Advanced Engineering Days

aed.mersin.edu.tr

Numerical analysis of the geosynthetic reinforced stone columns with Plaxis2D finite element code

Sadi Berkay Dural *1, Özgür Lütfi Ertugrul 1

1Mersin University, Civil Engineering Department, Mersin, Türkiye, sadiberkaydural@gmail.com, ertugrul@mersin.edu.tr

Cite this study: Dural, S. B., & Ertuğrul, Ö. L. (2022). Numerical analysis of the geosynthetic reinforced stone columns with Plaxis2D finite element code. 5th Advanced Engineering Days, 165-167

Keywords
Stone column
Finite element method
Geotextiles
Geogrids

Abstract

Stone columns applications are becoming widespread as a ground improvement method owing to their economical and efficient use. Contrary to typical reinforced concrete bored piles, stone columns generally fail to the low confining stresses coming from the soft and loose soils. In order to overcome this problem, geotextile or geogrid wrapping can be a good alternative for soil improvement. Within this study, results of numerical analyses of the stone columns performed with finite element technique were reported. For the simulations, unwrapped and geosynthetic wrapped stone columns were modeled. According to the results of the numerical analyses, the amount of lateral expansional deformation of the stone column under vertical load was 24.76 mm, while this value decreased by 6.82% in the geogrid-wrapped model, 12.29% in the G300-wrapped model and 34.20% in the G1000 geotextile-wrapped model. These results indicate the geotextile and geogrid type reinforcement provides significant contribution to the load bearing capacity of the stone columns.

Introduction

Stone columns are widely used for reducing settlements of soft soils under vertical loads which may be induced by embankments and building loads. The stone column method is among the most efficient improvement techniques for soft foundation soils, both in terms of cost and installation time. This method has been extensively used in projects involving embankments founded on soft soils, with columns generally containing sand or gravel [1]. One of the major shortcomings of the stone columns when compared to the reinforced concrete bored piles is their failure risk due to low confining stresses. It is well known that stone columns lose their bearing capacity as a result of lateral deformations caused by these loads. Covering the stone column perimeter with geosynthetic materials produces alternative solutions to limit the lateral displacements that occur. Geosynthetic materials are generally polymer-based. Geotextiles include geogrids, geocells, geocomposites and geomembranes.

The greatest properties of geotextiles are flexibility and durability. A special type of geomaterial is known as geogrids [2]. These materials can be used as a wrapping material around the stone column body in order to provide confining support. This additional support can increase the load bearing potential of the stone columns while decreasing the deformations. Stone columns, encasement of stone columns in geogrid affects the distribution of lateral stress by improving the strain–stress behaviour and also reduces the ultimate settlement in certain loading conditions. Therefore, geogrid-encased stone columns can be used as a ground improvement technique for very soft soils [3]. The geosynthetic-encased stone column was first proposed by Van Impe (1989) and extensively studied by many researchers [4]. According to Miranda the main advantages of encased columns compared to ordinary columns are the extra lateral support provided by the geotextile encasement, and stopping fine particles of the soft soil squeezing inside the column avoiding clogging [5].

Material and Method

Within this study, numerical analyses were performed with PLAXIS 2D software. The simulations were performed by using the geometrical dimensions of the physical test which is performed to investigate the load bearing capacity of geotextile wrapped stone columns. In the analyses, due to symmetry, axisymmetric model was considered. Material properties which are used in the analyses were selected by using the typical values available in the literature for stone column material and bedding sand which is present along the stone column. A rigid raft foundation is modeled in the analyses. The foundation modeled in the analyses have the dimensions of 200×200×15 mm. Finite element mesh used in the modeling process is shown in Figure 1.

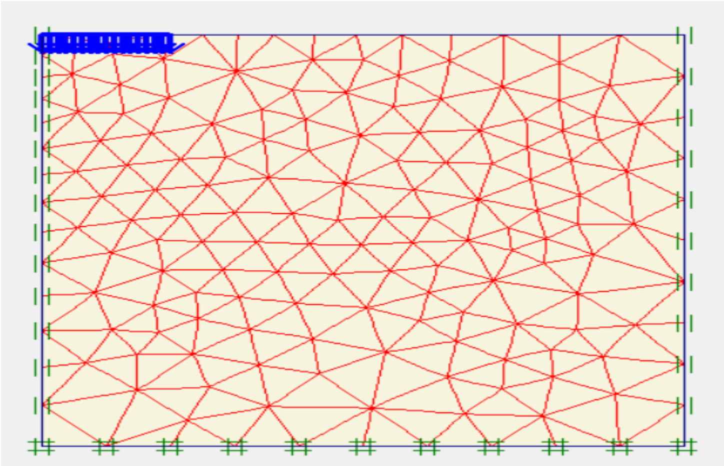

Figure 1. Finite element mesh used in the numerical analyses

Since the experiment was conducted on dry sand, groundwater pressure was not taken into account. The initial state of stress in the soil is produced by Ko procedure defined in the software. Vertical loading is applied as a prescribed dynamic displacement since the loading is applied gradually in the actual physical model tests. The loading of the foundation is depicted in Figure 2.

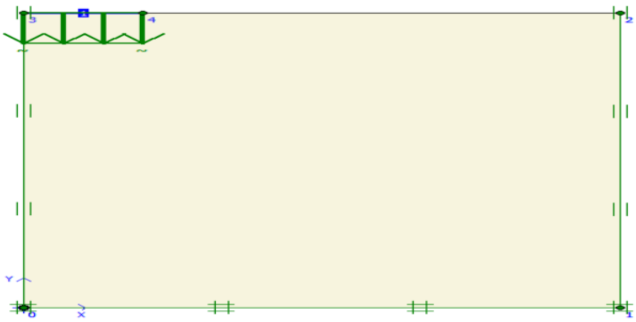

Figure 2. Plaxis2D dynamic loading pattern

Results

The behavior of the unwrapped stone columns and the geosynthetic reinforced stone columns were compared based on the data obtained from finite element analyses. The contribution of the geogrid and geotextile materials on the load bearing capacity of the single stone columns was evaluated with the help of the data obtained. The resulting load -displacement graphs are shown in Figure 3 for different stone column configurations.

The analyzes were continued until the failure of the stone column. Ultimate bearing capacities for unimproved and the improved soil models are given in the table below in MPa.

Table 1. Bearing capacity values

Without stone column	0.524 Mpa
Unreinforced Stone Column	0.956 Mpa
Geogrid	0.964 Mpa
G300	0.961 Mpa
G1000	0.989 Mpa

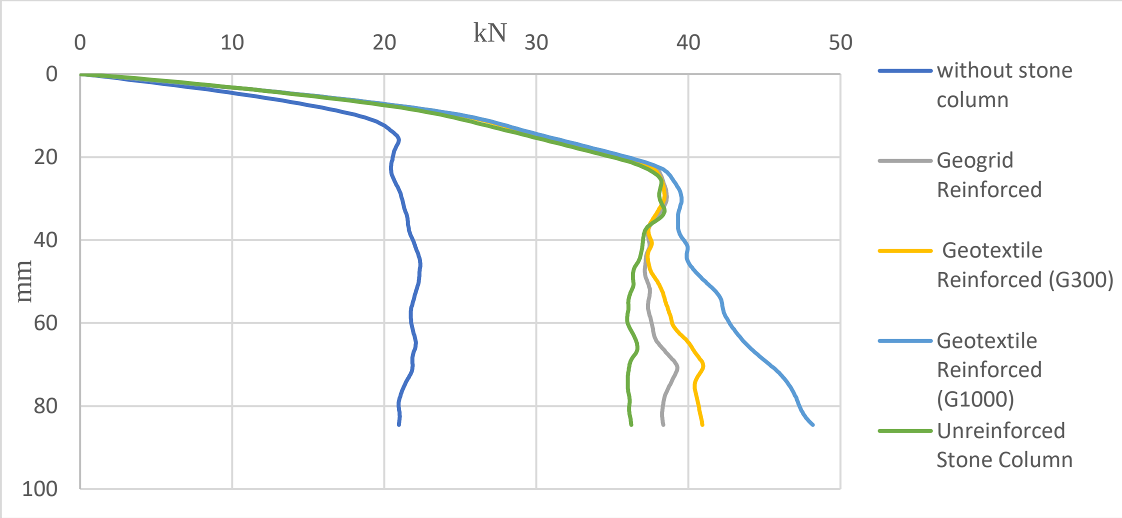

Figure 3. Comparison of the load - displacement behavior for different stone column configurations

According to the results obtained, it has been observed that the ultimate bearing capacity of the foundation soil increases when a stone column is installed. The confining effect of the geogrids and the geotextiles provides further capacity for the load bearing of the foundation soils. The presence of the stone columns also provides significant reduction for the foundation settlements. Finite element outputs indicate that the expansion of the column towards the sides occurred in the upper 2D and 3D portion of the stone column.

Modeling results indicate that the column expanded to the sides, and the sand around the column was compressed and swelled upwards with the effect of the loading. The average horizontal displacement values along the column surface, which have decreased due to the wrapping material applied around the column in this horizontal direction, are shown in Table 2.

Table 2. Horizontal displacement values.

Without stone column	28.23 mm
Unreinforced Stone Column	24.76 mm
Geogrid	23.18 mm
G300	22.05 mm
G1000	18.47 mm

Conclusion

According to the results of finite element analyses, the bearing capacity of the soil increases with the installation of the stone columns and it reaches to even higher values with the use of geotextile wrapping around the stone column body. The analyses data indicates that the stone column reaches its ultimate capacity at around 0.524 MPa. For the analyses where stone columns are present, ultimate bearing capacity reaches to a peak value of 0.956 MPa for the unreinforced stone column, 0.961 MPa in the stone column wrapped with G300 geotextile, 0.989 MPa in the stone column wrapped with G1000 geotextile and 0.964 MPa in the geogrid reinforce stone column.

The lateral expansional deformations of the stone column is also compared in this study. While the amount of lateral deformation on the column surface was 24.76 mm in the unwrapped stone column, this value decreased by 6.82% in the geogrid-wrapped system, 12.29% in the G300 geotextile-wrapped stone column, and 34.20% in the G1000 geotextile-wrapped stone column.

References

1. Alkhorshid, N. R., Araujo, G. L., Palmeira, E. M., & Zornberg, J. G. (2019). Large-scale load capacity tests on a geosynthetic encased column. *Geotextiles and Geomembranes*, *47*(5), 632-641.
2. Dural, A. (2019). Temel altında uygulanan geogridin oturma miktarına etkisinin incelenmesi, (Master's thesis, Toros University).
3. Xu, F., Moayedi, H., Foong, L. K., Moghadam, M. J., & Zangeneh, M. (2021). Laboratory and numerical analysis of geogrid encased stone columns. *Measurement*, *169*, 108369.
4. Zhang, L., Xu, Z., & Zhou, S. (2020). Vertical cyclic loading response of geosynthetic-encased stone column in soft clay. *Geotextiles and Geomembranes*, *48*(6), 897-911.
5. Miranda, M., Da Costa, A., Castro, J., & Sagaseta, C. (2017). Influence of geotextile encasement on the behaviour of stone columns: Laboratory study. *Geotextiles and Geomembranes*, *45*(1), 14-22.