Analysis of Earthdam Body and Foundation Seepage using Seep/w 2004 Software with Investigation of Cutoff Operation (Case Study Marvak Earthdam)

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**ABSTRACT**

Today has been a great development of Dam Science. Branches of science in Earth dam design engineers must analyze the various structural, Seepage analysis of earth dam body and the foundation also seriously consider. Due to the existence of very sophisticated mathematical models that work with finite element approach, Software model SEEP/W is also present accurate models and advanced. Marvak Dam located at 37 km from the Dorud city. Marvak reservoir volume is 120,000,000 m³ with 55,000,000 m³ of annual volume. It designed to water management and agricultural water supply to irrigation Silakhor plain, flood control and hydroelectric power generation. In this paper, with software SEEP/W seepage analysis of earth dam body and foundation has been in steady state. Then obtained results can be useful to investigate performance of Earth dam against water seepage and the yield strength of the barrier against penetration of water. In the end, concluded that Seepage flow below the dam foundation Reduced from 76.83 %. Also in core and body of Earth dam is Seepage reduced the same amount.

**Introduction and Necessity:**

The Earth dam Seepage has about 25% of Construction or damage Statistics or consequences related to Seepage is important topic in accounting, analysis and design of the dams. Seepage in Earthdam body is Inevitable So in Calculation procedures and plans must be operated in a manner which at first the Seepage flow from the dam body and foundation decrease to The drain course is designed to properly. Obviously, study and research on the performance of drainage systems or the same amount of importance and credibility. The research on the issue of Seepage, analyze and calculate it and ponder to Investigate the best strategy for optimal control and drainage water flow in the body and Foundation of Earth dams are discussed. Actually, the result of this research is somehow helpful for possible future dams project in Lorestan, especially can be done in parallel to required computations in the analysis and design of dams in the Dorud city area. The original work of drainage system is in this way that must be execute the fine impermeable layer and because that they don’t operate any resistance against water penetration, so became as course for transfer of water seepage. There are several methods for determining the flow rate of water leakage that in below the general disadvantages are listed [1].

1- drawing method, based on the principle of trial and error with the number of experiments are carried out that also consuming too much the quantitative accuracy is low [5].

2- Laboratory method, which may be referred to the electrical simulation models [10].

**Lecture Review:**

Today many research be found in the field of earth dam leakage that can be done as follows.

Soultan nejad and Et al in 1391 in their research titled Study controlling soil piping by arming have been mentioned the piping phenomenon is due to upward seepage occurs in terrestrial environments. Piping occurs in hydraulic structures such as earth dams, irrigation channels and drainage system and causing losses and the destruction of structures. In this study, several tests was carried out on compacted silty soil samples and Density samples with different percentages of synthetic fiber in the device that was developed for this purpose. In this experiment been measured Critical hydraulic gradient and resist against Seepage force, the results showed that reinforced soil samples with synthetic fibers have sufficient strength against piping.

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Hashemi Jokar and Soultani in 1391 in a study titled Investigation of influence compression energy on leakage and variability in unsaturated soils. In this paper, the relationship between compression energy, permeability and suction matrix of unsaturated soils are discussed. Importance of study on permeability of unsaturated soils, especially in Embankment dam is very necessary issues of the detailed and economic design. One of the main problems in unsaturated soil compaction, make changes in soil suction matrix that these changes cause fluctuations in pore water and air pressure in the soil. However, changes in suction matrix of unsaturated soil has considerably effects on permeability. leak water from the body and the earth dam in unsaturated soil and currently most relevant are designed with regard to the saturated soil being a case that in this situation the body maximum leak Dubai and the criterion of the dam design and assumption of saturated soil with reality and adjusting what might be cause of error and the plan-economical.

Fadayie Kermani et al in 1390 in a study titled Use finite Difference method in numerical solving water Seepage equation from the body of earth dam, say that stability of a concrete dam or earth dam depends to the manner of water seepage and balance of static and hydraulic forces. They who use finite difference method in analytical solutions and numerical solution with Geostudio software research to solve equation governing the use seepage, announced that mechanism in analytical solution using finite difference limited with chose smaller place the results have better accuracy with results achieved software 2007 Geostudio.

Saba and valizadeh in 1390 in a research titled study of Hasanloo Earth dam seepage using SEEP/W and Plaxis softwares and comparison between software and real results, say that between SEEP/W and Plaxis softwares results, the results of SEEP/W has most accuracy in comparison with else and may be trusted.

MATERIAL AND METHODS

Marvak Earth dam height 68 feet of level, 154 meters wide and 451 meters long Crown and the volume of the reservoir 120 million m$^3$ that the Thames dark river of Doroud and in the distance 37 kilometers of this town and the kind of Rockfill dams with clay core. The river with annually water volume 79.2 million m$^3$ after the construction of Kamal Saleh Dam in the Markazi province with the level 8100 hectares irrigation network and drainage area. Water leak the same movement in soil by water potential on both sides the water mass. Water seepage inside or under water in a dam if the stream from the permitted plan does not exceed the issue. seepage in the earth dams and in some Rockfill dam is important problems that needs to the special safety arrangements for the control it, so the Underground searches and permeability tests must have such of quantity and quality with proper distribution to accure logical understanding of the conditions and Hydraulic regime the place of earth dam. So should multilateral control change form in soil and gravel dams, in different stages. Hydraulic gradient is essential factor in soil that forced water to move under the pressure. This force apposed by friction that it in Hydrodynamic public laws when a water drop into soil mass always move in the direction of more gradient and less friction [7].

![Fig. 1: Marvak Dam Plane.](image)

Move a little bit or drop of water in the soil in the theoretic vacancy according to following equation:

$$K_x \frac{\partial^2 h}{\partial x^2} + K_y \frac{\partial^2 h}{\partial y^2} = 0$$

$K_x$, $K_y$ are symbol of Hydraulic permeability in horizontal and vertical axis and $h$ indicates head water level. This Differential Equation can be solve in some way like finite difference, finite volume, finite element. In below finite difference method is explained shortly and then finite element method that SEEP/W software going based on it will illuminate.
In finite difference method, differential equation solved by Taylor formula. In approximation of $h_{i+1,j}$ and $h_{i,j}$ based on Taylor formula can write that:

$$h_{i+1,j} = h_{i,j} + \Delta x \left( \frac{\partial h}{\partial x} \right)_{i,j} + \frac{\Delta x^2}{2!} \left( \frac{\partial^2 h}{\partial x^2} \right)_{i,j} + \cdots \tag{2}$$

In $X_0=a$ when both side of equation divides on $h$:

$$h_{i,j} = h_{i-1,j} - \Delta x \left( \frac{\partial h}{\partial x} \right)_{i,j} + \frac{\Delta x^2}{2!} \left( \frac{\partial^2 h}{\partial x^2} \right)_{i,j} \tag{3}$$

Now if (3) and (4) be totaled and abandon and forget the greater than 4 exponent terms:

$$h_{i,j} = h_{i-1,j} - \Delta x \left( \frac{\partial h}{\partial x} \right)_{i,j} + \frac{\Delta x^2}{2!} \left( \frac{\partial^2 h}{\partial x^2} \right)_{i,j} \tag{4}$$

In same way for Y axis can be continued:

$$h_{i,j} = h_{i,j-1} - \Delta y \left( \frac{\partial h}{\partial y} \right)_{i,j} + \frac{\Delta y^2}{2!} \left( \frac{\partial^2 h}{\partial y^2} \right)_{i,j} \tag{5}$$

Then:

$$K_x \frac{h_{i,j} - h_{i+1,j}}{\Delta x^2} + K_y \frac{h_{i+1,j} - h_{i,j+1}}{\Delta y^2} = 0 \tag{6}$$

if $\frac{K_x}{\Delta x^2}$ and $\frac{K_y}{\Delta y^2}$ sequential assign by $\alpha$ and $\beta$ can write:

$$h_{i,j} = \frac{1}{2(\alpha + \beta)} [\alpha h_{i-1,j} + \alpha h_{i+1,j} + \beta h_{i,j-1} + \beta h_{i,j+1}] \tag{7}$$

![Fig. 2: Finite Difference Method Sheme.](image)

Above Relation indicates that for determine of Total Potential in any point must should be enjoys neighboring points with the point in both direction should be determinable [6].

One of other methods for solving water movement in soil Differential Equation, is finite element method that SEEP/W software going based on this approach. In this model with using of the import approximate coordinates of points from 2D photo of earth dam and export to software environment and definition Steady state 2D analysis, after the definition of Hydraulic specifications of different materials and assign to each region of Dam body and foundation, then seepage analysis is done. for accrete semi saturation conditions in software and due to inaccessibility for permeability Function for materials that used in dam body and foundation that are nonlinear functions, two points has been considered that it should be according to this two point ordinates can simulate permeability Function. in this way in first point must be assign head of water level -10 and permeability assign to $K_{sat}$ then for second point head of water level must be assign -100 and permeability assign to $K_{sat}/100$ [3]. So can see permeability conditions of Earth dam materials in the table(1).

<table>
<thead>
<tr>
<th>Number</th>
<th>material</th>
<th>Permeability (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shell</td>
<td>1.0E-02</td>
</tr>
<tr>
<td>2</td>
<td>Foundation</td>
<td>1.0E-02</td>
</tr>
<tr>
<td>3</td>
<td>Cutoff</td>
<td>1.0E-06</td>
</tr>
<tr>
<td>4</td>
<td>Clay Core</td>
<td>1.0E-06</td>
</tr>
</tbody>
</table>

**Analysis and Results:**

After analysis by software in 2 control sections has been defined in the center of Clay core of Earth dam (Core or Central section) that first section elevation is the crown of the dam to impervious stone layer, and other section in Foundation layer thickness, the seepage value is in table(2). This analysis is done in three head of water level maximum, normal and Minimum of reservoir level. also in this research, the result of the difference
of Core section seepage value and the central section value of the Earth dam is entitled as Core seepage flow section and the seepage flow value from the dam foundation section entitled as seepage flow value of body:

**Body Seepage : (Core section) – (Foundation section)**

**Table 2:** Seepage Flow value with Clay core without any Impervious Element.

<table>
<thead>
<tr>
<th>Number</th>
<th>Reservoir Water level (m)</th>
<th>Core section</th>
<th>Foundation section</th>
<th>Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
<td>1.80E-04</td>
<td>1.15E-06</td>
<td>1.79E-04</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
<td>1.46E-03</td>
<td>9.45E-06</td>
<td>1.45E-03</td>
</tr>
<tr>
<td>3</td>
<td>91</td>
<td>1.73E-03</td>
<td>1.11E-05</td>
<td>1.72E-03</td>
</tr>
</tbody>
</table>

**Table 3:** Seepage Flow value with Clay core with Cutoff Wall.

<table>
<thead>
<tr>
<th>Number</th>
<th>Reservoir Water level (m)</th>
<th>Core section</th>
<th>Foundation section</th>
<th>Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
<td>4.21E-05</td>
<td>2.68E-07</td>
<td>4.18E-05</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
<td>2.53E-04</td>
<td>1.61E-06</td>
<td>2.51E-04</td>
</tr>
<tr>
<td>3</td>
<td>91</td>
<td>3.25E-04</td>
<td>2.07E-06</td>
<td>3.23E-04</td>
</tr>
</tbody>
</table>

After done analysis on Earth dam without Impervious element, the analysis is done with concrete Cutoff again that seepage analysis results in table(3) have been published. With regard to the examination of the Flow Grid conditions and Potential of the flow of water from the Upstream to Downstream can use the ability of software in study of Graphic picture and figurative of dam body and foundation. In continuance while in the figure of seepage flow from body and foundation of earth dam due to the performance of cutoff in comparison with clay core showed, to see impact of cutoff wall on seepage flow from earth dam body and foundation, the figures of permeability and phreatic line status in the body of the dam has been shown.

**Fig. 3:** Foundation Seepage flow (m$^3$/s/m).

**Fig. 4:** Body Seepage flow (m$^3$/s/m).

**Fig. 5:** 2D Earth dam in SEEP/W.

**Fig. 6:** Conductivity (H.W.L=91m).
Fig. 7: Phreatic line (H.W.L=91m).

**Conclusions:**
After done Numerical Analyse using software, In view of the Seepage analysis carried out on Marvak Earth dam we can observe that the most of Cutoff effect is on reducing the leak from Dam Foundation. This effect value about 76% - 83% is variable. It is obvious that without Cutoff wall, there is Erosion and internal piping in Earth dam materials. Also with Cutoff wall the Output Hydraulic Gradiant in Plastic Concrete in Cutoff is Maximum. So Cutoff can be applicable method for use in Earth dam.

**REFERENCES**


