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Determination of Seepage and Analysis of Earth Dams (Case Study: Karkheh Dam)

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Abstracts: Because of the increasing trend of building dam throughout Iran; it is necessary to optimize dam buildings and operations. Dam or Hydropower industry has two types of buildings; normally: (1) Concrete dams (2) Embankment (earth) dams. Generally, scientists and engineers use different methods to enhance safety and decrease any errors in calculation due to maintenance of water storage especially hydro structure of the dam. It is necessary to investigate the dam seepage control; commonly used by several methods. Seepage is one of the important issues for design, build and maintenance of dams awareness. Seepage problem and its rules helps scientist to select a suitable method of monitoring and solving such problem. These methods of analysis were carried out at civil and construction project. In this study, one of latest method of investigation of seepage behavior were analytically evaluated and compared with the actual rules. Based on determine results; several suggestions and optimization method were suggested. Therefore, an optimum method was scientifically selected. Besides that, flow condition of porous environment with application of numeric program was analyzed. Finally, all the results were lunched out from seep/w soft which is the most significant program about this matter; use of finite elements method is specified for saturated and unsaturated environment. Thus; leakage and seepage were defined as function of (time and position). Subsequently, the best seepage solutions for the dam constructing were scientifically identified.

Key works: Seepage % Hydraulic structures % Net flow % Finite elements % Karkheh dam

INTRODUCTION

In eyes of engineers, dams are known as alive structures. Because of changes of geology and other criteria of dams, these structures may also changes. For these reasons, dams should certainly be designed and built with high assurance for a long duration of time. Awareness of such changes is related to dams and the specified surrounding environment. Special devices are required to predict dams behavior. Water through reservoir may possibly move behind and depth of dams [1]. Water running from dam's reservoir, especially from earth dams has important role on dam stability [2]. Generally, different methods for decreasing water running through dams have been used [3]. Specially, type of construction material for dam foundation, borrowing materials, type of design, geometrical shape and empirical limitation has influenced on water stopping factor of dams [4, 5].

Water leakage at earth dams and it's method of seepage control, is the first step of designing embankment dams [6, 7]. Science and technologies related to basic seepage rules have given necessary information to scientists to control and overcome any encountered problems [8-10]. Recently many scientists studied and analyzed the effective parameters on seepage process and they were able to solve many cases by designing issues [11, 12]. Kamanbedast *et al*. [3] have investigated on earth dam; they have demonstrated a powerful software which was able to determine the seepage [3, 13]. But each dam has its own descriptive design and configuration. Special attention is required to know detail information about the seepage. In this research, a practical software has been applied to predict seepage. A successful attempt was made through numerical designing. The desired methods of control and monitoring techniques of leakage such as trench depth, thickness of clay blanket, some physical and geometrical characteristics of dams such as

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infiltration, upstream and down steam protections have been used and extensively investigated [2, 4, 6, 7, 12, 14, 15]. In this study, Karkheh dam as prototype was used. The dam is located at Khuzestan province in southwest of Iran.

Karkheh dam with capacity of water maintaining (about $7.4x10^9m^3$) and (volume equal to $5.6x10^9m^3$ at flood events) is the biggest dams in Iran. Basic aim of this dams is to provide the demanded water flow rate of greater than $32x10^4$ (Hectares) for Ilam and Khuzestan land. In addition to generate power with annual rate of about 934 gig Watt Hours electrical power. This structure was also used for flood control of Karkheh River. Karkheh Dam is an earth type with centre clay core and elevation is about 127 meters. Crest length is equal to 3030 meters. Crest elevation is 234 meters and bottom of foundation at minimum level is 107 meters up from the free surface of sea level.

The dam was build at Bakhtiary geological layer; this layer is included conglomerate and some sandstone small layer. This type of stone has high infiltration rate and has been divided into flower stone layer. For stopping water running through reservoir (dam), at some dam hand and middle of it, some water stop walls (with plastic concrete) were used. Almost all of it has been injected at upper zone of central core and at down section, (using this part of dam, foundation has been joint to the floor stone layer at downstream of the structures). Sum up of water stop wall at vertical direction and floor stone layer at Horizontal direction have been known as water stopping system. At any dam seepage has began from dam ditch (because of water movement through the soil). Velocity of water movement at ditch is depended on type of soil, its compaction and type of handed wall and foundation of the dam. some catastrophic phenomena, (related to dike) on dam were rely on control seepage at fault scale and some faults at foundation seepage could cause liquefaction phenomenon at soil or sliding of dike deduction and two events may caused dam break may happen. This event (specially) earth quake period may create many problems for dams. At these situations, strengthening of dams against seepage is kind of management before critical situation occur.

Aim and Necessary Method of Operation: This research is necessary to be conducted, because of dam the structure (Kharkheh is the biggest dams in Iran) and its role in electricity generation and water reservoir management for the agricultural usage. First of all several methods of seepage control calculations were carried out; then, seepage for Karkheh dam was mathematically analyzed. Finally based on the best outcome the best method has subsequently been driven.

MATERIALS AND METHODS

Dams Geographical Location: Earth dams of Karkheh are located on west side of Andimeshk city has about 170 kilometers distance from the north of Ahwaz city. It's longitude is 48°7.8' and latitude is 32°, 29.6'. Karkheh River is the third River, after Karoon and Dez, (by the view point of discharge). Hydro potential (based on Hydrometric statistical data) is about $5.6x10^9$ m^3. Annually and the average flow rate is 177 m^3/s and from this resource more than $4.6x10^9m^3$ (without any use) were fallen to Hoor Alazim and Hoor Alhowiezeh swamps, these rivers are originated from middle and southwest of Zagros mountains. The mountains after 900 kilometer

Fig. 1: Landscape of down-stream of Karkheh dam

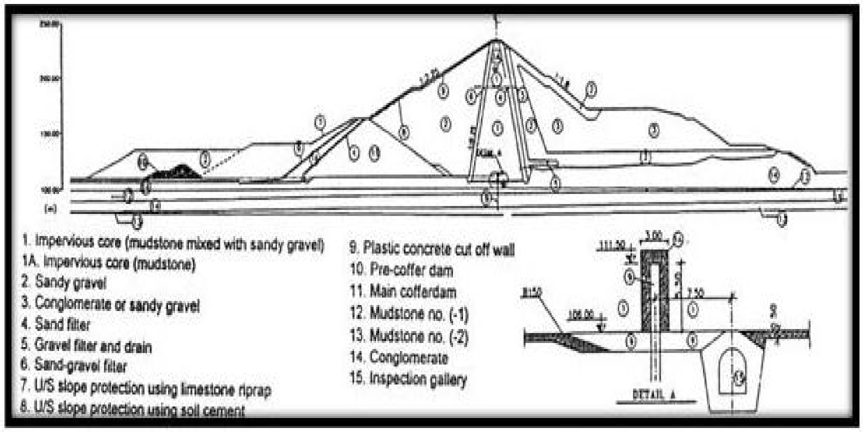

Fig. 2: Schematic section of Karkheh Dam

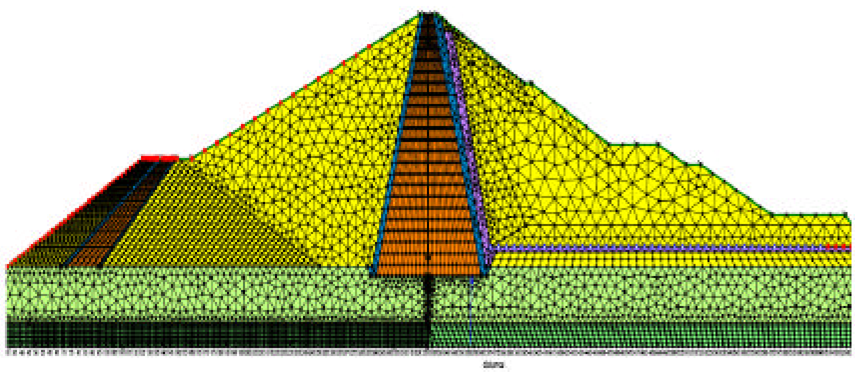

Fig. 3: Mesh of Karkheh Dam

(with equal 120 m) were ended at Khuzestan boundary line. Its watershed is about $5x10^3$ square kilometer (3% of total area of Iran). Annual rainfall is about 200 to 800 mm and it's average is 290 mm, minimum and maximum temperature range is from 25 and 53.6°C (respectively) annual average temperature is about 24.6°C [3].

Introducing Software: Seep/w software is one of powerful program works based on finite elements technique and it is able to simulate and analyze isometric water distribution through soil and rocks. Prefect developed formula of software make it possible to analyze very complex water seepage formula.

Method of Analysis: For simulation and investigation of seepage through dams (seep/w) software was used. Continuity phase of liquid, Darcy equation behavior of seep zone and UN isotropic are the assumption utilized in the equations. In a porous environment analysis, with different boundary conditions effectively been used (Figure 2). Kaerkheh Dam is made up in mesh within the assigned compartments is shown in Figure 3. In the computational program, two dimensional analysis were successfully carried out with the assumption of uniform seepage at critical section [4, 11].

Producing Seepage Model: Analysis of the schematic cross sectional earth dam of Karkheh showed that five zones are distinctly observed.

- Zone 1 is clay core (impervious core)
- Zone 2 is upstream cover includes conglomerate and Stone.
- Zone 3 is upstream skin include (sand and conglomerate)
- Zone 4 is Water stop wall
- Zone 5 is the stoned bed

Table 1 summarized the hydraulic gradient coefficients recorded by the flow rates at different layers of the dam.

Use of the obtained data and specification of different layers of the dam and seepage analysis (with the aid of software) some meaningful tables and figures are driven. The demonstrated sectional analysis is illustrated as follows:

Table 1: Hydraulic gradient coefficients by the flow rates at different layers of the dam

No	Type of material	K9 Hydraulic Gradient Coefficients
1	Center core	1x10G^{7}
2	Skin	1x10G^{3}
3	Conglomerate	5x10G^{3}
4	Water stop wall	1x10G^{6}
5	Floor store	5x10G^{6}

Table 2: Discharge rate with respect to dam elevations water depth

Water level (m)	discharge (m^3/day/m)	Measured discharge (m^3/day/m)	Percentage of fault
180	14.46	14.64	1.20
190	14.60	14.88	1.90
200	17.63	17.91	1.60
210	19.27	19.44	0.86
220	21.17	21.25	0.35
230	1.20	Water still didn't arrive to normal range	-

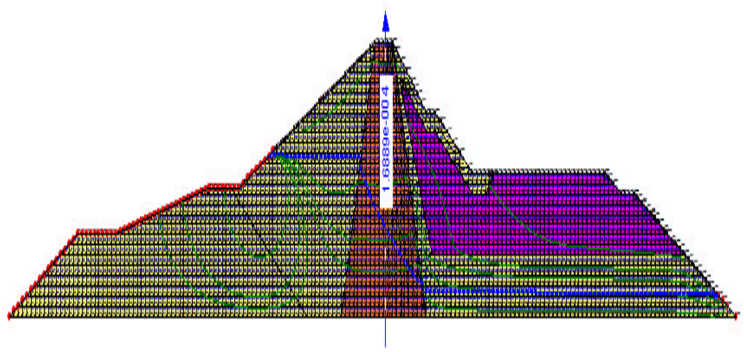

Fig. 4: Flow rate under earth dams at elevation of (120 m) above the free surface

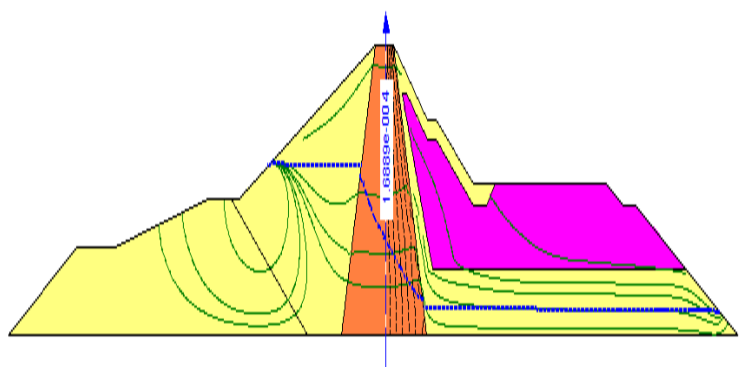

Fig. 5: Phonetic line and seepage before concrete blanket

Table 2 shows the calculated and measured seepage discharge flow rates with respect to dam elevations of reservoir water depth. The seepage rates have been gradually estimated for the different elevation of reservoir water depth. It was observed that, the calculated seepage flow rates were very close to actual values. These steps were carried out at variable conditions such as concrete blanket, banknote and clay mixing plus geo membrane larger and all of obtained results were compared to actual recorded values.

First Option; Using Concrete Blankets: The actual samples have been tested on Pindari dam at Australia (Rock fill dams with impervious core) [16]. At this structures concrete covered the upstream slope at same sizes (plate with 20mx50cm) has practically been used. In this research, for Karkheh dams, first of all the cover was tested, results are summarized and presented in Table 3 (thickness of concrete cube is about 500m). In this table, it is obviously shown the rate of seepage was completely decreased.

Table 3: Comparison of concrete cover of upstream

Water level	discharge (seepage)	Predictable discharge	Rate of seepage decrease
180	14.46	12.91	1.55
190	14.60	12.62	1.98
200	17.63	15.53	201
210	19.27	16.90	2.37
220	21.17	17.63	3.54
230	22.55	18.40	4.15

Table 4: Measured and predicted seepage flow rate

Water level	Measured flow (m^3/day)	Predicted flow rate	Seepage difference rate
180	14.46	13.95	0.51
190	14.60	14.05	0.45
200	17.63	14.86	2.77
210	19.27	15.33	3.93
220	21.17	16.45	4.63
230	22.55	18.33	4.22

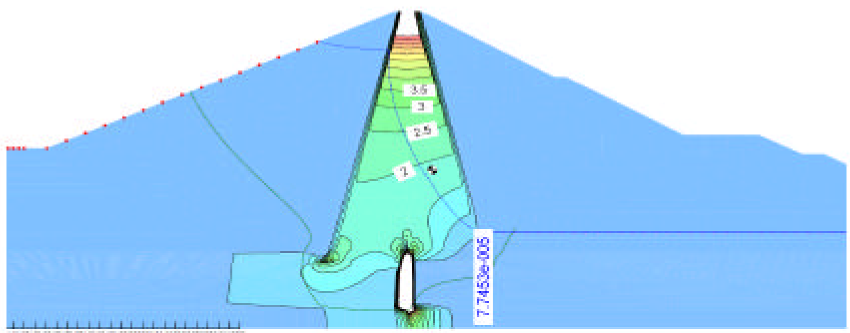

Fig. 6: Model with up saturation before cut off and semi saturation for downstream

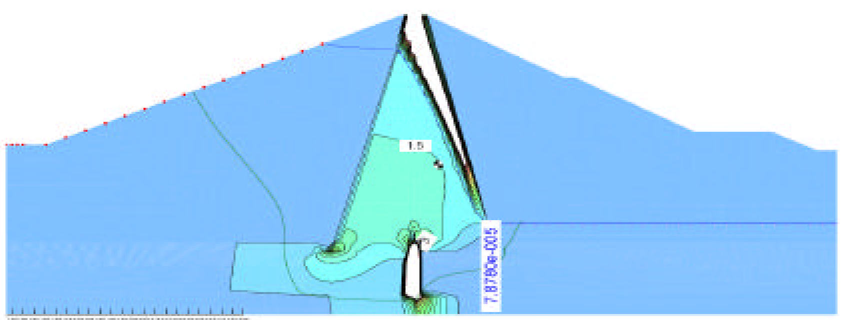

Fig. 7: Model with up saturation and semi saturation for core and downstream

Second Option: In the cover at up-stream mixture of clay and betonies with a layer of geo- membrane were used. Using material is included of clay sealant of bantonite with a layer of geo-membrane. Geo-membrane plates has been made up of polyethylene with high compression rate (for water stopping in dams at conveying channel water) some problems of high density of upstream cover, in filtration, stability may be used these type of geo-membrane are developed in all over the worlds. Geo-membrane is a kind of polymeric cover with high flexibility rate and seepage flow rate is very low ($7.7x10^{-8}$ m^3/s) but flow rate of clay is about $1x10^{-7}$. Geo-membrane includes almost 97% compressed polyethylene and 2.5% black carbon and 0.05% anti oxidant. These materials with high strength rate are used against any catastrophic phenomenon. Finally, results are summarized for the mixture of clay and betonies plus geo-membrane are shown in Table 4.

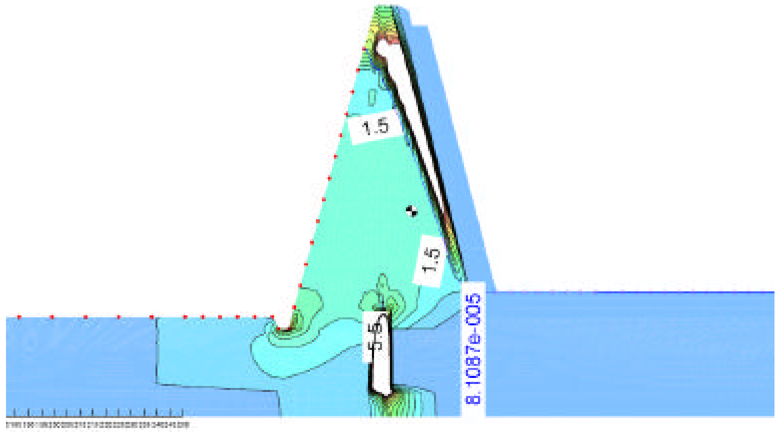

Fig. 8: Model with up and down streams with drain and filter

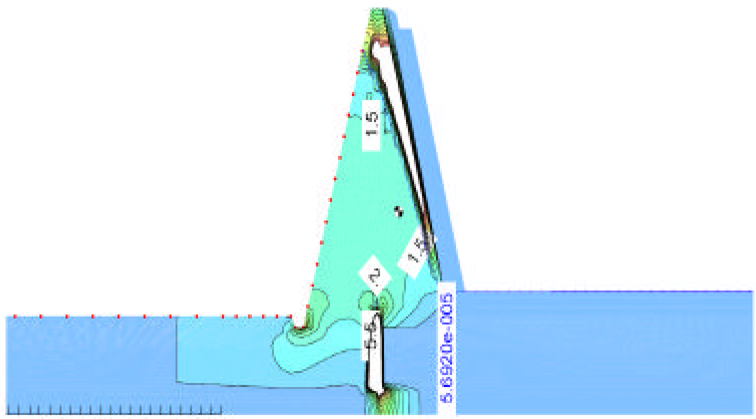

Fig. 9: Model without up and down streams with drain, filter for reduce conductivity

Third Option: Use of saturation condition for the cover, core and foundation at up and down streams (with filter and drain) were evaluated; the results are shown in Figures 6-9.

DISCUSSIONS AND CONCLUSIONS

- Seepage analysis was successfully carried out with the use of two dimensional models. In addition, one has to consider the restriction and limitation of the software.
- In order to have accurate analysis, it is recommended to carry out three dimensional analyses using advanced software to handle required calculations.
- Because of utilization of Karkheh dams, not only seepage control was practically limited; but also use of these methods is very expensive. It is recommended to investigate methods of seepage control before dam constructions.
- In a similar dam condition (like Karkheh). It is desired to conduct control of seepage operation at the time dam constructions and dam building period and before water intake. Firstly, open trench and drain pipe are often utilized with higher efficiency. Separation walls are empirically restricted beneath core.
- Finally it necessary to add and consider practical limitations. The best way to decrease water run at Karkheh dam would be the use of concrete blanket at upstream side of the dam.
- Besides that, it is recommended another underground water gallery to be built at water runs beneath the core.
- For determination of seepage in earth dam, it is desired for the modeling and simulation without considering up and down streams shell and exist drain and filter and condition core, foundation saturation before cut off; because of the limited time. In that case the seepage is exactly determined.

- It was concluded that the result of seepage software, seep/w software is reliable and trustable software to model one dam.

It is worthy to mention that all measurements in one dam's sections such as complex and hard layers can be modeled by the seep/w software.

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