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A REVIEW ON SETTLEMENT BEHAVIOR OF SHELL FOOTINGS ON GEOCELL REINFORCED FOUNDATION BEDS

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Abstract – *Geocells are a type of geosynthetic polymer manufactured in the shape of 3D interconnected cells, can be used as a reinforcement to the soil to enhance the behaviour of soil. Geocell helps in imparting lateral confinement to the soil, increases the stiffness and strength, and reduces the surface permanent deformation. This paper reviews the performance of shell footing resting on a geocell reinforced foundation bed, the effect of the influence of several layers of geocell imparted on the foundation soil. The results of the study indicates that conical footing gives better performance in considering the settlement and bearing capacity of the soil. As increasing the layers of geocell in weak soil, the settlement can be easy reduced.*

Key Words: Geocell, bearing capacity, settlement

1. INTRODUCTION

The use of shells in foundation engineering came into existence in the 1950s. Shell foundations are a typical kind of structure that is capable of transferring the foundation load to the soft soil in a much wider area [4]. There are different kinds of shell footings are used like conical shell footing, pyramidal shell footing, etc. Many researchers have conducted the influence of shell footings in cohesive soil. And the result shows that shell footing is capable of carrying the loads that are acting on the foundation to the soft soil in a much wider area. Adding an edge beam at the bottom side of the shell footing increases the bearing capacity of the soft soil. Conical shell footing increases the ultimate bearing capacity of the soft soil and reduces the settlement behavior compared to the conventional flat foundation. Geocell-induced conical shell foundation shows better results compared with the unreinforced soil [8].

When a significant load is applied, conventional flat footings resting on weak soil create excessive settling. Shell footings, on the other hand, boost the soil bearing capacity and transfer heavy loads through weak soil. Conical shell footing performs better than pyramidal shell footing and shows an 80 percent reduction in settlement when the weak soil is strengthened or reinforced with geocell layers. With the addition of a geocell layer to the weak soil, the performance of the weak soil can be improved. This aims in boosting the foundation bed bearing capacity as well as its settlement behavior [17] [7]. Geocell is three-dimensional in shape, combined together to form a cellular-like network. The geocell layers are infilled with soil improving the bearing capacity, stiffness, and shear strength of the weak soil. Fig.1 shows the geocell filled with soil. They are manufactured from a polymer called high-density polyethylene. The cellular-like structure for the geocells gives all-round confinement to the infill soil. The cells or the pockets of the geocells are filled with locally available compacted soil as in the form of different layers [21].

Due to its three-dimensional shape, the geocell helps in distributing the vertical pressure acting on the soil to a larger area under the geocell layer [18]. Geocells are developed by the US army corps for military application in the 1970s to improve the performance of poorly graded soil. The cells of the geocell pockets are filled with locally available materials, like sand, finely graded aggregate, and soil. A settlement reduction of about 78% resulted in the case of geocell pockets infilled with aggregate. Moreover, soil and sand can also be used as the infill material for geocell, and the test result shows a settlement reduction of 73% and 70%. [11]. Introducing stone columns and geocell mattresses in the soft soil also enhances the performance of the soil. The stone column has high stiffness and strength, due to that they are more capable of transferring the load to the soft foundation soil [3].

Figure 1: Geocell filled with sand

2. ANALYSIS OF REINFORCED FOUNDATION BED

Foundation bed reinforced with geocell was analyzed using PLAXIS 3D software. A quarter of the portion is considered for better accurate result. A geocell of 24 cm x 20 cm x 15 cm was used. And the effect of conical and pyramidal shell footing reinforced with geocell layer was analyzed. The model parameters are summarized in Table 1 and Table 2.

Table 1: Parameters of geocell reinforced foundation bed

Parameters	Pyramidal	Conical
Number of elements	9248	7822
Core sand		
Young's modulus, E (kN/m^2)	11000	11000
Poisson's ratio, ν	0.3	0.3
Cohesion, c (kPa)	0.35	0.35
Friction angle, ϕ (°)	37	37
Dilatancy angle, Ψ (°)	7	7
Unit weight, γ (kN/m^3)	17.6	17.6
Bed sand		
Young's modulus, E (kN/m^2)	11000	11000
Poisson's ratio, ν	0.3	0.3
Cohesion, c (kPa)	0.35	0.35
Friction angle, ϕ (°)	37	37
Dilatancy angle, Ψ (°)	7	7
Reference depth	0	0
Unit weight, γ (kN/m^3)	17.6	17.6

Table 2: Parameters of geocell reinforced foundation bed

Parameters	Pyramidal/ Square	Conical/ Circular
No. of elements	14540/14359	14686/14523
Footing		
Material model	Linear elastic	
Young's modulus	1.61 x 1010	
Poisons ratio, ν	0.25	
Width, D/B (mm)	1.60	
Geocell		
Material model	Isotropic elastic	
Axial stiffness (Kn/m^2)	300	
Cell size (mm)	240 x 200	
Cell height (mm)	150	
Embedded depth	20	

The main difference between the shell foundation and a conventional flat foundation in reinforced soil is that the shell footing improves the bearing capacity of the foundation bed as well as transfers the load to a much wider area. The geocell used in the study is of size 24cm x 20cm x 15 cm and is inserted at a depth of 2cm below the top surface of the soil. The foundation has a base size of 100 mm x 100 mm for pyramidal footing and conical footing has a base diameter of 100 cm. since the model has a symmetric dimension, a quarter of the portion is used for the analysis. The pyramidal footing having a number of elements equal to 35539 and the conical footing has a number of elements equal to 36100. Fig.2 shows the model of geocell reinforced conical and pyramidal shell footing.

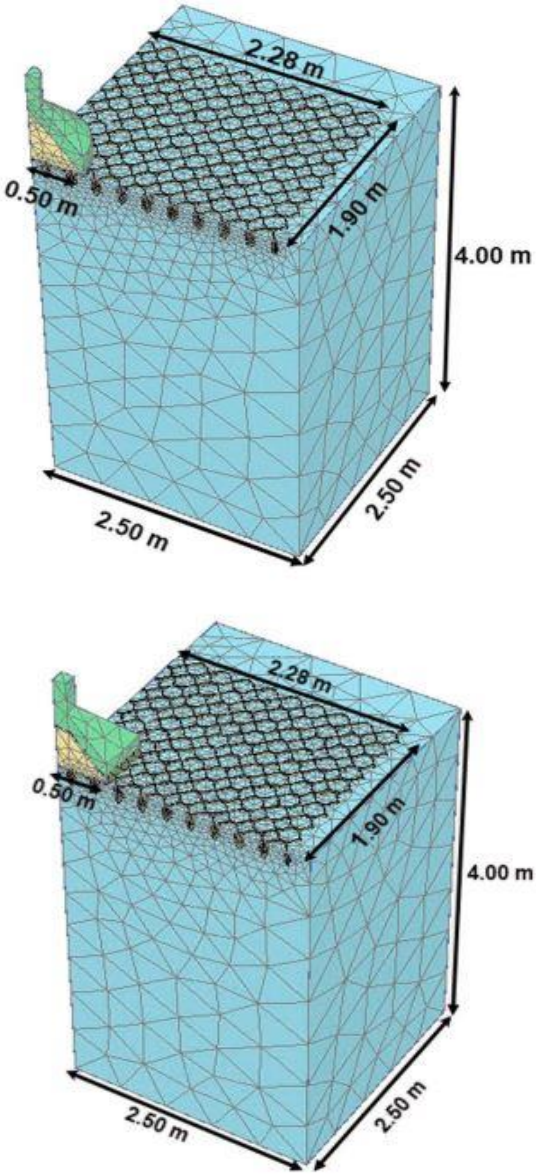

Figure 2: Geocell reinforced conical and pyramidal shell footing

The validation of the above model shows a significant variation in the settlement behavior for the reinforced and unreinforced cases. The graphs below show the settlement behavior for the reinforced and unreinforced beds shown in fig.3 and fig.4. The validation and corresponding graph indicate that, a reduction in settlement for the soil which is reinforced with geocell. A foundation bed reinforced with geocell helps in improving the bearing capacity of the soil. The higher increase in the bearing capacity of the geocell can be achieved by widening the depth of the foundation soil bed. And there shows a significant reduction in settlement for the conical shell footing compared with the pyramidal shell footing. The conclusion of this research is that there shows an improvement in the bearing capacity of the soil and a reduction in settlement with the addition of geocell for the weak soil for conical shell footing compared with the pyramidal shell footing. The reduction in settlement for the conical and pyramidal shell footings are 80% and 74% [1].

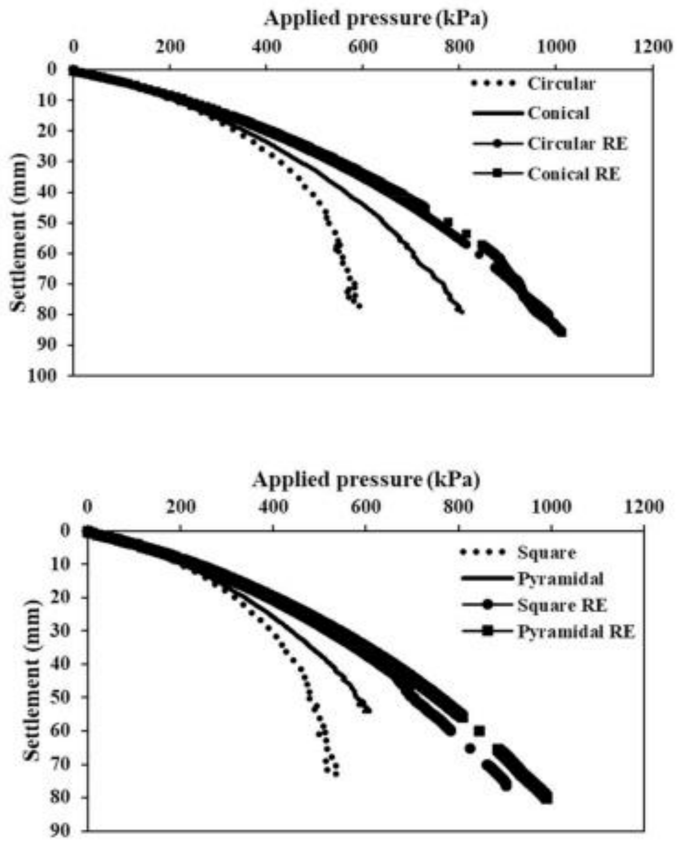

Figure 3: Applied pressure v/s settlement curve for reinforced and unreinforced foundation bed

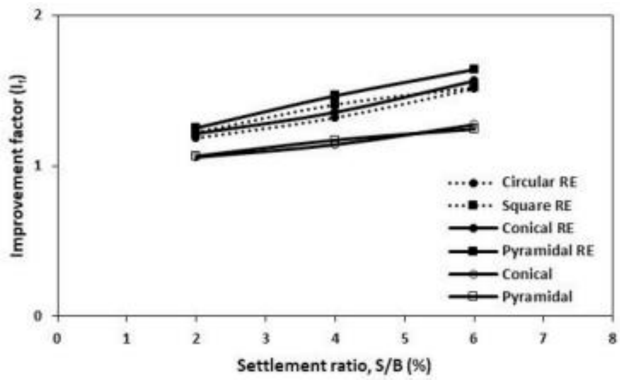

Figure 4: Settlement ratio v/s improved factor for reinforced and unreinforced foundation beds

3. EFFECT OF INFILL MATERIALS

Normally geocell pockets are filled with sand or finely graded aggregate. Many researchers have conducted experiments on geocell filled with sand, aggregate, and river sand. The test results obtained from the experiment were that the geocell pockets filled with sand show better performance under static loading conditions. And geocell pockets filled with aggregate are more effective under dynamic loading conditions. Researchers also conducted experiments on a mixture containing sand and tyre scraps, and the result obtained affected the performance of the geocell [11].

3.1 Experimental set up

Hedge and Sitharam conducted an experiment test regarding the soil reinforced with geocell. 900mm x 900mm x 600mm test tank is used for the preparation of the foundation bed. 150mm sides rigid steel plate with 20mm thickness was used as the footing, ie. Square footing. With the help of epoxy glue, the base of the footing was made rough by coating a layer of sand. Loading is applied with the help of a hydraulic jack. The applied load is measured with the help of the proving ring. The model test setup is shown in fig.5 .

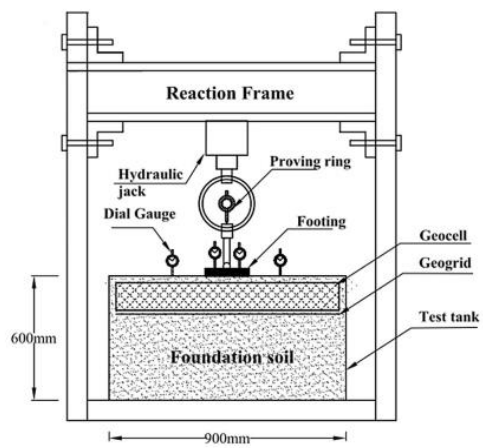

Figure 5: Model test setup

3.2 Materials used

The foundation bed was prepared with silty clay of medium compressibility. The specific gravity of the soil was 2.66. The soil was having a plastic limit and liquid limit of 40% and 19%. The geocell was made of polyethylene material and had a density of 0.95g/cm3. The dimension of the geocell was 250mm in length, 210mm in width, and 150mm in thickness. Geocell is having an ultimate strength of 20 kN/m. A geogrid of 35mm x 35mm aperture size geogrid was used at the base of the geocell which is made from a material called polypropylene with an ultimate tensile strength of 20 kN/m. For the test purpose, locally available red soil, aggregate and sand were used. The chosen red soil was having a liquid limit and plastic limit of 33% and 16%. From the direct shear test, the sand was found to be a friction angle of 35°. Fig.6 shows the tensile load strain of geocell and geogrid. Table 3 shows the properties of geocell and geogrid [10].

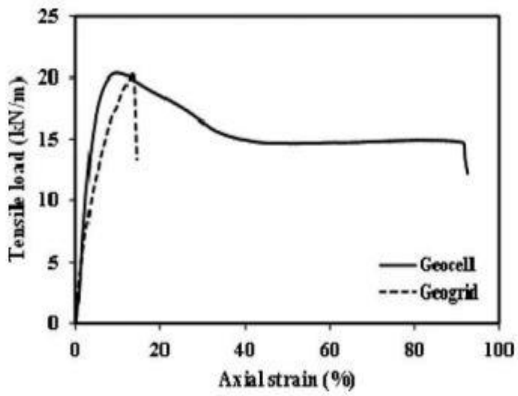

Figure 6: Tensile load strain behaviour of geocell and geogrid

Table 3: Properties of geocell and geogrid

Parameters	Quality
Geocell	
Polymer	Polyethylene
Cell size (mm)	250 x 210
No. of cells/m^2	40
Cell depth (mm)	150
Strip thickness	1.53
Cell seam strength (N)	2150(±5%)
Density (g/cm^2)	0.95(±1.5%)
Short term yield strength (kN/m)	20
Geogrid	
Polymer	Polypropylene
Aperture size (MD x XMD)	35 x 35
Ultimate tensile strength (kN/m)	20
Mass per unit area (g/m^2)	220
Shape of aperture opening	Square

3.3 Bearing pressure settlement curve

Fig.7 shows the bearing pressure variation curve corresponding to different infill materials. And the result from the graph shows that there is a failure for the unreinforced foundation bed. And there shows no failure for the foundation bed reinforced with geocell material corresponding to different infill materials. Geocell directly transfers the footing load to the foundation soil. Since there was no failure occurred to the footing, at S/B = 45% the tests were stopped. Geogrid was placed below the geocell layer, this helps in strengthening the clayey bed and restricts the movement of the soil. Aggregate shows better performance among the three infill materials. Aggregate is having higher friction compared to red soil and sand [11] [18].

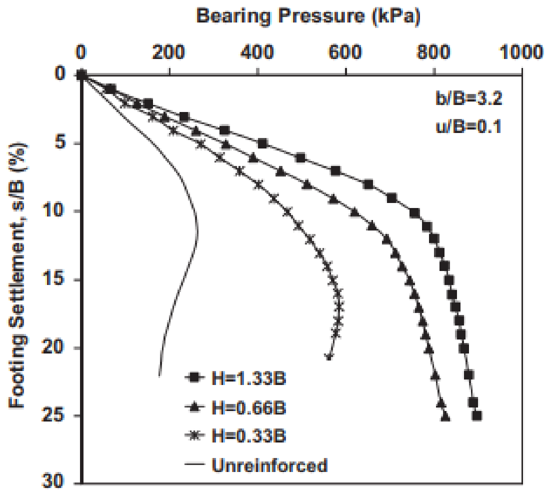

Figure 7: Footing settlement v/s bearing capacity curve for reinforced and unreinforced foundation

4. SIZE AND SHAPE OF GEOCELL

The circular shape geocell shows better performance compared to other shapes. Circular-shaped geocell increases the bearing capacity of the weak foundation beds and shows higher stiffness than other shapes. Based on the elastic modulus of the geocell layer, the performance of the geocell reinforced foundation bed can be enhanced [11]. Increasing the number of layers of geocell also increases the performance of the foundation soil [20]. In order to get better performance for the geocell reinforcement, the width of the footing selected should be 13 – 27 times the medium grain size of the material [5]. Increasing the height and width of the geocell and increasing the number of layers of geocell in the weak soil, helps in increasing the characteristics of the geocell, the ultimate bearing capacity, and reduction in the settlement of the soil [14]. Different shapes of geocells are available in the market like circular, box-type, elliptical, etc. Sanat, Jie, Dov, Robert, and Izhar conducted an experimental investigation on an elliptical-shaped geocell having a dimension of 260mm x 185 mm. The test result obtained was that, the elliptical shape was changed to an almost circular shape with a dimension of 235mm x 200mm. Fig.8 shows the change in the shape of the geocell. Then they conducted an experiment on circular-shaped geocell having a diameter of 205mm. and the test obtained was, circular-shaped geocell implementation on weak soil improves the performance of the foundation bed [17].

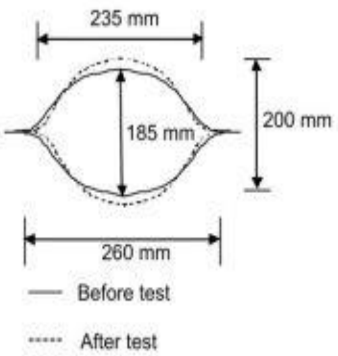

Figure 8: Change in shape of geocell

When the geocell is laid on a crushed stone bed, there shows an increased bearing capacity of the soil [15]. A combination of geocell and geogrid shows better results for the soft soil than implementing geocell alone [12]. Increasing the height of the geocell increases the bearing capacity and performance of the geocell reinforced foundation bed. For the unreinforced and reinforced bed, decreasing the thickness if the geocell increases the bearing capacity of the foundation soil. Geocell of section thickness 120mm shows ultimate bearing capacity and stiffness of 1.9 and 1.6. And for geocell section thickness of 170mm, it shows an ultimate bearing capacity and stiffness of 1.6 and 1.3 [17]. Geocell offers greater apparent strength to non-cohesive soil also [19].

5. EFFECT OF FOOTING

Geocell offers better performance for shallow foundation [2]. Increasing the value of the coefficient of variation and decreasing the value of correlation length in the horizontal and vertical direction, shows a significant increase in the randomness and spatial variation with a reduction in load-carrying capacity. If the value of soil friction increases, the soil dilatancy can be found significant. Increasing the dimension of the footing helps in increasing the bearing capacity as well as reducing the settlement behavior of the weak soil if the soil is reinforced with geocell and geogrid [3]

CONCLUSION

With the inclusion of geocell and shell footing in the weak soil, there is a significant increase in the bearing capacity and reduction in the settlement ratio under cyclic load. Increasing the height and width of the geocell and increasing the number of layers of geocell in the weak soil, helps in increasing the characteristics of the geocell, the ultimate bearing capacity, and reduction in the settlement of the soil. Reinforcing the soil with geocell increases the strength of cohesive soil as well as non-cohesive soil. When the geocell is laid on a crushed stone bed, there shows an increasing bearing capacity of the soil. To get better performance for the geocell reinforcement, the width of the footing selected should be 13 – 27 times the medium grain size of the material. Load-carrying capacity is one of the main factors that affect the randomness and spatial variation in soil.

REFERENCES

[1] A. Ari and G. Misir, "Three-dimensional numerical analysis of geocell reinforced shell foundations", Geotextiles and Geomembranes, vol. 49, Feb. 2021, pp 963-975

[2] P. F. Dehkordia, M. Ghazavib and U. F. A. Karim, "Bearing capacity-relative density behavior of circular footings resting on geocell-reinforced sand", Taylor & Francis, 2021,

doi: https://doi.org/10.1080/19648189.2021.1884901

[3] K. Halder and D. Chakraborty, "Influence of soil spatial variability on the response of strip footing on geocell-reinforced slope", Computers and Geotechnics, vol. 122, 2020, pp 103533

[4] M. A. Rahman, "Lateral loading resistance for shell foundations", Taylor & Francis, vol. 16, 2020, pp 27–241

doi: https://doi.org/10.1016/j.geotexmem.2019.03.003

[5] Gh. T. Mehrjardia,, R. Behrad, S.N. M. Tafreshi, "Scale effect on the behavior of geocell-reinforced soil", Geotextiles and Geomembranes,, vol. 47, April 2019, pp 154-163

[6] H. A. Sawsan, A. S. Madhat and M. A. Shahad, "Behavior of Pyramidal Shell Foundations on Reinforced Sandy Soil", Geotechnical Geological Engineering, Dec. 2018, doi: https://doi.org/10.1007/s10706-018-00767-z

[7] W. Mohamed and P. Austrell, "A comparative study of three onshore wind turbine foundation solutions", Computers and Geotechnics, vol. 94, 2018, pp 46-57

[8] S. N. M. Tafreshi, T. Shaghaghi, Gh. T. Mehrjardi, A.R. Dawson, and M. Ghadrdan, "A simplified method for predicting the settlement of circular footings on multi-layered geocell-reinforced non-cohesive soils", Geotextiles and Geomembranes, 2015, pp 1-13

[9] A. Hegde and T.G. Sitharam, "3-Dimensional numerical modelling of geocell reinforced sand beds", Geotextiles and Geomembranes, 2014, pp 1-11

[10] A. M. Hegde and T.G. Sitharam, "Effect of infill materials on the performance of geocell reinforced soft clay beds", Taylor & Francis, 2014,

doi: http://dx.doi.org/10.1080/17486025.2014.921334

[11] T.G. Sitharam and A. Hegde, "Design and construction of geocell foundation to support the embankment on settled red mud", Geotextiles and Geomembranes, vol. 41, 2013, pp 55-63

[12] S. K. Dash and M. C. Bora, "Improved performance of soft clay foundations using stone columns and geocell-sand mattress", vol. 41, 2013, pp 26-35

[13] S. N. M. Tafreshi and A. R. Dawson, "A comparison of static and cyclic loading responses of foundations on geocell-reinforced sand", Geotextiles and Geomembranes, vol. 32, 2012, pp 55-68

[14] L. Zhang, M. Zhao, C. Shi and H. Zhao, "Bearing capacity of geocell reinforcement in embankment engineering", Geotextiles and Geomembranes, vol. 28, 2010, pp 475-482

[15] S. N. M. Tafreshi and A.R. Dawson, "Behaviour of footings on reinforced sand subjected to repeated loading – Comparing use of 3D and planar geotextile", Geotextiles and Geomembranes, vol. 28, 2010, pp 434-447

[16] S. K. Pokharel, J. Han, D. Leshchinsky, R. L. Parsons and Izhar Halahmi, "Investigation of factors influencing behavior of single geocell-reinforced bases under static loading", Geotextiles and Geomembranes, vol. 28, 2010, pp 570-578

[17] S. Sireesh, T.G. Sitharam and S. K Dash, "Bearing capacity of circular footing on geocell–sand mattress overlying clay bed with void", vol. 27, 2009, pp 89-98

[18] S. K. Dash, N.R. Krishnaswamy, K. Rajagopal, "Bearing capacity of strip footings supported on geocell-reinforced sand", Geotextiles and Geomembranes, vol. 19, 2001, pp 235–256

[19] K. Rajagopal, N.R. Krishnaswamy and G. Madhavi Latha, "Behaviour of sand confined with single and multiple geocells", Geotextiles and Geomembranes, vol. 17, 1999, pp 171—184

[20] R. J. Bathursta and A. Knight, "Analysis of Geocell Reinforced-soil Covers Over Large Span Conduits", Computers and Geotechnics, vol. 22, No. 3/4, pp. 1998, pp 205-219