Monitoring of Alborz Earth Dam During The Operation, Using Calibration and Numerical Results

Saeed Arefpour

Master of Civil Engineering, hydraulic structures, Azad University of Sistan and Baluchestan, Iran

Email: Omran_pnu@yahoo.com

Abstract

In this paper an attempt is to reach the logical data using the calibrator data, finite difference numerical method, FLAC code return analyzes of initial data during the construction period. Then the operation period which is started from 1389 is considered. The rate of pore-water pressure during 20 years of operation is slowly uptrend. Upstream crust materials are saturated in second half of the second decade of operation. Stress level affected by imbibition was increased till the end of first decade but beginning the second 10 years was downtrend.it transferred from core low level to the upstream crust in first imbibition till end of first decade. Maximum shear strain ratio and its increase is uptrend in first imbibition till the first and second decade which states the less stability of dam. Vertical relocation in Alborz dam is slightly uptrend which is more slowly in the upstream crust because of water existence. Horizontal relocation is also uptrend but its speed in downstream due to lake water is more that upstream. Regarding these analyzes more than 90% of relocations were in construction time.

Keywords: Soil dam, Reverse analysis, Calibration, FLAC

1- Introduction

Earth dams are such important massive structures which not only are based on the natural rock and earth materials but their raw materials are also made of natural rock and earth materials. Advantages of earth dams have led to 70% of these dams are this type in whole world.

This is necessary to notice that Design and implementation of a dam, are just some parts of project activities and reliability control and stability of different elements regarding to the dam structure importance, during the constructing and operation are also important problems. So it can be resulted that dams must be ever monitoring. Continuous monitoring of dams performance specially earth dams, Not only from the perspective of the development of dam’s different parts behavior cognitive is Significant, but also is important for the reliability and omitting Possible errors and helping to Inhibition factors that may cause damage to the dam[1].
Controlling of earth dam during the operation and construction is conducted with monitoring. Monitoring is defined as Observation and measurement of dam performance and its related Structures, with Calibrators which are able to provide and register accurate information. Monitoring is generally starts from beginning the dam construct and continues to the end of its longevity. During the life of structure, all critical parameters of the plan performances are considered and reviewed if it was necessary in Control purposes during the research and constructing performance, absolute values are desired but in operation period, parameter changes over the time or the impact of the external factors on them are desired [2].

2- An overview of the background of previous researches in this area

The field of monitoring seriously rose in 1930s and 1940s with producing the geotechnical Calibration and has been progressed well in recent years.

In the late nineteenth century, open piezometers were used in order to check the leaky aquifer from Under irrigation dams Built on alluvial materials in India. These Calibrators were used to determine the free surface of the water in a homogeneous earth dam by in 1970 English engineers [3].

Return analysis were done in order to check the performance of dam by common soft wares and the results of the Calibrator information’s comparison with real behavior of dam also were done in different dams in whole world. One of these cases is Beliche dam which was constructed 1982-1985 in west south of Portugal. Return analysis conducted on this dam in construction period after imbibition completion for 4 years and the stresses and deformations obtained from numerical analysis were compared with Values measured by the Calibrator [4].

Return analysis on the papaadai dam in Italy is another remarkable case. This sandy dam with upstream Concrete is based on the argillaceous foundation. Monitoring of the dam’s body and foundation has done in order to reach the behavior patterns of reformations and pore -pressure changes during the construction period and next 7 years. Districted two dimensional analyses conducted with simple pattern to check the soil action during the construction and storage imbibition. Studies on this dam show that accurate choice of the parameters used in analyses and correct inference from mechanical behavior of soil in place leads to satisfactory prediction of general reaction of soil structure and the construct [6].

Monitoring of karoon dam in first and second stage of imbibition is another case which was done by Tehran university students mastering Dr. plasy. Dam’s behavior is analyzed by FLAC 3D software and results such pore pressure, abate and stress are compared with information achieved by Calibrator [4].

Karkheh dam is one of the most important and biggest earth dams in Iran which it’s monitoring was done by Hbaib Niroomand. During his studies the results of the numerical analyses is compared with Calibrators information [5].

One of the other studies done by mr niroomand with dr. mirghasemi mastering, is monitoring of Karkheh dam using the Calibrator results during the construction. Return analyses were performed by CA2 software. The pore-water pressure amount generated during dam construction is obtained half of the predicted value due to the long runtime and converting the core material from pure clay to mixed clay. Core abate rates are largely corresponded to predicted rate at design period [5].
Pore-water pressure evaluation of Karkheh dam after imbibition is conducted by Dr Pakzad and Mirhosseini. In their study behavior of dam is analyzed regarding the imbibition in early 1378 and continuous checking the Calibrator mounted in body and foundation. According the measurement by piezometers mounted in foundation and both sides, significant loss of static balance in both sides of water stop can be seen. Read results by piezometers of clay core, had stated the Consolidation phenomenon, pore-water pressure factors during the earth filling operation and impossibility of hydraulic fracturing [7].

One of the other studies belongs to Mr. bemani yazdi mastering Dr. Mir Mohamad Hpsseini. This study paid notice to Karkheh earth dam monitoring after imbibition and used the Plaxis and CA2 soft wares in order to return analyze and stress-strain behavior modeling. Paying Attention to behavioral characteristics of dam such as pore-water pressure and reformation and remaking of the process by numerical model is one of the remarkable points of this study. Abate amount, pore-water pressure and total vertical pressure regarding the changes and Limit values in construction and imbibition period are analyzed.

Pore-water pressure and arc rejection factors are analyzed in 2 aspects of reading and modeling. Also the behavior of dam facing the increase and decrease the dam storage balance is predicted at the end of their paper [8].

Maroon dam’s internal movements using the Calibrator information are analyzed in the other research by Hassan Hajiani mastering Dr. Pelasi. In this study the internal motion performance of dam is considered regarding the chronic changes and vertical relocations of dam’s body. Abate quantity changes in height and over the dam are considered in addition to comparing these results with initial analyses of the plan [4].

Ebrahim nezhad sediq, Emami tabrizi and barari, presented the study entitled by “monitoring of Alavian dam’s foundation and body during the operation” and relocations, foundation and body’s vertical reformations of Alavian dam with 80 meter height and over the 4 years after the construction are analyzed in their research [9].

3-Computational details of current research

This research is done for the purpose of monitoring the Alborz earth dam during the operation using the numerical model and Calibrator results.

To conclude the comprehensive information about the monitoring the following factors are essential.

1-dam’s features: A major factor that influences the Calibratoration system is the sections of dam. Alborz dam is earth dam and includes core, filter, crust and etc. that Calibration is applied regarding the role and sensitivity of each one.

2-storage water level: lake water pressure causes the stress and reformations and all sections are affected by that. so the continuous monitoring of the storage water is necessary.
3-support water level: interaction effects of storage and backrest water requires knowing the water table level to evaluation the interactions.

4-Weather conditions and wind speed: Weather conditions such as rainfall and region Temperature provide useful data about the moisture percent of fine grained and Qualitative and quantitative changes in the reservoir.

5-earthquake: earth relocation and movements can apply major stresses and the resulting reformations to dam and relative buildings. Thus Attention to this problem is essential.

6-internal stresses of core: Due to the fine-grained role in dam safety and performance And the probability of occurrence of different phenomenon enough information about the distribution of stresses in the dam Should be provided.

7-abate of relative buildings: since the dam’s safety is directly affected by relative buildings safety such as overflow, therefore it is necessary to control the relocation amounts and abates.

8-internal water pressure of the core: dam’s core stability is completely depended on the pore-water pressure of dam, so the enough attention should be paid to prevent the destructive water pressure.

9-dam’s body reformation: control and measurements of dam reformations provide proper recognition of dam’s behavior which its results are accurate and correction the parameters and hypothesizes.

10-sealing performance: the purpose of dam building is to create a barrier for wasting water, storage and control it. obviously the output water level should be considered.

3-1- Alborz dam’s general information

Alborz storage dam is constructed over the Babolrood River At the confluence of Chakhani and Gazo branches Located in 45th km of Babol south-east and 269 km of Tehran east-north, Longitude 52 degrees 48 minutes and 36 degrees 14 minutes latitude.
The access road from Tehran-Ghaemshahr is asphalt over 240 km until Shirgah tee, and Shirdar tee for 13 km, the rest of the road to the dam is 16 km rural asphalt. There is another 45km asphalt access road of Babol-Ganj afrooz till Shirdar tee [12].

In this case study, the 78meter earth dam with a clay core is located at Mazandaran. The additional information of soil mechanic laboratory report obtained from Mazandaran Regional Water Company. This information is as follows: special weight parameters, Modulus of elasticity, Poisson's ratio, Adherence, Angle of friction, Dilation angle, Permeability(Longitudinal and transverse), Porosity and device data(Piezometers, stress meters and abate meters reads) in construction time, first imbibition and operation(1389-shahrivar 1392).in the following the cross section (13-13) is analyzed by FLAC software as is shown in fig(1-3).the purpose of this research in one hand is to study the behavior of Alborz earth dam and on the other hand is forecasting the future behavior in two operation decades.
- Calibration of Alborz dam

There were 5 section of calibration in Alborz earth dam which are as follow [11]:

**Fig 3-1** Calibrated cross section of Alborz dam 13-13[11]

**Fig 3-4** Longitudinal profiles of Alborz dam section [34]
1- Static tube piezometer 39 pcs
2- Turnkey and abate meter 18 pcs
3- Deviation 24 pcs
4-electrical piezometer 145 pcs
5-code pressure cells 220 pcs
6- Accelerometer
7- Leak detector
8- Weather station
9-measuring ruler
10- Gallery internal Drainage
11- Cue points
12- Triangular ruler to measure fugitive waters

3-2 An overview on the FLAC software

FLAC A2 computational code is abbreviation of Fast Lagrangian Analysis of Continua. FLAC is finite Difference software which is able to modeling the behavior of soil, rock or other material which may like plastic flow under pressure. This software is based on the Lagrangian calculation which is proper to modeling the huge reformations.

The main formulation of the FLAC 2D, which is used in this research, is based on the two-dimensional plane strain. The used computational lagrangian method and special partitioning technique will help the software to a better modeling of plastic reformations and Plastic flow of materials.

Since there are no matrix calculations in computations, the required amount of memory by long 2D calculations won’t be much. The abilities of this software listed here:

- Linear alastym and nonlinear elastoplastic problems
- Geometric model of plane strain, plane stress and Axial symmetry
- Study of soil-structure interaction
- Examine the interaction between mechanical deformation and fluid flow( two-Dimensional consolidation and swelling.)
- Ability to solve big strain problems
- Ability to modeling earth dams or digging tunnel step by step
RESEARCH ARTICLE

- Axial symmetry problem solve
- Including visco elastic and visco-plastic model to simulate the creep
- Ability to solve the model in total and effective stress
- Structural elements to simulate structures
- Thermal modeling capabilities
- Slope stability check
- Static and dynamic analysis of structures
- Rapid flow of fluid and 2 kind of fluid study
- Analysis of linear and nonlinear flexural elements like frames
- Ability to add user behavior models for C++ and FISH programming languages
- Interface elements to simulate the occurrence sliding or detachment plates

The main disadvantage of this software is low speed and Convergence models in consolidation issues.

In earlier versions GIIC graphical future is added which makes possible to define and solve problems without initial file.

The GIIC is based on Java and operate independently [13].

-The general process modeling in FLAC

The model definition in FLAC is shown here [14]:
Proper area selection and creating element network

We must choose a proper area for modeling in the first step. The model boundaries should be far enough from stressed or reformation district so that no changes in stress and reformation were seen before and after applying the changes in model. Defining model sizes, the element network should be created. They must be made in accurate proper sizes. Elements are selected with small dimensions in places with more stress and reformation and Elements are gradually changed. In other words more zone (element) density is are considered. For areas that have more gradients or stresses but it is necessary to notice that The length and width of the area must be close to the unit. If this value exceeds 1.5, answers were not quite accurate. The amount of adjacent areas should not be exceeding 1.4. Additional elements increase the accuracy of answers, but it can’t be resulted that more elements in network lead to optimization [15].

Accuracy of the number of elements in the numerical analysis results (Grid study)

To perform the return analysis and essence of numerical calculations more and more, an Analysis was conducted on the accuracy. For this purpose 4 models were created as same material and geometric shape as the Alborz dam and with 78 meter height. Fig 3-7
Meshing of first sample has 1254 elements, second sample has 1865 elements, third one has 3425 elements and the last one has 6921 elements.

Three important parameters were compared for the accuracy of meshes. These three parameters include vertical relocation, total vertical stress and pore-water pressure. Results of each parameters comes in follow.

Fig 3-8 shows the relocation meters of the four case study meshes. With increasing the elements from 1254 to 6921, core relocation number has changed slightly almost 4%, while increasing the elements, the runtime of program Increases exponentially.
Fig 3-8 vertical relocation of 4 meshing samples

Fig 3-9 is the chart of dam’s core abates in 4 considered mesh by height. It is seen that these abates amount are almost overlap and have negligible difference about 4%.
Next parameter is pore-water pressure. As is shown in fig 3-10 pore-water pressure is slightly decreased with increasing the elements so that the average difference between smallest and largest meshing is about 3-5%.

1) Mesh size (1254)

2) Mesh size (1865)

3) Mesh size (3425)
4) Mesh size (6921)

As shown in fig 3-11 we have overlapped pore-water pressure in 4 meshing sample and results in all of them almost are the same and in other areas has negligible difference so that that the average difference between smallest and largest meshing is about 3-5%.

Fig 3-10 pore-water pressure in 4 meshing sample

Fig 3-11 pore water pressure changes in 4 meshing sample
Third considered parameter is total vertical stress. Fig 3-12 presents that total stress is slightly decreased with increasing the elements so that the average difference between smallest and largest meshing is about 2-4%.

1) Mesh size (1254)

![Mesh size (1254) diagram]

2) Mesh size (1865)

![Mesh size (1865) diagram]

3) Mesh size (3425)

![Mesh size (3425) diagram]

4) Mesh size (6921)

![Mesh size (6921) diagram]

Fig 3-12 vertical stress in 4 meshing sample

Fig 3-13 presents the total vertical pressure of the 4 meshing sample. In most points lines are overlapped. Most of the differences are in dam’s downstream which the average difference between smallest and largest meshing is about 2%.
Fig 3-13 the chart of vertical stress created in dam’s body at 4 meshing sample

Regarded to the obtained results of analyzes conducted on the 4 meshing sample, we saw that increasing the elements is slightly effective in pore-water pressure results, total vertical stress and abates. On the other hand the analyze time Exponential increases with increasing the elements and leads to increase runtime. Large number of runes for return analysis is needed, so to save the time, second meshing sample is selected to return analysis which its elements are 1865pcs. the results of that is in the next chapter.

-Behavior model selection and parameter definition

FLAC provide these characteristics models for users [37]:

- Hook-broon plastic model
- Isotropic elastic model
- Hardening and looseness plastic strain model
- Moore-coulomb Plastic model
- Drucker-Prager plastic model
- Modified Low-General plastic model
- Re-submission plastic model

There existed more models in FLAC software for the plastic and creep models which lead pore-pressure in dynamic analysis. One of the futures of FLAC code is possibility to define the behavior model by the C++ user interface and adding it to the FLAC [37].

3-3 process of build and imbibition of Alborz earth dam modeling

In this section the steps of modeling the earth dam by FLAC and is summarized. These steps are:
Create the elements network
Create the model geometry
Apply the boundary conditions
Define the material futures
Omit the total model except the foundation
Foundations analyze and apply the initial condition to it
Adding the barrier and it’s analyze
Adding the model layers and apply initial conditions
Reservoir modeling

-Define the material characteristics

To define the material for an area firstly the behavior model should be defined. In order to do that in FLAC after geometry modeling, behavior model of Moore-coulomb Plastic model is selected which is the most well-known model in soil materials. Required parameters in this model include: unit weight, Modulus of elasticity, Poisson coefficient, Adherence, internal friction Angle, Dilation angle. In strengthening of permeability saturation and void degree are added. Dam’s body is modeled to five layers with 2.15 meter and 23 layers with 2.95 meter in order to modeling step by step.

Table 3-3 initial values of material parameters

<table>
<thead>
<tr>
<th>Permeability ratio (cm/s)</th>
<th>Void(%)</th>
<th>Dilatation angle (degree)</th>
<th>Poisson's ratio</th>
<th>Modulus of elasticity (Mpa)</th>
<th>Adherence (Kpa)</th>
<th>Internal friction Angle (degree)</th>
<th>Saturated unit weight (KN/M2)</th>
<th>Pure unit weight (KN/M2)</th>
<th>Material parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*10^-7</td>
<td>37</td>
<td>0</td>
<td>0.3</td>
<td>15</td>
<td>20</td>
<td>18</td>
<td>10/6</td>
<td>16/5</td>
<td>core</td>
</tr>
<tr>
<td>1*10^-1</td>
<td>30</td>
<td>6</td>
<td>0/28</td>
<td>30</td>
<td>0</td>
<td>32</td>
<td>19</td>
<td>17/2</td>
<td>crust</td>
</tr>
<tr>
<td>1*10^-3</td>
<td>35</td>
<td>6</td>
<td>0/29</td>
<td>28</td>
<td>0</td>
<td>34</td>
<td>21</td>
<td>20</td>
<td>Filter and transferred zones</td>
</tr>
<tr>
<td>1*10^-11</td>
<td>25</td>
<td>7</td>
<td>0/23</td>
<td>400</td>
<td>120</td>
<td>31</td>
<td>23/4</td>
<td>21/4</td>
<td>foundation</td>
</tr>
</tbody>
</table>

-Adding the model layers and apply initial conditions
To layer modeling of dam and studying the phenomenon of Consolidation and pore-water pressure, firstly the schedule of construction should be determined regarding the real time of earth filling which is about 2515 days with 78 meter height. For each layer the deadline is determined which is end of Farvardin 1389 and it’s given to the software. In this way the first layer is created and Unbalanced force reaches to 0 by doing the computational mechanic steps and sudden deformation, total pressure and pore-water pressure of each node in load moment is obtained. After each layer analyze and before adding the next layer, the top border vertical deformation must be zero.

**-Return analysis model**

The main aim of the return analyses is reach to real parameters of consumed materials during the construction. Soil mechanic examines were done on the loan materials and initial parameters of them after that were carried to the dam construct place, and reach to the saturation, so we must obtain the real parameters using the calibrators and return analyses when they are imply in the dam’s body. For this purpose software input parameters should be changed regarding the real reaction of dam which recorded by the device. This behavior must be created either in the model. It should be noted that it is very sensitive and complex because almost all parameters have an influence on each other and change by changing the others. That is why in each analyze just one of the parameters logically is changed and then we will know which parameter change is required.

**-Parameters of material determination (obtained from return analyzes)**

The real reaction of dam during the construction which is obtained from calibrator is summarized in the table 3-4 in which balk water module is KW=1.35e7.

**Table 3-4 final values of material parameters (obtained from return analyzes)**

<table>
<thead>
<tr>
<th>Permeability ratio (cm/s)</th>
<th>Void (%)</th>
<th>Dilation angle (degree)</th>
<th>Poisson's ratio</th>
<th>Modulus of elasticity (Mpa)</th>
<th>Adhesion (Kpa)</th>
<th>internal friction Angle (degree)</th>
<th>Saturated unit weight (KN/M 2)</th>
<th>Pure unit weight (KN/M 2)</th>
<th>Material parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*10^-7</td>
<td>37</td>
<td>0</td>
<td>0/42</td>
<td>22</td>
<td>10</td>
<td>18</td>
<td>19/6</td>
<td>16/5</td>
<td>core</td>
</tr>
<tr>
<td>1*10^-1</td>
<td>30</td>
<td>6</td>
<td>0/3</td>
<td>34*35</td>
<td>0</td>
<td>42</td>
<td>19</td>
<td>17/2</td>
<td>Upstream crust</td>
</tr>
<tr>
<td>1*10^-1</td>
<td>30</td>
<td>6</td>
<td>0/28</td>
<td>33*30</td>
<td>0</td>
<td>42</td>
<td>19</td>
<td>17/2</td>
<td>Downstream crust</td>
</tr>
<tr>
<td>1*10^-3</td>
<td>0/35</td>
<td>6</td>
<td>0/0/4</td>
<td>30</td>
<td>0</td>
<td>34</td>
<td>21</td>
<td>20</td>
<td>Filter and</td>
</tr>
</tbody>
</table>
4-calculations and results
Since the real process of earth filling should be applied in stability analyze of Alborz earth dam, the time used in charts starts from 82/2/1 which is base date. The real time of construction is longer than predicted time.

Since the actual process of earth filling should be applied in the numerical analysis, the actual speed is used in the numerical analysis. Then all the above were examined using the Calibrator information till 20th Farvardin 1389. In imbibition analyze of dam with this program, storage imbibition was the start of construction. The normal level of imbibition is 302 meter which is simulated in two stages and the estimated time to reach the reservoir to normal level is considered for a year. Operation period is divided to two decades.

1-4 the pore-water pressure of the Alborz dam’s body
During building and after it in the fine-grained, low-permeable sections and foundation, Captive pore-water pressure increases initially but gradually decreases and bottom layers Consolidate. Intensity and distribution of pore-water pressure is not only depended on material Consolidation and permeability characteristics and board drainage conditions, but depends largely on implementation and performance order. According to the analyzes of the dam’s body after complement and initial imbibition in first operation decade, pore-water pressure in dam core reaches to 578(kpa) which is in the middle of the core level.
Fig 4-21: The pore-water pressure model in first decade of operation

Affecting the different layers of soil compaction and reducing the free space between aggregates, used water during the operation creates a pore-water pressure and finally can cause the local cracks. By increasing the height of the dam, these cracks tolerate more soil stress are often closed.

Fig 4-22: The pore-water pressure model in second decade of operation

As you can see in the above picture, pore-water pressure meters in second decade of operation, pore-water pressure in dam core reaches to 650(kpa) which is in the middle of the core level.

Fig 2-23: Meter of materials saturation in dam’s body in first operation decade
Fig 4-24 meter of materials saturation in dam’s body in second operation decade

-Stress and Strain in soil mass of Alborz dam’s body
Measuring stress is so important at different stages of earth dam monitoring specially in imbibition period to investigate the phenomenon of hydraulic fracturing and also hypothesis approve. For this purpose, total pressure is used to check the distribution, direction and internal stress of dam’s body. Consultants and Contractors in most cases, applying the Calibrator measuring data face uncertainty in results, so we need the data calibration before using this Calibrator’s data. In practical terms, for a total pressure cell device buried under soil, Contact pressure on the pressure cell is not quite uniform and the cell surroundings are not continuous because of arc rejection and contact between the cell and the soil. In other words, contact pressure in a Granular and discrete environment is a function of the Cell surrounding environment size. Thus it is clear that the answer of pressure cell devices is depended on materials which are buried in, and the stress measured by this Calibrator not exactly the one which in the absence of tools comes. In this regard, According to the review and processing of data obtained from total pressure measurement cells mounted in Alborz dam’s body, and return analyses of 78meter earth embankment body height, we had a relatively good behavior of the dam and only in few cases arc rejection had occurred. Regarding to these results, the normal behavior is expected for dam after total analyze. Also, due to having the actual parameters the total vertical pressure at the end of construction is 1290 kpa.
According to the total stress meters and obtained numbers, total stress at the end of first decade is 1311 kpa and in second decade is 1363 kpa which their Place is transferred from the lower level of the filter to the upstream crust. Reducing the stress level reduces the pressure which is needed for crack development, thus Areas of the dam in which Stress levels have decreased for any reason are at risk of hydraulic fracturing. Differential abate, arc rejection and cracking are some of important factors leading the stress level reduction in each of these mechanisms, if reduction of stress level leads cracks soil, focused stress in crack tip spread out by water pressure and makes hydraulic fracturing easier.

Strain and shear resistance play an important role in earth dam stability respect that open cracks made resulted by abate changes create strains under earth filling pressure which causes Imbalances in dam’s
internal distribution in this situation the internal pressure in some parts increases and decreases in other places.

By increasing the water pressure in the soil mass probability of hydraulic fracturing increases. It should be noted that the purpose of water pressure is not pore-water pressure but is the dam's wall pressure which try to be expand the crack. Obviously, this pressure increases during imbibition. Any level of Pore-water pressure is not enough powerful to create crack in soil mass while it may be cause of phenomenon of liquefaction, but water pressure increase in a mass edge can create crack and spread it.

Fig 4-32 maximum shear resistance increase at the end of first operation decade

Fig 4-33 shear resistance increase ratio at the end of first operation decade
Fig 4-34 shear resistance increase ratio at the end of second operation decade

Fig 4-35 maximum Shear resistance increase at the end of first operation decade

As the maximum shear resistance meters present, develop and size of shear strain during initial imbibition till first and second decade has uptrend which is not a good process.

4-2 relocation of Alborz dam’s body

The final amount of abate in a dam generally is depended on the terrain and the height of dam but in consolidation abates it depended on foundation permeability and drainage condition. As shown in this chapter, abate of different parts of the Alborz dam were examined and compared with return analyzes and satisfactory results were presented. The most amount of abate was in the core which is naturally because of the materials used in this section. This rate by the end of first decade was 111 cm and in second decade was 114 cm. The rate is in abating acceptable range of earth dams which is less than 2% of dam’s height.
Fig 4-36 vertical relocation meter model at the end of first operation decade

Fig 4-37 vertical relocation meter model at the end of second operation decade

The abate amount of Alborz dam at the end of first and second decade is slowly uptrend but it is more slowly in upstream crust rather than downstream because of water existence.
As presented in fig (4-38) and (4-39) horizontal relocation is decreased in upstream crust and increased in downstream because of the lake water pressure.

5- Results

This paper tends to provide a general evaluation of dam’s performance during the operation using the results obtained from Alborz earth dam Calibrator, modeling, numerical analyzes of the pore-water pressure, vertical and horizontal movements and total and effective stress. Regarded to 5 section of erecting the Calibrator through Alborz dam’s body and since there is no possibility to analyze all sections, we paid to monitoring for the critical section, 13-13 section of the erecting Calibrators. Obviously, accurate Understanding the behavior of the dam at the critical section leads to generalization of all sections. Firstly we reached the logical data using the construction Calibrator data, Numerical finite difference method and business code of FLAC with return analyze of primary data. To continue the
process during the operation, project is divided into two periods of ten years that the start of the first operation was in 1389 and the results are as follow:

1-upstream pore-water pressure increases starting the imbibition but in downstream it decreases. Pore-water pressure in the core is trend a slow upward over 20 years of operation.

2-Upper crustal materials based on the results in the second half of the decade reach to the full saturation.

3-Effective stress level of the initial imbibition has increased by the end of the first period of ten years but it has been declining with the start of the second period of ten years but at the top of the fuselage section has uptrend that should be examined.

4-The tension has been rising in the dam body which starting first imbibition till the end of second decade, is transferred from lower level of the next core in the filter to the lower level of upstream crust.

5-arc rejection ratio of dam has the appropriate amount of 46%.

6-The maximum shear strain rate is Uptrend from first imbibition till the first and second decades which Shows a decrease in the stability of the dam and its core.

7-vertical relocation in Alborz dam is slowly uptrend that is lower in upstream crust rather than downstream crust because of the water.

8-horizontal relocation is as the same as vertical which is generally uptrend but the speed is more because of the lake in upstream crust.

9-Comparing abate, pore-water pressure and stress obtained from analyzes with results recorded by Calibrators, it can be stated that there is good agreement between the results.

References
1-Oliaei .m, dam’s stability control and Calibration importance in Iran. Course project in rock mechanics group of Amir Kabir University, School of Mining Engineering, 1357.

2-dams monitoring, general considers, ICOLD journal Number 60 .Hamid Ghanizade, development of standards in water engineering, Department of Energy 1377.

3-Najm.K. monitoring and Calibrators in dams.4th conference of Dam Construction1379.

4-Pelasy M. studies of the internal movements of Maroon dam using Calibrator information. 4th conference of Dam Construction 1379.


7-Pakzad M. evaluation of the pore-water pressure in Karkheh’s body and foundation after imbibition. . 4th conference of Dam Construction 1379.

8-Bemani yazdi P. monitoring of Karkheh dam after imbibition using the Calibrator results. Master thesis of foundation and soil field in civil and environment School of Amir Kabir University 1381.

9-Ebrahim Nezhad ,s. Alavian dam’s foundation and body monitoring during the operation. 4th conference of dam Construction 1379.

10-Ziaei .Mohammad. Pore-water pressure changes in earth dam cores during the operation . case study. Makoo dam , 7th national congress of civil engineers 1392.

11-Report of Calibrator design of Alborz dam. Mahab ghods Consultant company 1377

12-Report of partial construction of Alborz dam . Mahab ghods Consultant company 1377

13-Zamiran s. modeling and analyze of earth constructions in FLAC Noavar publish 1391


15-Tarmashi h. stability analyze od Alborz dam during construction using the Calibrator results and numerical method. Master thesis. IAU bafgh branch .1287