# Performance of geocell reinforced soil beds

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**Abstract.** The usage of geosynthetic material as ground improvement technique has gained its widespread approval due to its quality of construction, simplicity and time-saving parameter. This study focuses on the use of geocells made from geotextiles as a reinforcement material for reducing settlement. A structure of these cells interconnected by joints to form a cellular network could be used for the confinement of soil. This paper represents results of laboratory model tests on square footings supported by geocell – reinforced soil beds such as sand and red soil. The influence of varying parameters such as depth to the first layer of geocell, the width of geocell, the height of geocells and the density of soil were studied. It was found that the load-carrying capacity of the foundation can be significantly enhanced by the inclusion of geocells and also the configuration and arrangement of geocell reinforcement has a pivot role in the performance.

**Keywords:** Geocell, Model tests, Sand, Red soil.

## 1 Introduction

Foundation is a substructure that transmits structural loads to the earth in such a way that the supporting soil not overstressed and doesn't undergo deformation that causes excessive settlement of the structure. Construction of foundation over weak soil is a commonly encountered problem by geotechnical engineers. Because low shear strength of soil will result in excessive settlements and bearing capacity failure. In such situations, either select a foundation like pile, raft, etc. or select ground improvement techniques. The use of geosynthetics as ground improvement technique offers advantages such as space-saving, environmental sensitivity, material availability, technical superiority, higher cost savings and less construction time (Dharmesh lal et al. 2017). Geocell is one of the various recent forms of reinforced soil used in civil engineering construction. The term "geocell" refers to polymeric, honeycomb-like cellular material. A structure of these cells interconnected by joints to form a cellular network could be used for the confinement of soil. Geocells could be either manufactured on-site using planar geosynthetics, preferably using geogrids or geotextiles, or could be purchased readymade. These geocells completely encase the soil and provide all-round confinement and thus helps in reducing vertical and lateral deformations of the foundation soil to a large extent besides increasing the bearing capacity of the foundation soil (Madhavi Latha, G. et al. 2009).

The present study focuses on the use of geocells made from geotextiles as a reinforcement material.

# 2 Experimental program

Laboratory plate load tests were conducted to evaluate the degree of improvement in introducing geocell reinforcement on the sand and red soil.

## 2.1 Materials used

**Soil.** Local river sand and red soil were used in the study. River sand was collected from the Manali River, Kanayannur Taluk, Thrissur and red soil from Thejus Engineering college campus, Talappilly Taluk, Thrissur. The geotechnical properties of sand and red soil are given in table 1.

**Table 1.** Geotechnical Properties of soil

| Properties | Results | |
|---|---|---|
| | Sand | Clay |
| Specific gravity | 2.62 | 2.71 |
| Percentage of gravel-sized particle (%) | 0 | 0 |
| Percentage of sand-sized particle (%) | 89 | 41 |
| Percentage of clay-sized particle (%) | 11 | 59 |
| Liquid Limit (%) | - | 48 |
| Plastic Limit (%) | - | 22 |
| Shrinkage Limit (%) | - | 16 |
| Soil Classification | SW | CI |
| Maximum Density (kN/m$^3$) | 17.26 | 15.15 |
| Minimum Density (kN/m$^3$) | 15.19 | 12.97 |
| Friction angle for dense soil (in degrees) | 42 | 39 |
| Friction angle for loose soil (in degrees) | 40 | 35 |

**Geocells.** The woven polypropylene geotextile of the GF04 series used for manufacturing geocells was procured from V. M. Polytex Private Limited, Kanjikode, Palakkad, Kerala. Geocells were made by cutting geotextiles to requisite length and height from full rolls and stitched them to obtain a honeycomb-like structure. The pocket-size of the geocell used for the entire series of experiments was kept as 30 mm. Fig. 1. Shows the materials used for the study and Table 2 shows the properties of geotextile which is obtained from manufactures manual. Grab tensile strength test was used to determine the tensile strength and elongation.

(a) (b) (c)

**Fig. 1.** Materials used in the study (a) Sand (b) Red soil (c) Geocell

**Table 2.** Properties of geotextile (V. M. Polytex Private Limited)

| Properties | | Value |
|---|---|---|
| Fabric size | | 2.5 m |
| Tensile strength | Warp | 20 kPa |
| | Weft | 20 kPa |
| Elongation | Warp | 24% |
| | Weft | 25% |
| Weight | | 17.5 kPa |
| Mesh | Warp | 394 No. per m |
| | Weft | 394 No. per m |
| Color | | Milk white |

### 2.2 Laboratory testing

**Sample preparation.** To achieve a uniform density of soil in foundation beds, rainfall technique or sand raining technique was used to fill the test tank. The height of fall to achieve the required dry density was determined by performing a series of trials with different height of fall. The height of fall for different density condition was obtained as follows: for loose condition = 0.2 m, medium dense condition = 0.3 m and dense condition = 0.35 m.

**Reinforcement layout.** All the tests were conducted at a single layer of geocell reinforcement. The pocket size of the geocell was kept as 0.03 m throughout the study. The parameters varied were depth to the top of reinforcement (u), the width of reinforcement (b) and thickness of reinforcement (h). The reinforcement layout is shown in fig. 2.

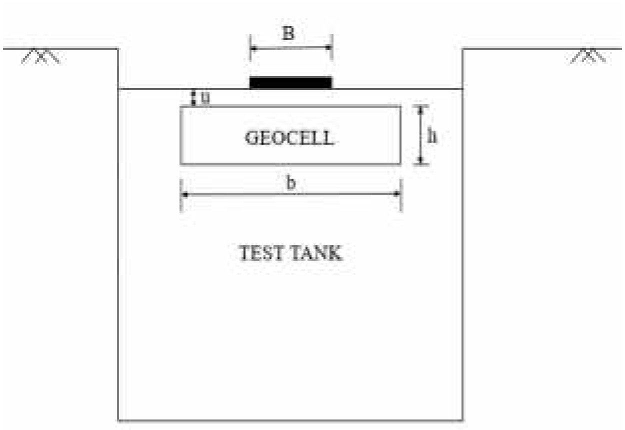


**Fig. 2.** Reinforcement layout

**Test setup and procedure.**

Details of instruments used are given below;

a) Footing – 0.1 m x 0.1 m x 0.025 m

b) Test tank – 0.52 m x 0.52 m x 0.62 m
c) Hydraulic jack – 60 kN capacity
d) Dial gauge – 0.01 mm accuracy
e) Proving ring – 50 kN capacity

Photograph of the test setup is shown in fig. 3.

**Fig. 3.** Plate load test set-up

After the preparation of unreinforced/reinforced sand bed, the footing was placed over the top of the sand bed in such a way that the center of the footing and that of the test tank came along the same line of action. Hydraulic jack of 60 kN capacity was placed over the footing. The load transferred to the footing was measured through proving ring placed over this setup and the whole set up was restrained against the reaction beam. Footing settlements were measured through two dial gauges placed at the diagonally opposite corner of the footing. The load was applied with the help of a hydraulic jack which was using a handle, manually. The load was increased at a uniform rate in such a way that each load increment was maintained until the settlements were constant. The settlement values from two dial gauges were noted and their value was taken. Then the load settlement curve was plotted and the bearing capacity was determined.

The performance improvement, in terms of ultimate bearing capacity due to the provision of geocell reinforcement, is quantified through a non-dimension factor called improvement factor.

$$\text{Improvement factor} = q_r / q_u \quad (1)$$

Where $q_r$ is the bearing capacity of geocell reinforced soil and $q_u$ is the bearing capacity of unreinforced soil.

# 3 Results and discussion

## 3.1 Effect of depth to the top of reinforcement

Laboratory tests were conducted by varying depth to the top of the the reinforcement as 0.1B to 0.3B (u = 0.01 m to 0.03 m) while width and height of reinforcement kept as 3B (b= 0.3 m) and 0.3B (h = 0.03 m) respectively. Fig. 4. shows the Load settlement behavior of geocell reinforced sand and red soil varying depth to the top of reinforcement.

It can be seen that geocell-reinforced foundation beds provide better performance than unreinforced ones in all cases. This is due to interface friction developed between soil and geotextile, the interlocking of soil between the apertures of geocell and also due to the confinement effect provided by the three-dimensional geocell. The effect of reinforcement gets reduced with an increase in depth to the top of reinforcement in the case of both sand and red soil. The maximum improvement is obtained when u = 0.1B, but there obtained slight damage to the geocell surface and considering that optimum u value is selected as 0.2B for sand and 0.15B for red soil.

## 3.2 Effect of the width of reinforcement

By keeping placement depth (u = 0.2B for sand and 0.15B for red soil) and height of reinforcement (h=0.3B for both sand and red soil) as constant, the width of reinforcement (b=B to 4B) were varied. Fig. 5. shows Load settlement behavior of geocell reinforced sand and red soil varying width of reinforcement.

The improvement factor increased from 1.66 to 2.74 and 2.11 to 2.66 for sand and red soil respectively when the reinforcement width was increased from B to 3B. It can be seen that beyond that there is an only a slight improvement in the bearing capacity for both soils. For effectively mobilizing the frictional strength, the reinforcement should lie in the pressure zone beneath the footing, beyond this the effect of reinforcement is negligible, which is the reason for the above phenomenon. So that the optimum width of reinforcement is selected as 3B for both sand and red soil.

## 3.3 Effect of the height of reinforcement

By keeping the reinforcement at optimum placement depth and the width, the height of reinforcement had varied from 0.15B to 0.75B. Fig. 6. shows the load settlement behavior of geocell reinforced sand and red soil varying height of reinforcement.

The improvement factor increased from 1.96 to 3.90 and 2.22 to 4.3 for sand and red soil respectively when the height of geocell reinforcement increased from 0.15B to 0.6B. With an increase in height of geocell, the quantity of confined soil mass increases and also load is spread into deeper layers, which results in higher improvement values. It can be seen that beyond that thickness, there is only a slight improvement in the bearing capacity of both sand and red soil. Hence for this study optimum height of reinforcement is taken as 0.6B.

### 3.4 Effect of density

By keeping geocell reinforcement at optimum placement depth, width and thickness, the density of both soil were varied as loose, medium and dense. Fig. 7. shows the load settlement behavior of geocell reinforced soil foundation under different densities.

The bearing capacity values go on increasing with an increase in density for both reinforced and unreinforced soil foundation. By introducing geocells, the bearing capacity of reinforced loose, medium and dense sand improved by 2.27, 2.73 and 3.84 times the unreinforced loose, medium, and dense sand beds respectively. In the case of red soil beds, the improvement is 2.55, 3.44 and 4.33 times the bearing capacity of unreinforced soil beds for loose, medium and dense conditions respectively.

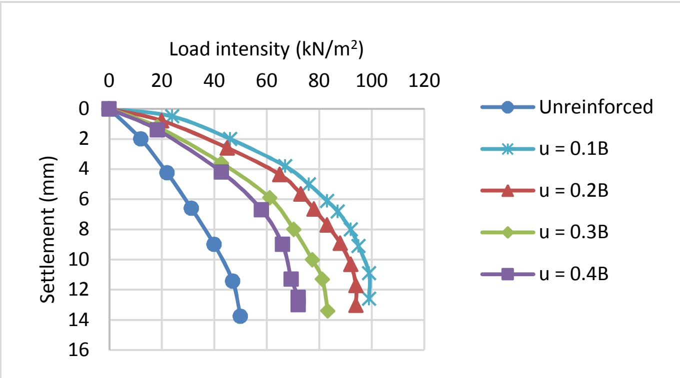


**Fig. 4.** Load settlement curve for sand at various placement depth of geocell

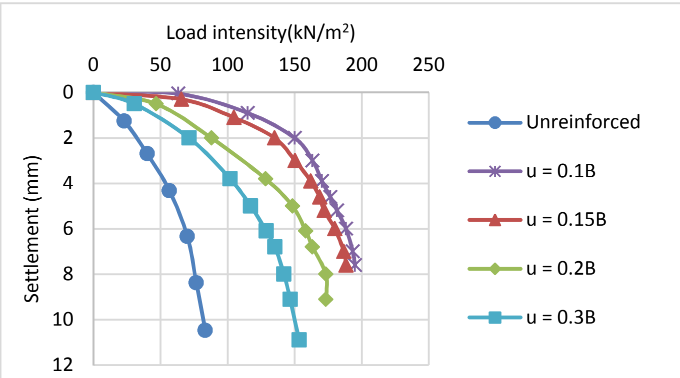


**Fig. 5.** Load settlement curve for red soil at various placement depth of geocell

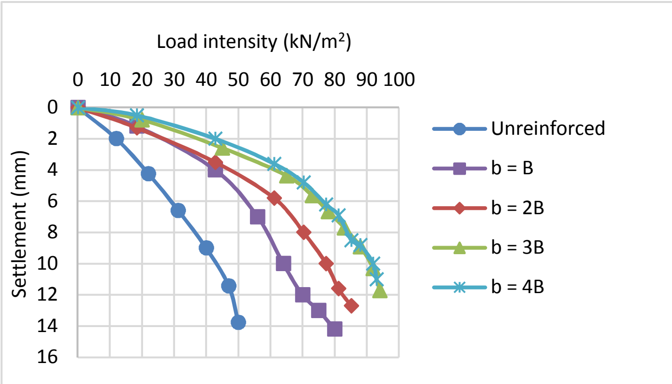


**Fig. 6.** Load settlement curve for sand at various reinforcement width

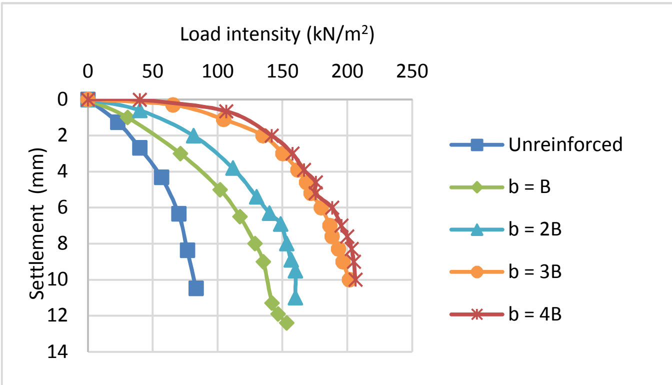


**Fig. 7.** Load settlement curve for red soil at various reinforcement width

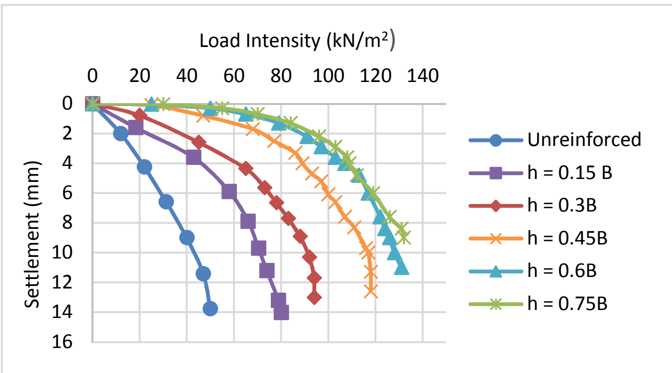


**Fig. 8.** Load settlement curve for sand at various reinforcement height

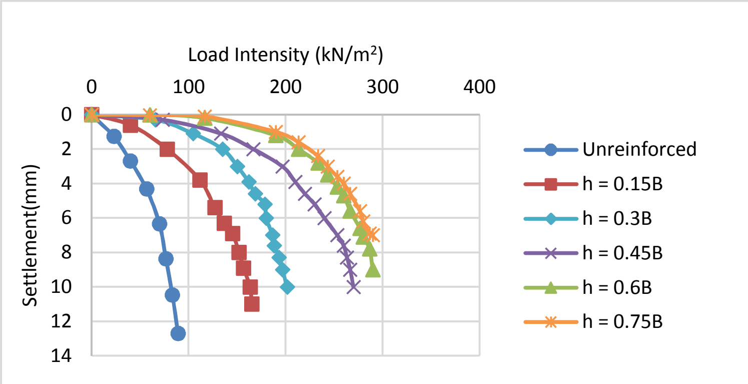


**Fig. 9.** Load settlement curve for red soil at various reinforcement height

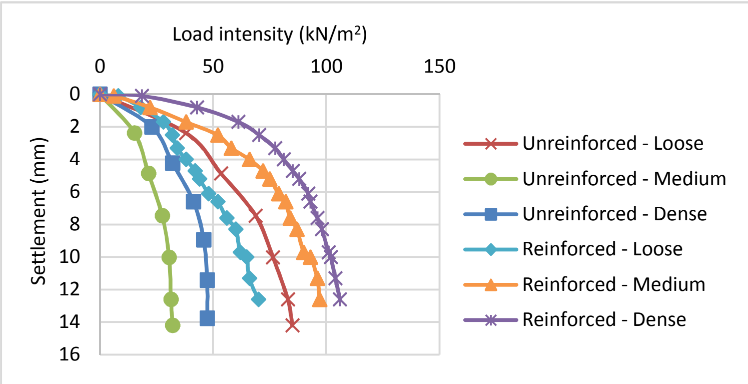


**Fig. 10.** Load settlement curve for sand at different densities

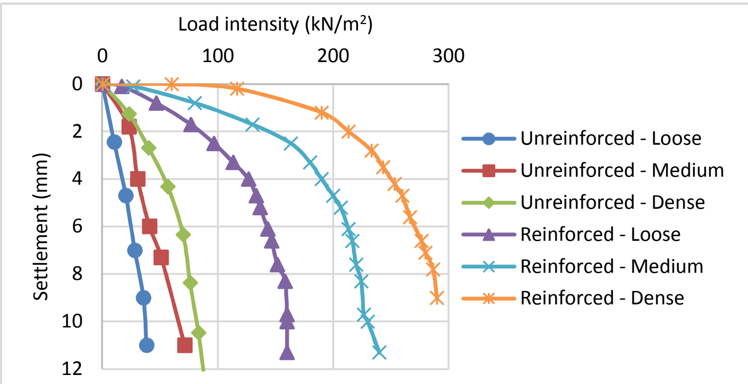


**Fig. 11.** Load settlement curve for red soil at different densities

The table 3. shows the bearing capacity and improvement factor obtained on reinforcing with geocells on the sand and red soil beds.

**Table 3.** Bearing capacity and improvement factor for sand and red soil under various reinforcement configurations

| Parameter | | Sand | | Red soil | |
|---|---|---|---|---|---|
| | | Ultimate bearing capacity (kN/m$^2$) | Improvement factor | Ultimate bearing capacity (kN/m$^2$) | Improvement factor |
| Width of geocell (b) | B | 274 | 1.66 | 274 | 2.11 |
| | 2B | 377 | 2.30 | 377 | 2.38 |
| | 3B | 449 | 2.74 | 449 | 2.66 |
| | 4B | 460 | 2.78 | 460 | 2.77 |
| Height of geocell (h) | 0.15B | 323 | 1.96 | 298 | 2.22 |
| | 0.3 B | 449 | 2.74 | 359 | 2.66 |
| | 0.45 B | 602 | 3.66 | 512 | 3.83 |
| | 0.6 B | 629 | 3.84 | 583 | 4.33 |
| | 0.75 B | 640 | 3.90 | 594 | 4.4 |
| Density | Loose | 372 | 2.27 | 347 | 2.55 |
| | Medium | 449 | 2.73 | 459 | 3.44 |
| | Dense | 629 | 3.84 | 583 | 4.33 |

## 4 Conclusions

A detailed study on the performance of geotextile geocell reinforced sand and red soil foundation and reached on the following conclusions;

- The performance characteristics of the foundation can be significantly increased by the introduction of geocells made of geotextiles. Because these cells completely encase the sand and provide all-round confinement and thus reducing vertical as well as lateral deformation of the foundation soil.
- The performance characteristics vary with the reinforcement layout such as depth to the top of reinforcement, width and height of reinforcement.
- The best results obtained when geocell reinforcement placed at a depth of 0.2 B and 0.15B from the bottom of the foundation for sand and red soil respectively.

- The optimum width of geocell reinforcement is 3B for both sand and red soil, beyond that there is no significant improvement in the bearing capacity.
- The optimum height of geocell reinforcement is 0.6B for both sand and red soil.
- The improvement factor increases with an increase in the density of soil. This is due to the dilation of soils at higher densities.
- The improvement factor is 3.84 and 4.33 for reinforced sand and red soil respectively. That means improvement is higher for red soil as compared to sand by the inclusion of geocell.
- With the inclusion of geocell, footing settlement had reduced considerably.
- Thus geocells made from geotextiles can be used as a good soil reinforcing material.

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