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REVIEW PAPER

EFFECT OF PLACEMENT DEPTH OF GEOCELL REINFORCEMENT IN SAND DEPOSIT: A REVIEW

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Abstract: In general, the tensile strength of the soil is poor. For this reason, the soil will need to be strengthened. The main objective of strengthening the soil mass is to improve stability, increase bearing capacity and reduce settlements and lateral deformation. There are several methods for improving the soil. One of the approaches is the use of geosynthetic materials. Geosynthetic is a well known technique in soil reinforcement. The use of geosynthetic three dimensions, can significantly improve the soil performance and reduce costs in comparison with conventional designs. In this paper, a review of experimental test carried out by different researchers for optimum depth of geocell in the sand had been made. The test results indicated that the inclusion of reinforcement in optimum depth of sand, decreased settlements and leading to an economic design of the footings.

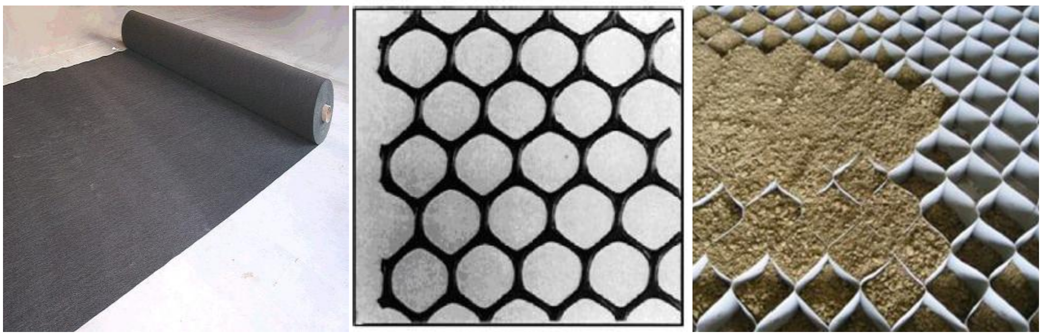
Keywords: *Bearing capacity, geocell, soil reinforcement, sand*

1.0 Introduction

In recent decades, due to its economy, ease of construction and performance, reinforced soil has been widely exploited in geotechnical engineering applications such as in the construction of roads, railway embankments, retaining walls, stabilization of slopes and improvement of soft ground (Moghaddas Tafreshi *et al*., 2012). Soil reinforcement is determined as a process for improving the engineering characteristics of soil. The soil can be considered as four basic type combinations: gravel, sand, clay and silt. The soil usually has the characteristics of low shear and tensile strength and is highly dependent on environmental conditions (Ling *et al*. 2003).

The main objective of the soil reinforcement is to improve stability, increase capacity and reduce settlements and lateral deformation (Yarbasi *et al*. 2007, Hejazi *et al*. 2012). Over the past 40 years, innovative approaches to improving soil have been extended to solve soil problems. These approaches are generally regarded as the most economical ways to improve the conditions of undesirable sites compared to traditional construction methods. One of these approaches is the use of polymeric materials, called as geosynthetics. Geosynthetics have transformed many aspects of geotechnical engineering practice, and some applications have been replaced building materials entirely conventional. The use of geosynthetic in many cases, it can significantly improve performance, increase safety, and reduce costs compared to a conventional design (Boushehrian *et al*. 2011).

A geosynthetic can be defined as "a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure or system" (ASTM D 4439-11, 2011). The main objective of using a geosynthetic is to improve physical, mechanical, and hydraulic properties of soils. The geosynthetics that are frequently used in construction are geotextile, geogrid, geomembrane, geonet, geocell, geosynthetic clay liner, geofoam, and geocomposites. Geosynthetics have been successfully used in several areas of civil engineering, including roadways, airports, railroads, embankments, retaining structures, reservoirs, dams, landfills, etc. (Han *et al*. 2011). Figure 1 shows the pictures of various kinds of geosynthetics.



(a) (b) (c)

Figure 1: Various kinds of geosynthetics (a) Geotextile (Pokharel, 2010), (b) Geogrid (Alamshahi and Hataf, 2009), (c) Geocell (Yang *et al*., 2012).

In the recent decades, several experimental investigations have been carried out to determine the bearing capacity of shallow foundations on different soil types reinforced by a number of methods. Also, the beneficial effects of using planar reinforcement to increase the bearing capacity of sand have been clearly demonstrated by several investigators. The most recent advancement of reinforced soil is to provide three-dimensional confinement to the soil by using geocells (Dash *et al*., 2001).

Shallow foundations are widely used in transmitting loads from the superstructure to the supporting soils. After the foundation is constructed, the soil is permanently loaded by both the gravity loads and the live loads of the superstructure. (El Sawwaf and Nazir, 2010). In this paper, an overview with the experimental test on the effect of optimum depth of geocell in sand on bearing capacity and settlement of soil is discussed.

2.0 Geosynthetic Reinforcement

The types of soil improvement methods, including grouting, vertical drains, soil replacement, complete, piling and geosynthetic reinforcement has developed to solve the problems (Liu *et al*., 2008, Rowe and Taechakumthorn, 2008). Among these methods, geosynthetic reinforcement has been used (Rowe and Li, 2005). Li *et al*. (2012) reported the work in this field of research. Geosynthetic produced from polymers is widely used to reinforce soils. The reinforced soil structures are under to stress or creep. (Leshchinsky *et al*., 2010, Liu *et al*., 2009). Geogrid is used in layers with aggregate fills or other suitable soils to create a strong layer. So the bearing capacity of soil under the load of the foundation will be improved. Many experiments have shown sand usually has been used as backfill material. (Rowe and Taechakumthorn, 2011, Karimpour and Lade and Yeo and Hsuan, Kongkitkul *et al*., 2010, Lade *et al*., 2009, Kim *et al*., Lade, Pham Van Bang *et al*., 2007) and geogrid reinforcement material (Bathurst *et al*., 2009, Jones and Clarke, 2007, Shinoda and Bathurst, 2004, Kuwano and Jardine, 2002, Li and Rowe, 2001, Perkins, 2000, Sawicki, 1998).

3.0 Geocell

Geocell is honeycomb three-dimensional cell structures that provided containment of compacted fill soils. Decreased the lateral movement of the soil particles and form a mat or rigid for the distribution of loads applied to a wider area slab movement. Geocells were used in the construction of canals, embankments, retaining walls, railways and roads (Dash *et al*., 2003).

New types geocell are made of a new polymer structure characterized by low temperature flexibility similar to high density polyethylene (HDPE). (Pokharel, 2010, Yang, 2010). The base layer reinforced geocell mattress In road construction, acts as a rigid slab or a mattress for distribution the traffic load vertically on a broader subgrade. Therefore, the vertical forces applied to the subgrade was decreased and the capacity was increased. (Marto *et al*., 2013). Pokharel *et al*. (2010) stated that the concept of lateral confinement cell structures dating back to 1970. Geocells come in different shapes and sizes. Figure 2 shows the typical configurations of geocell reinforcing elements: (1) Vertical perforated elements prepared as a cellular, honeycomb-like structure. (2) Vertical geogrid elements prepared by cutting geogrids. This type of geocell is hand made from geogrid chevron or diamond pattern.

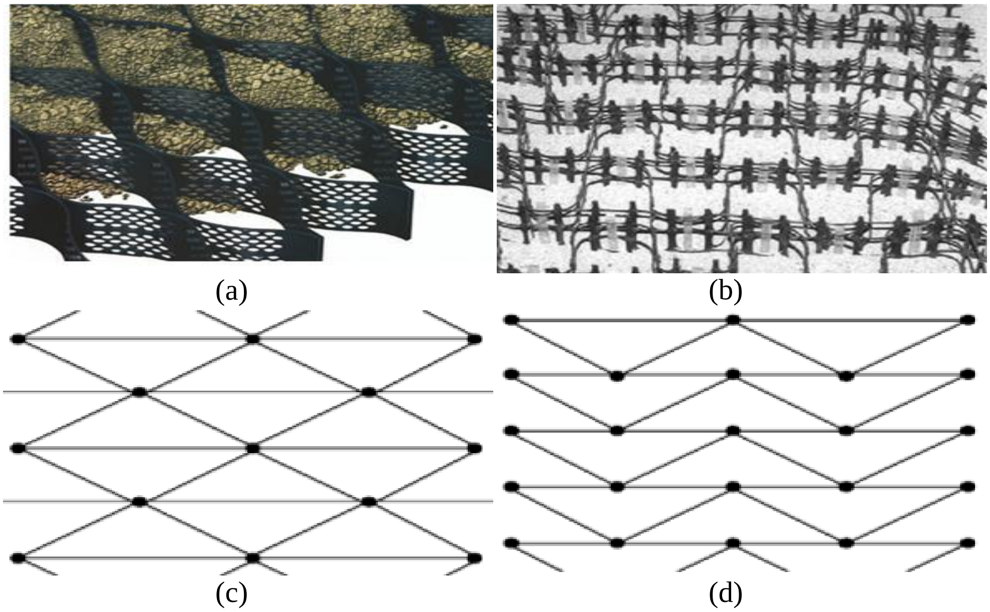


Figure 2: The typical configurations of geocell reinforcement elements. (a) Perforated geocell (Bathurst and Jarrett, 1998). (b) Handmade geocell (Dash *et al*., 2003). (c) Handmade geocell diamond pattern (Dash *et al*., 2003). (d) Handmade geocell chevron pattern (Dash *et al*., 2003).

4.0 Reinforcement Mechanisms

As compared with the unreinforced base, the geocell-reinforced base can provide lateral and vertical confinement, tensioned membrane effect, and wider stress distribution. According to Giroud and Noiray (1981) lateral confinement, increased bearing capacity, and tensioned membrane effect was identified as the major reinforcement mechanisms for geotextile reinforcement. Boushehrian *et al.* (2011) studied experimentally and numerically the effect of the depth of the first reinforcement layer (u), spacing between reinforcements (h), and reinforcement stiffness on the bearing capacity of circular and ring foundations of sand. Using footing width, B, Chung and Cascante (2006) have shown that a zone between 0.3B and 0.5B is identified to maximize the benefits of soil reinforcement. They noticed that the accommodation of reinforcements within one footing width below the foundation can lead to an increase in bearing capacity ratio (BCR) and the low strain stiffness of the reinforced system. This increase is due to the transferring of the foundation loading to deeper soil layers, as well as a reduction in the stresses and strains underneath the foundation. Mosallanezhad *et al*. (2008) dealt with the influence of a new generation of reinforcement (named as Grid-Anchor) on the increase of the square foundation bearing capacity. It was found that the critical value of u/B was equal to 0.25. They also showed that BCR for this system was greater than ordinary geogrid. Shin *et al*. (2008) showed that within the soil-reinforcement system the shear modulus of soil increases with the number of layers in depth under cyclic loading. The geometry of the test configurations for the geocell considered in the investigation is shown in Figure 3.

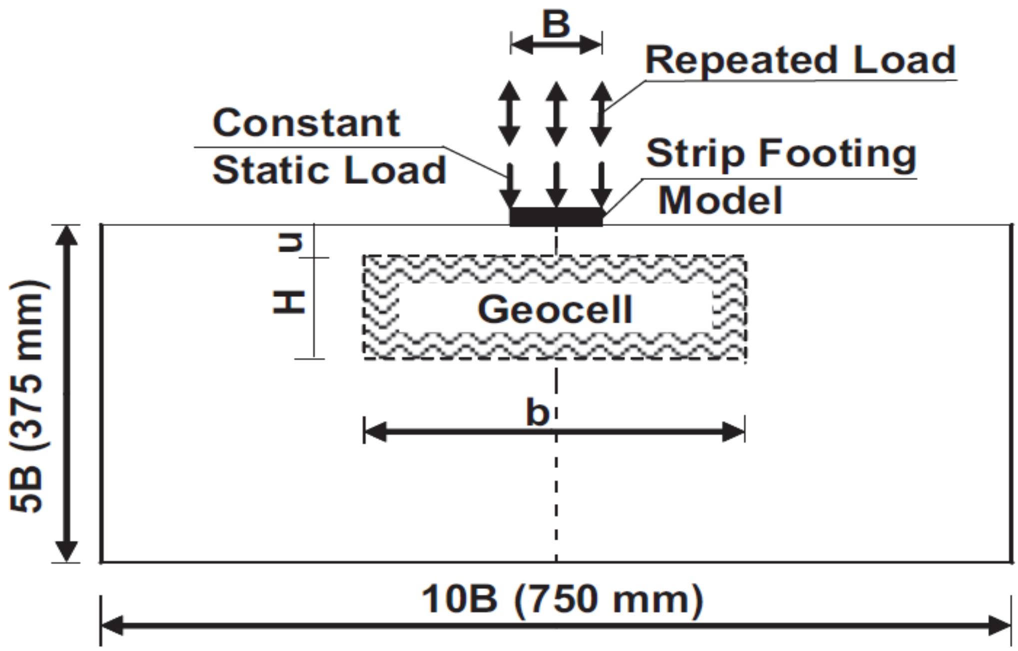


Figure 3: Geometry of the Geocell- reinforced foundation bed (Moghaddas & Dawson, 2012).

5.0 Laboratory tests conducted on geocell reinforced soil

Researchers (Moghaddas and Dawson, 2012, Sitharam and Sireesh, 2012, Ling Zhang *et al*., 2010, Madhavi *et.al*,. 2009, Dash *et al*., 2001) mentioned the load spreading action of the reinforced layer and a subsequent reduction in the vertical stress in the layer underlying the geocell layer. They showed that there is an increased performance on the footing over a buried geocell layer even with the geocell mattress width equal to the width of the footing. The geocell mattress transfers the footing load to a deeper depth through the geocell layer. An increase in the bearing capacity of the geocell mattress with an increase in the ratio of cell height to cell width was observed by Rea and Mitchell (1978) and Mhaiskar and Mandal (1992). Dash *et al*. (2001) found that the load carrying capacity of the foundation bed increased with a rise in the cell height to diameter ratio, up to a ratio of 1.67, beyond which further improvements were marginal. The optimum ratio, reported by Rea and Mitchell (1978) was around 2.25. Krishnaswamy *et al*. (2000) reported an optimum ratio of about 1 for geocell supported embankments constructed over soft clays. Table 1 summarizes several previous researches on the effect of geocell optimum parameters of soil reinforcement.

Several researchers have found an improvement in the load bearing capacity of the foundation with an increase in the mattress thickness, up to a geocell height of twice the width of the footing. Figure 4 shows the corresponding improvement in bearing pressure factor (IF) with u/B at different values of settlement. Figure 5 shows the variation of improvement factors with settlement for various depths of placement of geocell (Moghaddas and Dawson, 2012, Dash et.al, 2001). In Figure 5 shown the influence of the depth of placement of geocell layer (defined by u/B ratio) on the bearing capacity improvement factor (If). This is reflected in the reduction of If for higher u/B ratios. These results suggest that to get maximum benefit, the top of the geocell mattress should be at a depth of 0.1B from the bottom of the footing. Up to u/B ratio of 0.25, the footings have not shown evidence of failure even at large settlements. When u/B is 0.50, the footing had an initial failure at a settlement of about 0.2B and later starts taking higher loads and finally reaches its ultimate load at settlement of about 0.4B. When the u/B ratio is increased beyond 0.5, the footings have reached ultimate pressures at much smaller settlements of about 0.15B.

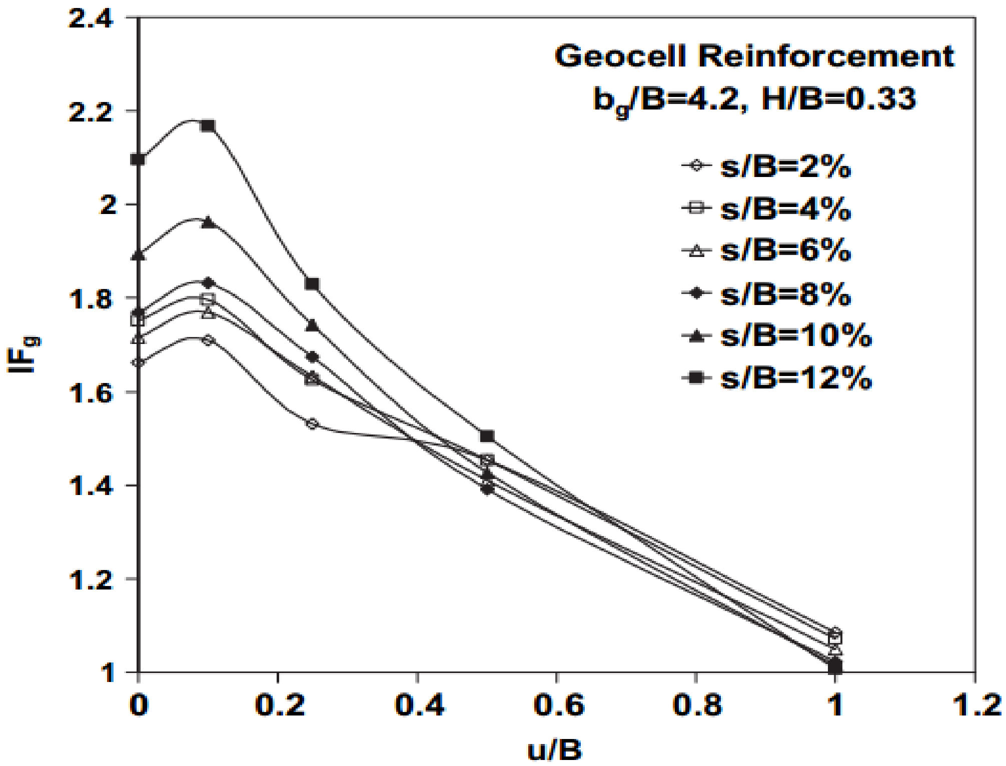


Figure 4: Variation of bearing pressure with settlement for static loading of unreinforced and reinforced foundation beds (Moghaddas & Dawson 2012).

Table 1: Summary of previous studies on geocell reinforced soil

Name of researcher (Year)	Result
Sitharam and Sireesh (2012)	1- Better performance of the footing can be obtained if the depth of placement of cellular mattress is 0.05D from the base of the footing in the case of sand beds. 2- At 40 % footing settlement values, 30 % improvement is observed in load carrying capacity in the case of reinforced sand beds.
Boushehrian, Hataf and Ghahramani (2012)	1- The large-scale results show that by using the grid-anchors, the amount of permanent settlement decreases to 30%, as compared with the unreinforced condition.
Hataf, Boushehrian and Ghahramani (2011)	1- The amount of dimensions settlement needed to reach its constant value decreases up to 17% relative to ordinary reinforcements and up to 50% relative to an unreinforced condition.
Moghaddas (2010)	1- The optimum depth of the topmost layer of planar reinforcement is u/B=0. 35 while the depth to the top of the geocell should be approximately u/B=0. 1. 3- For bearing capacity greater than 200% and reductions in settlement by 75% can be achieved with the application of geocell reinforcement, whereas planar reinforcement arrangements can only deliver 150% and 64% for these two quantities, respectively.
Moghaddas and Dawson (2010)	1- The optimum depth of planar reinforcement is u/B=0.35 and the 3D geotextile should be u/B= 0.1.
Dash *et al.* (2001)	1- To obtain maximum benefit, the top of geocell mattress should be u/B=0.1 from the bottom of the footing. 2- The optimum aspect ratio of geocell pockets for supporting strip footings was found to be around 1.67.

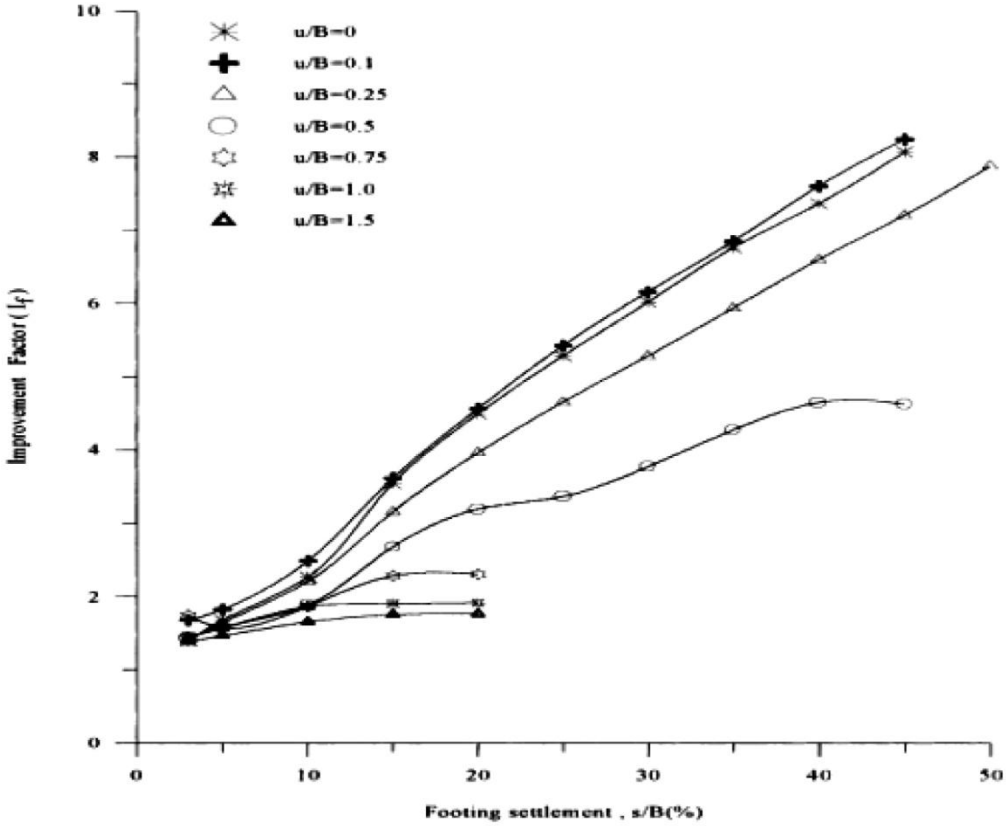


Figure 5: Variation of improvement factors with settlement for different depths of placement of geocell (Dash et.al, 2001).

6.0 Conclusions

Experimental study results obtained by previous researchers on reinforced soil with synthetic material can be concluded as follows:

1. The reinforcement reduces the magnitude of the final settlement.
2. In case of sand beds, the increased performance of the footing is observed to increase in footing settlement.
3. The optimum depth of geocell reinforcement is about (u/B) = 0.1.
4. With the provision of a geocell layer, indicating that the geocell mattress transmits the footing load to a deeper depth, thereby bringing about a higher load carrying capacity.
5. The value of the mobilized shear stress ratio for geocell supported footings is only 0.35–0.5, unlike the unreinforced footing where it reaches 1.

7.0 Acknowledgements

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