Determine the height of the vertical filter for in heterogeneous earth dams with vertical clay core

Abstract:

In order to determine the height of the filter in heterogeneous earth dam, three embankment models were provided in a flume laboratory, with the length of 4.2 m at the base of dam, the width of 60 cm and the height of 1 m and body slope 1H: 2V. For embankment of model, two types of fine and coarse grained soils were used. The texture of the soil was made using hydrometer method. In the first model, the fine-grained and coarse-grained soils were used in downstream and upstream of the dam crest respectively. In Models 2 and 3 with cutting fine grained soil from the toe of the dam to the dam crest, vertical clay core was replaced. Index of a / L (a thickness of clay core and L is the length of base dam) was 1.7 and 1.10 in the second and third models respectively. Seepage experiments in 3 water height of 80 and 55 and 30 were performed. The phreatic surface was determined using wells and 30 embedded Piezometer in the models. Then rate of falling head due to clay core was measured and it compared with software PLAXIS V 8.5 results. Height of filter the clay core with safety factor 1.2 (Encounter Line Leak with 20% of the bottom filter) was introduced. The thickness and hydraulic conductivity of the clay were affected decline of water level.

Keywords: Model of heterogeneous earth dam, Height Filter, thickness of the clay core, software PLAXIS V8.5

Introduction:

Ghahremani and sahebzade surveyed the rate of leakage and Static and dynamic sustainability in the earth dam Black –rock with using of The finite element method and Using software PLAXIS and GEO-SLOP in 1383.then Based on analysis For leak ,Best injection depth in the dam foundation 28 meters was recommended. Fatholahi Marani and Sabagh Yazdi harvested the effect of having drainage in upstream slope on the pore pressure and upstream slope stability. During the rapid depletion of the reservoir, Since entering bar of water On the upstream slope The effective stress and Safety factor are reduced in this region .

In This article has been expressed If incompressibility shell, pore pressure distribution will follow the Laplace equation (Jiang et al. 2014). But if it is compressible Due to the relatively large volume change of shell during the drop in water levels in the reservoir and changes in porosity and permeability of the material Laplace's equation cannot be used unless this changes to be considered. Results on a hypothetical model of earth dam with a height of 25 m showed the use of drains in the dam located on rigid foundation that all wedge Rupture is in the body, had a more impact. In the case of dams located on non-rigid foundations the use of drains in upstream will not work. It also recommended.

Due to the focus of the pore pressure As much as possible embedded drainage should be placed in higher elevation than the Foundation. More importantly, piping effects in these areas should not be neglected (Kazemzadeh-Parsi and Daneshmand 2013).

Mirghasemi and Pakzad in 2005 examined Permeability in Foundation of Karkheh Dam in Iran plus Uncertainty associated with the results of the surveys.

To determine the permeability, Lejeune tests and pumping tests and finite element method was used. by comparing the results Was determined that The permeability obtained of Lejeune method About 100 times lower than the permeability obtained from other methods.

This is due to areas with high permeability in the foundation. Pumping test methods and indirect methods due to consider a whole pile of stones display this phenomenon better. In the Lejeune method because the obtained data associated with a point cannot represent the whole permeability layer (Garcia et al. 2011).

Rakhshanderoo and Bagherie Investigated How leak on Panzdah Khordad earth dam after dewatering in 2006.this investigation by SEEP3D software and with using of Finite element method and in three-dimensional was performed. Water head in the upper crust was assumed equal to the water level in the reservoir. And downstream of the core was removed from the calculations. Finite element analysis was performed for a constant pore pressure. Whereas According to The observed results in some months. In the construction process and dewatering, Pore pressure was variable And it was not sustainable.

Based on the results observed when increasing the water level in the reservoir Piezometers near the upstream dam were immediately impressed and showed this increase faster. Well as the waste water pressure near Piezometers that were near the downstream filter were faster displayed. The pore pressure observed with the results of finite element analysis showed good coordination (Fredlund et al. 2011).

Finally, it was observed that the leakage characteristics of the dam and rate of that Almost are determined by saturated zone and unsaturated zone or Suction area have very little impact on that. And even can be said that had no effect.

Bagheripur and Marandi in 2005, with modelling Homogenous and isotropic earth dam, the model Nomorof evaluated to Control of seepage from Homogenous and isotropic earth dam. Nomorof model was compared with built model and good results have been obtained.

Mohammad Vali Samani and the Nabavianpoor in 2009 determined the exact location of the leak by the boundary element method. Require less time and memory for modelling problem.

Solve Equation as analytical and Limitation of approximations to the borders is The advantages of this method.

Researchers with modelling of homogeneous earth dam investigated effect of tiller drainage with different angles and length and height on the leak. Modelling was performed with software SAS and PLAXIS Version 8. That with 95% confidence level, there wasn't error between experimental data and software. Finally, the height of drainage increase (Wang et al. 2014).

Length towards the height of the water behind the earth dam And also reduce the angle α the rate of Leak flow Rises. Considering these results to choose the best high drain Toward the water behind the dam embankment, and The optimum angle for design of toe drains, After ensuring

Crossing Line free of leaks from inside the drain, Drainage design should be such Be minimized leakage flow rate (Chen et al. 2011).

Materials and method:

Laboratory flume: the experiment was performed in a height laboratory flume, which was 6 meter long, 60 centimetres wide and 1.2 meter high, in Soil Mechanics Laboratory of Shahrekord university of Iran. The structure of flume was consisted of a 2-millimetre thick galvanized sheet on the floor and on the back wall and 15 millimetres Plexiglas on the other septum. To avoid galvanized sheets developing in the bottom, some metal backrests were used. An entrance door was placed on the ending of the home for the ease of access; and two evacuation valves were placed at the bottom of the flume (on starting and ending) to be embedded in the water.

Draining Box: To collect the drainage water, a draining box with the length of 0.6 meter, width of 0.9 meter and the height of 0.4 meter was prepared. It consisted of an access hatch and an evacuation valve on the bottom. The box was filled with sand up to a height of 20 centimetres for the filtration of drainage water. This was installed and isolated at the end of flume's bottom. Some 3 mm diagonal holes (up side of drainage box) with 2.5 centimetre distance from each other were applied in the box, 0.9 long and 0.6 meter wide, to enter drainage. It should be noted that according to USBR standards, some 3 mm diagonal drainage holes were used.

Piezometers and observation wells: To measure water pressure into the flume, 30 piezometers were reticulated from the middle to the end of Plexiglas septum which were embedded and isolated as well. These had inbound filter and plastic tube. The inbound filter of these piezometers was sunk into the clay in a depth of 5centimetres.

Device Multimeter: To read the water in the wells of a multi-meter device was used. That is the positive and negative poles of the device without connecting to the bar together were placed in isolation and when you connect this area with the Multimeter water resistance survey, resistance shows that the water level is indicated. Also the entry of water into the soil fines into the wells of a filter cloth was used that the entry of water into the well in the fine increased.

Soil Mechanics Tests:

Grading: In order to determine the aggregation curve of used soil in body dam, standard sieves and hydrometer method was applied (Fig. 1 and Table 1). Using a hydrometer test the grading of fine grain size (diameter less than 0.075 mm) was determined. For fine-grained soils after grading standard elks, The fine (diameter passing through a sieve of 200) after drying and weighing aggregation, aggregation was determined by hydrometer tests and then by buffering of the three samples drawn diagrams It was clear that about 20 percent coarse soil and about 60% of the second soil had Fine-grained. This amount fine-grained includes clay and silt .It is noteworthy that the position of this elks is according to the table 1. Used soils specifications were shown in table 2.

Density testing: To assess the density of dams, test weight per unit volume of dry soil in place was donning. With this test can be surveyed true or false of density testing. Also by this test can determinate the amount of energy required to compress the soil layers. As was mentioned the purpose of this experiment is calculate γd of soil. There are several ways to do this. But the most common of them that is handled in most projects, is Sand Cone Method and Rubber Balloons method (Askorchi). In many soil cases, it is necessary to dry density of soil in place being 90 to 95% dry density that is obtained in lab. Sometimes this topic defined as the relative density and shown as R

Equation.1

$$R(\%) = \frac{\gamma_d}{\gamma_{dmax}} \times 100$$

γd : dry density of soil in place

γd_{max} : dry density of soil in Laboratory

In this research to reach an acceptable density, first by Proctor test standard the damp of Soil samples whit 20 and 60 percent fine were determined. That is cleared Laboratory Equipment and also graphs of dry density and Optimum damp for tow soil samples are shown in Figs 2 and 3.

After determining dry density and Optimum damp for tow soil samples, to reach required density we do in this way: we divided section of dam to different trapezoid and with this trapezoid layer within dam, (that was 0.6 meters) Their volumes were calculated and by dry density and required volume of soil; Weight of dry soil obtained. And by adding Optimum damp to the soil, and Condense it(using Standard hammer) as far as total weight to be placed in the desired volume.

In this case, since the specific gravity of the volume reached percent concentration is reached to one hundred percent. But often some of the weight of the soil remains that According to the following relations dividing the weight of dry soil to the total weight of soil on the volume soil compaction is achieved.

Equation 3

$$\gamma_{d\ max} = \frac{Ws}{V} \Rightarrow W_s = \gamma_{d\ max} \times V$$

Equation 3 : relative compression percentage determination of layers

$$R(\%) = \frac{\gamma_d}{\gamma_{d\ max}} \times 100 = \frac{\frac{W_s}{V}}{\frac{W_t}{V}} = \frac{W_s}{W_t} \times 100$$

Used soil parameters: The measured characteristics of the soils used are described below.

Types of materials used in the main body of the model:

In order to reduce permeability and prevent excessive leakage of water heterogeneous earth dam of SC (sand and clay) was selected. Range size of sand used to build the model was 0.5 to 5 mm. In this study, two sources of clay were used to supply clay: According to the available sediment in reservoirs of dams properties are fully accessible; the first source of sediment accumulated in the reservoir of Pirbalut dam located 20 kilometres from Shahrekord and the second source of clay soil on the Campus. According to clay minerals used due to viscosity and high compressibility should be made of kaolinite. The two amount of clay was combined and liquid limit of them was determined using Casagrande. Humidity of 25 beats of it was 48 percent.

Laboratory hydraulic conductivity: Two soil types using Proctor Experiment were beaten and reached to laboratory maximum density. Hydraulic conductivity tests were performed on samples in their terms. For 20% fine-grained soil is located in the coarse range constant head-method was perfumed. Falling head-method was perfumed for fine-grained soils (60% fine-grained).at the end Hydraulic conductivity was determined using this Equation and k_2=0.035m/day k_1=0.2m/day Obtained.

Performed experiment:

In this study, three executive models were used (Figs 4 and 5). The first model was included of fine-grained and coarse-grained soils .that from dam crest to upstream coarse-grained soils was used and from dam crest to downstream fine-grained soil was used. The second model was included of three parts: $\frac{a}{L}=\frac{1}{7}$ base of the dam consist of fine-grained soil and on both sides of that coarse-grained soils was used. Due to the use of the second and third models was the effect of the thickness On-line free of leaks Located in The body of the dam. In this model, three experiments were performed without drainage. In The second model same as the first model, experiments for the maximum height with $\frac{a}{L}=\frac{1}{7}$ was performed. And the volumetric flow rate of leakage was measured. Also phreatic line was drawn using Observation wells. In The third model same as the first model, experiments for the maximum height with $\frac{a}{L}=\frac{1}{10}$ without drainage claws was performed. Also phreatic line was drawn using Observation wells.

Flow rate: Discharge leak Came from the body of the earth dam with Using the volumetric method was measured. Line free leak at the First with using the observation wells and then with using resistance - high was drawn. In resistance – high method with using Resistance between two metal bars in the water column and the relationship between the height and Resistance readings by the device resistance thermometers The water height in the body of earth dams was determined. In this study, Metal rods calibrated In parallel with a diameter of 10 mm and height of 120 Cm inside the insulating sheath in The observation wells were placed . But because of the high resistance of the device; Welding wire was used too. Long rods, Genus bars, the spacing between the bars, Impurities of water and the semiconductor between two rods was fixed. In a series of experiments to investigate the leak without water drainage, Water upstream of the dam for the first model In 3 heights 30, 60 and 80 was considered. And For other models maximum height of the water that is 80 cm was considered. It should be noted that in each experiment the water gradually reached the desired height and until the end of each experiment, the water level at the three height mentioned was kept constant. With the passage of water leakage flow, the water Inside Piezometers Gradually rose. And with saturation of the soil environment was fixed. It should be noted that Saturation of the Soil porous medium About 72 hours and sometimes up to 96 hours was performed. And every 15 hours, the water height was adjusted at the desired height. That it was performed with the constant flow of drainage, Drop in upstream water level and the height of water in Piezometers. In 30, 60, 55 cm height of the first model, The first line (Phreatic line) At a height of 80 cm of upstream water did not cut No point of downstream slope , Phreatic line cut downstream slope from dam claw.

Results:

The results of Laboratory models of heterogeneous earth dams: Phreatic lines with using observation wells and Piezometers Installed in the flume, in experimental models of heterogeneous dam Was determined as follows. Experiments when the water level in the experimental model is 80 cm in height on the model of in homogeneous earth dams in the laboratory were performed.

Definition Model and determine the initial conditions and Border in Software: After harvest and survey data obtained from experiments, modelling in PLAXIS software was performed. First, a geometric model of a section of the dam must be created. To do this work According to the Executive section of laboratory model in flume, geometric model in PLAXIS program was created. In the second step is required data related to the materials used in the body of the dam. It is noted that the data relating to hydraulic conductivity was measured with using constant head experiment and falling head experiment. And by comparing these values with the table and different relations finally the acceptable value was considered.

Discussion

Comparison of experimental results in heterogeneous model with software model PLAXES V8.5: With Measuring the hydraulic conductivity of the shell and core of earth dams that was performed with using constant head-method and Falling head-method. Modelling in software PLAXES V8.5 was performed. Phreatic line of software models and laboratory models were compared together (Figs 6,7 and 8). Using statistical software SAS, P-values were calculated. Accordingly, there is no significant difference in the level of confidence of 90 to 98 percent. Also, some root mean square error (RMSE), was calculated for all conditions that the results are given in Table 3.

The results of the software for the heterogeneous model:

The results for the inhomogeneous model with using the software are provided. With changing various design parameters were suggested. That, with changing the hydraulic conductivity of the core and shell heterogeneous earth dam and also changing the thickness of the clay core as shown in Fig. 10 and Measure the rate of decline in the clay core in software(Fig. 11). Therefore with having k2/k1 Optimum height of the filter with safety factor 1.2 can be determined.

Obtaining the rate of decline in fine-grained soils with using software model:

According to the rate of decline in water level in fine-grained soils with using of software data Fig. 10 was drawn that in heterogeneous state the rate of decline in water level in fine-grained soils According to the ratio of hydraulic conductivity for shell to core is shown.

So it is harvested when $\frac{k_2}{k_1} \leq 0.002$ layer thickness of fine-grained have little effect on the rate of decline in water level

Determine the height of Suggested filter with Using of software model:

Analysis and comparison between water failure in interface of fine-grained and coarse-grained soils, both of software model and laboratory model have a relatively well fit. To obtain the height of suggested filter (Fig. 9), the software model was used to simulate the experiments and Subtracting the thickness of the fine-grained. Finally, given that in the engineering design of earth dam, After the clay core, usually the height of the filter layer is used as the height of clay and due to decline in free leakage line in fine-grained soil and encounter with soil in shell of dam with height h2 (The height of the free leakage line from the bottom of impermeable layer in interface of coarse-grained and fine-grained soil in downstream.) In Fig. 11 values according to the thickness of the fine-grained and hydraulic conductivity ratio of core to shell dam and the maximum height of the dam dewatering was introduced. By applying safety factor of 1.2, height was designed to filter and after the clay core was introduced.

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Table.1: Percentage of Fine-grained of coarse grained soil

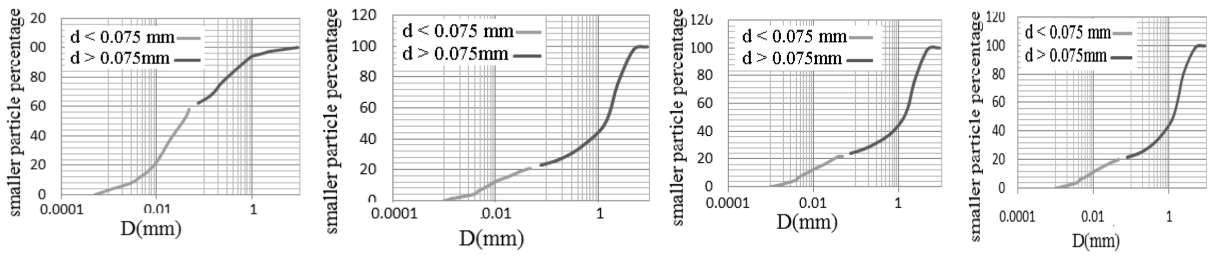
Number of layer	1	2	3
Percent of fine soil	19	20	22

Table 2: used soils specifications

Parameter	Curse	Core	Filter & Drain
γ_{dry} (KN/m^3)	17.5	18.5	17.5
γ_{sat} (KN/m^3)	19	20	19
K_x (m/day)	0.2	0.035	30
K_y (m/day)	0.2	0.035	30
$E_{ref} * 10^4$ (KN/m^2)	11	200	7
υ	0.35	0.3	0.3
C_{ref} (KN/m^2)	1	2	1
φ (phi)	40	35	45
ψ (psi)	10	10	10

Table.3: Comparison between measured piezometers and calculated using PLAXIS software

model	1	2	3
P-value	0.03	0.095	0.062
Confidence limit	97	91	94
RMSE	0.561	0.424	0.475



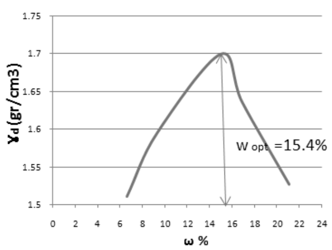
(d):Fine-grained soil(60%)

(c): Third layer of coarse grained soil

(b):Second layer of coarse grained soil

(a):First layer of coarse grained soil

Fig.1 : Aggregation curves of fine and coarse grained soil



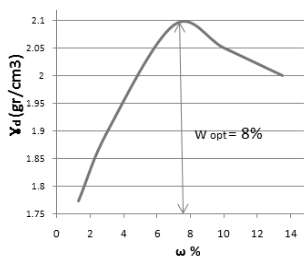


Figure 2: dry density and Optimum damp of 60% fine

Fig.3: dry density and Optimum damp of 20% fine.

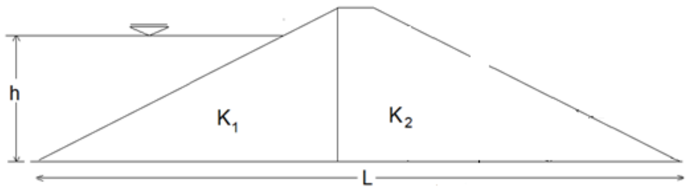


Fig.4:Scheme of the first operational heterogeneous earth dam model

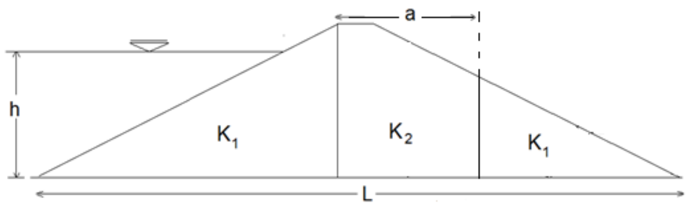


Fig.5:Scheme of the second and third operational heterogeneous earth dam models(a/L=1/7,1/10 in the second and third models respectively)

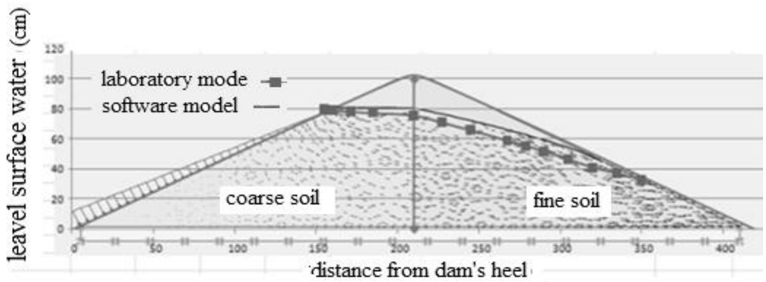


Fig.6 : Comparison of laboratory model No.1 with PLXIS model

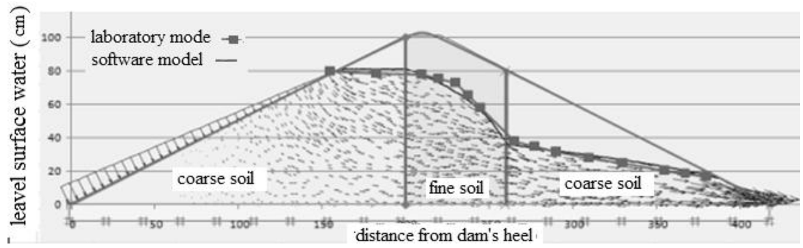


Fig.7 : Comparison of laboratory model No.2 with PLXIS model

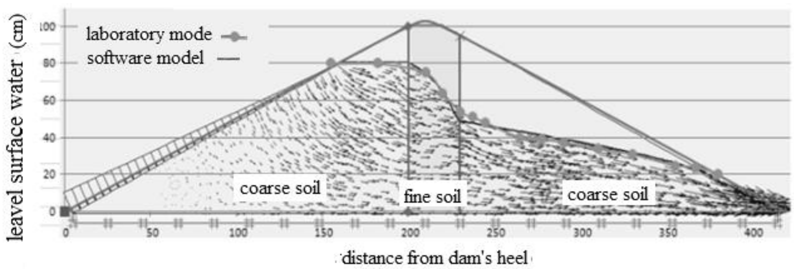
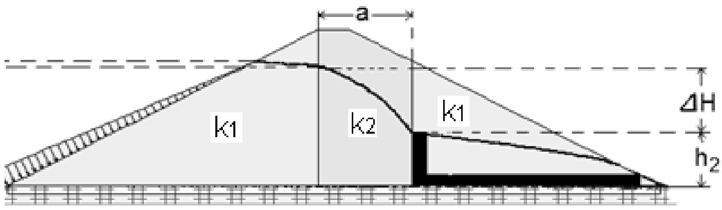


Fig.8 : Comparison of laboratory model No.3 with PLXIS model



h_2 : height of drain

Fig. 9: Scheme of vertical filter

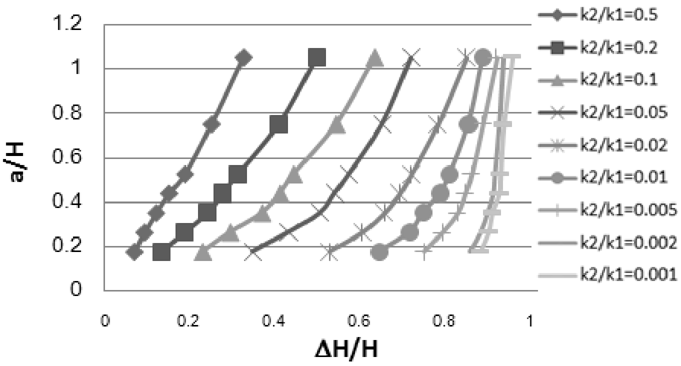


Fig.10: Effect of thickness and hydraulic conductivity of the clay on decline of water level

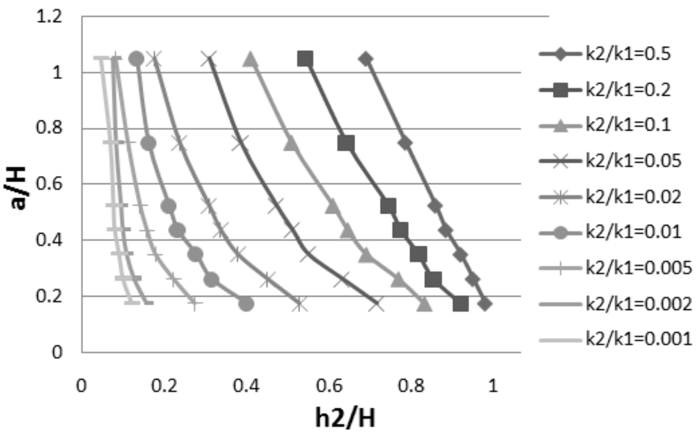


Fig.11: Height of filter with safety factor of 1.2