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Application of Geocells in Reinforcement of Soil: A Review

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Abstract : **Soil reinforcement is one of the most popular ground improvement techniques. Availability of different material and techniques for reinforcement is one of the major reasons for the continuous increase in the application of the soil reinforcement. Geocell reinforcement is one of the soil reinforcement techniques. Three dimensional confinements provided by the geocell membrane increase the load carrying capacity of soil. Many works on geocell reinforcement through field study and laboratory test were done by researchers, which show the significant potential of this technique. Now, Geocell are widely being applied in the field of geotechnical engineering, which controls erosion of slopes and river banks, enhancing the bearing capacity of retaining structures, pavements, reinforcing soft grounds, protect shores and channel beds. In this paper review on the different field application of geocell reinforcement and its impact on the geotechnical structures are presented.**

Keywords: Geocell, Soil reinforcement, Confinement.

1. INTRODUCTION

Behaviour of soil is the most important parameter which we have to consider before the construction of any type of civil engineering structure. Failure in the structures takes place mainly because of the soil. Generally weak soils or poor soils cause the instability of overlying structures. In such soil failure takes place due to excessive settlement because of insufficient bearing capacity of the sub grade. Construction of civil engineering structures over weak soil can be a problem for any designer, and also the backfilling and excavation is not always economical. So it is important for a civil engineer to improve the soil properties by some techniques. Soil reinforcement is one of the ground improvement techniques. Ease in the construction, overall economy, less time consuming etc. are the advantages because of which soil reinforcement is popular worldwide (Dash et al. 2003). Use of reinforcement in form of planar, bars, strips etc. are traditional way of soil reinforcement. Planar reinforcement has been used in different construction like; foundation, roads, and in walls from the past few decades (Binquet and lee 1975, Guido et al. 1986, Khing et al. 1993, Htamai et al. 2001, Leonard et al. 2002). Geocell is one the new technique first used by the US Army Corps of Engineers for stabilization of sand beach (Webster 1979). Geocells are three dimensional, expandable panels made from high density polymer material in which soil is filled (Figure. 1). All around confinement provided by the geocell membrane increase the load carrying capacity of soil. Geocell reinforcement is now successfully utilized for different geotechnical structures like slope stability, retaining wall, embankment etc.

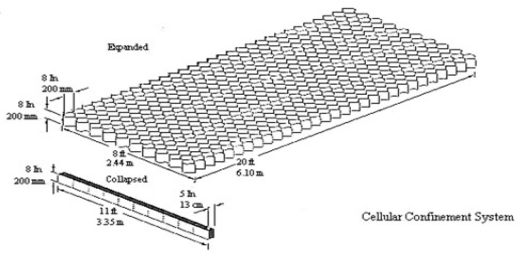

Figure. 1 Geocell structure (Bathurst and Knight 1998).

2. MECHANISM OF THE GEOCELL REINFORCEMENT

The geocell is a three dimensional, polymeric, honeycomb-like structure of cells interconnected at joints (Bush et al. 1990). The reinforcing action in case of planar reinforcement is primarily due to restraining of strain in soil, through mobilization of frictional resistance at soil reinforcement interface While, in case of geocell it is through overall confinement. The reinforcing mechanism in the geocell provides all round confinement to the materials by virtue of its interconnected cells as a result it prevents the lateral spreading of soil on the application of load (Figure. 2). Because of this a better composite material is formed and the geocell layer behaves as a stiffer mattress that redistributes the footing load over a wider area (Dash et al. 2007). On the application of load, the footing increases pressure on soil, because of which soil deforms laterally and exerts pressure on the membrane of the geocell. Deformation in the geocell membrane takes place because

of the pressure from the soil. This circumferential deformation of membrane mobilizes stress in the geocell membrane due to which increase in the confinement pressure of soil takes place (Bathurst and Karpurapu 1993). This increase in the confinement pressure increases the resistance against the deformation due to which soil can take more load. The interlocking and frictional resistance between the soil and membrane also contributes in the resistance against the deformation of soil (Biswas et al. 2012).

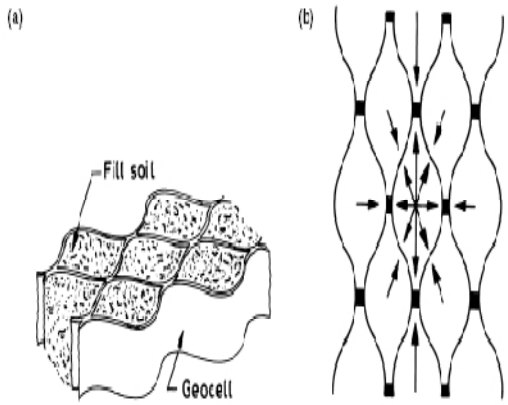

Figure. 2 Confinement of soil using geocell (Rai 2010).

3. FIELD INSTALLATION OF GEOCELL REINFORCEMENT.

Bush et al. (1990) had explained the construction of geocell and installation in the field. Prior to construction of geocell mattress in the field, the site is cleared of all obstructions and the ground is levelled. The basal Geogrids layer is unrolled onto the levelled ground in such a way that a minimum overlap of around 300 mm is maintained between adjacent rolls of basal Geogrids layers. The overlaps are preferred over stitching to reduce Construction time. Sheets of Geogrids of required size are cut from long rolls to construct the three dimensional structure. After the laying of basal Geogrids, a sheet of Geogrids is laid in a transverse direction with one of its end stitched to the basal Geogrids. The sheet is then rotated about the stitched edge to bring it to a vertical position and temporarily tensioned using timber posts (Figure. 3). Similarly, a number of transverse sheets covering the entire area are laid out. The cellular structure is formed by placing another Geogrids sheet between the two transverse sheets and connecting it to the transverse sheet using hooked steel bars or polypropylene 'bodkin joints' as shown in (Figure. 4). The bodkin joint (Simac, 1990; Carroll Jr. and Curtis, 1990, is formed by pulling the strands of transverse geogrid up through the diagonal geogrid and slipping a dowel through the loop created.

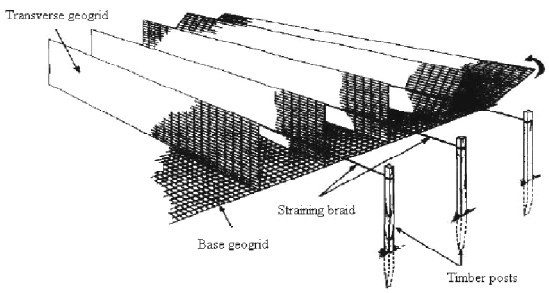

Figure. 3 Geocell mattresses (Bush et al., 1990).

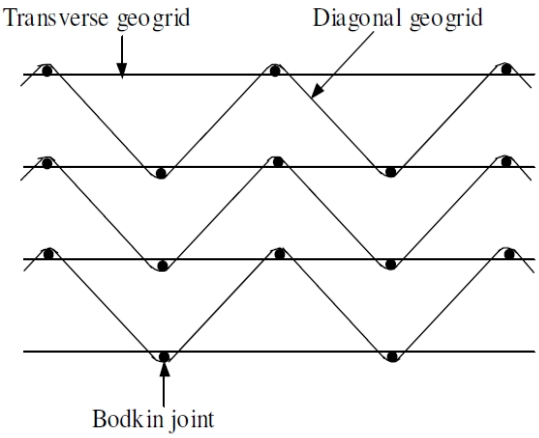

Figure. 4 Connection of geocell mattresses (Bush et al., 1990).

4. APPLICATION OF GEOCELL REINFORCEMENT

Geocells are widely used for the reinforcement of soft soil. There are bundle of areas where geocells are applied successfully. These are widely being used for enhancing the bearing capacity and shear strength of soft soil under the different types of civil engineering structures. Geocells have been now used for different structures like embankments, foundations, retaining walls, and also for slope stability. The review on the application of the geocell reinforcement is presented in the following sections.

4.1. Embankment

The soft soil often poses design, construction and maintenance hazards to civil engineering structures founded on them. Construction of embankment over soft soil or weak soil is very difficult work. Some soils are so weak that they can't take the load of construction equipments. Problems may arise during the construction stage due to the inability of the soft soil to provide adequate support to the construction equipments. Post construction, the excessive settlement and insufficient bearing capacity of the soft subgrade may lead to loss of stability of the overlying structures. Rotational slip failure of embankments, cracking

and differential settlement of soil under embankments are some of the failures associated with construction of structures on soft soils.

In such condition generally upper layer of weak soil is removed and some strong soil is used. The depth of removal of weak soil depends upon the load coming on the soil and strength of the soil. This process governs the overall construction cost of embankment. Use of geocell mattress over the soft soil can reduce the settlement and increase the load carrying capacity (Zhang et al. 2010). Geocell act as rigid mattress and it distribute the applied load over larger area due to which pressure intensity on the soft soil decreases (Dash et al. 2007). Johnson (1982) reported the use of geocell mattress at Greatham Creek Bridge, England. The mattress was placed under a 5 meter high embankment over soft silt which was 7 meter deep. The lateral strain reported was small and the vertical settlement was found to be reduced by 50%. The author attributed the reduction in settlement to the lateral restraint offered by the geocell material that prevents the material from spreading and hence reduces the stresses coming onto the soft sub grade. Similar type of performance was found by Cowland and Wong 1993 for road in Hong Kong when Geocell mattress was used under the embankment. Use of geocell increases the stiffness of embankment and it can also reduce cost up to 30% (Bush et al. 1990).

4.2. Foundation

Strength and stiffness of soil is most important criteria for the construction of foundation of over the soil. Failure of foundation takes place when soil is not strong enough to take load or because of excessive settlement may be a reason of failure. Construction of foundation over the weak soil can be done either by selecting suitable foundation like pile, raft etc. or can be done by modification of properties of soil by some ground improvement techniques. Generally use of modification of soil properties may economical.

Several studies and researches have been done over the use of geocells reinforcement under the foundation. Most of the studies were done through the model test. Rea and Mitchell [7] and Mitchell et al. [8] through laboratory model tests on sand reinforced by interconnected paper, identify the different modes of failure of geocells. Mhaiskar and Mandal (1996), Dash et al. (2001, 2003), Sitharam et al. (2007), Sireesh et al. (2009), Pokharel et al. (2010) have performed model test on different type of footing and investigated the behavior of geocell reinforced soil and found that geocell reinforcement increase the load carrying capacity and decrease the settlement. Value of sub grade modulus can be increased by inclusion of geocells. As it provides the 3D confinement to soil, thus provides rigidity to the soil and thereby increasing the bearing capacity of soil. Test results shows the value of sub grade modulus reinforced using geocells increased by 8 times as compared to unreinforced sub grade (Dash et al. 2008).

4.3. Reinforce wall

Use of geocell in the retaining wall is very popular now. In such retaining wall concrete panel is not required (Figure. 5). Vegetation can also be grown in such reinforced wall. Geocells are used to confine the soil which results in the increase of shearing strength and preventing the failure of the structure. So there are lot of applications of geocells in reinforce wall. R.H. Chen and, Y.M. Chiu (2008) studied about the use of geocells in reinforce walls. It has been seen that deformation settlement on both wall and backfill is increased with increasing the facing angle and surcharge. In facing type walls displacement and settlement is more as compare to the gravity type because of its light weight. While in gravity type two modes of failure often seen are failure due to sliding and failure due to overturning. So to avoid these circumstances reinforcement of retaining walls is required. Geocell reinforced retaining walls are also performed better in case of earthquake loading. Due to geocell reinforcement the deformation in such retaining wall can be suppress effectively. (Ling et al. 2009).

Figure. 5 Geocell flexible retaining walls.

4.4. Slope stability and Erosion control

Slope stability and erosion control are important for the condition when structure is situated near to flowing water. Conventionally use of vegetation is and effective way of slope stability and soil erosion. It helps to bind the soil particles as one but in some places like steep slopes and region of high intensity rainfall trees are not enough to prevent these two problems. So to overcome these problems geocells are used to hold the soil particles as a unit.

Wu and Austin (1992) have reported the successful use of geocells for erosion control as well as slope stability. Economical and Environmental concerns lead to the

increasing use of geosynthetics materials for the purpose of reinforcement of soil to prevent soil erosion due to surface runoff. In most of the places soil erosion on slopes take place due to high intensity rainfall. Soil erosion takes place due to detachment of particles, and flowing of particles with surface runoff. So to prevent this cause geocells are used, it assists to slow down the surface runoff and hold the soil particles in their cells. The geocells are used to avoid the mass sliding of soil by providing the confinement to the soil.

The stability of channel lining is always a problem for a civil engineer. After a lot of research on the stability of channel lining some researchers found out the materials which are able to protect the channel surface from erosion. Some researchers used concrete revetments for the stability purpose but it is expensive as well as very difficult to install. So one more material used by researchers is geocell which is economical as well as it can protect slopes from erosion and provide confinement to the infill materials. Due to the confinement provided by the walls of geocell to the infill materials the down slope movement of materials is prevented (Wu and Austin 1992).

In steep slopes tensile strength of geocell is tested in preventing the land slides. In areas where vegetation is not possible or erosion overcome the strength of root system , in these places use of geocell is economical and very effective to the soil erosion or help to retain the soil on slopes. Geocells are also used in areas of heavy surface runoff where main cause of soil erosion is surface runoff. Soil erosion can be avoided by providing the confinement to the soil and by decreasing the velocity of surface runoff passing through the cell (cancelli et al. 1993).

5. CONCLUSION

In this paper the brief review on the application of geocell reinforcement is presented. It is found from the studies that the load carrying capacity and reduction in the settlement of the soil both takes place because of geocell reinforcement. Geocell can be used for different types of structure like embankment, foundation, wall etc. The use of geocell is suitable from the stability as well economical point of view. Further more study is required to evaluate the potential of the utilization of the geocell technique in different application.

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