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THREE DIMENSIONAL DYNAMIC ANALYSIS OF REINFORCED EARTH SLOPE BY GEOGRID UNDER OVERHEAD EFFECTS

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ABSTRACT

Today, analysis of the stability and study of the behaviors of retaining walls and soil slopes are important topics in soil mechanics/geotechnical engineering. Soil improvements, especially performance must give attention to behaviors particularly for reinforced earth slopes is their performance against earthquakes. In this study, we attempt to perform numerical modeling studies using FLAC3D finite difference software. With the FISH programming language available in this software as well as the existing attenuation models, some arbitrary behavior and precise modeling are done. The main purpose of this study is to investigate the dynamic and nonlinear behavior of reinforced earth slope. For this purpose, an instrumented articulated roof attic that has been constructed and operated as a road embankment is used as the base model. Seismic conditions are applied to the model using the acceleration mapping of several major earthquakes of Iran and the world. The soil behavioral model has been based on a soft or hardened Mohr-Coulomb model with the capability to incorporate nonlinear behavior in static analysis with nonlinear attenuation models in dynamic analysis.

1. INTRODUCTION

The invention of the reinforced earth system in the 1960s and its ever-expanding development opened a new chapter in soil engineering [1]. Benefits such as improved ductility and enhanced resistance to embankment behaviors, the use of built-in elements, and economic savings have led to the expansion and use of this system worldwide [2], [3].

The emerging of polymeric reinforcers, or geosynthetics in the 1970s, as a replacement for tape and metal reinforcers, with the aim of solving problems such as corrosion and high cost, accelerated the use of this type of system in became the world [4],[5]. Therefore, the discussion of the behavior of reinforced earth structures has been one of the topics of the day in the scientific forums and the subject of many research articles. From the placement of tensile elements such as steel belts and geogrids as soil reinforcement elements and their protection by coating special weapons arise.

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According to the AASHTO standard, reinforced wall slopes over 75 degrees are called reinforced soil walls and less than reinforced slopes [5], [6].

One of the most important behaviors of reinforced earth slope is its performance against earthquakes. The experience of various earthquakes over the past years has shown the good performance and the behavior of these structures [7],[8]. The percentage of overall failures and breakdowns in the walls and slopes of reinforced soil is limited compared to other traditional stabilization walls and systems. However, a complete lack of understanding of the earthquake response of these structures has led designers to resort to conservative assumptions to avoid the risk of failure. These assumptions include the use of large confidence coefficients in quasi-static design methods. The result of such an approach would be to present non-economic plans [8], [9].

2. LITERATURE REVIEW

During the past four decades, research has been conducted on the performance of reinforced soil structures. The results of these studies show that different parameters are involved in the dynamics and behavior of these structures, which can be divided into four general categories [10],[11]. This classification is as follows: 1) Parameters related to reinforced dams, litter and retained soil. 2) Parameters related to armaments and how they are arranged. 3) Parameters related to the movement of drive inputs such as earthquakes or traffic loads on road bumps or collapses. 4) Geometrical parameters of structures such as elevation and slope angle [12],[13],[14].

Relevant studies have been carried out in the form of general categories, laboratory studies, numerical analyzes, and mathematical theoretical methods. Due to the complexity of the laboratory methods and the problems that exist in these methods, including the effect of boundary conditions, scale effect, instrumentation problems and looking at the available possibilities, the use of numerical methods with regard to its high accuracy and capability providing comprehensive results as an alternative and cost-effective approach seems justified. However, it is necessary to prove the validity of the modeling by making similar numerical models in the software and comparing the results with the physical models [15], [16]. The main purpose of this study is to analyze the 3D dynamic analysis of geogrid reinforcement overhead impacted terrain.

3. RESEARCH METHOD

In this research, the effect of different parameters on the response of a reinforced earth slope is investigated using numerical modeling using FLAC 3D finite-difference software and its internal programming language. The simulations were performed to investigate the dynamic and nonlinear behavior of the arable soil slope. For this purpose, first the numerical modeling accuracy is demonstrated using the results of the dynamic loading of a laboratory model and then the slope behavior under different conditions is analyzed using the numerical model.

The Mohr-Coulomb failure or strength criterion used for soil behavior. The Mohr-Coulomb failure or strength criterion has been widely used for geotechnical applications. Indeed, a large number of routine design calculations in the geotechnical area are still performed using the Mohr-Coulomb criterion. The Mohr-Coulomb criterion assumes that failure is controlled by the maximum shear stress and that this failure shear stress depends on the normal stress. This can be represented by plotting Mohr's circle for states of stress at failure in terms of the maximum and minimum principal stresses. Figure 1, the Mohr-Coulomb failure line is the best straight line that touches these Mohr's circles. where τ is the shear stress, σ is the normal stress (negative in compression), c is the cohesion of the material, and ϕ is the material angle of friction.

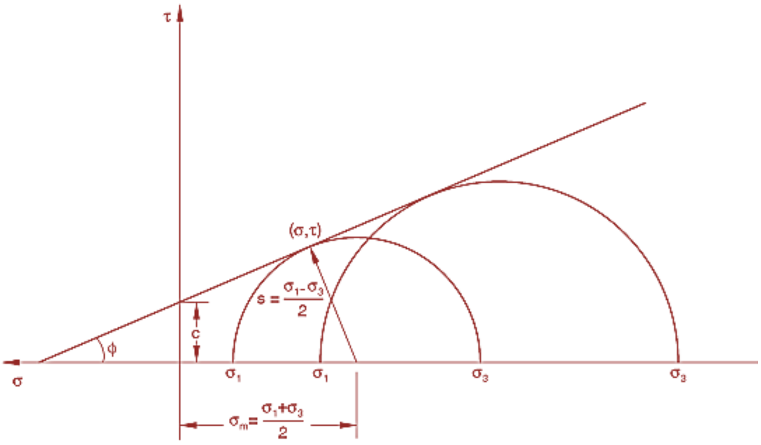

Figure 1: Mohr-Coulomb failure criterion.

4. SIMULATION DESIGN AND VARIABLES

With simulations design, the behavior of a reinforced slope with geogrid under seismic loads have been investigated. The analysis is carried out dynamically and in 3D and the loading is carried out as overhead on the embankment and applying the base acceleration. Since embankment behavior is based on the performance level, the degree of horizontal and vertical deformation is the main criterion for assessing and comparing the behavior of the embankments. The parameters whose effect on the embankment behavior is investigated include

- Soil specifications,
- The angle of gradient,
- The height of the embankment,
- The width of the embankment,
- The amount of overhead on the embankment,
- Arranging the embankment.

5. DATA ANALYSIS

In order to evaluate the impact of soil type on the behavior of soil gradients reinforcement with geogrids, the results of simulations A1 to A4 are investigated, for soil type 1 to 4, respectively. The most important soil parameter is the internal friction angle, setting at 25, 30, 35 and 40 degrees for soil type 1 to 4, respectively. Figure 2, the displacement contours are colored as red is the highest, followed by yellow, green, and blue.

From temporal lateral displacement data in Figure 2 for soil type A4 simulation, the highest displacement seems to be at $z/h = 0.5$ (where z is the depth from the surface being considered and h is the total embankment depth. So z/h is the ratio of these depths). For all z/h ratios, all the lateral displacement stops after 10s-11s (time unit in seconds).

The distribution of persistent horizontal displacements (after dynamic loading) at the height of the embankment with geogrids is shown in Figure 3 for simulations A1 to A4. Comparing the graphs, it can be said that with increasing soil resistivity parameters, the horizontal displacements have generally decreased.

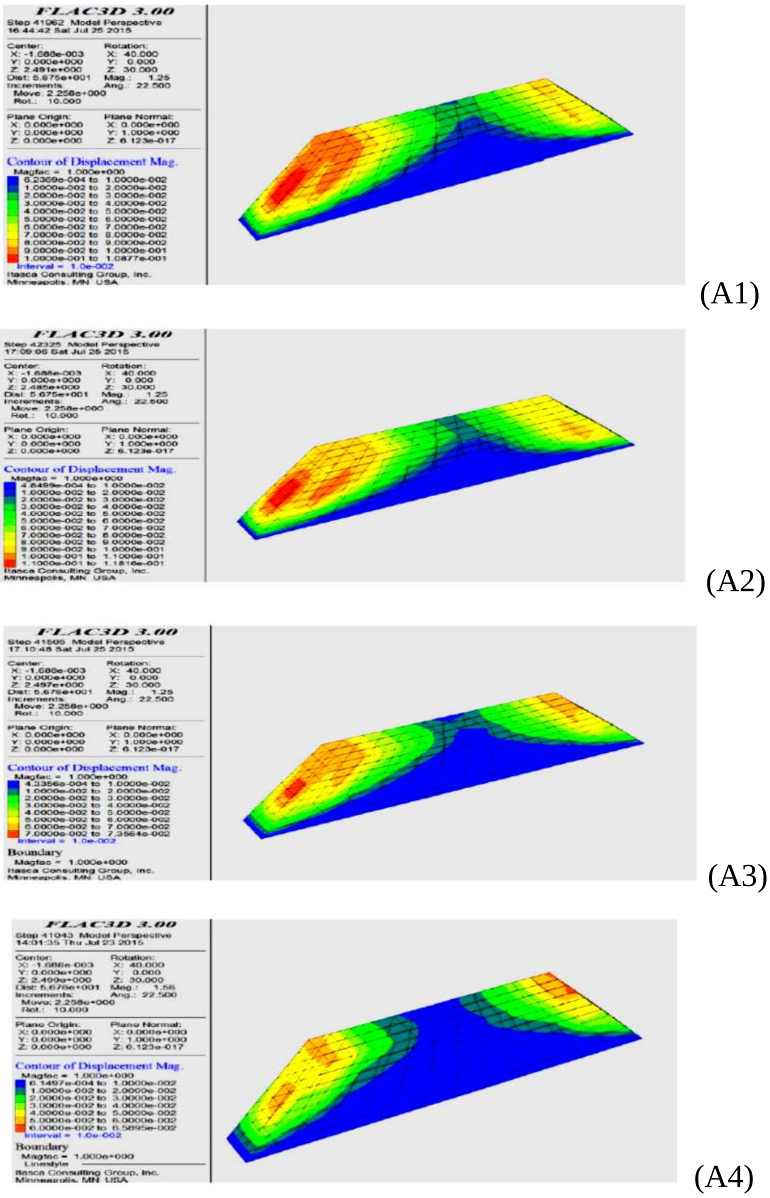

Figure 2: Displacement Meters in Simulations A1 to A4.

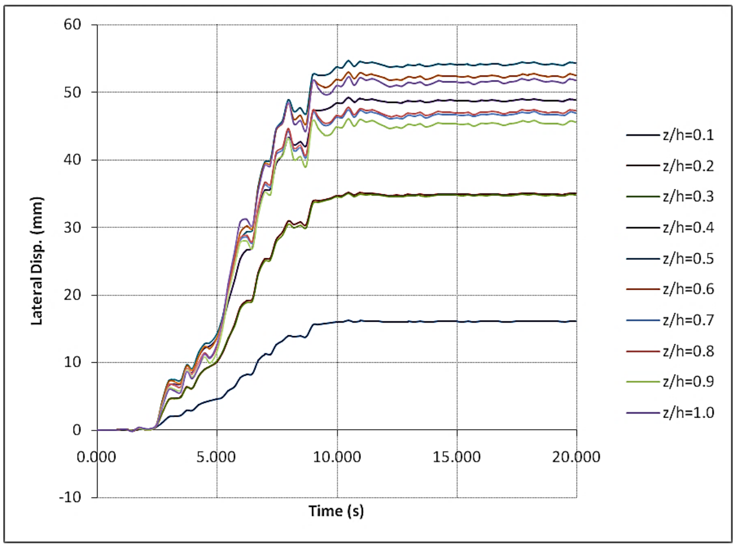

Figure 3: Time history of horizontal embankment shifts at different levels (for A4 simulation).

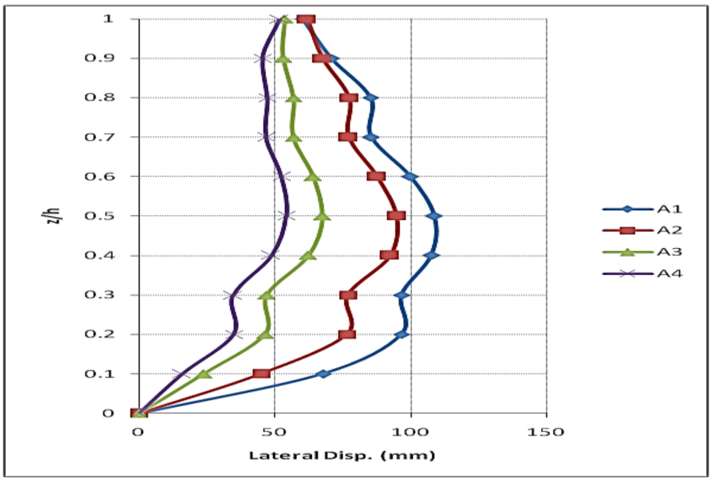

Figure 4: Persistent horizontal embankment shifts at different alignments (simulations A1 to A4).

Variations of the maximum mobilized force in earth slope reinforcers (geogrids) per unit of geogrid width are shown. According to Figure 4, it is observed that with increasing soil strength, the force mobilized in the geogrid elements decreases, that is, the soil tolerates a greater share of the applied forces.

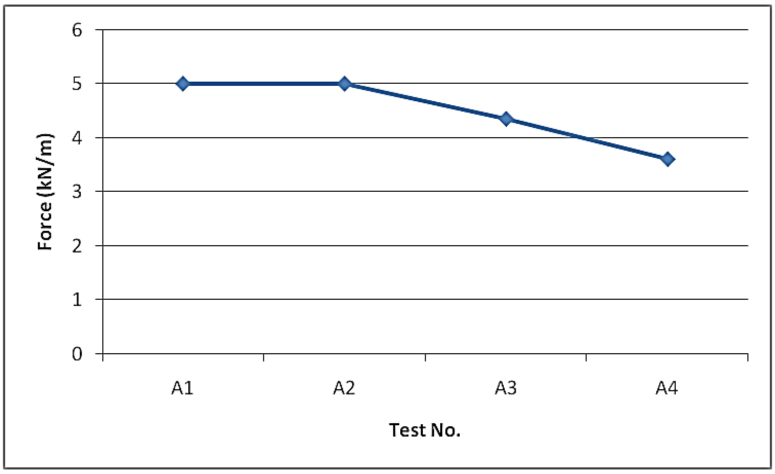

Figure 5: Maximum mobilized force in geogrids (simulations A1 to A4).

5.1 SLOPE ANGLE EFFECT

In order to evaluate the effect of the slope angle on the behavior of geogrid-armed soil slopes, the results of simulations B1 to B4 are investigated. In these simulations, the slope of the embankment surface to the horizon is 40, 45, 50 and 55, respectively. The time history diagram of the embankment horizontal displacements in different levels corresponding to simulations B1 to B4 is shown in Figure 5. In order to allow for a better comparison, the alignments are expressed in relative terms (the height of the displacement point divided by the total height of the embankment). An example of the B1 simulation is given in Figure 6.

5.2 OVERHEAD EFFECT

Evaluation of overhead impact on the behavior of soil gradients armed with geogrids. The results of simulations E1 to E4 has been investigated. In these simulations, the overhead values are 1, 3, 5, and 7 kPa, respectively. The temporal history of horizontal embankment shifts has been shown in different levels corresponding to simulations E1 to E4. In order to allow for a better comparison, the alignments are expressed in relative terms (the height of the displacement point divided by the total height of the embankment). As can be seen from the comparison of these figures, with the increase of the overhead value 1-7 kPa, the rate of displacement of the horizontal embankment is increased due to seismic loads. The graphs also show that as the amount of overhead changes, the pattern of increase in horizontal displacement also changes. According to the time history charts of horizontal displacements, it can be said that with the increase of overhead the time of beginning and end of the horizontal displacements did not change much.   Figure 7 is for the E1 simulation.

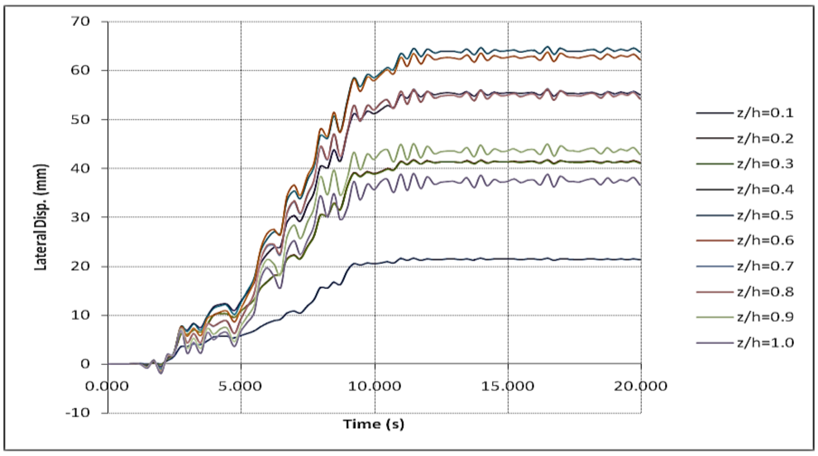

Figure 6: Time history of horizontal embankment shifts at different levels (Simulation B1)

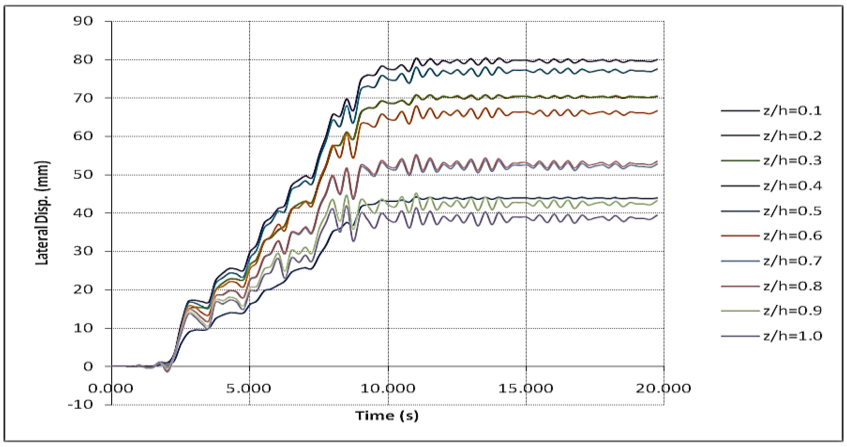

Figure 7: Time history of horizontal embankment shifts at different levels (E1 simulation)

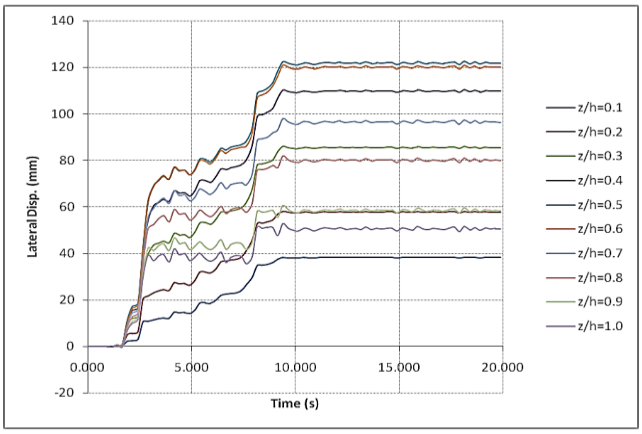

Figure 8: Time history of horizontal embankment shifts at different levels (F1 simulation).

5.3 EFFECT OF GEOGRID LAYER INTERVALS

In order to evaluate the effect of distance between geogrid layers on the behavior of reinforced earth slopes, the results of F1 to F4 simulations are investigated. In these simulations, the distances of the successive geogrid layers are 20, 40, 60, and 80 cm, respectively. These graphs show that the pattern of increase in horizontal displacements changes significantly with increasing distance of the geogrid layers. According to the time history charts of horizontal displacements, it can be said that with the change of geogrid layers, the time of start and end of horizontal displacements did not change much. F1 simulation is shown in Figure 8.

6. CONCLUSION

In this study, 3D dynamic analysis of reinforced earth slope was investigated using numerical modeling. Based on the studies, it was found that with increasing the internal friction angle of the soil, the amount of change in the horizontal axial load changes due to seismic loads was reduced. Be. Also, with the change of the friction angle, the time of start and end of the change in the horizontal location did not change significantly. Based on the study, it was found that with increasing the slope of the embankment, the rate of change of the horizontal axis of the reinforced soil increases with the application of seismic loads. Also, with increasing seismic height, the change in horizontal seismic load locations due to seismic loads is increased. Comparing the temporal history of soil horizontal displacements at different levels, it is clear that with increasing the width of the embankment, the overall change in the horizontal locations of reinforced terrain is increased by the application of seismic loads, which may be due to the changing dynamic properties of the terrain and how it responds. It was applied to seismic loads. A comparison of the time history of soil horizontal displacements at different levels revealed that the increase in the amount of displacement of the horizontal soil sites was enhanced by the application of seismic loads. Also, a comparison of the temporal history of soil horizontal displacements at different levels showed that with increasing geogrid layers, the amount of displacement of horizontal gray areas due to seismic loads does not show a significant trend. Also, a comparison of the temporal history of soil horizontal displacements at different levels revealed that with increasing hardness of the geogrid layers, the amount of displacement of the embankment horizontally decreases due to seismic loads. Finally, by comparing the temporal history of the axial horizontal displacements at different levels, it was found that with the change of acceleration, the amount of change in the horizontal position of the reinforced soil also changes due to seismic loads, which is due to the varying acceleration frequency content. Applied and different earthquake response to these accelerograms.

7. DATA AND MATERIAL AVAILABILITY

Data involved in this study can be requested to the corresponding author.

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