Stability Analysis of ZIVIEH Earth Dam with Numerical Methods

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Abstract
Dams may be classified according to their purpose as diverting dams or weirs and as storage dams. In order to, Stability analysis of earth dams such ZIVIEH has utmost of importance under conditions of static and quasi-static. Applied methodology in this study is based on numerical methods and analysis based on the method of limiting equilibrium which respectively has taken by FLAC and slide software's. Results show that the maximum vertical displacement is about 25 cm in the dam crest. Also, Safety factor which obtained by FLAC2D and slide software's shows note that the coefficient is greater than 1.5 and in the static and hydraulic approaches the dam will be stable.

Key words: ZIVIEH Earth Dam, Numerical Methods, FLAC2D, Slide Software

1. Introduction
Water control and redirect it to the areas where have water scarcity is the main purpose the construction of dams. An dam can be designed with different goals that these goals can be include of arable land irrigation, drinking water supply, power generation, water supply, flood control, soil conservation and etc. purposes. Stability analysis of rock and soil slopes is one of the most important parts of the design of mines, tunnels, mountain roads, dams and the overall projects that in them there is land sliding potential on the slopes. Including of these cases is the stability analysis of earth dams. Stability analysis of dams has utmost of importance under conditions of static and quasi-static. Water moving in a permeable soil media produces a force on the volume of soil which is proportional to hydraulic gradient in desired direction and is called the seepage force. Determination of the seepage force is required to calculate stability of dams and other hydraulic structures (Das, 1983). Dams may be classified according to their purpose as diverting dams or weirs and as storage dams. The former may be located upon any portion of a stream where the conditions are favorable, and the water used for manifold purposes, being conveyed by means of canals, flumes, tunnels and pipe lines to places of intended use (Ansys, 2009). In the case of modification of the structure, including repairs and reconstruction of the dam, economic feasibility and social goals need to be addressed. When evaluating the priority of the dam rehabilitation, a risk-based analysis is a potentially useful approach. Moreover,

overtopping is one of the most important risk factors inducing dam failure. According to the International Commission on Large Dams (ICOLD, 1973), overtopping causes about 35% of all earth dam failures; seepage, piping, and other causes make up the rest (Kuo & et al, 2007). Dams are barriers constructed across streams (above ground or underground) to impound water or the underground streams. Any discussion on the history of dams is incomplete without a mention of beavers (industrious furry animals of the rodent family who live under water) that build astonishing water impounding structures across streams and rivulets using tree branches which they cut themselves, chopped wood, twigs, and mud; to provide themselves with comfortable ponds to live in (Murthy, 2013).

Nowadays with increasing developments and becoming pervasive of computer, the use of numerical methods for the analysis and design of earth dam is greater than ever before. Using these methods, especially in dynamic stability analysis of slopes, can increase the precision of the calculations. In the numerical methods, in addition to can be removed the above restrictions, and can be imposed the similar accelerogram of earthquakes to the dam and can evaluate the deformation that caused by the earthquake.

2. Background

In current research, stability of the earth dam and its deformations has been done using numerical methods (software FLAC2D) thus far has not been done in the case of ZIVIEH earth dam. Also with Slide software were obtained the results of reliability and then are compared with the results of numerical method. Dam safety is a major concern to the general public. In recent years, many countries have experienced frequent floods that may have overtop dams. Such deficiencies can cause dams to break and extreme floods to occur downstream. This leads to various problems such as loss of social capital, large scaled economical expenses, and the loss of life seriously (Kwon & Moon, 2006). All earth dams must be provided with a waste away, ample to discharge.

Slope became unstable when the shear stresses required to maintain equilibrium reach or exceed the available shearing resistance on some potential failure surface. For slopes in which the shear stresses required to maintain equilibrium under static gravitational loading are high, the additional dynamic stresses needed to produce instability may be low. Hence the seismic stability of a slope is strongly influenced by its static stability. Because of this and fact the most commonly used methods of seismic stability analysis rely on static stability analysis. The procedures for analysis of slope stability under static conditions are well established. An excellent, concise review of the static analysis was presented by Ducan (1992). Detailed descriptions of specific methods of analysis can be found in standard references such as National Research Council (1976), Chowdhury (1978) and Huang (1983). Currently, the most commonly used methods of static slope stability analysis are limit using numerical methods (software FLAC2D) analysis. Gables will suffer from instability when they generated shear stresses in the hypothetical rupture of surface was equal or larger than the shear strength the surface potential in on return. In order to, it is well developed the dam stability analysis in the absence of earthquake forces. The most common used methods in the present is based on limit equilibrium analysis and Stress - Change methods.

Pseudo-Static-Analysis is done routinely as a traditional approach for comparison with other dams. Yield accelerations are calculated, for possible future deformation calculations. No effort has been made by DSOD to associate pseudo static coefficients with a design earthquake. The factor of 0.15 a/ g is typically used with a required minimum factor of safety of 1.10. Undrained strengths are used where they are less than drained strengths. Low undrained strength envelopes are considered indicative of soils subject to strength loss during shaking. DSOD seismic stability evaluations never end solely on the basis of satisfactory pseudo-static factors of safety (P.E & Stephen, 2013). Earthquake or seismic loads are the major dynamic loads (Major 1980, Schoeber 1981) being considered in the analysis and design of dams especially in earthquake prone areas. The seismic coefficient method is used in determining the resultant location and sliding stability of dams. Seismic analysis of dams is performed for the most unfavorable direction, despite the fact that earthquake acceleration might take place in any direction (Subramani & Ponnuvel, 2012).

In other side, one of the most consistent methods of determining the response of earth dams to earthquake loading is dynamic analysis. Use this technique is recommended on major dams, the dams that damage can lead to detrimental consequences and the dams that have been built near active fault. In dynamic analysis, the estimated rate of change of locations around the dam will be done using finite element or finite difference and of course, the results of this analysis are strongly influenced by the seismic parameters and deformability parameters of the materials.

3. Research hypotheses

The present study is regarding the stability analysis of ZIVIEH earth dam. Methodology in this research is based on numerical methods. FLAC software is based on finite difference of numerical method and it has written for calculation and analysis of geotechnical. By collecting the data's such as geometric and geotechnical characteristics of ZIVIEH earth dam, examined to investigate the stability of the dam and the results are placed analyzed. In this regard, it is assumed that:

1. dam body is continuous, homogeneous and isotropic.
2. Soil behavioral model is intended the Mohr – Coulomb.

4. an overview of the characteristics of ZIVIEH earth dam

Storage ZIVIEH dam with normal volume of 16 million cubic meters is considered in 1585 normal level above of sea on the Shaheeni River. The objectives of Zivieh barrier is as follow:

1. Prevent the potential water loss of Shahheeni River.
2. gathering the waters that caused by rainfall and floods.
3. Utilized to irrigation of downstream of the dam.
4. Increasing the irrigation efficiencies using pressurized irrigation systems.

With attention what said in above, can be said that:

1. Zivieh dam is a dam with soil type and vertical clay core.
2. The normal level of this dam is 1585/0 and the dam crest level is about 1588/1.
3. Flood diversion system of Zivieh dam is composed a culvert with 215 meters length, stilling basin type of usbr3 on the left side and able to discharge 44 cubic meters of flood water per second in the era of construction.

4. Tipper and lower dewatering system of Zivieh dam is made up of two pipes in diameter of 1000 mm that alongside of diversion culvert and run simultaneously executing body of the Calvert.

5. Methodology

In primarily was used of Sangan iron ore mine contained information's as the main source. Also has been used of published papers in journals, Books and available entity references in the research center databases, inquire the views of experts consisting of university professors, engineers working in the industry and mining sector and technicians with the high working experience. The method that was used in the study of stability of ZIVIEH Earth Dam is based on numerical method and analysis based on the method of limiting equilibrium which respectively has taken by FLAC and slide software's.

6. Discussion and Results

6.1. Mode of dam construction and modelling the initial conditions

Behavioral model of materials and frame is intended as Mohr – Coulomb. In figure 1 is shown the overall elements of model. Boundary applied conditions to the model is consist of the closure of nodes in the vertical direction on the bottom part of the wake and in the horizontal direction of wake aspects. In the calculation of all steps of static and hydraulic analysis, the displacement rate of previous step are considered as zero.

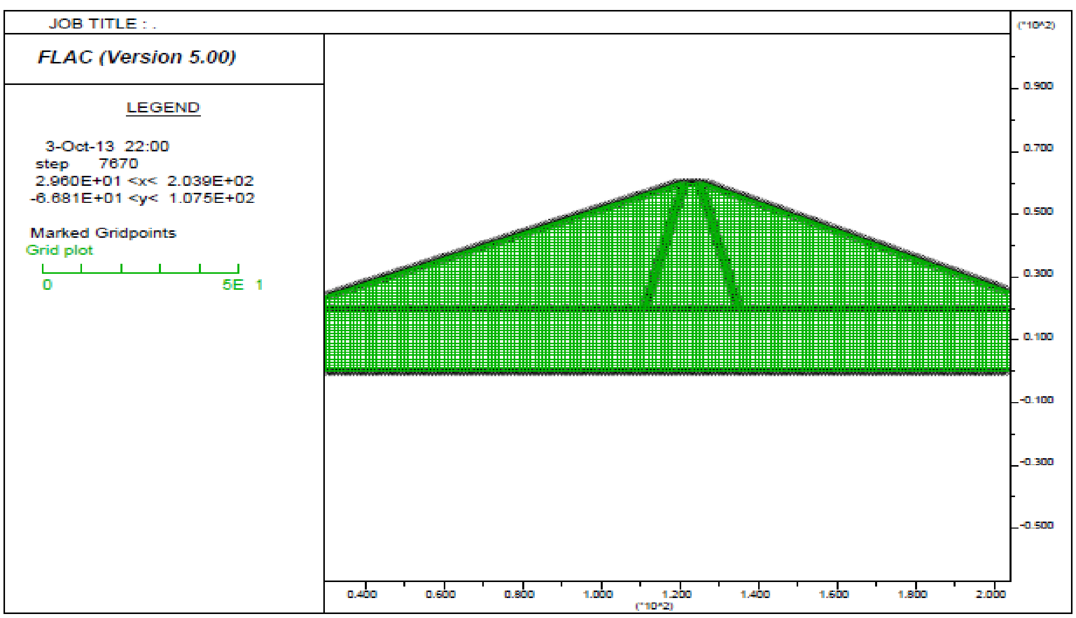

Fig.1. Elements classified of Model.

7. Results of static analysis

In this section, the results of the static analysis of the dam are presented immediately after completion of construction of the dam.

7.1. Unbalance force

The best way to check the balance of a system is investigating the value of unbalance force. If in any parts of the model, the resultant forces reaches zero, it can be argued that the model is in fully reach equilibrium. However, in the numerical analysis the resultant forces will not reach to absolute zero any time. But if the ratio of the unbalanced force to the forces in the model be very small, can be assumed that the model is reached to its overall balance. Whereas in the analysis process, unbalanced forces doesn't reach to the extent amount of zero, it can be expected that the model is broken. In various stages of analysis, a graphing is obtained as the output of software that the vertical axis represents the maximum unbalanced force and its horizontal axis is indicates the number of taken steps in the analysis model. Figure 2 shown the initial equilibrium of the first stage of the dam without taking water, as can be seen, after the mechanical analysis at each stage, dam is reached to static equilibrium and the maximum of unbalanced forces is asymptotic to its minimum rate (zero). In analysis with FLAC2 software, if one of the following conditions occur, the analysis ends:

1. the ratio of the unbalanced force reached to 10^{-3}.
2. Unbalanced force was equal to 100 units of power (usually Pascal).
3. Number of equal analysis steps reached to 100000.
4. Analysis of time be equal to 1440 min.

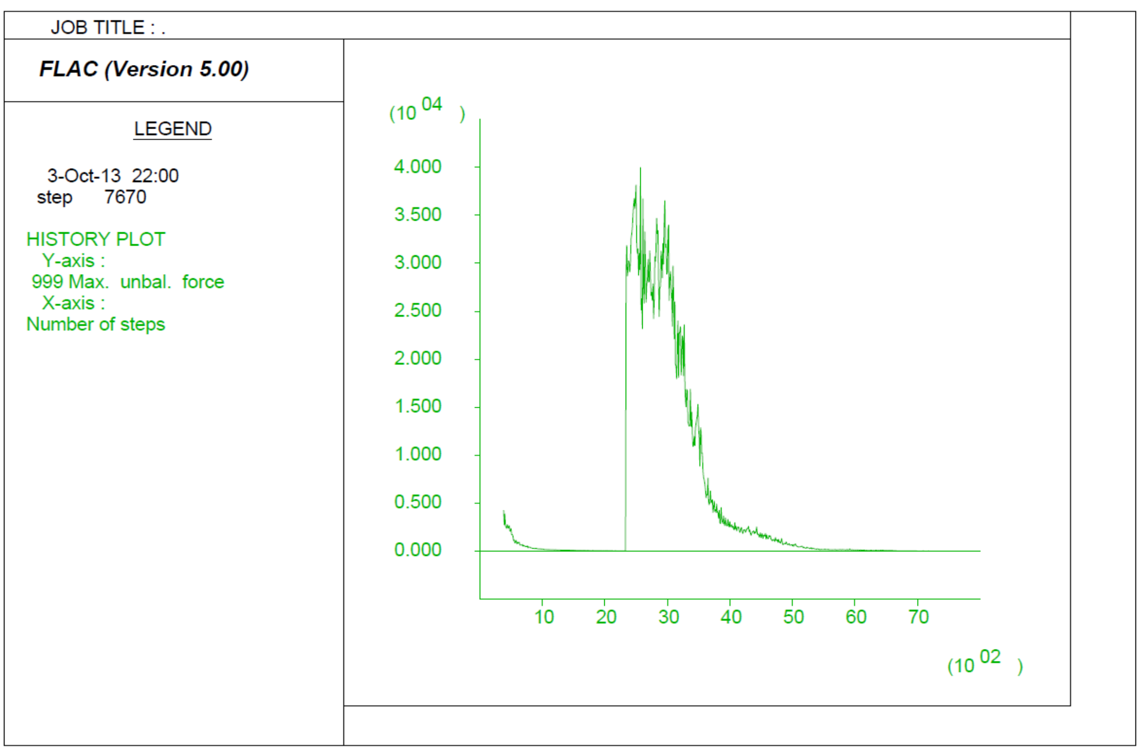

Fig.2. Unbalanced forces changes in different steps of analysis.

7.2. Subsidence (vertical displacement)

Vertical displacement under the weight of the materials and immediately after completion of construction is presented in Figure 3. It is noted that the maximum vertical displacement is 25 cm in the dam crest. In this figure it is clear that dam crest due to the greater thickness of materials with more deformability has more subsidence than the surrounding.

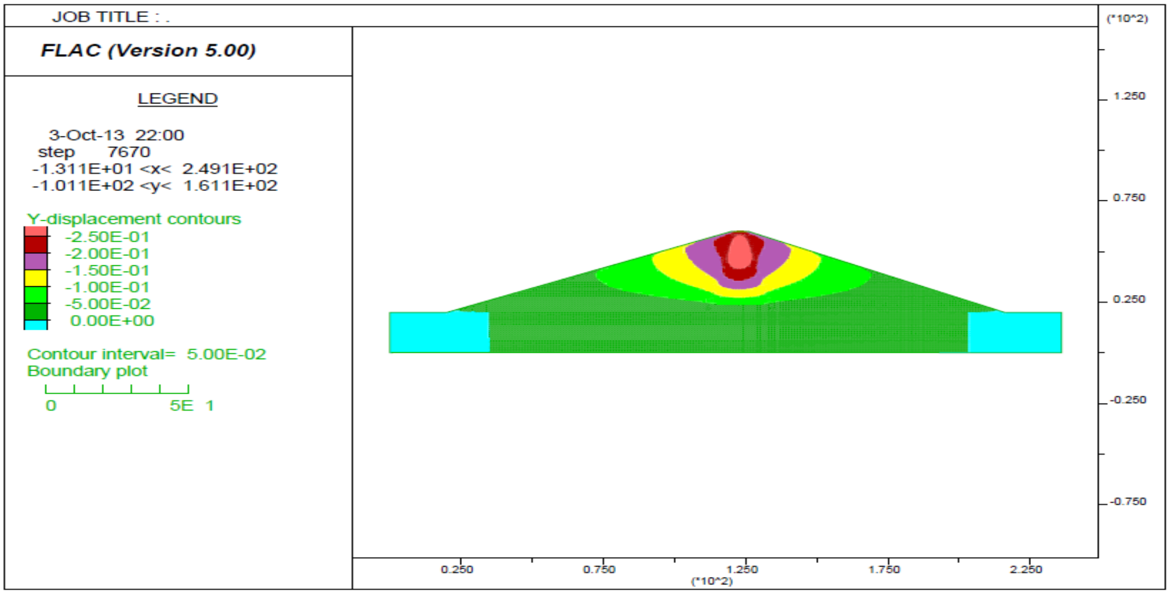

Fig.3. Zivieh Dam vertical shift in the static mode.

7.3. Vertical the stress distribution

The stress distribution in the vertical direction at the end of the first phase of construction of the dam is shown in Figure 4. As is considered, stress in the vertical direction from the top to down due to weight gain of layers is increased and in the floor of model has reached to its maximum rate.

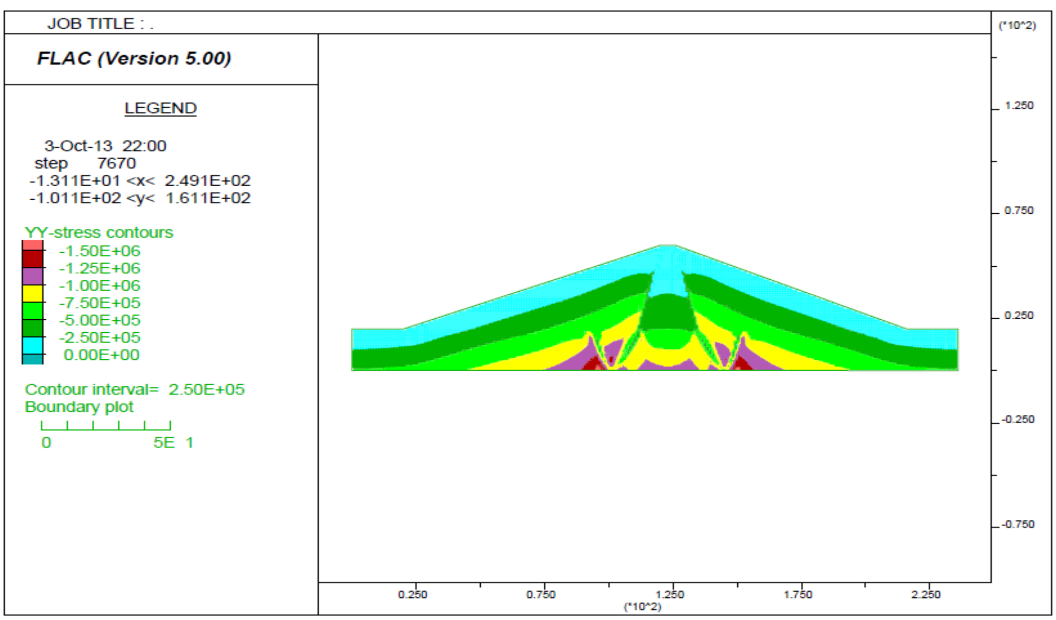

Fig.4. the stress distribution in the vertical direction in the state of static equilibrium.

8. Hydraulic applied load

After construction of the dam body, the role of water behind the dam has been modeled in two forms of mechanical performance (materials weight) and the hydraulic performance (water flow in the dam body).

8.1. Vacuolar water pressure

Water pressure to the wake and the upstream of slope is introduced using linear distribution technique. In numerical model, the wake saturation and upstream slope due to the constant exposure of water can be kept constant considering. The changes of vacuolar water pressure (state of sustained leak) is shown in figure 5. After the filling of tank and establish a stable flow, pore pressure in high parts due to dry environment, zero, and with distance from the crest of the dam towards wake, due to the water pressure to upstream of the dam has increased due to the free flow in the dam body.

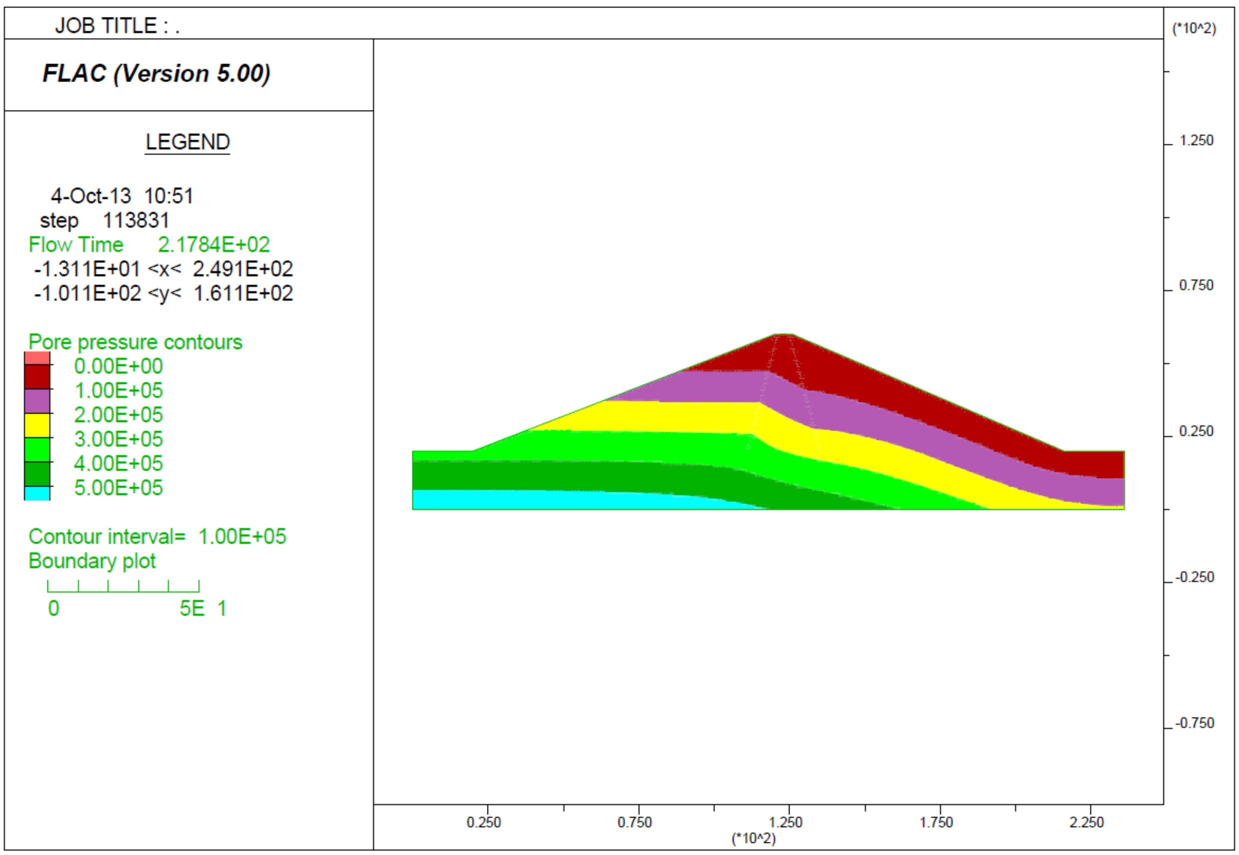

Fig.5. Contours of pore water pressure changes after the hydraulic applied load .

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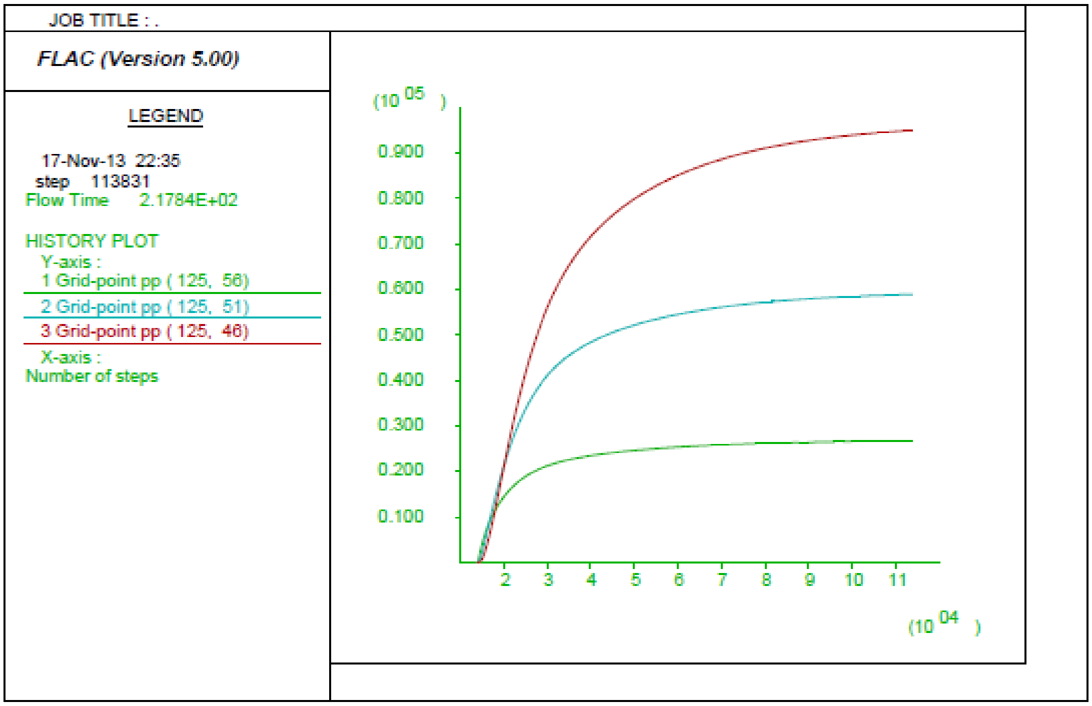

Fig.6. The changes of vacuolar water pressure in during of analysis steps for depths of 5, 10 and 15 meter dam.

8.2. Vertical stress distribution

With make flow and increasing in the pore water pressure, the tensions will be moderated. In Figure 7 effective stress contours show that from the existing stress is reduced to the size of the pore water pressure.

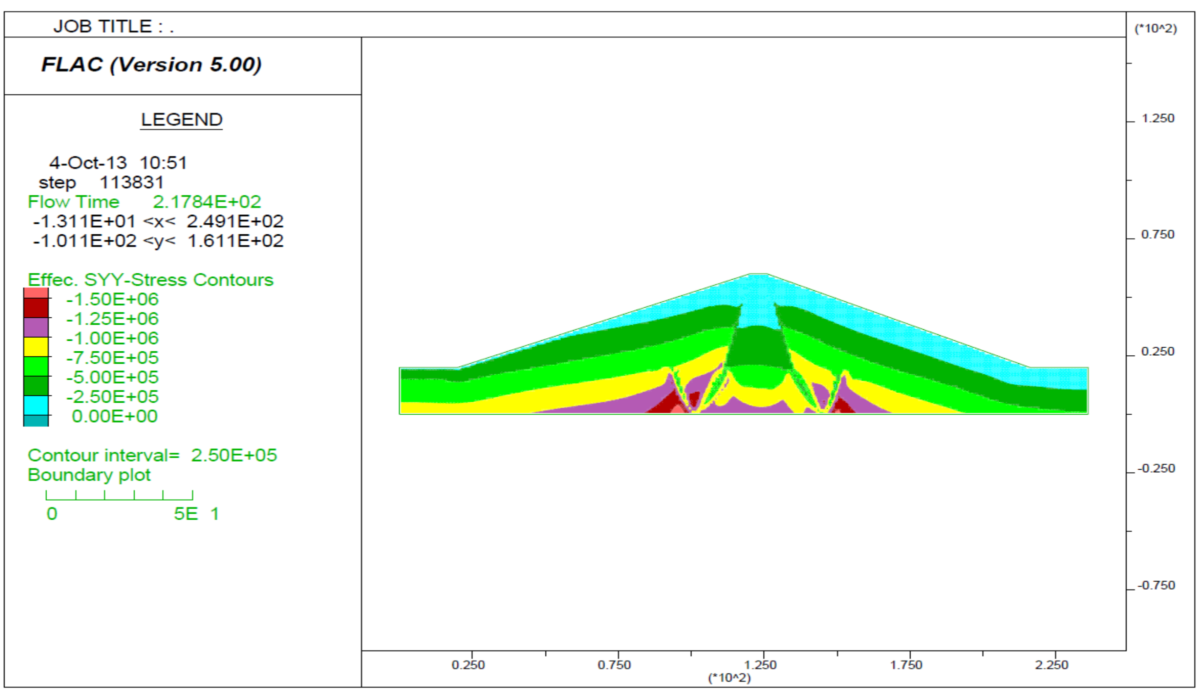

Fig.7. Vertical effective stress contours after theapplied of hydraulic load.

8.3. Displacement

In the figures of 8 and 9 are shown the respectively displacement of contours in the vertical and horizontal direction after the applying of water tank pressure and flow establishment. Accordingly, the maximum vertical displacement at this stage was 3 cm. Also the maximum horizontal displacement is 3 cm. As can be seen at these figures, upstream of the dam have more displacement due to the water applied load.

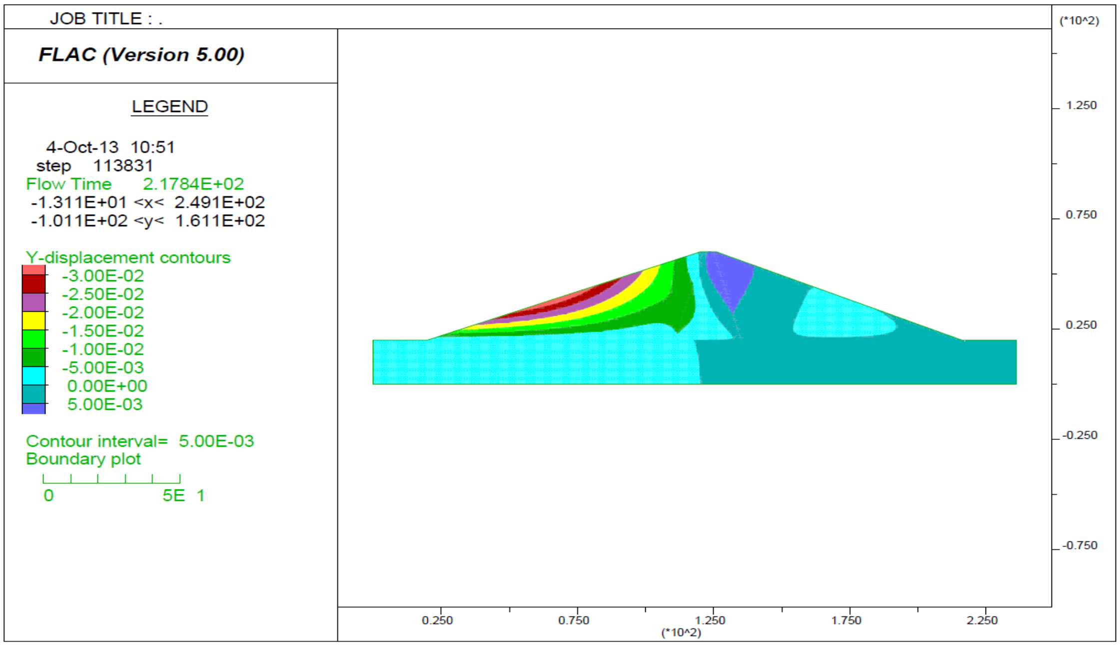

Fig.8. vertical displacement After the applied of hydraulic load.

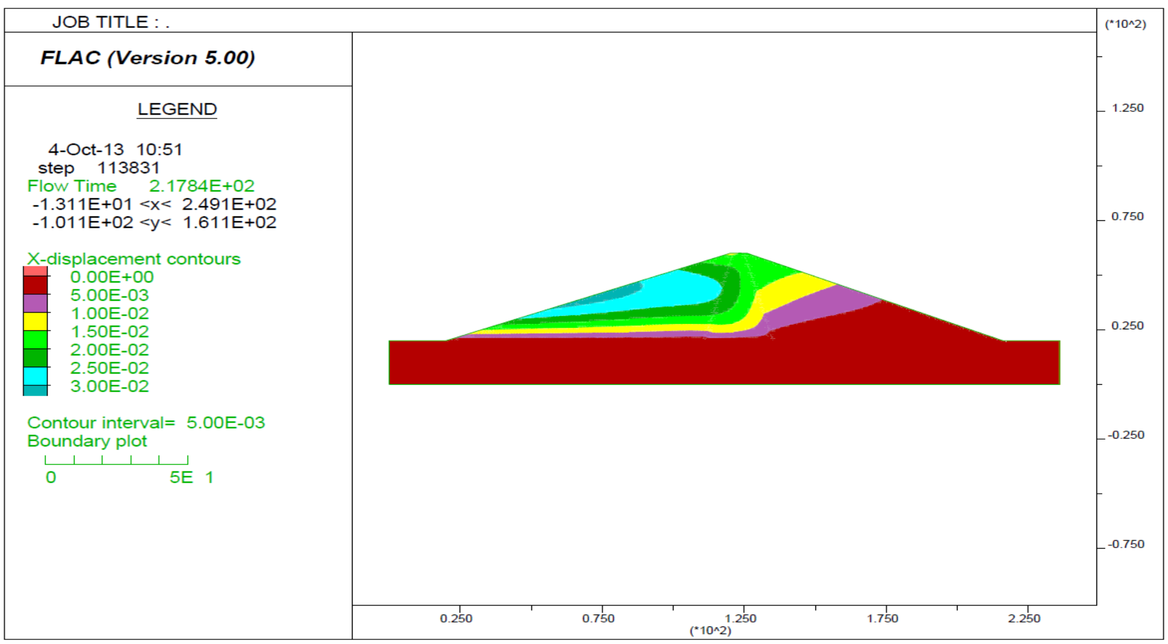

Fig.9. Horizontal displacement after the applied hydraulic load.

9. Calculation of confidence ration

Slide software has a great capabilities and in it, can be modeled the rock or soil materials in gable forming, external load, water table level and confirmatory measures. This software has the reliability of analysis into the Bishop, Spencer, Morgenstern and etc. methods. Meanwhile, automatic analysis on the potential slip surfaces and also on a sliding specification surface is possible.

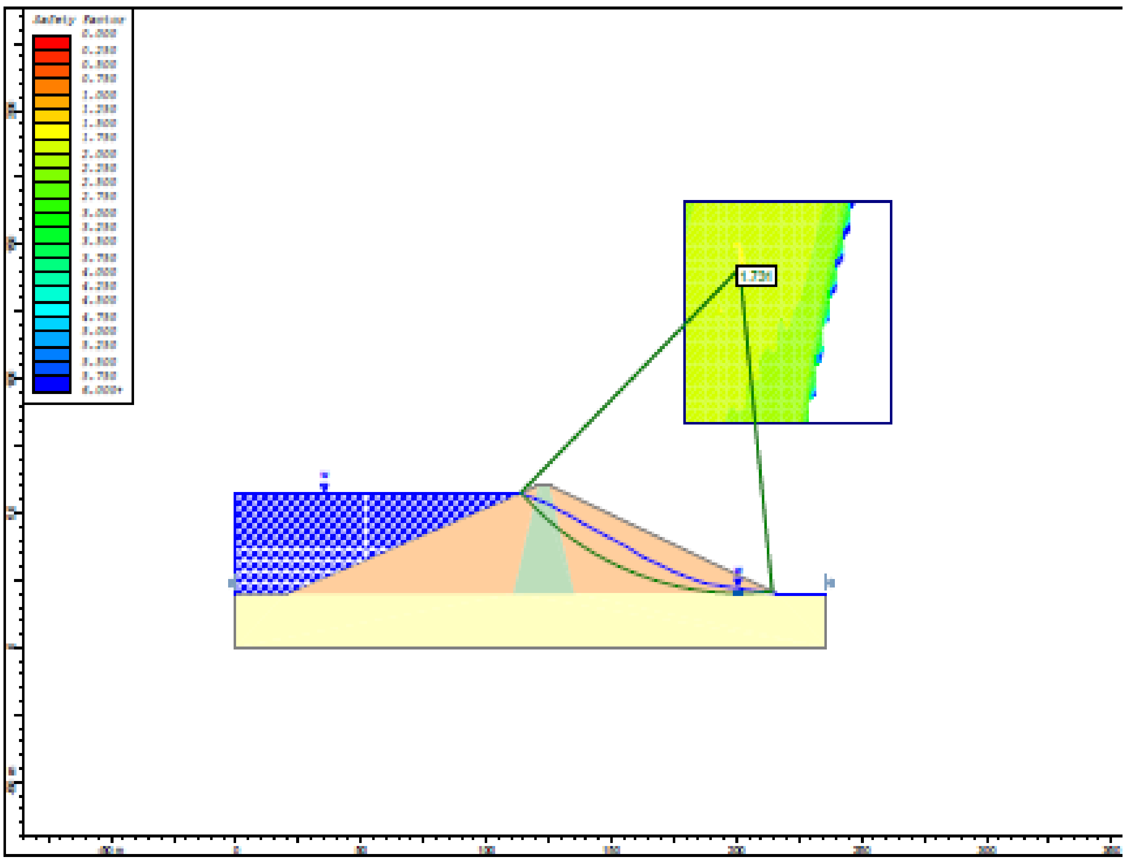

Fig.10. Obtained confidence ration by Slide software after the filling of dam by Bishop Method.

10. conclusion

The maximum vertical displacement that obtained in static mode was 25 cm. also, the maximum allowable subsidence is 1% to 2% of the height of dam. In the hydraulic conditions the movements in the horizontal and vertical directions were lower than 4 cm and the dam would be stable. Safety factor which obtained by FLAC2D and slide software's shows note that the coefficient is greater than 1.5, it can be concluded that in the static and hydraulic mode the dam will be stable.

References

Ansys. Inc, 2009. Ansys Guide Release 12.0.1. 2009. SAS IP, Inc.

Chowdhury, R, 1978. Propagation of failure surfaces in natural slopes. Journal of Geophysical Research 83: doi: 10.1029/0JGREA000083000B12005983000001. ISSN: 0148-0227.

Counil, J, 1976. Splitting grouting on earth reinforcement. Journal of Solid Structure,.

Das, B.M, 1983. Advanced Soil Mechanics. McGraw-Hill. New York.

Duncan, J.R, 1992. Influence of prey abundance and snow cover on great gray owl breeding dispersal. Ph.D. Thesis, University of Manitoba. pp. 127.

Huang, XU, 1983. Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res. 1982-1983; 17(1):37-49.

ICLD. R. 1973. Calculation of the stability of earth dams, Transaction. 2nd International Congress on Large Dams. ICLD, Washington, DC. 445-459.

Kuo, J.-T., Yen, B.-C., Hsu, Y.-C., et al., 2007. Risk analysis for dam overtopping – Feitsui reservoir as a case study. Journal of Hydraulic Engineering – ASCE 133 (8), 955–963.

Major, U. 1980. Applied load in earth dam. Journal of Engendering, pp. 147-154.

Murthy, GSR, 2013. Designing Earth Dams Optimally. 40th Anniversary Volume, IAPQR, pp. 91- 126.

P.E, ESQ, Stephen, C, 2013. “Earthquake Analysis of Arch Dams. Even Safety Committee - Steve Verigin, Chair.

Schoeber, P. 1981. Applies of splitting grouting in the anti-seepage processing of earth dam. Talents of the Westfälische Wilhelms University Münster.

Subramanian, S. Ponnuvel, K.M. 2012. Seismic and Stability Analysis of Gravity Dams Using Staad PRO. International Journal of Engineering Research and Development ISSN: 2278-067X, Volume 1, Issue 5. P.p 44-54.