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Stability of Slope and Seepage Analysis in Earth Fills Dams Using Numerical Models (Case Study: Ilam DAM-Iran)

[1]H. Hasani, [2]J. Mamizadeh and [2]H. Karimi

[1]Department of Civil Engineering Payame Noor University, Ilam, Iran
[2]Agriculture faculty, Ilam University, Iran

Abstract: Geostudio software is one of geotechnical program that is based on the finite element and can consider analysis like stress-strain, seepage, slope stability, dynamic analysis and also fast water drop in reservoir. In this research seepage analysis in ilam earth fill dam has been done by seep/W software. In order to evaluate the type and size of mesh size on the total flow rate and total head through the dam cross section, four mesh size such as coarse, medium, fine and unstructured mesh is considered. Result showed that average flow rate of leakage under the different mesh size for ilam dam equal 0.836 liters per second for the entire length of the dam. Slope/W software is used under different conditions to evaluate slope stability. Analyzes for each state and each slope with Bishop, Janbu, ordinary method of slides and Morgenstern methods is calculated that the minimum safety factor in each of these methods, be considered as a safety factor of slope stability.

Key words: Slope stability · Seepage · Geostudio · Safety factor · Ilam dam.

INTRODUCTION

Among various engineering projects, dams construction and their industry involves major challenges. Since 1980 construction of earth and rock fill dams are more common than other type of dams. The reasons for this common usage are: the method of construction is based on ordinary technology with utilization of cheap raw soil materials, subsurface materials and does not depend on particular valley shape. Also, geometric design of embankment dams depends on barrowed soil materials, subsurface conditions and type of construction. Consequently feasible design can cause significant reduction on construction time, materials and costs. One of the main important factors for the failure of earth dams is the seepage in their body and foundation. In order to prevent the dam failure, it is essential to control the leakage in the dam. leakage in dams, caused the water waste and, the decline of dam stability. therefore, the water leakage analysis in dam is the first effective step and one of the main important issues that has been considered for the related experts. Panthulu *et al* [1] studied the utilization of electrical methods for delineation of seepage zones at two of the four Saddle dams of the Som-Kamla-Amba project, Rajasthan State, India; Electrical resistivity method was used to delineate zones favourable for seepage, whereas, self-potential (SP) method was used to delineate the seepage paths. SP measurements have shown negative anomaly of the order of 10-20 mV in amplitude, indicating low seepage, coinciding with the seepage measurements made by the project authorities. Taghavi *et al* [2] investigated geotechnical parameters effect on embankment dam analysis and design. Variation of strength parameters are discussed when soil is sheared in different situations and stress- strain level. Results have indicated that the method of analysis and the type of software were highly reliant on strength parameters. Zomorodian and Abodollahzadeh [3] investigated the effect of horizontal drains on upstream slope of earth fill dams during rapid drawdown using finite elements and limit equilibrium methods. Changing of pore water pressure, outpouring seepage flow and factor of safety are inspected. In this research, it would be investigated the amount of water leakage and seepage in the dam by using the Seep/w software and the static slope stability analysis by using the Slope/w software.

Corresponding Author: J. Mamizadeh, Agriculture faculty, Ilam University, Iran.

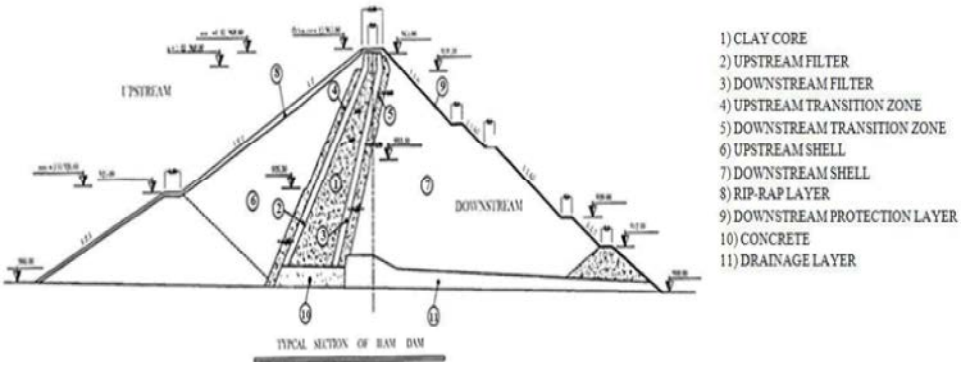

Fig. 1: Cross section of ilam dam

MATERIALS AND METHODS

Ilam dam constructed in 2001 is located on konjancham river 22km to the south of ilam city center-iran. The main objectives of this plan are the long-term supplying 22 million cubic meters per year drinking water to the city of Ilam and irrigation of 6800 ha of mehran plains. Both main and coffer dams are earth fill type with central clay core followed by one layer of filter on both sides and supported by sand and gravel shell as shown in Figure 1. Permeability of materials used in the dam body is shown in Table 1.

In order to achieve the objectives of this study, Geostudio software is used. Geostudio is software products based on finite element code that can be used to evaluate the performance of dams and levees with varying levels of complexity. The Geostudio suite includes eight products:

SLOPE/W for slope stability, SEEP/W for groundwater seepage, SIGMA/W for stress-deformation, QUAKE/W for dynamic earthquake, TEMP/W for geothermal, CTRAN/W for contaminant transport, AIR/W for air flow, VADOSE/W for vadose zone & covers. in this research SEEP/W and SLOPE/W is used. SEEP/W software calculates the leak using partial differential equations makes the water flow. Differential equations governing the flow in two-dimensional mode to be the following:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y \frac{\partial H}{\partial y}\right)=0 \quad (1)$$

Where: Kx, Ky= coefficient of permeability in (x,y) directions. H= total head of water. SLOPE/W is the leading slope stability CAD software product for computing the factor of safety of earth and rock slopes. SLOPE/W can effectively analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, analysis methods and loading conditions. In the present study, several methods for slope stability analysis such as Bishop, Ordinary, Janbu, Morgenstern-Price, Spencer and GLE are used.

Table 1: Permeability of materials

Materials type	Permeability(m/s)
Foundation	10^{-6}
Shell	10^{-5}
Cut of wall	10^{-8}
Core	10^{-8}
Filter	10^{-4}
Transition	10^{-2}

RESULTS AND DISCUSSION

Regarding the permeability soils, in the semi-saturation status, because of the prevention of water movement by the air bubbles existed in soil is lower than the saturation status. Seepage analysis result for these two types of permeability is differing from each other. In order to prevent this error, a function can be defined in which the permeability can be changed linearity in that range and in outlet of the range, it would be fixed. This function can be defined so that in p=0 kpa, the permeability coefficient equals to the k_{sat} and in p= -100 kpa, the permeability coefficient is considered to be k_{sat} /100. Figure 2 show a typical function between pressure and permeability coefficient.

After allocation functions for permeability, boundary conditions for the model are defined. The water height for the permanent seepage is considered as normal water surface in dam (60 m). Total depth of permeability layer in

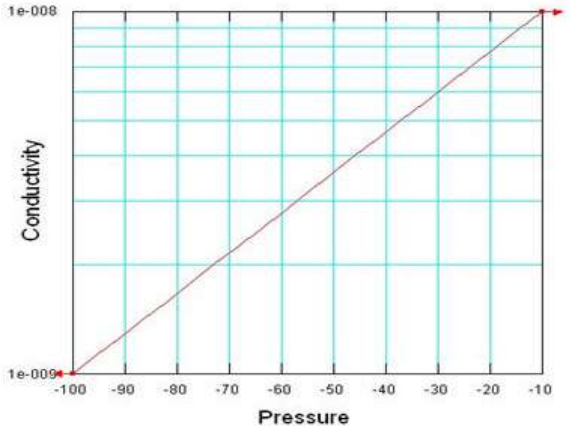

Fig. 2: The relationship between pressure and permeability coefficient

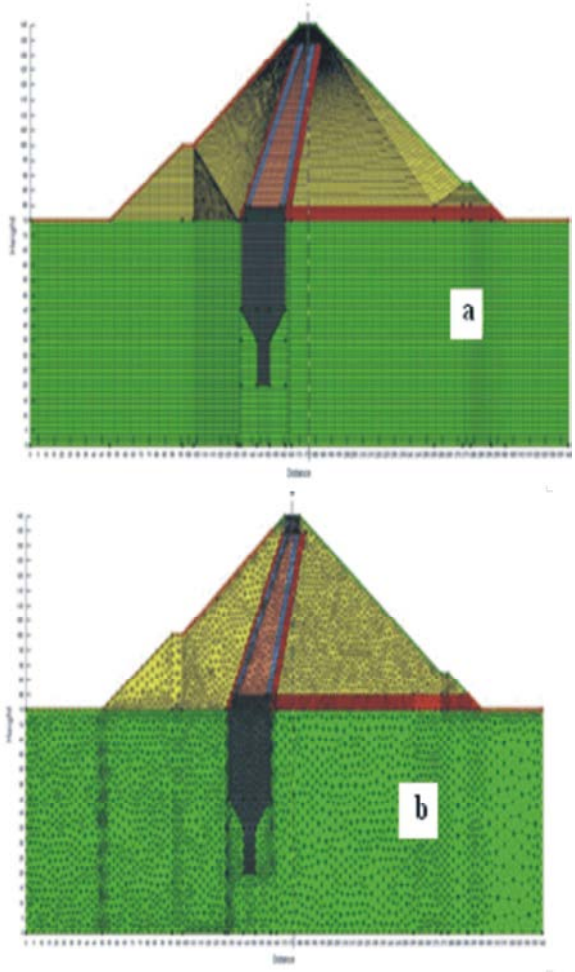

Fig. 3: a: fine mesh b: unstructured mesh

foundation is about 75 meters and 55 meters of this foundation is constructed with impermeable clay soils. In order to evaluate the type and size of mesh size on the

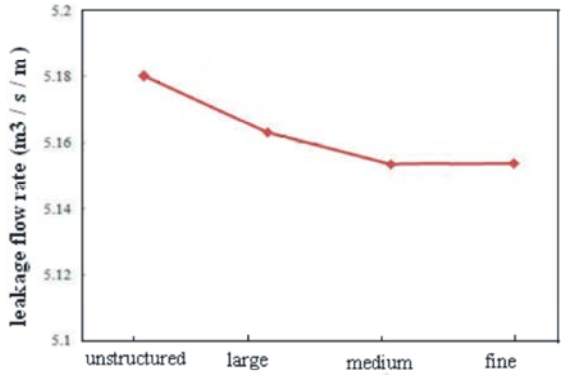

Fig. 4: Effect of mesh size on the amount of dam seepage

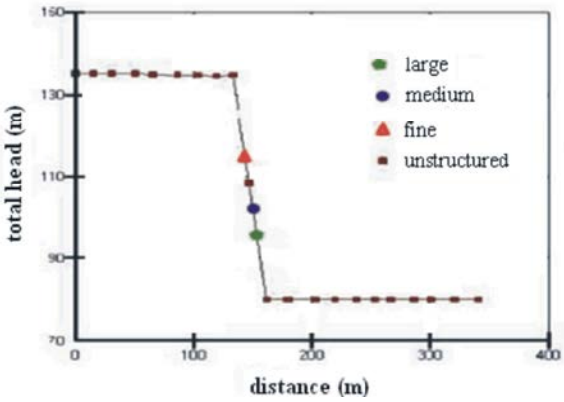

Fig. 5: Effect of mesh size on the total head

total flow rate and total head through the dam cross section, four mesh size such as coarse, medium, fine and unstructured mesh is considered (figures 3). Width and length of mesh for large, medium and fine are 6 × 6 m, 3 × 3 m and 2 × 2 m respectively.

The figure 4 and 5 show the seepage and total head analysis by the SEEP/W software under the mentioned the mesh size. According to figure 4 can be seen that the leakage rate difference is negligible under the different mesh size and average flow rate of leakage for ilam dam equal to 5.1625×10^{-6} cubic meters per second per unit length of the dam, which is equivalent to 0.83 6 liters per second for the entire length of the dam. obtained of Total head obtained difference for different mesh size (Figure 5) also shows a negligible change.

Figure 6 and 7 shows the phreatic line and iso potential line. As seen in the results, low permeability clay core with good resistance against water seeping into the dam so that the flow inside the core will drop sharply. Thus, the downstream slope of earth dam always remains dry.

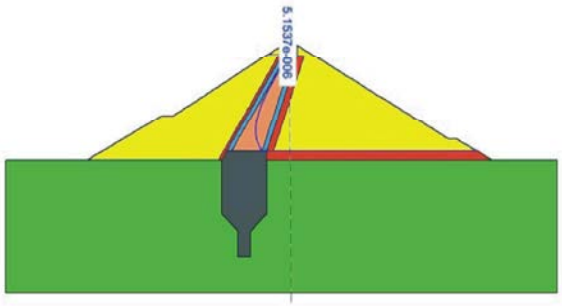

Fig. 6: Phreatic line in ilam dam cross section

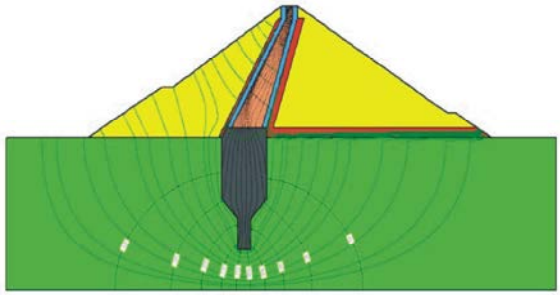

Fig. 7: Iso potential line in ilam dam cross section

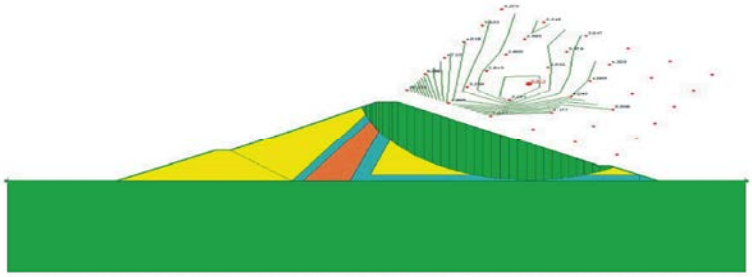

Fig. 8: Minimum safety factors equal 2.371 for Bishop method

Table 2: Materials property for stability slope analysis

Materials		Wet Specific weight (KN/m^3)	Saturated specific weight of (KN /m ^{3})	Angle of internal friction (degrees)	Adherence (Kpa)
Core	UU State	20	6/20	10	100
	CU State	20	6/20	20	50
	CD State	20	6/20	28	0
Upstream shell		21	22	43	0
Downstream shell		21	22	43	0
Foundation		26	5/26	55	350
Filter and drainage layer		20	22	34	0

Table 3: Summary results of safety factor for stability slope analysis

Analysis method	Downstream slope after construction	Upstream slope after construction	Downstream slope in steady-state leakage	Upstream slope in steady-state leakage	Sudden drop in reservoir water level
The Morgenstern	2.330	2.112	1.892	1.811	2.169
Ordinary methods	2.028	1.705	1.690	1.688	1.868
Bishop Method	2.371	1.981	1.938	1.769	2.090
Janbu method	1.971	1.740	1.700	1.642	1.821

In order to evaluate slope stability for ilam dam, Slope/W software is used under the following conditions: During or immediately after the construction of dam, establishment of steady state leakage and sudden drop in water level of reservoir. Analyzes for each state and each slope with Bishop, Janbu, ordinary method of slices and Morgenstern methods is calculated that the minimum safety factor in each of these methods, be considered as a safety factor of slope stability. Materials property related to slope stability analysis is shown in table 2.

Location of critical slope surface and safety factors obtained by different methods. Typical result for downstream slope after the construction of dam by bishop method is shown in figure 8. Summary results of stability slope analysis with different methods is shown in table 3. In the phase immediately after construction is

expected that dam safety factor of various methods of analyzing the stability higher than other phases, because of no pore water pressure. In the steady-state leakage phase, due to pore water pressure in the dam is expected dam safety factor less than the phase immediately after construction.

CONCLUSION

In the present study using the Geo-Slope software, leakage and stability slope analysis in ilam earth fill dam is studied. Seep /W software is used for seepage analysis. four mesh size such as coarse, medium, fine and unstructured mesh is considered to evaluate the type and size of mesh size on the total flow rate and total head through the dam cross section. Result showed that average flow rate of leakage under the different mesh size for ilam dam equal 0.836 liters per second for the entire length of the dam. Slope/W software is used under different conditions to evaluate slope stability. Analyzes for each state and each slope with Bishop, Janbu, ordinary method of slices and Morgenstern methods is calculated that the minimum safety factor in each of these methods, be considered as a safety factor of slope stability.

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