iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** X **Month of publication:** October 2022

DOI: https://doi.org/10.22214/ijraset.2022.47147

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue X Oct 2022- Available at www.ijraset.com

Numerical Simulation of Stiffened Granular Pile

Himanshu Gupta[1], Jitendra Kumar Sharma[2], K. S. Grover[2]
[1]*Research scholar, Department of Civil Engineering, Rajasthan Technical University, Kota., India*
[2, 3]*Professor, Department of Civil Engineering, Rajasthan Technical University, Kota., India*

Abstract: Granular piles are suitable for increasing soft clay's strength and consolidation properties. Stone columns offer a practical, affordable solution for enhancing the earth and are crucial for stabilizing the soil. In order to carry higher shear stresses and prevent settlement, stone columns behaved as stiff elements, which enhanced the deformability and strength characteristics of the soft type of soil. The usage of granular piles has been shown to improve slope stability, increase bearing capacity, decrease differential and total settlements, decrease sand liquefaction, and lengthen settlement times. The present study studied the effect of stiffening on the granular pile using PLAXIS 2D. Mohr-Coulomb failure criterion was considered for the stone column, expansive soil, and granular material used for stiffening. The present study results are validated with the experimental results and are in good agreement. Numerical results show that stiffening in granular piles increases the load settlement response and stress transformation to a depth of granular pile and reduces the bulging.
Keywords: Granular pile, Bulging, Stiffened GP, Settlement.

I. INTRODUCTION

Granular piles are one of the ground improvement techniques that have been recognized as economically and environmentally friendly methods. They are called dense columnar elements made of granular material in weak soil that different methods can construct. The advantages of this technique are increasing the bearing capacity, reduction of the settlement, accelerating the consolidation due to the vertical drainage, improvement of slope stability, and mitigating liquefaction potential. Moreover, they can be constructed to support the foundations of buildings, embankments, and storage tanks. So far, several studies have been carried out on the behavior of improved ground with stone columns by various researchers using various methods such as experimental [1], [2], [3], [4] and numerical [5]. [6] conducted thorough experimental research by adjusting variables such as the shear strength of the soft type of clay, the distance between the columns, and the loading situation, on the behavior of a single column and a group of seven columns. In order to determine the stiffness of improved ground, tests are either performed with the complete equivalent area loaded or only one column loaded. Finite-element calculations were also performed using the 15-noded triangular elements using the PLAXIS software tool and concluded that the columns spaced more than thrice the diameter of the column do not greatly improve the issue. [7] hypothesized a mechanism for the failure of the granular trench, and expressions are developed for the supreme capacity of bearing footings like stabilized soils, analytically. For various combinations of the characteristics taken into consideration, bearing capacity factors are shown. It has been confirmed that granular trenches considerably strengthen deposits comprised of weak clay [8] examined how laboratory tests on model stone columns set in clay beds prepared in monitored conditions in a big tank for testing can improve the individual load capacity of stone columns by encasing them.

[9] offered an overview of ground improvement techniques for geotechnical engineering projects that use reinforced stone columns. The performance and evaluation of ground improvement utilizing reinforced stone columns for specific applications are given significant attention. The previous findings showed that the reinforced stone columns greatly enhance the soil's tension and bearing capacity. Critical values were examined and advised based on prior findings. [10] performed experimental tests on reinforced geotextile encased and unreinforced stone columns. The diameter of the column is taken as 60, 80, and 100 mm, and the ratio length to diameter is taken as 5. To study bearing capacity on reinforcement type, horizontal reinforced stone columns (HRSC) and vertical encased stone columns (VESC) were used. Tests and analysis show an increase in bearing capacity using both reinforcing horizontally and vertically. As well as strength of reinforcement increases bearing capacity. [11] study's major goal is to evaluate the effectiveness of vertically enclosing different stone column diameters under identical conditions.

Additionally, experiments on groups of stone columns with a diameter of 60 mm were conducted to examine the effects of the reference-loaded stone column's presence on neighbouring columns. According to the findings, adding vertical reinforcing material increases the stone column's bearing capacity. The stone column carrying capacity of VESC increases with increased reinforcing length and strength. Additionally, the columns' stress concentration ratio improves as well.

Moreover, the use of geotextiles reduces lateral bulging. [12] introduced a straightforward hypothesis to anticipate the behavior of soft ground supported by granular piles with a GB under and on top rigid foundation and, they recognized that position of the GB on the OGP further developed ground reduced the stress concentration factor on top of the granular pile and decreased the settlement. The present study investigated a numerical simulation of the stiffened granular pile on 'load-settlement response' with varying lengths of a stiffened portion of the granular pile from the top.

II. METHODS AND MATERIALS

The finite element model was created using 15 nodded triangular elements to increase the accuracy level of the data generation. In contrast, medium mesh was adopted for the global coarseness of the axisymmetric model. The axisymmetric model was adopted to simulate the stiffened granular pile with a diameter of 80 and 100 mm. The length of the granular pile is considered four and five times the diameter of the granular pile. However, the simulated soil model is only half due to the symmetry where the vertical axis passes through the centre of the stone column. Based on [13], the boundary effect will be negligible when the depth and width of the numerical model are four times larger than the footing diameter (4D). In this study, the model boundary was assigned larger than 4D in vertical and horizontal directions to prevent the results from being influenced by the geometry. Besides, the model's boundary conditions were fully restrained at the model's base and controlled horizontally along the vertical boundaries. A Uniform downward prescribed displacement of 50 mm was applied on a rigid circular steel plate. The rigid plate diameter was two times the granular pile's diameter, and nodal points were selected at the centre of the loading surface to measure the settlement and respective stress.

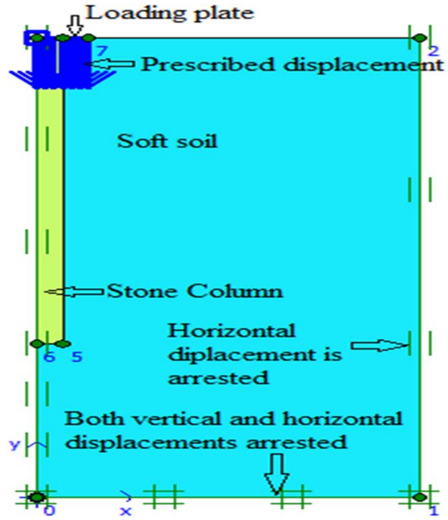

Fig. 1. Soil parameters

The granular pile was stiffened using the higher grade of granular materials as compared to soft clay and granular pile materials, as shown in Table 1. The granular pile was stiffened for 1.5D, 2D, and 3D from a top portion of the granular pile, where D is the diameter of GP. Mohr-Coulomb failure criterion and drained behavior were considered for all the materials.

Table 1. Properties of soft clay and granular materials

Parameter	Soft Clay	Granular pile	Stiffened material	Unit
γ_{unsat}	15.50	14.30	15.5	kN/m^3
γ_{sat}	19.10	16.90	15.5	kN/m^3
E	500	40500	61000	kN/m^2
ν	0.45	0.3	0.3	---
C	6.5	0	0	kN/m^2
Φ	0	46	30	^{0}
Ψ	0	7	4	^{0}

III. RESULT AND DISCUSSION

The results obtained in this analysis have been validated with those of [13]. The agreement has been closed, as depicted in Fig. 2. The 100mm dia. of GP and length to dia. ratio 5 was used for the validation. The modulus of elasticity was used as 50 kPa for soft soil.

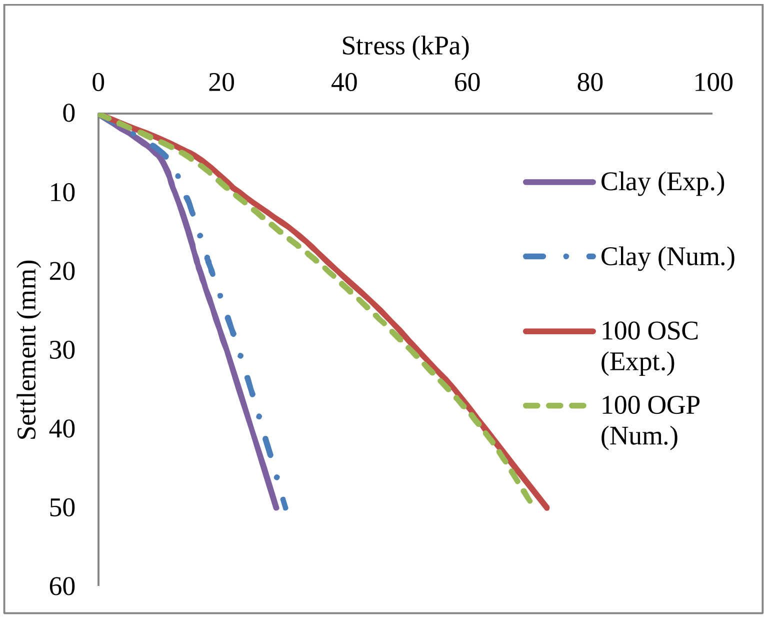

Fig. 2. Validation of results

A. *Influence of Stiffening on a Granular Pile*

1) *For 80mm*

The common kind of failure of the granular pile is due to bulging, and to avoid such type of failure, encasement/stiffening can be used. Even though numerous specialists have done examinations on the encasement length of GESC, there is no way from about the ideal length of encasement to utilize this procedure economically. Investigation on a single GESC indicated that the ideal encasement length is 2D – 4D, where D is the diameter of the GESC Murugesan and Rajgopal (2006). In this present study effect of the length of stiffening on load-displacement response is carried out for 1.5D, 2D and 3D, where D is the diameter of the granular pile.

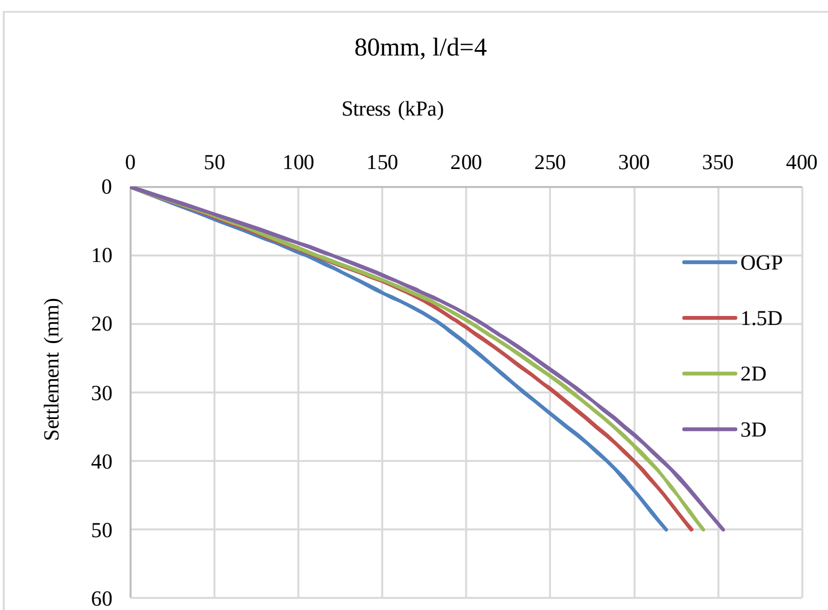

Fig. 3 Effect of stiffening on granular pile 100 mm dia. and L/D = 4

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue X Oct 2022- Available at www.ijraset.com

For D = 80 mm from Fig. 3 is observed that, the stress for (L/D =4, 80 mm dia. GP) at 50 mm prescribed settlement is 319 kN/m^2, 334.15 kN/m^2, 341.16 kN/m^2, and 353 kN/m^2 for OGP, 1.5D, 2D and 3D respectively. Thus the respective capacities are 2.04, 2.14, 2.18 and 2.26 times the OGP soft soil.

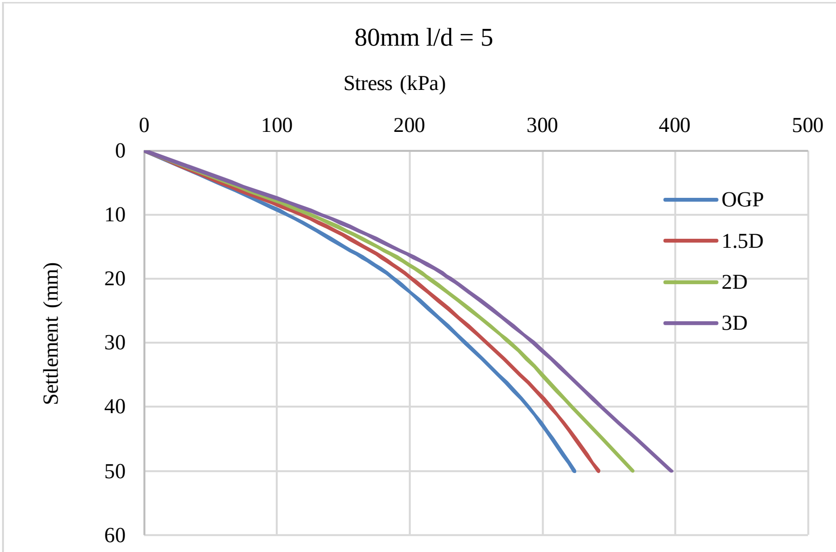

Fig. 4 Effect of stiffening on granular pile 100 mm dia. and L/D = 4

For D = 80 mm from Fig. 4 is observed that, the stress for (L/D =5, 80 mm dia. GP) at 50 mm prescribed settlement is 324 kN/m^2, 342.00 kN/m^2, 368.00 kN/m^2, and 397.1 kN/m^2 for OGP, 1.5D, 2D and 3D respectively. Thus the respective capacities are 2.07, 2.19, 2.36 and 2.54 times the OGP soft soil.

From Fig. 3 and 4, it can conclude that the stiffening of the granular pile at the top portion is more beneficial to increase the bearing capacity of the granular pile. As the length of stiffening increases, load settlement response also get increases and more loads transferred to the base of the granular pile. Also, it is observed that the bulging of the pile reduces in case of provision of stiffening.

2) For 100 mm

For D = 100 mm from Fig. 5 is observed that, the stress for (L/D =4, 100 mm dia. GP) at 50 mm prescribed settlement is 337.54 kN/m^2, 349.09 kN/m^2, 365.57 kN/m^2, and 384.1 kN/m^2 for OGP, 1.5D, 2D and 3D respectively. Thus the respective capacities are 2.16, 2.23, 2.34 and 2.46 times the OGP soft soil.

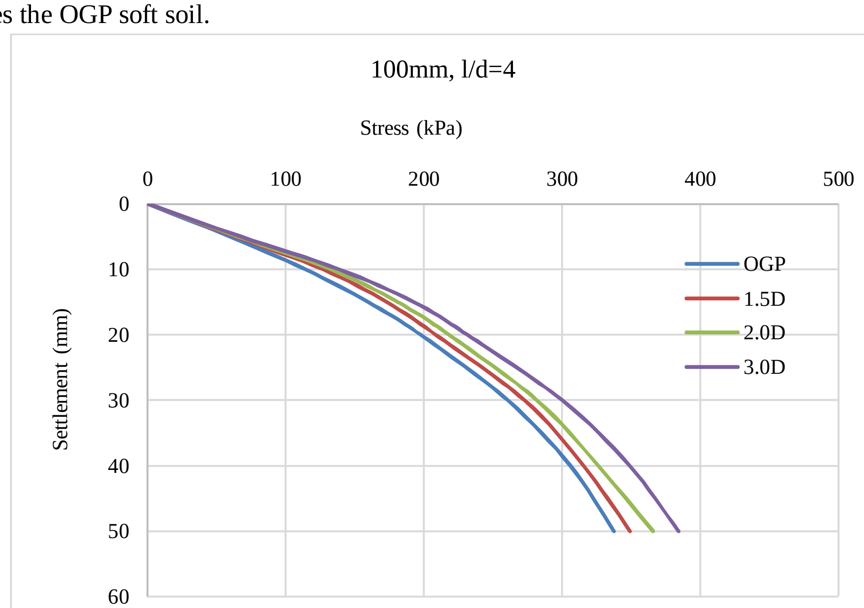

Fig. 5 Effect of stiffening on granular pile 100 mm dia. and L/D = 4

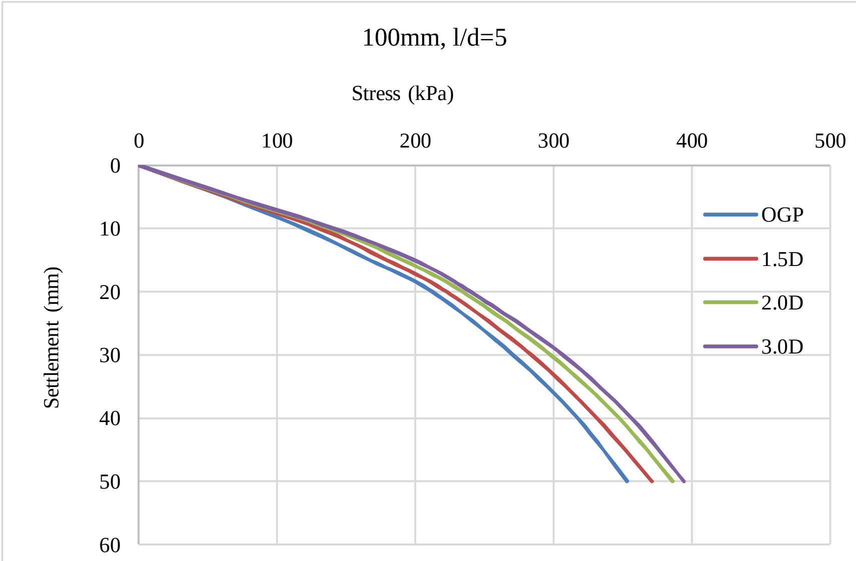

Fig. 6 Effect of stiffening on granular pile 100 mm dia. and L/D = 4

For D = 100 mm from Fig. 6 is observed that, the stress for (L/D =5, 100 mm dia. GP) at 50 mm prescribed settlement is 353.54 kN/m^2, 371.09 kN/m^2, 385.57 kN/m^2, and 394.1 kN/m^2 for OGP, 1.5D, 2D and 3D respectively. Thus the respective capacities are 2.26, 2.38, 2.47 and 2.52 times the OGP soft soil. From Fig. 5 and 6, it can be concluded that the stiffening length increases load settlement response, and more loads are transferred to the base of the granular pile. Also, it is observed that the bulging of the pile reduces in case of provision of stiffening. It happens due to the provision of a stiffer portion at the top portion of the granular pile.

IV. CONCLUSION

1) The degree of lateral bulging decreases in stiffened granular piles compared to the ordinary granular pile due to getting more stiffness at the top of granular pile.
2) The load settlement response of stiffened granular piles increases as the length of the stiffened portion of the top of the granular pile increases.

REFERENCES

[1] J. N. Nazariafshar, M Ghazavi, Experimental studies on bearing capacity of geosynthetic reinforced granular piles. Arab J. Sci. Eng. 2014;39(3):1559–1571.https://doi.org/10.1007/s13369-013-0709-8
[2] N. Mehrannia, F. Kalantary, N. Ganjian, Experimental study on soil improvement with granular piles and granular blankets. J. Cent. South University 2018; 25:866−878. https://doi.org/10.1007/s11771-018-3790-z
[3] J. Nazariafshar, N. Mehrannia, F. Kalantary, Bearing Capacity of Group of Granular piles with Granular Blankets. Int. J. Civil Eng. 2019;17, 253–263. https://doi.org/10.1007/s40999-017-0271-y
[4] J. Nazari Afshar, M. Ghazavi, A simple analytical method for calculation of bearing capacity of stone-column. Int. J. of Civil Eng. 2014;12(1):15–25.
[5] M. Han,M. A. Gabr, Numerical Analysis of Geosynthetic-Reinforced and Pile-Supported Earth Platforms over Soft Soil. J. of Geotechnical and Geoenvironmental Eng. 2002;128(1). https://doi.org/10.1061/(ASCE)1090-0241(2002)128:1(44
[6] A. Ambily, S. R. Gandhi, Behavior of granular piles based on experimental and FEM analysis. J. Geotech Geoenviron Eng. 2007;133(4):405–415.https://doi.org/10.1061/(ASCE)1090-0241(2007)133:4(405)
[7] M. R. Madhav,R. P. Vitkar, Strip footing on weak clay stabilized with a granular trench or pile. Canadian Geotechnical J. 1978;15(4):605–609. https://doi.org/10.1139/t78-066
[8] S. Murugesan, K. Rajagopal, Studies on the behavior of single and group of geosynthetic encased granular piles. J. of Geotechnical Geoenvironmental Eng. 2009;136(1):129–139https://doi.org/10.1061/(ASCE)GT.1943-5606.0000187
[9] H. Niroumand, A. K. Khairul, S. Y. Chong, Soil Improvement by Reinforced Granular piles Based on Experimental Work. Edge. 2011;16:1477-1499
[10] M. Ghazavi, J. Nazariafshar, Bearing capacity of geosynthetic encased granular piles. Geotextiles and Geomembranes. 2013; 38: 26–36. https://doi.org/10.1016/j.geotexmem.2013.04.003
[11] J. Shahu, M. Madhav, S. Hayashi. Analysis of soft ground-granular pile-granular mat system. Computers and Geotechnics. 2000; 27:45-62. https://doi.org/10.1016/S0266-352X(00)00004-5
[12] X. Tan, M. Zhao, W. Chen, Numerical simulation of a single granular pile in soft clay using the discrete element method. Int. J. of geomech. 2018;18(12):0401817-https://doi.org/10.1061/(ASCE)GM.1943-5622.0001308
[13] M. M. Rezaei, S. H. Lajevardi, H. Saba, A. Ghalandarzadeh, E. Zeighami, Laboratory study on single columns reinforced with steel bars and discs. Int. J. of Geosynth. and Ground Eng. 2019;5:2.