THE NOVEL GEOCELL ANCHOR CAGE SYSTEM

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Abstract. *This study proposes a new technique called 'Geocell Anchor Cage (GAC)', in which the geocell reinforcement layer is supported by a structure comprising of a grid and several anchor pins to enhance the overall performance of the geocell layer in reinforcement applications. Plate load tests were carried out on sand beds with a geocell mattress, and a 3D printed polymeric GAC positioned either above or below the mattress, with each geocell pocket reinforced by an anchor pin positioned exactly at the centre. Results revealed that the inclusion of GAC has substantial benefits in terms of increased load-carrying capacity and reduced footing settlements. Among the two tested configurations of GAC, the one in which the GAC is placed below the geocell layer is proved to be more effective, with the settlements reduced by an order of 38%. Based on the response of the geocells measured through pressure sensors and strain gauges, the internal mechanisms responsible for the beneficial effects of GAC are investigated.*

1 INTRODUCTION

Geocells, by virtue of their shape and depth, provide greater load bearing capacity and reduce lateral deformations in soils confined by them under static and cyclic loading conditions (Bathurst and Karpurapu, 1993; Rajagopal et al., 1999; Latha and Somwanshi, 2009). Mechanisms of geocell reinforcement include all-round confinement effect, stress dispersion effect, lateral restraint effect and membrane effect. When a geocell layer is placed within a soil system, one or more of these mechanisms aid in achieving increased load carrying capacity, improved stability, controlled soil flow and reduced settlements. Because of these merits, geocells are extensively used in pavements, slopes, foundations, embankments, and reinforced earth (RE) walls (Leshchinsky and Ling, 2013; Latha, 2021). Since its inception, geocell network is continuously evolving into a better reinforcing system, with improvements like textured walls to enhance the frictional resistance of soils, high strength polymers to provide better confinement and ultrasonically welded joints to maintain homogeneous strength of the cellular systems. However, the basic structure of the geocell layer remains the same, with interconnected cellular pockets filled with soil. Though the inclusion of a basal geogrid can restrict the deformation of the geocell layer to a certain extent, it cannot control the stress distributions within the geocell pockets, as its presence below the geocell layer limits its scope for any interventions within the cell pockets. It cannot restrict the outward movement of soil from the geocell layer under general shear conditions and hence it cannot stop the density changes within the geocell pockets. In this context, a simple structural add-on to the geocell mattress, which provides basal support as well as anchorage to the cells can be extremely advantageous. With this idea, the present study investigates the development of a novel geocell anchor cage (GAC) system, which interacts with the surrounding and infill soil more effectively and helps in substantially enhancing the load carrying capacity of geocell reinforced sand beds. In this system, a geogrid with several anchor pins strategically located to reinforce each of the geocell pockets is manufactured and its addition to the geocell reinforcement is investigated. To suit the geometry of the commercially available geocells, the GAC is customized and manufactured through 3D printing.

2 DESCRIPTION OF GEOCELL ANCHOR CAGE

Geocell Anchor Cages of desired dimension were manufactured through Fused Deposition Modeling (FDM) 3D printing using Poly Lactic Acid (PLA) filament. Though the options for choosing the dimensions and the geometry of the GAC were plenty, a specific geometry is chosen for this study to primarily establish the beneficial effects of the GAC. The geometric details of the GAC used in the present study are shown in Fig. 1. More details of the manufacturing of GAC and its geometry can be found in Latha et al. (2024). The GAC offers multiple advantages over the basal geogrid layer, which include (i) central anchor support to the infill, which allows better stress distribution within the cell (ii) additional and well-distributed reinforcement effect (iii) additional confinement and (iv) improved membrane effect during bending.

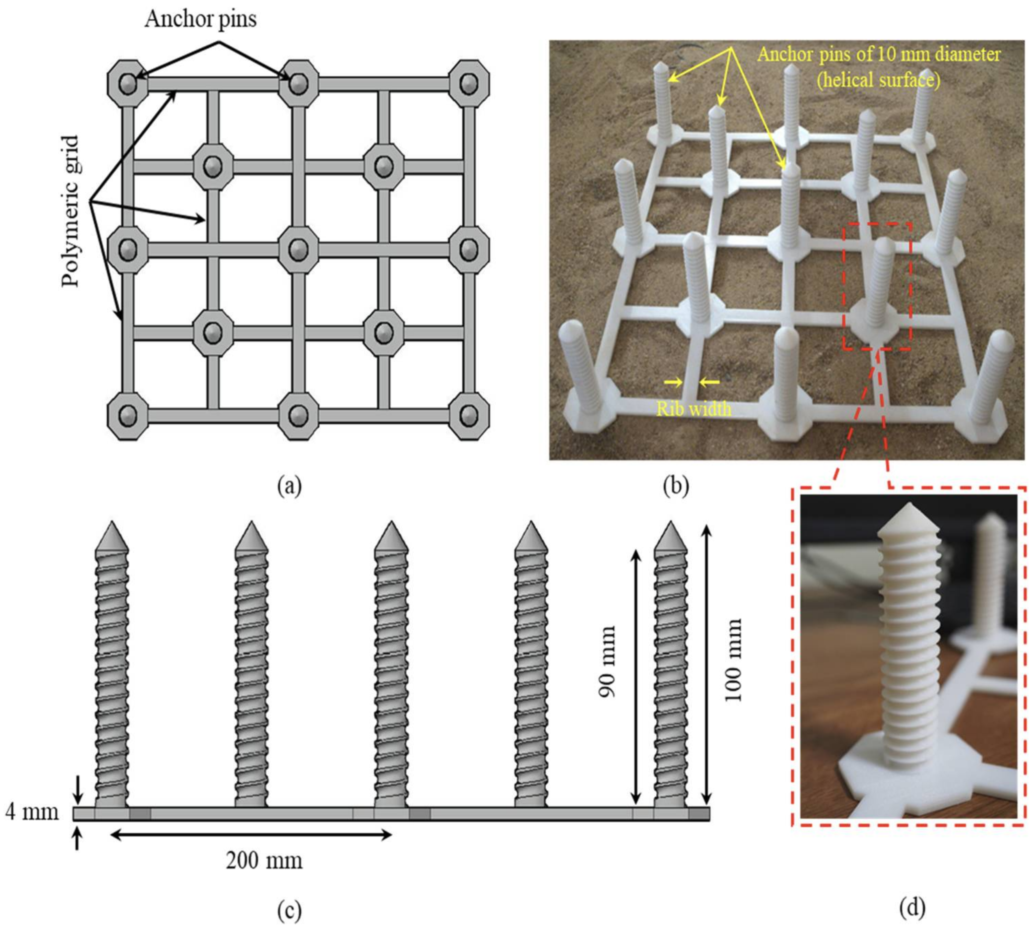

Figure 1: Details of Geocell Anchor Cage (a) plan view (b) perspective view (c) sectional elevation (d) close-up view of the pin

3 PLATE LOAD TESTS

A commercial High-Density Polyethylene (HDPE) geocell mattress with 200 mm pocket size, 100 mm height and 1.5 mm wall thickness was used in this study. The ultimate tensile strength of the geocell wall and the junction seem strength were determined as 12.31 kN/m, and 12.76 kN/m, respectively. The tensile strength of the 3D printed polymeric grid (without anchor pins) was determined as 20 kN/m from the wide width tension test in both the machine direction (MD) and cross-machine direction (CMD). Poorly graded river sand was pluviated to a relative density of 70% to create the sand beds in a steel test tank. A square steel plate of 200 mm width and 20 mm thickness was used to apply load on the sand bed created within the tank. Settlement of the footing and surface deformations of the sand bed were measured using noncontact displacement sensors. Further, strain gauges and pressure cells were used to understand the variation of strain on the geocell wall and pressure mobilized on the wall of geocell pocket, respectively. In test series with geocell reinforcement without GAC, the width of the geocell mattress (*b*) was varied as 3*B*, 4*B* and 5*B*, where *B* is the width of the plate. Load tests with geocell and GAC were carried with the width of the geocell mattress as 3*B* and keeping the anchor cage either below or above the geocell mattress (Fig. 2).

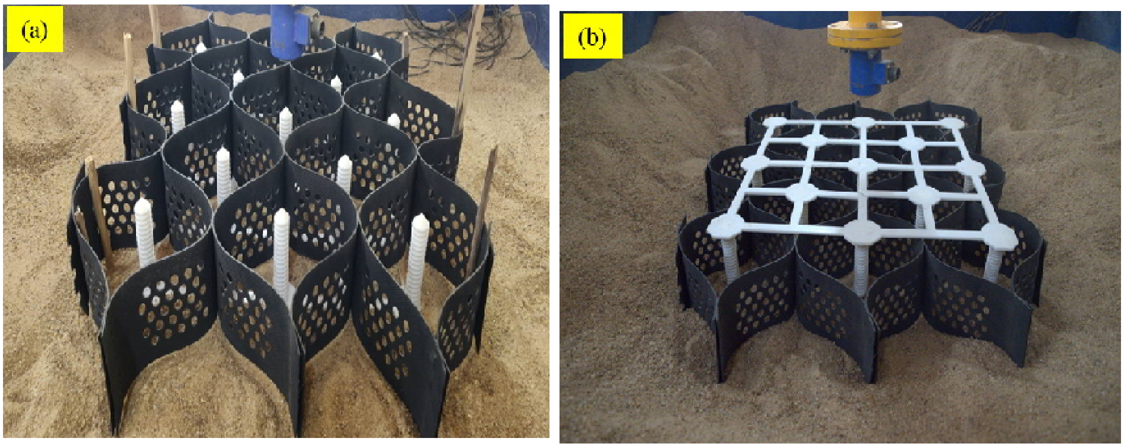

Figure 2: Geocell anchor cage configurations in plate load tests (a) below the geocell mattress (b) above the geocell mattress

4 RESULTS AND DISCUSSION

From the load tests, it is clearly established that GAC helps in effective integration of soil and geocell layer through basal support and anchorage. Inclusion of GAC has substantially increased the load carrying capacity, irrespective of the position of the GAC. However, maximum benefit in terms of increase in load carrying capacity and reduction in settlements at a given load was observed when the GAC was placed below the geocell mattress, with the anchor pins positioned upwards. The difference between the performance of the upward and downward configurations of the GAC is significant. The anchor pins act as shear connectors between the geocell and the geogrid. The sand inside and around the geocells develops frictional contact with geocell, anchor pins and geogrid, thereby linking them all. Under this condition, the soil-geocell-GAC system deforms as a stiffer layer, thereby reducing the permanent deformations in the geocell layer. Under the applied load, along with the geocell mattress, GAC also experiences bending. When GAC bends under the load, in the configuration where the pins are upward (GAC below the geocell mattress), the pins deform inwards, converging within the concave shape of the geogrid surface. While geocell layer provides confinement and membrane support, the converging pins provide secondary confinement and act like reinforcing anchors within the confined soil, like soil nails. The combined influence of tension membrane mechanism offered by the polymeric grid and secondary confinement offered by the anchor pins of GAC is responsible for the substantial increase in the bearing capacity with the GAC configuration in which anchor pins are upward. In the configuration in which the anchor pins are positioned downward, they diverge under the application of load and become inefficient in providing secondary confinement effect. With the inclusion of GAC, the value of Bearing Capacity Ratio (BCR) with a geocell layer of width 3*B* is computed as 3.46 with its pins up configuration and 2.45 with its pins down configuration. The percentage reduction in settlements is 58% and the pins down configuration was not able to reduce the settlements because the basal geogrid effect is missing in this configuration and the anchor pins are diverging during loading, thus not providing adequate hinderance to the settlements in the sand bed.

5 CONCLUSIONS

- The provision of GAC significantly improves the load carrying capacity and reduces the settlements of the geocell reinforced sand beds. For the tested GAC configuration, the bearing capacity increased by more than three times and the settlements reduced by about 58%.
- The major factors responsible for the increased load carrying capacity obtained with the inclusion of GAC are tension membrane support, effective connection of geocell with the geogrid through anchor pins and frictional sand medium and secondary confinement effect due to anchor pins.
- Placing the GAC below the geocell mattress with pins positioned upward into the infill soil yields better benefits compared to placing it above the geocell mattress with pins positioned downward into the infill soil.

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