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Effect of Geogrid on Increasing the Bearing Capacity of Strip Foundations in Sandy Soils

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ABSTRACT

One of the geosynthetics that is used in different parts of the world under surface foundations is geotextile, and relatively valid texts are available on how to use it and increase its load. But other geosynthetics have been geogrids, which have increased the load-bearing capacity of surface foundations in soft clay and silty loam soils. In this paper, our u/b variations are between 1 and 17.5 with step 205 and in three different b/B modes are 5, 10 and 15. Also, the b/B changes from 0.1 to 2 with a step of 0.25 and in three different u/B modes are equal to 0.25, 0.75 and 1. The purpose of this study is to compare the soil load in different cases of geogrid with non-geogrid. This comparison is also performed by the BCR dimensionless number which is the result of dividing the armed soil load into the soil load without geogrid. The results of this paper showed that the presence of geogrid increases soil fertility, but from a certain extent onwards, this amount of fertility does not show much difference. In this ratio, the geogrid dimensions are equal to 17.5 times the dimensions of the foundation. The presence of geogrids increased the soil fertility, but from a distance onwards, this amount of fertility does not show much difference. This ratio is equal to 1.75 times the dimensions of the foundation.

1. Introduction

During the last half century, the use of artificial materials in civil engineering projects has made great progress. With the invention of durable and reliable synthetic materials, materials called geosynthetics were introduced to the world. These materials are artificially made of elastic and plastic materials and are produced in different shapes and properties depending on the expected application and performance (Mansouri, 2003). Due to its widespread use, speed of execution and reasonable price, the production and consumption of these materials is growing rapidly (Rumi, 2006). The most important applications of geogrids are the creation of a reinforced soil system, the construction of retaining walls, the base layer materials and the reinforcement of the bed in road construction and similar cases. It is worth mentioning that walls made with geogrids do not have the problem of many deformations of walls made with geotextiles (Abrishami,

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Saeed, 2005). Geogrid is one of the important elements used in soil reinforcement and reinforcement methods and as an integral part of soil play an important role in increasing soil bearing capacity (Mansouri, Behrooz 2003). Most surface foundations, such as building foundations, may be affected by the dynamic loads caused by earthquakes during their lifetime. In these conditions, the soil under the foundation, depending on its material, may be affected and broken by loads beyond its final capacity. Now, one of the important solutions to strengthen the foundations is to use geogrids as reinforcement in the soil under the foundations (Alimardani, 2004).

The bearing capacity of surface foundations is one of the most important factors influencing the design of structures located on them. To improve the bearing capacity of surface foundations, the reinforcement method can be used by using geogrids in the soil under the foundation. To calculate the bearing capacity of surface foundations located on reinforced sandy soil, laboratory or numerical methods can be used (Rumi, 2006). Geogrids are a group of families of geosynthetics made of polyester and polyethylene or a combination of these and other similar materials. These products are produced in the form of three-dimensional networks in different thicknesses, sizes and dimensions. Geogrids are used as suitable reinforcements because they have high tensile strength and significant locking capability with the surrounding environment. These geosynthetics are usually located at the top and bottom of the geotextile layer in areas where the soil is saturated or moist. The thickness of geogrid fibers is 0.5 to 1.5 mm and the thickness at the node is 2.5 to 5 mm. The geogrids used to reinforce the soil have rectangular or oval springs with dimensions of approximately 25 to 150 mm. The most important applications of geogrids are the creation of a reinforced soil system, the construction of retaining walls, the base layer materials and the reinforcement of the bed in road construction and similar cases. It is worth mentioning that walls made with geogrids do not have the problem of many deformations of walls made with geotextiles.

Arafar and Abrishami (2010) has investigated the modeling of the effect of geogrid on the dynamic behavior of reinforced soils using PLAXIS. In this research, the behavior of strip foundations located on geogrid-reinforced soil has been studied. For this purpose, first, the numerical model is developed by finite element method using 2.8 v 2D PLAXIS software and how to develop it, including soil modeling, foundation, geogrid and their interaction, is stated. The developed model has been calibrated according to the results of the available static tests and the numerical simulation of the dynamic loading problem of the foundation in the armed and unarmed state has been done under different overheads. Comparison of the obtained results shows how different parameters affect the behavior of reinforced foundations (Ariafar and Abrishami, 2010). Parsai Moghadam and Rad (2015a) have investigated the effect of the number of geogrid layers in loose sand. The parameters studied in this analysis are the number of reinforced layers, which increase the number of geogrid layers by increasing the bearing capacity of the foundation in static mode, but reduce the percentage of vertical subsidence due to dynamic loading. It has one to 4 layers of type B geogrids. The soil used in this part is loose sand on which a concrete foundation with width = B1 has been constructed. As the number of geogrid layers increases, the bearing capacity of the foundation in the static state increases. This increase in soil bearing capacity is due to the fact that with increasing reinforcement layers, more depth of soil is involved in deformation, resulting in more load bearing (Parsai Moghadam and Rad, 2015a).

Parsai Moghadam and Rad (2015b) have studied the geogrid width in static and dynamic modes. For static loading mode, the final bearing capacity of the foundation has an optimal value for different values of geogrid width, after which the bearing capacity of the foundation does not change much with increasing the width of the geogrid. In the study, this value for static mode is equal to three times the width of BB = 3B. By increasing the number of geogrid layers, the bearing capacity of the foundation in the static state increases but decreases the percentage of vertical settlement due to dynamic loading. For the dynamic mode after an optimal value with increasing geogrid width changes in the settlement percentage will be small. In this study, the optimal width of the geogrid in the dynamic state is equal to three times the width of the foundation (Parsai Moghadam and Rad, 2015b). Biniaz et al., (2015) have analyzed the pressure-subsidence behavior of foundations located on a bed armed with geocell. In this study, we try to present an analytical method based on all three factors of lateral strength, vertical stress distribution and membrane effect to determine the pressure-subsidence behavior of circular foundations located on the bed of sands reinforced with geocell. The modulus of elasticity of the unreinforced layer and the geocell-reinforced layer (geocell and soil inside the cells of the geocell layer) as a composite material is obtained using the results of three-axis experiments on unreinforced soil and reinforced soil samples.

Acceptable matching of the results of the analytical method with the results of the experiment on the foundation located on the reinforced bed with a geocell layer, indicates the proper performance of the analytical method. Also, the effect of parameters such as the hardness of the geotextile used in the construction of the geocell and the height of the geocell layer on the pressure-subsidence behavior of the substrate has been investigated (Biniaz, 2015). Astaneh et al., (2015) have analyzed the meeting and bearing capacity of sand reinforced with geogrid on compacted soil. The results show that there is a significant difference in the structural distribution of the tested geogrids, which is in the range of 95% decrease in meeting, up to 2000% increase in plastic modulus and 320% increase in bearing capacity. Soil collapse is characterized as inelastic deformation. It has been discovered that the efficiency of the sand-geogrid system increases with increasing geogrid width and decreasing geogrid depth. To efficiently and economically reinforce the sand layer on the compacted soil, a geogrid width of four times the loaded surface diameter (D) and a depth of 0.1D is recommended (Astaneh et al., 2015).

Omar et al. (1993) investigated the bearing capacity of a strip foundation on reinforced sandy soil with geogrid. He concluded that the critical ratio value was (u / B) cr = 2 and also the number of optimal geogrid layers was N = 6. Awaji (2001) investigated a circular foundation on reinforced sandy soil with a geogrid. He obtained the optimal depth ratio of the reinforcers (u / D) cr = 0.1 (Khing et al., 1993). Ghosh et al. (2005) investigated a very soft and reinforced soil foundation with a geogrid layer and concluded that the optimal depth value of the first geogrid layer is obtained u / B (cr = 0.3) (Shin et al., 2002). Due to the high cost and time consuming laboratory methods, the purpose of this study is to use the numerical method using ABAQUS software to investigate the effect of geogrids on the bearing capacity of surface foundations located on geogrid reinforced soils. For this purpose, the number of geogrids, the dimension of geogrids, their distance from each other and from the foundation floor and the buried depth of the foundation are considered variable to investigate their impact. Finally, the results are compared with laboratory results.

2. Material and Methods

2.1. Research Method

One of the methods of mechanical stabilization and soil reinforcement is the use of tensile elements such as metal strips, geotextiles or geogrids. Over the last 40 years, many geotechnical structures such as retaining walls and embankments around the world have been constructed and operated using reinforced soil techniques (Abrishami, 2005). Due to the increasing use of polymeric materials such as geogrid as a tensile element to reinforce soils, the need to study reinforced soil issues to clarify its various dimensions (Ariafar and Abrishami, 2010). Especially since despite laboratory and numerical researches, there are still many ambiguities about how to model reinforced soil environments in different conditions and how they behave.

In this research, Abacus software has been used for numerical modeling of the bearing capacity problem of strip foundation (flat strain conditions) located on granular soil. In order to model the rigid and rough conditions, the model will be loaded by applying a velocity perpendicular to the nodes under the foundation. Nonlinear elastoplastic behavioral model (hyperbolic behavior in the elastic region and Mohr-Columb rupture cap) is considered for sand and elastoplastic behavioral model is considered for geogrid. To study the effect of reinforcement depth and length, dimensionless parameters B/u, B/b and (load capacity ratio) BCR were used.

2.2. Modeling with ABACUS

In this chapter, modeling of execution and assignment of materials to execution in Abacus software will be analyzed. The dimensions and implementation of the component are shown in Fig. 1. The dimensions of the studied bed soil are 2×2 square meters. Also, the dimensions of the foundation design are 10 × 10 cm, which is shown with B in Fig. 2. Another component of the analysis is the geogrid, which is underground. The length of the geogrid variable is denoted by b. The distance of the geogrid from the soil surface, which is variable, is also indicated by u. In this analysis, by considering u/B and b/B, the dimensionless state of the variables is used to interpret the results. In this dissertation, u/b variations are between 1 and 17.5 with step 205 and in three different b/B modes are 5, 10 and 15. Also, the b/B changes from 0.1 to 2 with a step of 0.25 and in three different u/B modes are 0.25, 0.75 and 1. The aim is to compare the soil load in different cases of geogrid with non-geogrid. This comparison is also done by the dimensionless BCR number, which is the result of dividing the load of reinforced soil into the load of soil without geogrid (See Fig. 3).

2.3. Modeling Process

In this section, soil constituents and geogrids are identified. Table 1 shows the soil characteristics used in the software. Soil characteristics are defined by the Mohr–Coulomb model. Table 2 shows the range of materials and geometric characteristics of geogrids.

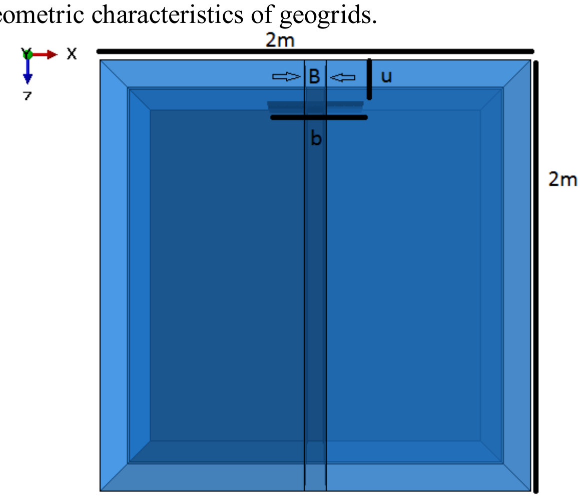

Figure 1. Dimensions and elements defined in software

Table 1. Applied soil characteristics

Density (kg / m³)	Elastic modulus (Mpa)	ν	Friction coefficient	Expansion coefficient	Final adhesion stress
1920	182	0.2	46	4	1000

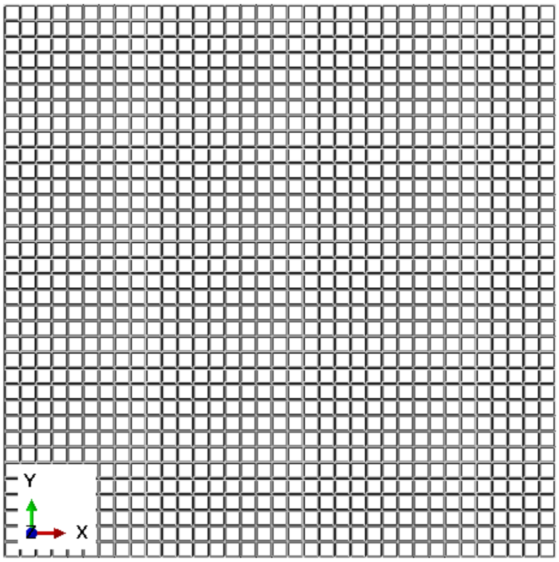

Figure 2. Simulated geogrid with dimensions of 1.75×1.75 cm^2

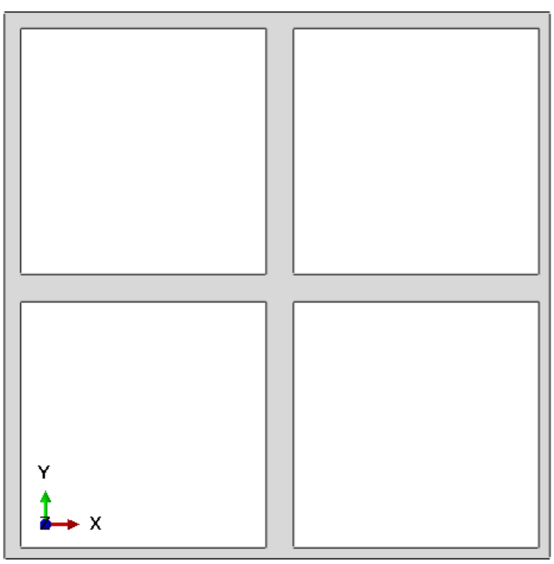

Figure 3. Simulated geogrid with dimensions of 0.1 * 0.1 m2

Table 2. Geogrid specifications

Thickness (mm)	Hole size (mm)	Density (kg/m^3)	Elastic modulus (Mpa)
1	4	1800	46.2

2.4. Boundary Conditions

Fig. 4 shows the force and boundary conditions. The forces include the force of weight and load pressure on the foundation and soil. Also, the speed of applying the load is equal to $6^{-10}\times$ 5.7 meters per second. Also, Fig. 5 shows the soil network. Fig. 6 also shows the meshing in the geogrid. The type of meshing is C3D8R for soil and S4R for geogrid. Of course, it should be noted that the geogrid is simulated using the SHELL element.

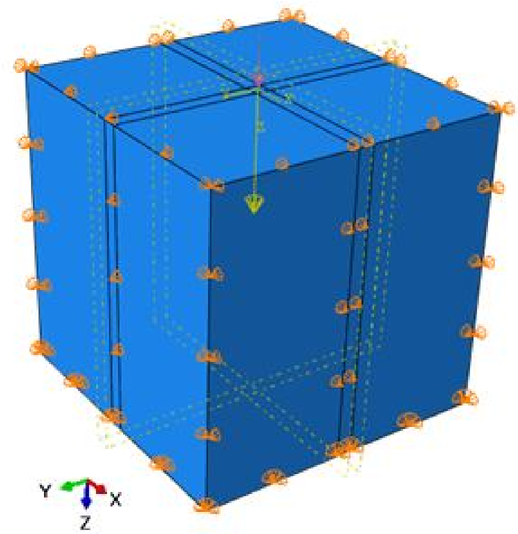

Figure 4. Boundary conditions and force applied

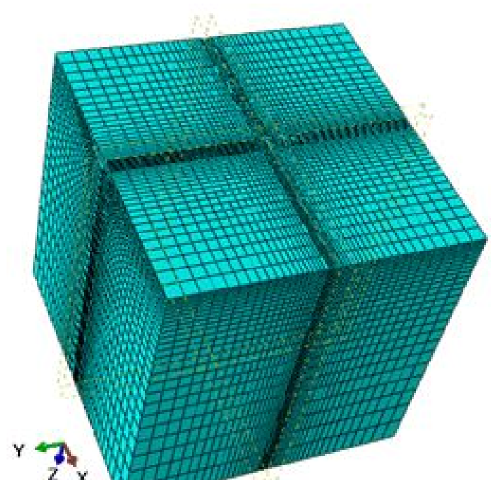

Figure 5. Soil networking in modeling process

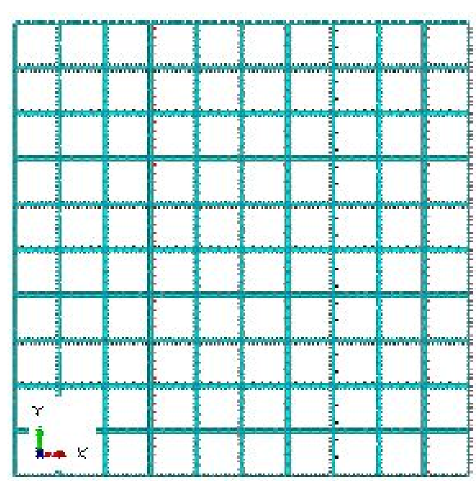

Figure 6. Geogrid networking in modeling process

3. Results and Discussions

3.1. Impact of Geogrid Distance

In order to investigate the effect of geogrid distance on soil fertility, geogrid dimensions have been considered in three different modes. Figures 7 to 9 Analysis outputs are 20 cm away from the soil surface and the geogrid length is 0.5, 1 and 1.5 m. Figure 10 also shows the comparison of soil load ratio at different distances from the soil surface in three different geogrid dimensions. It can be seen that the presence of geogrid increases the soil load, but from a distance onwards, this load does not show much difference. This ratio is equal to 1.75 times the dimensions of the foundation.

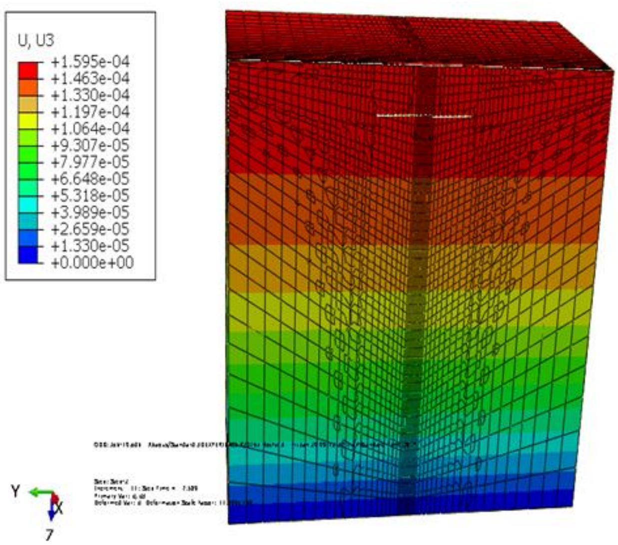

Figure 7. Distance from soil surface 20 cm and length of geogrid 50 cm

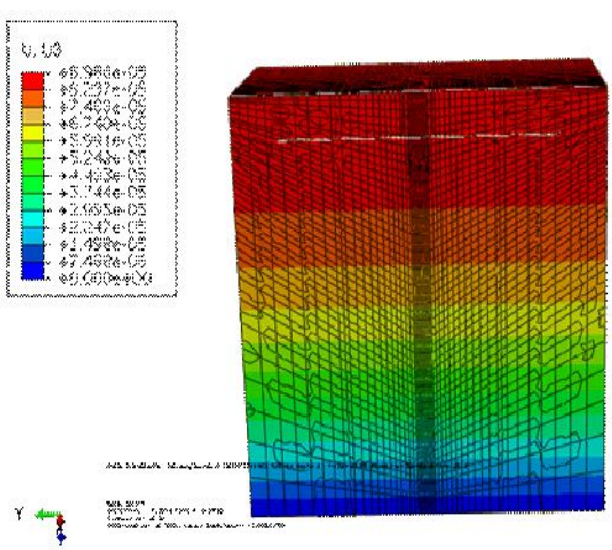

Figure 8. Distance from soil surface 20 cm and length of geogrid 100 cm

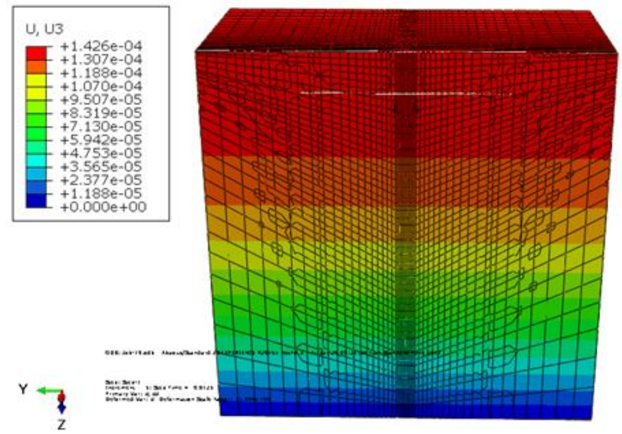

Figure 9. Distance from soil surface 20 cm and geogrid length 150 cm

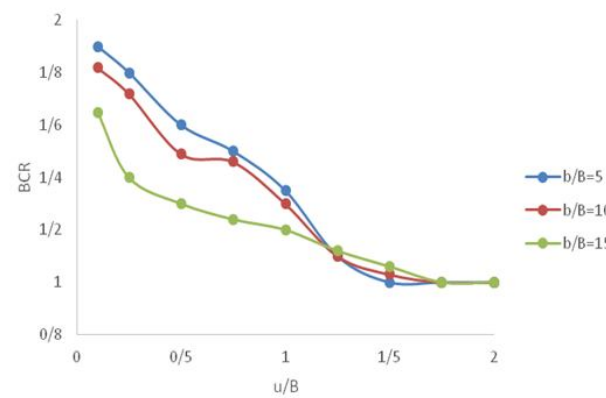

Figure 10. Comparison of soil load ratio at different distances from soil surface in 3 different dimensions

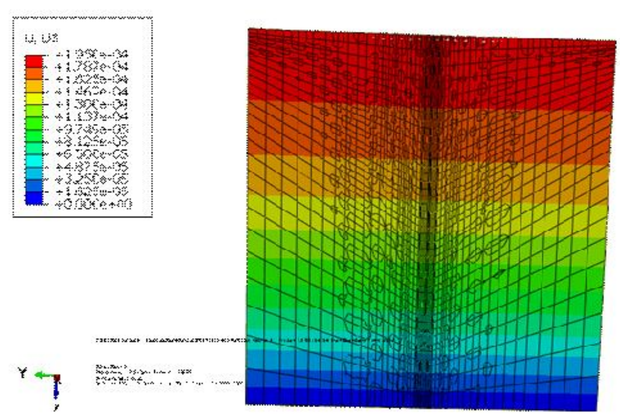

Figure 11. Distance from soil surface 2.5 cm and geogrid length 75 cm

3.2. Impact of Geogrid Dimensions

In order to investigate the effect of geogrid dimensions on soil fertility, the geogrid distance from the soil surface in three different cases has been considered. Figs. 11 to 13 are presented the output of the analysis is 75 cm in geogrid position and the distance from the soil surface is 2.5, 5 and

10 cm. Fig. 14 also shows the comparison of soil load ratio in different geogrid dimensions at different geogrid distances from the soil surface. It can be seen that the presence of geogrid increases the soil fertility, but from a size onwards this amount of fertility does not show much difference. In this ratio, the geogrid dimensions are equal to 17.5 times the dimensions of the foundation.

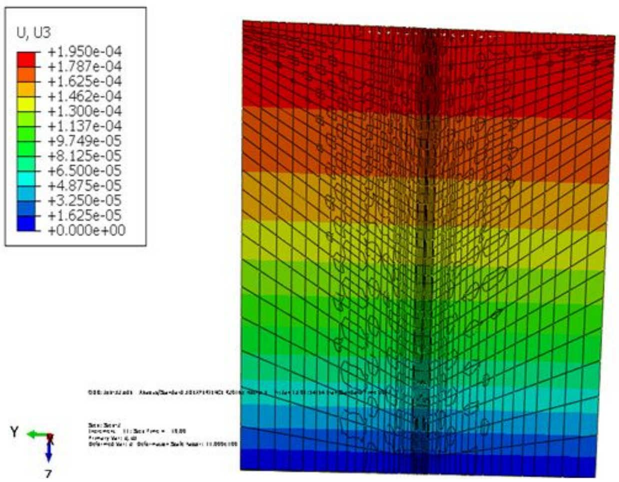

Figure 12. Distance from soil surface 5 cm and length of geogrid 75 cm

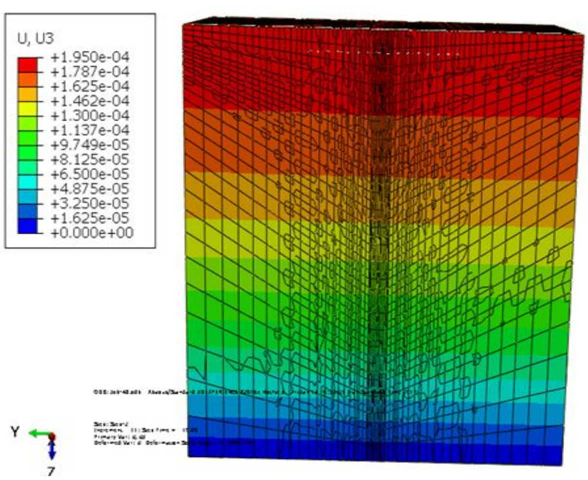

Figure 13. Distance from soil surface 10 cm and geogrid length 75 cm

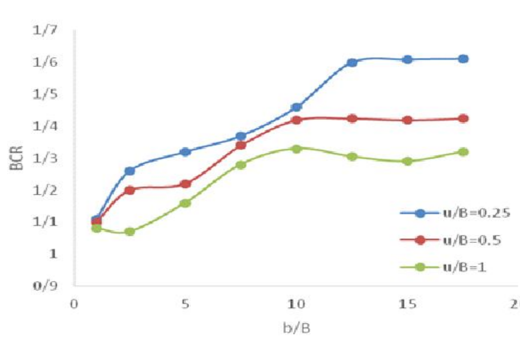

Figure 14. Comparison of soil load ratio in different geogrid dimensions at different geogrid distances from the soil surface

4. Conclusion

In this study, the effect of hybrid reinforcement on soil bearing capacity was studied. First, generalities of the work and goals studied and work hypotheses were mentioned. Then we explained and reviewed the background of the work done and the types of geosynthetics. In the next step, we referred to the modeling of execution and assignment of materials to execution in Abacus software and analyzes.

It can be seen that the presence of geogrid increases the soil fertility, but from a size onwards this amount of fertility does not show much difference. In this ratio, the geogrid dimensions are equal to 17.5 times the dimensions of the foundation. As can be seen, the presence of geogrid increases soil fertility, but from a distance onwards, this amount of fertility does not show much difference. This ratio is equal to 1.75 times the dimensions of the foundation.

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