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Analysis of static and dynamic stability of slopes armed with geotextiles (Case study: Maragheh Alavian earth-dam)

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ABSTRACT

Dams are one of the most important structures for storing water in today's society due to their use in industry. The structural failure of the dam containing water, in addition to economic losses, also causes irreparable damage. This increased the importance of dam design and retrofitting. The stability of earthen dams mainly depends on the shear strength of the soil and this shear strength in earthen dams is provided by the action of friction between grains. The greater the angle of internal friction between the soil grains, the more shear stress is tolerated by the soil, and the stability of the dam increases. Synthetic materials called geotextiles that have properties such as granular materials (soil) in terms of mechanical and chemical resistance are high. The use of polymer elements in dams mainly causes more stability and stabilization of embankments. In this study, the impact of geotextiles on the Alavian earth dam in Maragheh has been investigated. For this purpose, by modeling the earthen dam with the help of various softwares, the effect of the type of characteristics of geotextile materials the height of the dam, and the location and distance between each other have been analyzed and studied. In particular, the installation of geotextiles is very efficient in static analysis and has caused the effective stress created in the dam to be zero, which is very rare. In dynamic analysis, the installation of geotextiles has reduced by 34% the most effective stress created in the dam.

1. Introduction

The term slope refers to any natural or artificial sloping surface of the earth that may be earthy, rocky, or a combination of the two. Occurrence of instability, slip and leakage in natural and artificial slopes are among the phenomena that occur in abundance in Iran and in many parts of the world. The movement and landslide of land masses, including soil and rocks, have many destructive effects on communication roads and tunnels, water and sewage lines, and even buildings (Daqiq, 2015). These slips and instabilities cause the arteries to rupture or block or reduce their level of function, and in general reduce the general safety of the gables, which in turn will impose high costs of inspection, maintenance, repair and reconstruction on the authorities. In critical cases, the occurrence of this type of instability may cause casualties for road users at the

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bottom of the slopes (Srbulov, 2001; Azarafza et al., 2020). With the increasing population and lack of suitable urban spaces for construction, the tendency to build high-rise buildings has increased, which in turn has increased the need to build them on loose natural and artificial slopes, which to stabilize them method Different options are offered. Improper design of earthen and gravel dams with inappropriate reliability coefficients for any possible reason, in times of floods, causes internal scouring in such dams, sinking of the downstream slope and in some cases, their destruction. Earth-dams' destruction and a pebble on the one hand and a large volume of flood flow on the other hand, creates flows with high concentrations of sedimentary materials. Flood traps and in a wider area destroy the surface of the relevant catchment areas, causing trees and vegetation to be uprooted, and when the flood subsides, the catchment area is covered with a large amount of sedimentary material. And certainly prevents such damages and similar damages (Wang et al., 2014).

In geotechnical studies, such as slope stability calculations, variables that do not have fixed values are commonly used. For example, parameters such as adhesion, friction angle and specific gravity can be mentioned. However, in practice, computational methods are definite, ie they do not allow considering changes in the parameters. In cases where stability is controlled, a standard definition called reliability can be used and acceptable limits can be set for the whole. Compensate for deficiencies that may occur in connection with changes in these parameters (Michalowski, 1998). These acceptable limits for different loading conditions have been determined experimentally and based on observations. It is important to note that conservative conditions (such as accepting the minimum parameters and calculating the reliability at the most critical point) are generally used simultaneously in the calculation of criteria, which are used to compare them with acceptable values. The disadvantage of these methods is that they do not clearly define an estimate of the degree of uncertainty and there are different definitions in this regard that, although close to each other, but do not match. Most importantly, the acceptable limits of design criteria are not known due to their experimental nature, such as the reliability of new problems that enter the industry with advances in technology. In other words, slope stability is a random process that depends on the distribution of parameters affecting slope stability (Zornberg et al., 1998).Landslides occurs under a variety of conditions. Natural or man-made slopes suddenly slip under these conditions and cause human and financial damage. The onset of landslides begins mainly with the appearance of cracks in the upper levels gradually they expand and with the infiltration of water, they expand their range as well as accelerate their action. Slope analysis is of special importance. In this regard, the slope resistance of dams is studied in three modes: under construction, in operation, and sudden ascent and discharge, among which the sudden ascent and discharge of the reservoir. Dams are one of the most important causes of sloping slope failure. When the reservoir is full and the water level is constant due to water infiltration, a constant current network is created in the dam body which is affected by the water level in the reservoir of the dam. Damage in the dam opens the valves at once, and this causes a rapid drop in the reservoir water level, which results in a negative pore water pressure due to the saturation of the body at a higher level, and high effective stress in the dam body. And causes rupture in the slopes and sometimes slips occur. Slopes do not rupture, in which case due to the high cost of repair of the dam is questionable (Hassanzadeh et al., 2008). According to the contents mentioned in this research, we will study the static slope stability of Alaviyan Dam using geotextile and finite element method.

The purpose of this study is to investigate the static and dynamic stability of geotextile-reinforced soil cover located on an earthen dam slope. In this analytical study, soil geotechnical parameters are used as input information to determine the output of the analysis (reliability coefficient). Used to simulate and perform the required analyzes. The purpose of this simulation is to perform the static stability analysis of the earth dam and the number of layers and the length of the geotextile layer as well as the internal friction angle parameters of the soil. The soil models used are the Mohr–Coulomb (MC) model.

2. Material and Methods

2.1. Research method

Using Plaxis software, we will model and analyze the model under the effect of static and dynamic stability using the finite element method. To perform modeling and compare the obtained results, draw the dam model in the software and assign the materials to the model. Assign geogrids at different heights in different layers to the dam body and using the pheriatic level of the surface. We introduce water to MomardNazar Dam. By changing the number and arrangement of geogrids as well as the water level upstream of the earthen dam, we perform the modeling and after the completion of the project using the outputs obtained from the analysis, static and dynamic stability analysis of the Alavian earthen dam Maragheh armed with We will discuss geotextiles. Then, using the mentioned article (Stayesh, 1992), we will validate the model with the laboratory model. In order to perform meshing in this research, 15-node elements will be used, the outputs obtained from several models will be converted into Excel diagrams, and by comparing the coefficients of confidence, the stability of the gable in different geogrid arrangements of different water levels behind the reservoir. We will study and finally, by preparing a report, we will mention the results and introduce the optimal model and arrangement. Finally, we will end the topic with suggestions for future studies.

2.2. Plaxis software and design parameters

Until recent years, almost all issues related to geotechnical engineering such as bearing capacity of foundations, stability of gables, soil pressure and retaining walls, etc. were solved by limit equilibrium methods. In these methods, it is not possible to calculate the deformations, so the structures designed with these methods are usually modified with a suitable confidence factor, but it is now well known that many problems are of the control type with deformation and considering the confidence factor for critical loads. This alone is not an acceptable guarantee for operating surface deformations. Therefore, a full understanding of the load-deformation path is necessary for more realistic designs. With the development of numerical methods and the use of computers with high processing power, the application of numerical methods in solving geotechnical problems, including analysis of soil-structure interaction response, has been greatly developed in recent years and due to many problems in numerical simulation In terms of complex soil behaviors and different behavioral models, the presence of water in the soil and the problem of soil-structure interaction, these structures are still current issues in the world. In this regard, special software for analysis of geotechnical problems and response analysis of buried structures have also been prepared and compiled (Halimi and Asadi, 2014).

In a study, comparative, validation, and numerical and laboratory predictions of parametric models of earthen roofs reinforced by geotextiles with real dimensions have been performed. Based on this research, which will be used as an article for validation using two-dimensional and three-dimensional plaxis software and two-dimensional Flac software, as well as in laboratory conditions and in small modeling dimensions, or in other words at the stress level. Low and also study in real dimensions using dimensional analysis and magnification 10 times with respect to low stress conditions, stability of earthen slopes with the presence of geotextile reinforcement materials and outputs obtained for use in practical and theoretical cases in earthen structures Sloping is reported from the point of view of the optimal effects of the present reinforcing materials on the boundary of the soil slope layers. It should be noted that the slopes examined as restricted and unrestrained from the floor and side walls and in different positions and heights of the placement of reinforcing sheets, have been compared and validated in the form of 11 parametric models. According to this study, due to the fact that geotextile at low stress levels (laboratory) expresses a maximum of 3% of its tensile capacity, it is necessary to measure the capacity in the real model of its functional conditions, because in the article only real models are predicted and has been compared with laboratory and numerical conditions (Halimi and Asadi, 2014).

2.3. Static and dynamic stability analysis of geotextile

Alavian Dam has been built on Sufi Chai River, 3.5 km northwest of Maragheh city in East Azarbaijan province. The Sufi Chai River, which originates from the Sahand Heights, flows into Lake Urmia after passing west of Maragheh and south of Bonab. The purpose of constructing Alavian Dam is to collect and control the surface flows of Sufi tea to supply drinking water to Maragheh city and military barracks, to compensate part of the lack of irrigation and agriculture needs of Maragheh plain and surrounding gardens and also to produce hydropower.

In the second model, the general structure of the dam for long-term behavior of the drained dam to calculate the amount of deformation and discharge of outlet water and determine the potential curves and slope reliability in the long run and under static loads, despite geotext It is modeled above the dam.In the third model, the construction steps of Alaviyan Dam are modeled to investigate the dynamic stability under the Tabas earthquake load.

In the fourth model, the construction steps of Alavian Dam are modeled again to investigate the dynamic stability under the Tabas earthquake load despite the geotextile in the upstream slope of the dam.

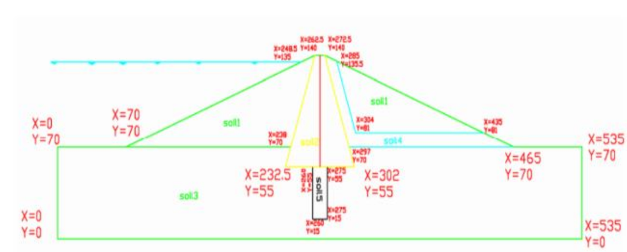

Figure 1. Geotechnical specifications of dam

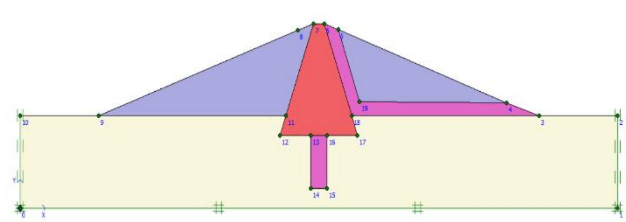

Figure 2. Geometrical modeling of Alaviyan dam

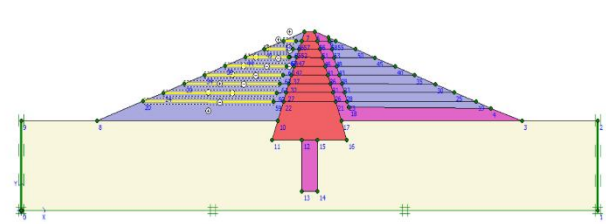

Figure 3. Modeling of Alaviyan Dam under static stability despite geotextiles

Table 1. Geotechnical characteristics of the dam material

Soil type	E (kN/m^2)	C (kN/m^2)	ϕ (degree)	K (m/day)
Soil1_Silty sand	5500	30	35	0.2
Soil2_Clay	2500	60	30	0.001
Soil3_Clayey sand	3500	1	33	0.4
Soil4_Sand	30000	1	35	10
Soil5_Grouted ground	4000	1	33	0.05

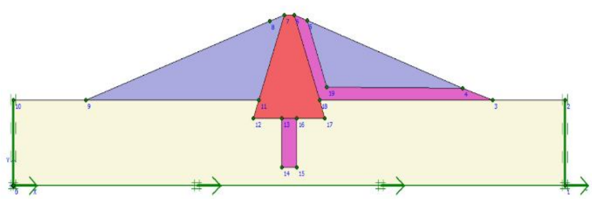

Figure 4. Modeling of Alaviyan Dam under Dynamic Stability

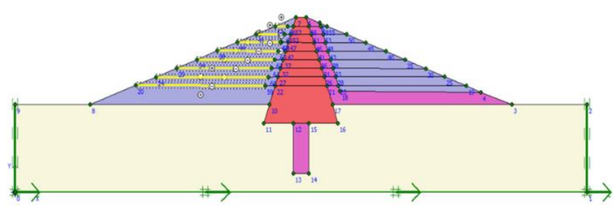

Figure 5. Modeling of Alaviyan Dam under dynamic stability despite geotextile

3. Results and Discussions

3.1. Modeling of static stability conditions

After introducing the material and assigning each material to its respective part, the static level of water is considered and the calculate model begins. In this model, we have three computational phases. The first phase is to calculate the initial stress. Because we have a sloping surface in this model, we cannot use the k_0 method; instead we use the Gravity Loading method. In the second phase, the main calculations of the dam, such as deformations and stress conditions in the dam body, are performed as plastic calculations. In the third phase, the slope reliability against slip is calculated by ϕ-C reduction method. It should be noted that the reliability coefficient in this case is equal to 1.54. The deformation created in the dam in this case is estimated and presented in Figs. 6 to 8.

After introducing the material and assigning each material to its respective part, the static level of water is considered and the calculate model begins. To model the geotextile, we consider its axial strength equal to 6000 kn.m and we consider the interface for it. In this model, we have several computational phases. The first phase is to calculate the initial stress. Because we have a sloping surface in this model, we cannot use the k_0 method; instead we use the Gravity Loading method. In the second to tenth phases, the main calculations of the dam, such as deformations and stress states in the dam body, are done as plastic calculations (in each phase between the second and tenth phases, a layer of soil is placed, then geotextile is placed. It will be given).

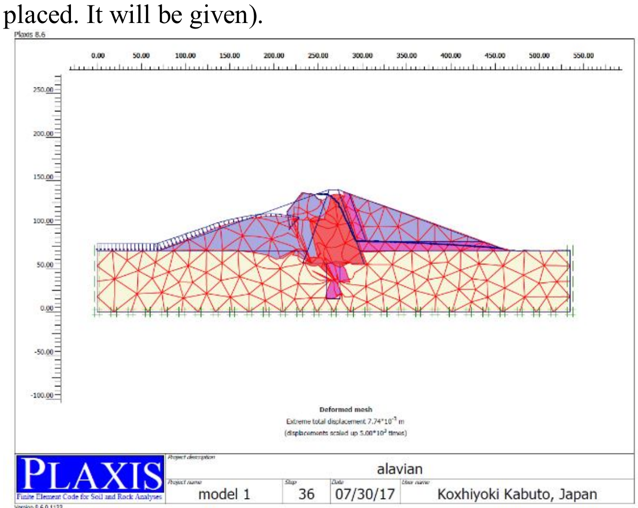

Figure 6. Deformation created in the dam in this case

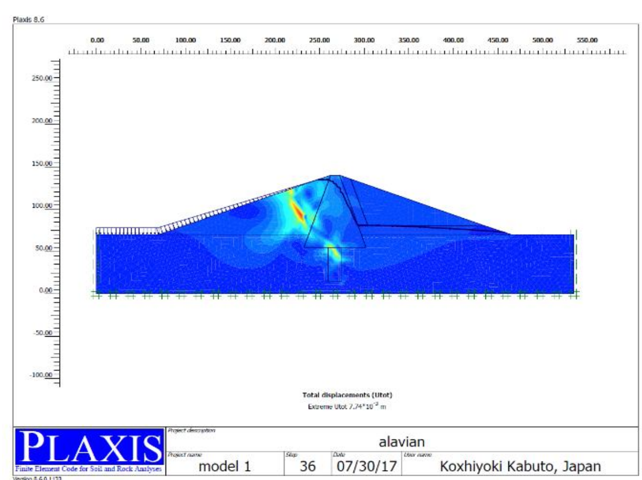

Figure 7. Displacement changes made in the dam in this case

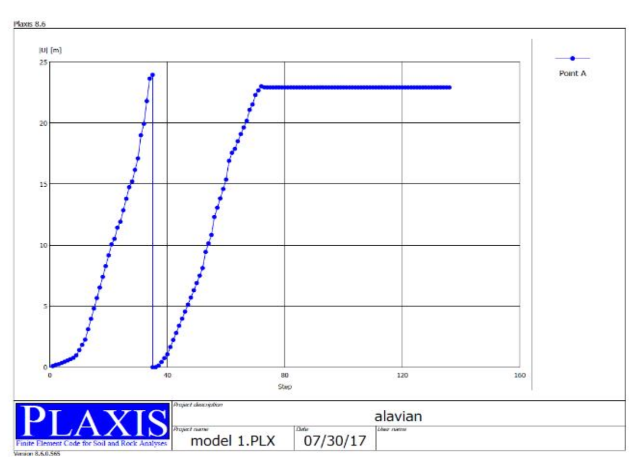

Figure 8. Graph of displacement changes in each step of analytical calculations

In the last phase, the slope reliability against slip is calculated by ϕ-C reduction method. It should be noted that the reliability coefficient in this case is equal to 15. The deformation created in the dam can be estimated and illustrated as Fig. 9. It is observed that in static loading by placing the geotextile in the upstream slope of the dam, no deformation will occur in the dam; thus, the displacement values created in the dam, in this case, are equal to zero according to the following Figs. 10 and 11. After introducing the material and assigning each material to its respective part, the static level of water is considered and the calculate model begins. In this model, we have four computational phases. The first phase is to calculate the initial stress. Because we have a sloping surface in this model, we cannot use the k_0 method; instead we use the gravity loading method. In the second phase, the main calculations of the dam, such as deformations and stress conditions in the dam body, are performed as plastic calculations. In the third phase, dynamic analysis of the dam is performed. For dynamic analysis of the dam, the results of Tabas earthquake acceleration mapping are used, which is taken from PEER site. In the last phase, the slope reliability against slip is calculated by ϕ-C reduction method. It should be noted that the reliability coefficient in this case is equal to 1.3. The deformation created in the dam in this case is as Figs. 12 to 15.

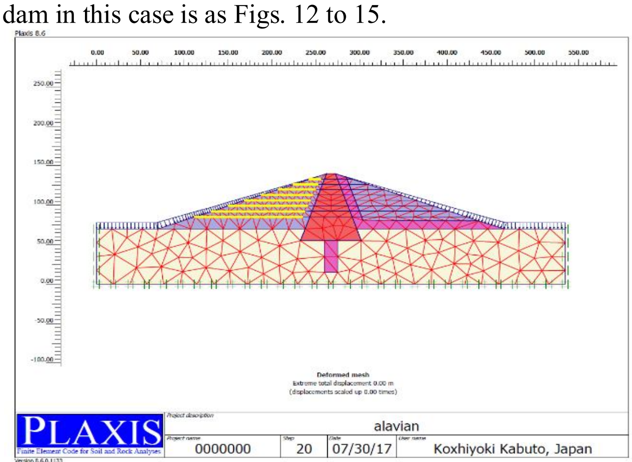

Figure 9. Deformation meshes created in the dam in this case

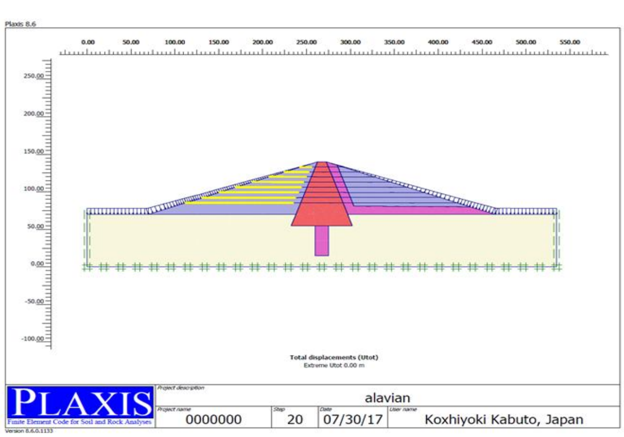

Figure 10. Total displacement created in the dam in this case

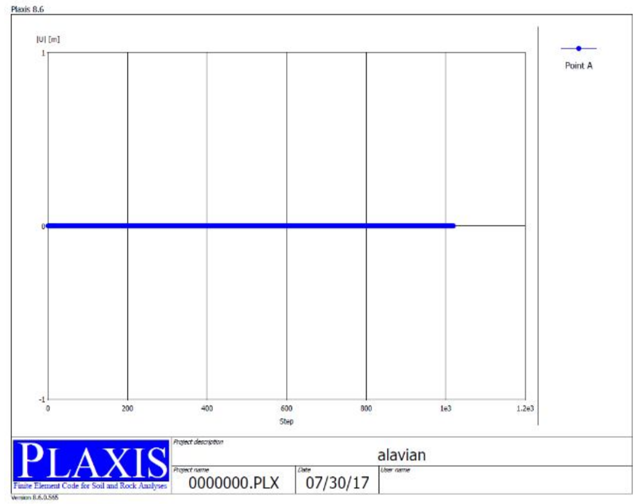

Figure 11. Graph of displacement changes in each step of analytical calculations

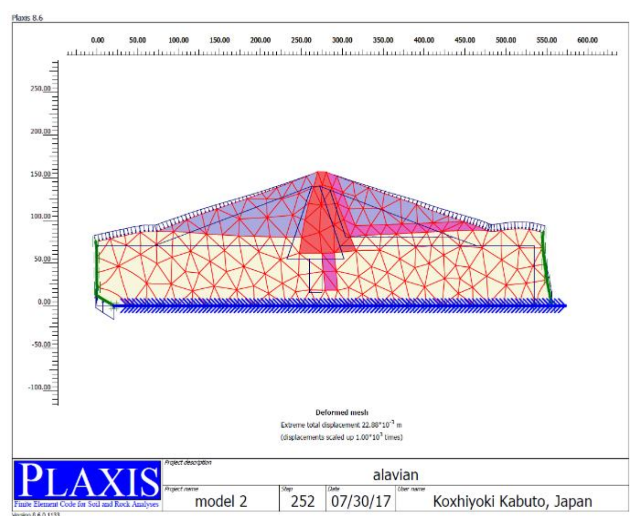

Figure 12. Deformation meshes created in the dam from PEER site

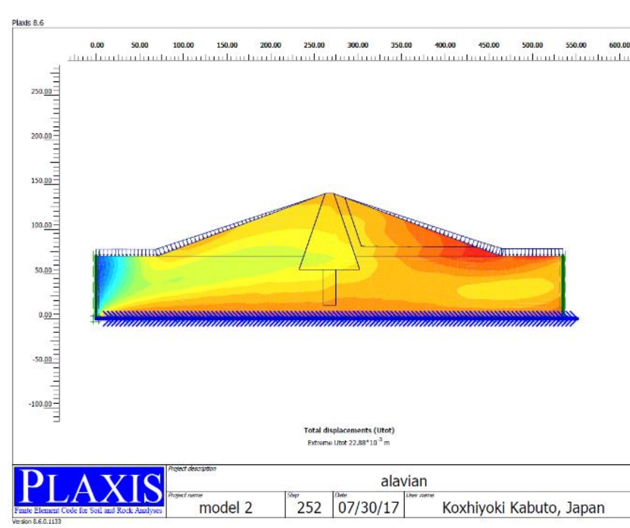

Figure 13. Displacement changes made in the dam from PEER site

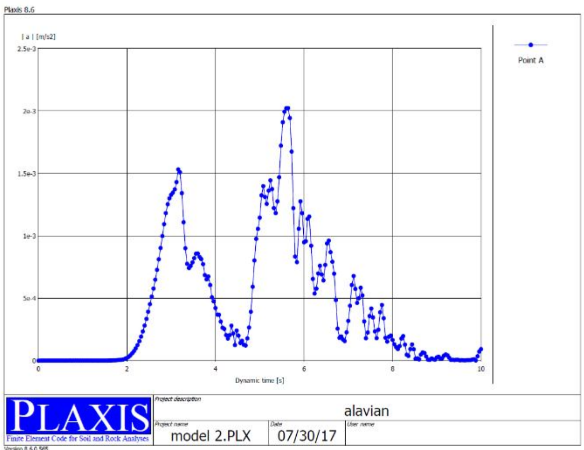

Figure 14. Graph of displacement changes in each step of analytical calculations

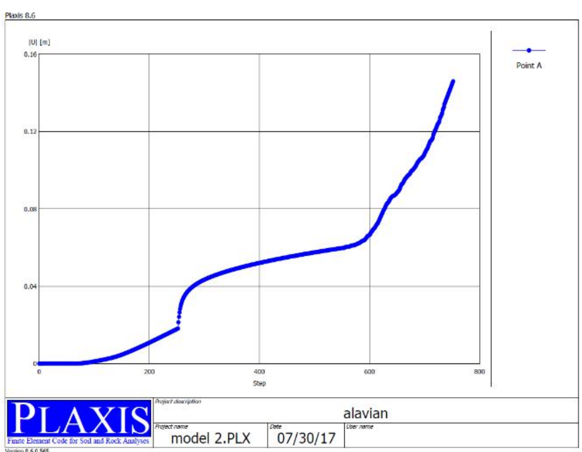

Figure 15. Graph of acceleration changes in the period of dynamic analysis of the dam

After introducing the material and assigning each material to its respective part, the static level of water is considered and the calculate model begins. To model the geotextile, we consider its axial strength equal to 6000 kn.m and we consider the interface for it. In this model, we have several computational phases. The first phase is to calculate the initial stress. Because we have a sloping surface in this model, we cannot use the k_0 method; instead we use the Gravity Loading method. In the second to tenth phases, the main calculations of the dam, such as deformations and stress states in the dam body, are done as plastic calculations (in each phase between the second and tenth phases, a layer of soil is placed, then geotextile is placed. It will be given).In the eleventh phase, dynamic analysis of the dam is performed; For dynamic analysis of the dam, the results of Tabas earthquake acceleration mapping are used, which is taken from PEER site. In the last phase, the slope reliability against slip is calculated by Q-C reduction method. It should be noted that the reliability coefficient in this case is equal to 2.5. The deformation created in the dam in this case is as shown as Figs. 16 to 19.

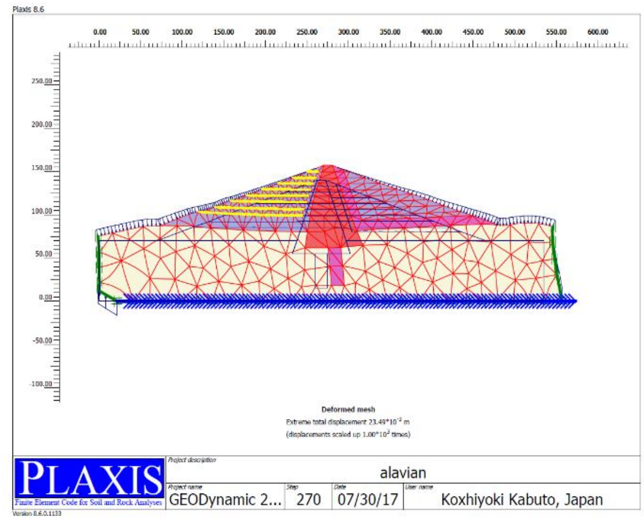

Figure 16. Deformation created in the dam in this case

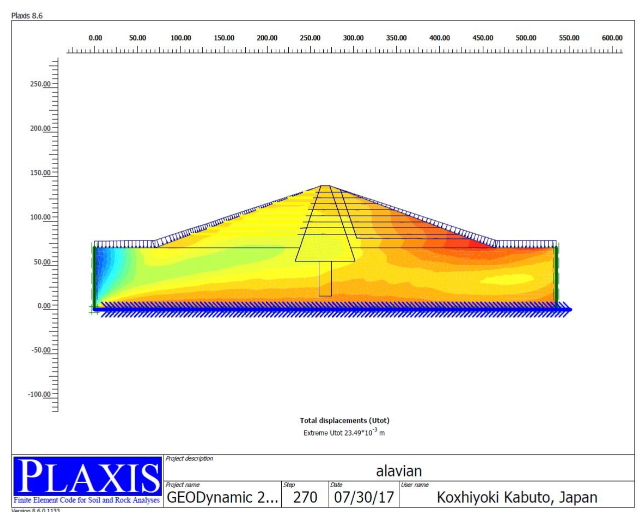

Figure 17. Displacement changes made in the dam in this case

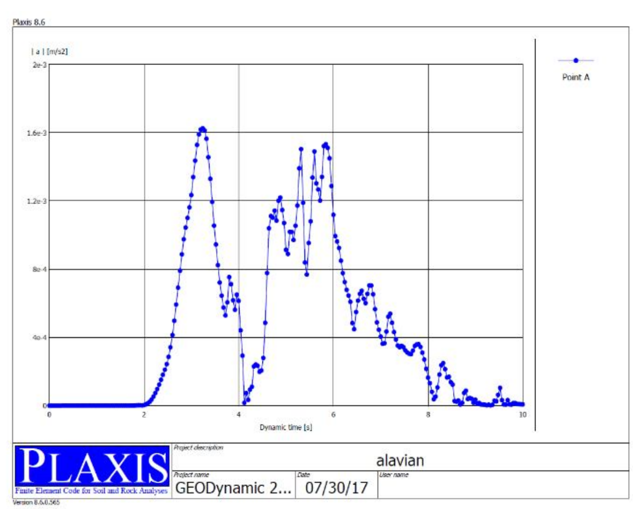

Figure 18. Graph of displacement changes in each step of analytical calculations

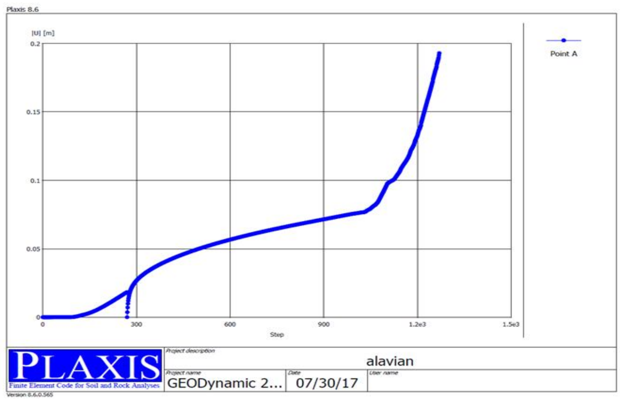

Figure 19. Graph of acceleration changes in the period of dynamic analysis of the dam

The comparative results of the statical analysis for different stages of stability analysis are presented in Figs. 20 to 23.

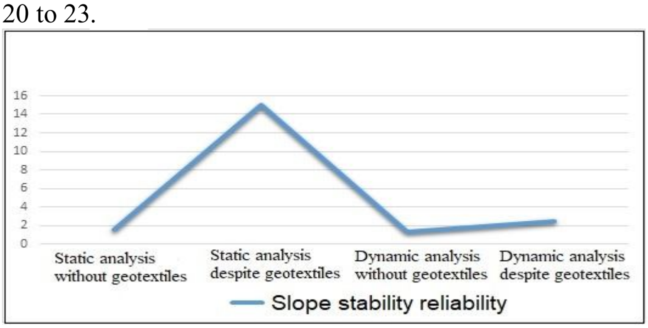

Figure 20. Comparative graph between reliability in four analytical models

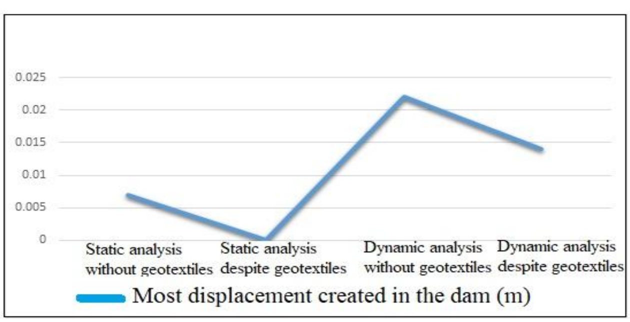

Figure 21. Comparative graph between the highest displacements created in the dam, in four analytical models

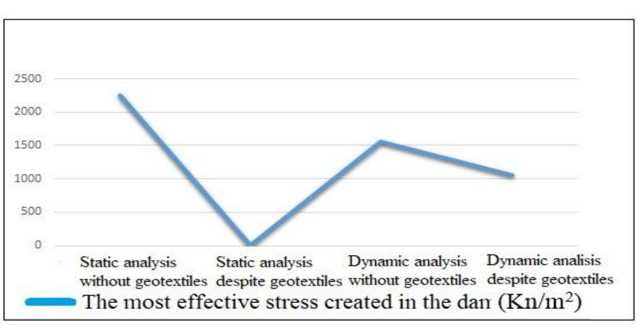

Figure 22. Comparative graph between the highest total stresses created in the dam, in four analytical models

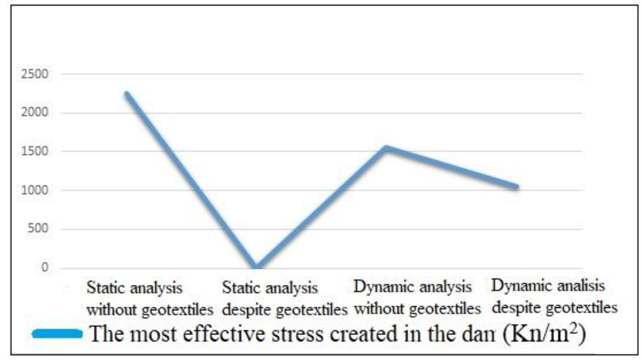

Figure 23. Comparative graph between the most effective stresses created in the dam, in four analytical models

4. Conclusion

The main purpose of this study is to investigate the effect of geotextile on static and dynamic analysis of Alaviyan Dam. By performing static and dynamic analysis of Alaviyan dam with and without geotextile using PLAXIS software, the following results are obtained:

A) The presence of geotextile has increased the reliability of the dam against slip in its static analysis. It was observed that with the installation of geotextiles in the slope of the dam, the amount of reliability of the dam against slip, increased significantly; From 1.54 to 15, which shows a tenfold increase.

B) Also, the presence of geotextile has increased the reliability of the dam against slip in its dynamic analysis. It was observed that with the installation of geotextiles in the slope of the dam, the amount of reliability of the dam against slip increased; It has risen from 1.3 to 2.5, which shows almost double the growth.

C) Geotextile installation has reduced the displacement created in the dam, in both static and dynamic analysis. In particular, the installation of geotextiles is very efficient in static analysis and has caused the displacement created in the dam to reach zero, which is very rare. In dynamic analysis, the installation of geotextiles has reduced by 27% the maximum displacement created in the dam.

D) Geotextile installation has reduced the total strain created in the dam, in both static and dynamic analysis. In particular, the installation of geotextiles is very efficient in static analysis and has caused the strain created in the dam to reach zero, which is very rare. In dynamic analysis, the installation of geotextiles has reduced by 6% the total strain created in the dam.

E) Geotextile installation has reduced the maximum total stress created in the dam, in both static and dynamic analysis. In particular, the installation of geotextiles is very efficient in static analysis and has caused the maximum total stress created in the dam to be reduced by 50%, which is very desirable. In dynamic analysis, the installation of geotextiles has reduced by 38% the maximum total stress created in the dam.

F) Geotextile installation has reduced the most effective stress created in the dam, in both static and dynamic analysis. In particular, the installation of geotextiles is very efficient in static analysis and has caused the effective stress created in the dam to be zero, which is very rare. In dynamic analysis, the installation of geotextiles has reduced by 34% the most effective stress created in the dam.

G) In general, it is observed that the installation of geotextiles in static analysis has been much more efficient than dynamic analysis of Alaviyan dam. Of course, in the dynamic analysis of Alavian Dam, the installation of geotextiles has been very effective in the field of dam stability, but its impact on static analysis is far greater than dynamic analysis.

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