Hydraulic Structures engineering study of the stress - strain behavior of earth dam with limited element software of Plaxis, Case Study: Darian dam

Mohsen Ketabi, Mahmood Shafaei-Bajestan, Mahsa Ketabi

Hydraulic Structure Department, Islamic Azad University, Kish International Branch, Kish, Iran.
Assistant Professor, Civil Engineering Department, Shahid Chamran University, Ahvaz, Iran.
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ABSTRACT

Considering agriculture, rural and urban development, water supply, hydropower production, control and regulation of water flow in rivers, dams have a significant importance. Advancement of engineering knowledge concerning the analysis and design of geotechnical structures has provided answers to many questions about the structure based on theoretical and experimental findings. Development of numerical methods such as finite element models of the materials behavior under static and dynamic loading conditions has provided the possibility to evaluate the behavior of geotechnical structures at different loading conditions with regard to types of boundary conditions and the effects of various parameters.

INTRODUCTION

Because of the high cost of building dams and severity of the consequences of dam stability, the issue of maintenance and continuous evaluation of dam stability is of utmost importance. Due to the fact that increases in the safety of the project would proportionally increasing the take up of costs, ensuring the stability of the dam in all stages of planning, implementation and operation is essential.

Being ensured about proper behavior of earth dam under different conditions of construction, and operation of dewatering is inevitable given the serious risks caused by the failure of these structures. Due to the uncertainty of the principles and assumptions adopted in the analysis of these structures, sufficient attention to the evaluation of dams and the studying the agreement of the results of analyzes with behavioral parameters in different conditions is necessary for dam’s life.

Uncertainty in Hypotheses:

Considering the earth dam, following factors lead to uncertainty in the assumptions and principles adopted for the analysis and design of dam structures:

- Inability to accurately estimate the parameters of the multiple factors affecting the behavior of materials
- Significant difference of structural aspects and dimensions of the samples
- The complexity of structural behavior in different loading conditions (during construction, dehydration, rapid water loss and steady-state conditions)
- Several factors influencing the behavioral characteristics of materials, lack of sufficient experience in using behavioral models and numerical techniques used in engineering analysis and design of geotechnical structures.

Importance of dam construct considering the safety and amount of risks due to breaking the dam makes it necessary to control the behavior of the construct. This control is done by measuring the changes in behavioral parameters under the effect of applied loads and reaction of the construct compared to them and by comparing the amount of parameters measured by predicted amounts of the analysis; the behavioral reactions of the dam are evaluated.

In other words, if the data of the dam behavior agrees with the results of the analysis, it can be concluded that the analysis shows the real behavior of the dam and the results can be used in providing the information related to parts of the dam in which there has been no behavior graphy. In fact if we can find a model with real parameters which have good agreement with measured parameters, this model can be used for making sure about the current behavior of the dam. Since the correctness of each measurement can be controlled through...
comparing it with the obtained pattern, this model can be used to predicting the behavior of the dam under the loading and the condition which are not experienced by the dam, yet such as dewatering or any kind of decline faster than the source in compulsive condition. On the other hand, if there is no compatibility between the compatibility between the measured behavior and behavior of the model, the analysis could be used for recognizing and interpreting the unnatural dimensions of the results by the used tools.

Regression Analysis:

During the recent decades, different numerical methods such as limited elements, border elements and separated elements are used in solving the engineering problems. These methods are widely used in designing the dams, underground spaces such as tunnels, underground caverns, slopes and others. The reliability of the design estimation completely depends on the preciseness of the analysis information so that if the information are not precise enough or do not show the real amounts of the mechanical parameters, determining the amount of geomechanical features such as tension, displacements, subsidence and others is very difficult.

The amount of parameters used in the body of the dam and also the geomechanical parameters of the dam site are determined by the experiments and are used in model design. It is clear that the results of these experiments generally show the significant distribution. Although, the experiments are done carefully, this means that the results of the experiments cannot be used as the input data. In order to overcome the problems, the measurements are done along with the project and this is due to controlling the stability of the constructs and also estimation of the input data of the geometrical and geomechanical features of the materials which are used in analyzing the design. These estimations should be done in a way that the distance of the real amounts and estimated one for the environment should be minimized.

This method of designing and simultaneous construct is used for measuring and is called the pack of observed method. in this process , one question is created and that is how to use the results of the readings for determining the needed amounts in design. Regression analysis technique is a method which is provided as the key to the question and can fill the empty space between reality and estimation.

Normal Regressive Analysis:

Regressive analysis is usually introduced as a technique which can control the parameters of a system and determine the analysis behavior. In regressive analysis related to the soil mechanic, the pressure conditions such as external loads and mechanical features of soil such as elasticity module, Poisson ration viscosity and internal friction coefficient, strains and measured pressures during the project performance and then they are calculated. This calculation process is in fact opposite the normal analysis process since in normal tension condition and mechanical features of the environment are parts of the input data for calculating the displacement and tension. So, this is called regressive analysis. The relationship between normal analysis and regressive analysis are shown in figure 1-4.

![Diagram of regressive analysis and normal analysis](image)

**Fig. 1-3:**

The application of regressive analysis in geotechnique becomes more and more every day and us used as a proper tool for data analysis. It should be considered that regressive analysis is not a new technique and it has been used for a long time in geotechnique engineering. For example in the single axis experiment the amount of elasticity module is measured by strain and it is calculated assuming the linear elasticity.
It should be emphasized that regressive analysis is not a simple analysis process. In normal analysis a mechanical model is made so that it can represent the soil behavior (elastic, elastoplastic and viscoplastic, ...). When this model is made, the stable mechanical amounts can be determined in laboratory or in place. These amounts are used as input analysis information for calculating the amount of displacement, tension and strain and it should be noted that this method leads to a single answer. On the other hand, in regressive analysis, tensions, strains and pressure amounts are first measured and then a mechanical model is assumed for the soil. The mechanical constants and external forces are determined by the readings and in regression form. It is seen that the obtained amount of this model depend on the assumed model for the soil and the environment around it. For example, if an elastic model for soil is considered, the amount of module elasticity and Poisson ratio are calculated and if the elastoplastic model is assumed, then these two amounts of viscosity, internal friction and Poisson coefficients are calculated, too. So, it is seen that considering different models and for same input amounts, different amounts and values are obtained.

The difference between the regressive and normal analysis is shown in figure (2-4). It is seen that in normal analysis, obtaining the same results is imminent and this happens even when the real behavior of the soil and the model are not same. But about the regressive analysis, imminent results are not same and this is due to the fact that the model is considered after gathering the data. In order to obtain the unique results of a regressive analysis, a lot of precision is needed so that the selected model is the real representative of the soil. So, modeling is very important in regressive analysis compared to normal analysis.

The analysis done by Plaxis:

In order to do static analysis and study the behavior of the tension-strain of the limited element software of Plaxis is used. Since the dam had a long length, two dimensional analysis is logical and so the two-dimensional model of even strain with six-node triangular elements were used.

Modeling the stepped building of the Dam:

Since the building of dam is not finished yet, the geometry and the structure of it is modeled to 771 related to embankment of the body in February 2014. Assuming the balance of the base in 670 bases, about 101 meter out of 170 meter is built. Body of the dam includes the peak and main body which is done based on real embankment in the dam. It means that due to the raining seasons in the region and since the raining season is about 6 month from Ordibehesht to Aban, the possibility of the embankment and grained material exists. In addition, due to high volume of the surface material over and lower than the central core and impossibility of simultaneous application of the core, each year a part of general width of the over and lower parts. Procedural building of the dam body according to mapping the last condition of the embankment at the end of the month is modeled.
So, first the peak of the dam and then the core including clay and grained material and the width of the surface are built and then the rest width of the surface is modeled. In fact, procedural building of the dam does not happen in the equal layers.

In figure (3-4) the general view of the model geometry is shown. As it can be seen, according to the same definition of the parameters for grained materials in the clay sides which include the upper and lower filters, the border between filer and lower draining and transition has not be seen.

![Fig. 4-4: The general view of dam body geometry in the model.](image)

It should be explained that modeling the base in ignored due to the following reasons:
1. Based on the geotechnique parameters and due to the weakness of the stone base in th weathered part, the weathered stones under the surface (2).
2. In order to minimize asymmetrical subsidence (at acceptable level) in necessary cases and the slope of the stones is corrected (2).
3. Since due to stoning, it is possible that the stone under the floor is weakened and then in order to fix the stone base, fixed injection is considered (2).
4. The core contact and basement, concrete slabs with a thickness of 30 cm which is more than one meter in some places to prevent leakage due to leaching of the clay grains. Joints or cracks in the foundation stone for any reason remain and creating a safe and uniform contact between the core and foundation stone is considered. The concrete pad prevents the penetration is the foundation stone. In addition, the very low permeability layer of foundation stone of (Hudson).

After modeling the geometry of the dam materials it comes to choose an appropriate model. Due to existing models in Plaxis models for soil Mohr - Coulomb, and hard-realizability, it is necessary to explain the reasons provided below, the geometry of the model is the following matter:

Based on the geotechnical parameters and due to weakness in the weathered basement rocks beneath the weathered crust are removed. They are among most popular models model of softening such as Mohr - Coulomb model which compared to other models has more experience at national and international level in the field of numerical analysis and its application.

After selecting the model, first thing to do is select the type of material of the drainage conditions. Due to the low permeability of the clay core materials, the untrained region of interest is selected, that is Pore water pressure to create the material in excess of the load is relatively fast. Building dams in other areas, such as shells, filters, drains and transition, due to the relatively high permeability, is defined as the drainage material.

**Numerical Analysis:**

For comparisons of model output with instrumentation readings, three major items on the meeting, pore pressure and total pressure were studied. Thus, the highest summit, the highest peak pore pressures and total pressure at baseline were compared. Since the maximum amount of the mentioned points is due to the readings of the tools, comparing is focused on the key points. The key points include 9 points for comparing the subsidence which were three points in peak, three points in upper surface and three points in lower surface which had been in one third of the height of the dam. In addition, they included 8 points for controlling the total pressure which were in first level of the electronic tool, two points in second level and third points in third level. In comparison to the final results of the control points, in case of proximity to reality, the time history of the results is studied, too. In fact, in numerical model, it is tried to change the different parameters of the material and maximum amounts and the changes in opening changes in the point in line with the Pisometer condition to calculate the changes process.
Except velocity along the embankment and drainage which have certain values, other parameters that have significant impact on the rate of pore pressure and the changes include core permeability and Young’s modulus of material and partly shell materials, respectively. During controlled pore pressure values simultaneously the second item is the meeting was also monitored.

Parameters that directly affect the value of the meeting, the Young’s modulus of the material, so we tried to change the Young’s modulus of the core and shell of the numerical model, the results obtained so and the same trend as the results were read. As mentioned Young’s modulus of the core and shell induced pore pressure values are also efficient.

Permeability between different materials should be further, so we will continue as the permeability coefficient for the materials despite its high permeability, is given in the input program as $5 \times 10^{-5}$ meters per second. The limitations and problems in the selection of the low layer thickness were created under the program. In addition, despite the effective stress analysis in this program, it is needed to implement the input program as material values.

**Comparison of numerical analysis and instrumentation readings:**

The results of numerical analysis and comparison with instrumentation readings in three locations of the vertical stress and pore pressure in the dam are proposed.

**Vertical deformation:**

Figure (8-1) shows the vertical deformation correction model in numerical model of the dam and the date of the last reading is presented. We can see that the highest levels of the medial nucleus of the meeting has taken place and away from the central part and close to the outer surface of the shell, which reduces the session represents the reasonableness of the settlement pattern in the numerical model.

![Fig. 8-1: The vertical deformation patterns of the dam in the numerical model.](image)

**Results of pore pressure:**

Figure (8-2) shows the pore pressure patterns induced by the model at the core of the dam construction phase. As can be seen from the maximum pore pressure has been created in the lower part of the core and the core of the sides going close to the border drainage of pore pressure decreases.

![Fig. 8-2: Pore pressure generated by the model at the core of the dam.](image)
The results of the tensions in the dam body:

Figure (8-3) shows the average total stress pattern obtained from the numerical model. As can be seen in figure the results in the sides of clay, near the borders of filters drainage, clay midpoints had no significant difference in results. This indicates that the barrier is low arch sting.

Fig. 8-3: Average total stress pattern .

Conclusions:

9.1 - as expected, it is noted that the maximum amount of the settlement happened at the balances at the central core 0.58 in height (the height of the embankment middle) and the value of 1.2 percent barrier height is given in the technical literature. The position of the maximum settlement block is acceptable in the center of the 0.5 to 0.7 embankment height and amount to 2%. (Technical Report of Phase 1, 2 &3 national Darian Design; Singh and Varshney, 1995; Sherard, et al., 1976; Maraha Das Neves, 1990; ICOLD/CIGB, 1989).

9.2. Changes in the embankment has been completely coordinated with the construction of the dam embankment and has also increased with increasing elevation, rate Meeting seasons do not assume Weir was a major meeting in layers above the embankment. This charge is observed that the dam treated fairly and shall not be considered "normal problem of stability in terms of this section.

9.4. Maximum nuclear summit in terms of both the location of occurrence is in the normal range. Being close to the maximum session limit is due to the fact that the clay materials used in the dam are quite dense. In this case, the bulk of the meeting will occur during construction and prior to dehydration.

9.5. the vertical stress, based on readings taken, the average vertical stress ratio coefficient arch is overhead. In other words rejection (γ h / σ v) cores within the first level and the last reading is equal to 68% of the case also was acceptable according to the literature cited in this regard (Technical Report of Phase 1, 2 &3 national Darian Design; Singh and Varshney, 1995; Sherard, et al., 1976; Maraha Das Neves, 1990; ICOLD/CIGB, 1989). [7,6,5,4,3].

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