections based on the profile of geological and also change the properties of soil and rock in place to increase and decrease, obviously with the increase in the number of sections the leakage analyze done precisely) based on the thickness of the layers of soil and rock, and the thickness of each, equivalent permeability was calculated that its summery represented in Table 1. To calculate the amount of water leakage through the foundation at the site of each segment compare to determination of geometric statue

of foundation and body, follows, Table 1 were set according to the layout of the dam.

Table 1: geometric features of foundation and body of Kocheree earthen dam

Segment	Horizontal distance of the upstream crust (m)	Horizontal distance of the downstream crust (m)	The core principle (m)
A1	12	10	7.4
A2	24	25	11.4
A3	39	65	19.8
A4	57	77.5	24.2
A5	87	85	29.4
A6	93	92.5	31.4
A7	90	90	30.6
A8	81	92.5	29.8
A9	69	92.5	28.2
A10	57	52.5	20.2
A11	51	35	16.6
A12	48	17.5	13.4
A13	30	10	9.8
A14	24	5	8.2

After determining the geometric features of body and foundation, its drawing was done in Seep/w software.

3-5-Features of Seep/w software

In order to analyze the permeation from the porous body in accordance with the considering plane, SEEP /W program has been used.

SEEP / W is a finite element software product that can be used in modeling the movement and distribution of pore water pressure within porous materials such as soil and rock and provides the possible analysis of simple and complex issues in water leakage. This software applied in analysis and design of geotechnical, constructional, hydrological and mining projects.

The program is able to analyze the saturated and unsaturated flows. In order to modeling of inside of spongy environment by this

program, different parts of filtering body and geometric shape of all its components and water balance of upstream and downstream were introduced to program as Cartesian coordinates. It should also permeability (K) body environment can be introduced to the program. There is a capability of to present permeability as a function of pressure in this program. Also volumetric moisture content can be presented to the program as a function of pressure and relative permeability in both the X and Y directions.

The program actually solves Laplace equation by the finite element method. So it is necessary to classify the porous components with good accuracy elements. As well as the definition of boundary conditions in some nodes, specific items such as rock (zero discharge) to be introduced to the program. The program is able to calculate

the amount of discharge from any desired point.

In order to analyze water permeability comply with the proposed project for of porous environment, geometry statue of porous environment fully introduced to the program and environment elements were classified accurately. At first, the calculation of the network fragmentize was done until reach to the adjusted network. Finally, after repeated multiple elements and nodes were shown below with dimensions of 1 x 1 meter

was chosen as the optimal network, because more fragmentize and increase the number of elements does not impact on the results, so other simulations was done based on the number of elements.

4. RESULTS AND DISCUSSION

4.1. Segments models

All fourteen segments were modeled to examine the leakages in Seep/w program and have been examined in term of safety from floor to the border of impermeability that the results are shown in Table 2.

Table 2: studying the potential of piping in Kocheree earthen dam

Ratio of critical gradient to available gradient (safety coefficient)	Critical hydraulic gradient	Immersion density	Saturation density	Available hydraulic gradient	Water insulation speed	permeability coefficient of foundation	Number of segment
	I(cr)	(gr/cm ³)	(gr/cm ³)	i(exit)	(m/s)	k(m/s)	
1	1.93E-06	4.14E-07	2.15E-01	2.18	1.18	1.18	5.5
2	1.99E-06	2.05E-06	1.03E+00	2.18	1.18	1.18	1.1
3	2.57E-06	2.83E-06	1.10E+00	2.18	1.18	1.18	1.1
4	2.94E-06	1.49E-06	5.07E-01	2.18	1.18	1.18	2.3
5	6.93E-05	2.52E-05	3.64E-01	2.18	1.18	1.18	3.2
6	4.40E-04	1.62E-04	3.68E-01	2.22	1.22	1.22	3.3
7	4.90E-04	2.74E-04	5.59E-01	2.22	1.22	1.22	2.2
8	9.00E-07	1.70E-06	1.89E+00	2.05	1.05	1.05	0.6
9	7.20E-07	4.56E-07	6.33E-01	2.05	1.05	1.05	1.7
10	2.50E-07	1.10E-07	4.40E-01	2.05	1.05	1.05	2.4
11	4.10E-07	2.56E-07	6.24E-01	2.05	1.05	1.05	1.7
12	4.50E-07	2.87E-07	6.38E-01	2.05	1.05	1.05	1.6
13	5.90E-07	6.87E-08	1.16E-01	2.05	1.05	1.05	9.0
14	8.40E-07	6.01E-22	7.15E-16	2.05	1.05	1.05	>100

All alluvial segments were calculated and evaluated without considering waterproof trenches in natural conditions and it was determined that all segments except 2, 3, 8, 9, 11 and 12 segments has a safety factor more than 2.

4-2- foundation waterproofing

One way to control particles washing phenomenon from the core to the foundation that is occur due to the pressure differences between two sides of waterproofing parts and also downstream of core and waterproofing

part that is reduced the waterproofing degree of the waterproofing part. Of course, this creates another problem, which is the high permeability of foundation and a significant increase in the amount of leakage. Experience has shown, according to the above limitations, the best situation of waterproofing in term of infiltration is the situation between two above limitations, it means the permeability of the waterproofing part should not be too low that lead to create a difference pressure on both sides of the waterproofing part and should not be a large to increase the water leakage. Based on experience, the best degree of waterproofing is about 65 percent, because pore pressure to spread is easier and the amount of leakage losses cannot be considerable [8]. Here it is used as a waterproofing plane.

Many dams in the world are built with the main objective of water supplying or power generation and flood control is considered as a secondary objective. Thus, the economic aspect of plan is very important in term of water supplying. Waterproofing proposed as a factor in economic feasibility of projects in a storage dams. Hence, the amount of entering water to the storage is defined as the allowable limit of permeability. This allowable limitation can be determined in

engineering with Lozhan number or rate of water absorption at a determine pressure to the stone and earthen part in order to calculate the piping. This amount is optional limitation that is determined based on the interaction of two factors at optimal cost and environment cost of water loss. Earlier leakage of water from the dam foundation was measured by software Seep/w at each segment and ultimately in all foundation that is equals to 750,000 cubic meters per year.

With regarding to the economic value of any plan that the maintenance and storage is important. The allowable water leakage of foundation is considered about 5% -2% on average from the total volume of the tank in a year which in the design of Kocheree earthen dam, water leakage volume ratio to the storage volume is equal to 34.7 percent that in this respect too, we find that it has a problem in this Water leakage from an economic standpoint, in this project.

So, in order to achieve the allowable leakage, waterproofing is required and with regarding to plan features and alluvial foundation, trenches of the seal used for waterproofing. The thickness of the permeable and depth and slope of the trench and also trench-permeable seal as well as the thickness of the waterproofing are shown in Table 3.

Table 3: thickness permeable layer and depth of the seal trench in Kocheree earthen dam

Segments	The initial thickness of the permeable ((m	The thickness of the permeable sealing (plan (m	Depth remaining after sealing plan (m)	Trench slope ((m	Trench depth ((m	Thickness of Troy after the construction of trenches seal (M)
A1	13.35	8.7	4.7	1/1	2	11.35
A2	9.88	6.4	3.5	1/1	2	7.88
A3	5.04	3.3	1.8	1/1	4	1.04
A4	4.87	3.2	1.7	1/1	3	1.87
A5	4.29	2.8	1.5	1/1	3	1.29
A6	6.5	4.2	2.3	1/1	6.5	0
A7	3.1	2.0	1.1	1/1	3.1	0
A8	1.6	1.0	0.6	1/1	1.6	0
A9	1.5	1.0	0.5	1/1	1.5	0
A10	1.2	0.8	0.4	1/1	1.2	0
A11	3.7	2.4	1.3	1/1	1	2.7
A12	7.6	4.9	2.7	1/1	1	6.6
A13	7.1	4.6	2.5	1/1	1	6.1
A14	5.1	3.3	1.8	1/1	1	4.1

Then by using Seep/w software trenches has been drawn under the dam foundation and results of potential piping examination are shown in Table 4.

Table 4: Studying the piping potential from Kocheree earthen dam after the construction of waterproofing trenches

Ratio of critical gradient to available gradient (safety coefficient)	Critical hydraulic gradient	Immersion density	Saturation density	Available hydraulic gradient	Water insulation speed	permeability coefficient of foundation	Number of segment
	I(cr)	(gr/cm ³)	(gr/cm ³)	i(exit)	(m/s)	k(m/s)	
1	1.93E-06	4.14E-07	2.15E-01	2.18	1.18	1.18	5.2
2	1.99E-06	1.89E-06	9.50E+01	2.18	1.18	1.18	1.2
3	2.57E-06	2.03E-07	7.90E+02	2.18	1.18	1.18	14.9
4	2.94E-06	2.17E-06	5.38E-01	2.18	1.18	1.18	>100
5	6.93E-05	3.83E-05	5.53E-01	2.18	1.18	1.18	2.1
6	4.40E-04	2.40E-04	5.45E-01	2.22	1.22	1.22	2.1
7	4.90E-04	9.45E-04	1.93E-01	2.22	1.22	1.22	2.2
8	9.00E-07	0.00E-06	0.00E+00	2.05	1.05	1.05	>100
9	7.20E-07	0.00E-00	0.00E-00	2.05	1.05	1.05	>100
10	2.50E-07	1.24E-07	4.96E-01	2.05	1.05	1.05	>100
11	4.10E-07	2.33E-07	5.68E-01	2.05	1.05	1.05	1.8
12	4.50E-07	2.07E-07	4.60E-01	2.05	1.05	1.05	2.3
13	5.90E-07	9.03E-08	1.53E-01	2.05	1.05	1.05	6.9
14	8.40E-07	1.55E-21	1.85E-15	2.05	1.05	1.05	>100

After building the waterproofing trenches in foundation, all segments will have a safety coefficient more than 2 except segments 2 and 11 that shown according to the below diagram.

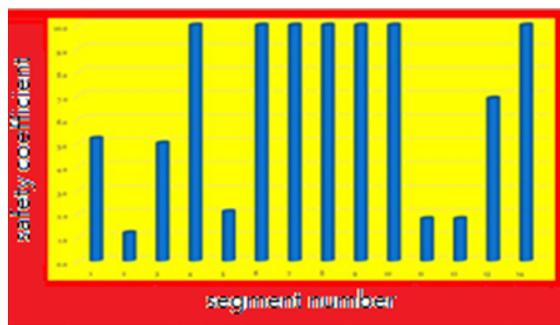


Figure 3: safety coefficients for each of following segments in foundation of Kocheree dam after construction of waterproofing trench

So, in order to prevent piping phenomenon, the above-mentioned points must be modified that issue was examined by building a dam wall that finally result is given in Table 5.

Table 5: studying the piping potential of Kocheree earthen dam after sealing wall construction

Ratio of critical gradient to available gradient (safety coefficient)	Critical hydraulic gradient	Immersion density	Saturation density	Available hydraulic gradient	Water insulation speed	permeability coefficient of foundation	Number of segment
	I(cr)	(gr/cm3)	(gr/cm ³)	i(exit)	(m/s)	k(m/s)	
1	1.93E-06	2.93E-07	0.15	2.18	1.18	1.18	>10
2	1.99E-06	1.36E-06	0.68	2.18	1.18	1.18	2.5
3	2.57E-06	2.03E-07	0.08	2.18	1.18	1.18	14.9
4	2.94-E 06	2.17E-06	0.74	2.18	1.18	1.18	>100
5	6.93E-05	3.83E-05	0.55	2.18	1.18	1.18	2.1
6	4.40E-04	2.40E-04	0.55	2.22	1.22	1.22	2.2
7	4.90E-04	9.45E-04	0.02	2.22	1.22	1.22	2.2
8	9.00E-07	0.00E+00	0.00	2.05	1.05	1.05	>100
9	7.20E-07	0.00E+00	0.00	2.05	1.05	1.05	>100
10	2.50E-07	1.24E-07	0.00	2.05	1.05	1.05	>100
11	4.10E-07	2.00E-07	0.49	2.05	1.05	1.05	2.2
12	4.50E-07	1.80E-07	0.40	2.05	1.05	1.05	2.6
13	5.90E-07	0.00E+00	0.00	2.05	1.05	1.05	>100
14	8.40E-07	9.50E-21	0.00	2.05	1.05	1.05	>100

As a result, all segments have a safety factor more than 2 by construction of a waterproofing wall that is shown in below diagram.

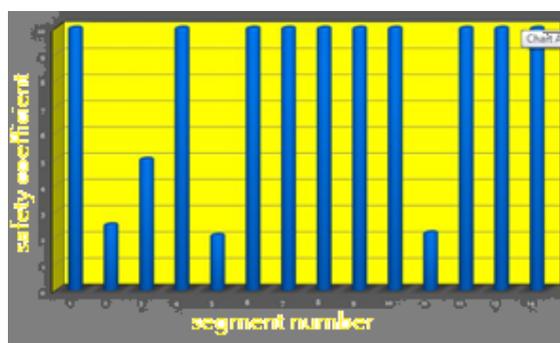


Figure 4: The safety coefficients of each of the following segments in Kocheree dam after construction of waterproofing trench

CONCLUSION

In the present study, we evaluated the amount of waterworn from Kochereer earthen dam in Golpayegan and the following results were obtained from it.

- ✓ In a condition without waterproofing plan, medium leakage is unacceptable and also the amount of safety factor in segments 2, 3, 8, 9, 11, 12 are not in acceptable area.
- ✓ Since the ratio of water leakage compare to the storage volume is a problem economically, so in order to prevent piping phenomenon, above points should be modified. For this purpose, to reduce the leakage in the two cases of trenches and walls of the seal have been examined:

After the construction of waterproofing trenches, all segments are in acceptable range except segments 2 and 11.

- ✓ With the construction of the waterproofing wall waterworn problem has been solved and all segments have a safety factor higher than 2 and the amount of leakage is acceptable.

REFERENCES

[1] Sahrbanoozadeh, M. Hesami Kermani, M. Barani, Gh. (2010). "The modeling of dam

foundation seepage flow by using Seep3D software", Case Study: Abbaspoor martyr Dam. First International Conference on plants, water, soil and air modelling of international center of advanced science and technology and environmental sciences of Bahonar University.

[2] Evert, F. K. 1985. "Rock Grouting with Emphasis on Dam Sites ". Springer, Berlin.

[3]Vafaeian, M "earthen dams", Jahad Daneshgahi publication Isfahan branch

[4]Rahmani, S, 2009. "Evaluating the performance of the accuracy instrument in earthen dams (Case Study: Ilam dam)," Water Engineering master's thesis, Islamic Azad University of Shushtar branch.

[5] Nonvieller, E. 1989. "Grouting theory and Practice". Elsevier Science Ltd., Amsterdam.

[6] Hosseinpour, A., 2009. "Studying the geological characterization of dam site engineering of Jangabad with an emphasis on waterproofing blind design" thesis of Islamic Azad University, Science and Research Branch of Tehran.

[7]The Iranian National Committee of Large Dams, 1996. "Leakage in the dam foundation and its control practices", published by the technical office of water - the Ministry of Energy, publication No. 6.

[8] Rahimi, H. 2010. "Earthen dam", Tehran University Press, third edition.