Geocell: An Emerging Technique Of Soil Reinforcement In Civil Engineering Field & Faster way of soil stabilization

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Abstract: In any civil engineering construction work there are two basic criteria’s which are to be followed. Firstly the structure should be safe against any type of failure and secondly structure should be economical as far as possible. When the structure is constructed over a loose or weak soil then it is very difficult to follow these basic criteria. Poor soil conditions usually is the reason behind the lack of strength, and associated deformability. Geocell is a Soil reinforcement technique which is proved to be a versatile method in terms of its cost effectiveness for the improvement of the strength of soft soils. It is the latest form of reinforcement which is both economical and durable in long term. It provides all round confinement to the materials hence it prevents the lateral spreading of soil on the application of load. So the use of Geocell reinforcement increases the strength and stiffness property of the soft soil. This paper deals with the study of overall mechanism and applications of Geocell in the field of civil engineering.

1. Introduction
Development of the infrastructure is the most important need in present time. To fullfill the infrastructural need of population, small multi-story buildings, express highways, high speed rail tracks, new bridges, airports etc. are required to be constructed. Ultimately loads from such structure come on the ground. Due to space constrains many times construction takes place on poor soil. Construction over poor soil with high loads is a challenge for civil engineers. Replacement of weak soil by some strong soil or improvement of engineering properties of weak soil by different ground improvement techniques are used in such situation. If such soil cannot be removed or uneconomical to remove then we can use ground improvement techniques. Soil reinforcement is one of the most popular ground improvement technique. Ease of construction, overall economy and less time consumption are major advantages of soil reinforcement. Use of metal bars, sheet, and strips were traditional form of reinforcement. Geosynthetics are man-made materials made from various types of polymers used to enhance, augment and make possible cost effective environmental, transportation and geotechnical engineering construction projects. They are used to provide one or more of the following functions; separation, reinforcement, filtration, drainage or liquid barrier.

2. Geocell
Engineers discovered that sand-confinement systems performed better than conventional crushed stone. In terms of the effectiveness of confinement, cellular confinement systems have more attractive features due to its 3D structure than any other planar geosynthetic reinforcement. Hence Geocell can provide better lateral confinement to in fill soils. The reinforced composite formed by the Geocell and the infill soil has a higher stiffness and shear strength than the unreinforced soil. The term Geocell also have two parts first is “geo” which means soil or earth and second is “cell” which means cellular type of shape for infill material such as soil. These cells completely encases weak material such as soil, stones etc. and provide all round confinement due to its three dimensional structure thus preventing the lateral spreading of the material due to which a much stiffer mat like structure is formed and distributes the overcoming load to a much wider area. Geocells were used in the construction of canals, embankments, retaining walls, railways and roads. Nowadays Geocells are made up of new type of polymer structure characterized by low temperature flexibility similar to high density polyethylene (HDPE). Geocell come in different shapes and sizes. Fig 2 shows the different type of configuration of Geocells.
3. **Mechanics of Reinforcement**

If we compare Geocell reinforced base with unreinforced base then it is experimentally proved that Geocell reinforced bases provide more lateral and vertical confinement, Tensioned membrane effect and wider stress distribution. Geocell reinforcement imparts apparent cohesive strength even to cohesion less soils and the induced apparent cohesive strength depends on the tensile modulus of the geosynthetic used to form the Geocell. Dash et al., (2001a)[8] concluded that Very good improvement in the footing performance can be obtained even with Geocell mattress of width equal to the width of the footing, because of the transfer of footing loads to deeper depths through the Geocell layer. The surface footing in this case behaves like a deeply embedded footing thus improving the overall performance also Chevron pattern for the formation of Geocells is more beneficial than the Geocells in diamond pattern. The geometry of the test configuration is shown in Fig 3.

![Fig 3. Geometry of the Geocell- reinforced foundation bed.](image-url)
The mechanics of Geocells as load support systems

Confined cohesionless soil within a Geocell system, when subjected to vertical pressure, causes lateral stresses in the confined soil, causing it to tend to deform laterally. However, any lateral deformation of the Geocell wall is restricted due to adjacent cells also filled with cohesionless soil, which is acted upon by similar vertical pressures which generate the same lateral stresses. The high hoop strength of the Geocell wall also constrains lateral movement. If $q_0$ is the vertical pressure, the lateral stresses generated along the walls of the individual cells would be $K_0 q_0$ where $K_0$ is the coefficient of earth pressure “at rest”, i.e. $(1-\sin \phi)$ where $\phi$ is the angle of internal friction of the infill soil. This increases the shear strength of the confined soil, thus creating a stiff mattress, which contributes to distributing the load over a wider area. This horizontal stress acting normal to the cell wall increases the vertical frictional resistance between the infill and the cell wall, which diminishes the stress of the applied load on the ground below the Geocell.

4. Confinement of Reinforcement

The confinement effect of Geocells improves vastly the shear strength of granular soil. The Geocells were made of high-density polyethylene sheets, and the influencing factors examined include the shape (circular, rectangular, and hexagonal cross-sections), size and number of cells. The effects of these variables on the compression strength of samples as well as the stress-strain behaviour were investigated. It has been found that the apparent cohesion of reinforced samples vary with the shape, size and number of cells, of which the cell size is the most significant factor. Among the cells of all shapes, the circular cells induce the highest apparent cohesion. Due to the three-dimensional structure, the Geocell can provide lateral confinement to soil particles within cells. Geocells have a three-dimensional cellular structure, which can be used to stabilize foundations by increasing bearing capacity and reducing settlements. In the study, a single Geocell was filled with sand and subjected to a vertical load to failure. This test process was modelled using the FLAC 3D numerical software to investigate the mechanisms of Geocell and sand interactions. Experimental and numerical results both demonstrated that the Geocell increased the ultimate bearing capacity and the modulus of the sand. Patterns of vertical displacements for the unreinforced and reinforced cases. Fig-5 shows the patterns of vertical displacements for the unreinforced and reinforced cases.

As shown in Fig 5, the patterns of vertical displacements for the unreinforced and reinforced cases are very similar, i.e., compression under the load plate but heave away from the load plate. However, the magnitude of the vertical displacement for the unreinforced sand was much larger than that for the reinforced sand under the same vertical load.

5. Application of Geocell

Geocells were first used for load support systems in the early 1980s in the US, followed by slope erosion control and channel lining in 1984 in the US, and earth retention in Canada in 1986. Today the applications are many, and broadly include:

a) Load support systems:
1. a) Increase in load carrying capacity of foundation spread and strip footings, and grade slabs.
   2. b) Reinforcement and support systems for embankments on weak ground;
   3. c) Reduction in pavement sections for all types of roads, lay-down areas and parking lots.
   b) Gravity walls for earth retention and surcharge load support.
   c) Erosion control:
       1. a) Embankment slopes and natural slopes;
       2. b) Water channel and water pondage linings.

5.1 In Railway

The confinement of the ballast using Geocell was quite effective in reducing vertical deformations, especially when low-quality material was used. Higher shear strength of the ballast reduces the need for reinforcement, reducing the need for substructure improvement.

Fig 6 shows the stabilization and support of the substructure of rail tracks on the soft and flexible soil (including during the application of sleepers, pre-tension prestressed concrete switch sleepers and jointless rail tracks), construction of stable and long-life road and rail crossing, liquidation of wet-beds, repeated used of breakstone during the repairs of railway. Geocell help the railway construction in following ways:
   i. Gell cell is very useful where there is limitation of deep soil replacement
   ii. It help in reduction of the propagation of oscillation and vertical and horizontal vibration from railway subgrades (protection of historic buildings),
   iii. It help in prevention of the occurrence of stray currents and extending the life of rails and crossovers.
   iv. It help in enabling the construction of stable and long-life connections of subgrades to bridges and viaducts,
   v. It help in enabling the application of any type of surfaces along and inside the railway subgrade that remain environmentally beneficial while taking care of the aesthetic landscape design,
   vi. It help in enabling quick repairs and modernization of stable road and rail crossings on poor subsoil,
   vii. It help in enabling a significantly faster modernization or repair of subgrade, frequently with tra4c continued on the neighbouring track,
   viii. It help in stabilization and corrosion protection of earth slopes, excavation slopes and embankments,
   ix. With the help of Geocell, embankments on poor load bearing soils may be form alongwith earth retention walls and soil sound absorbing structures.

5.2 In Pavement and Road Construction

Maintenance of paved and unpaved roads and highways has been a major issue for all road owner authorities. When the roads are not appropriately designed and constructed, life of the roads drastically
reduces causing disruption of the traffic. Such roads develop pot-holes, develop uneven riding surfaces, and tend to settle over stretches, thereby disrupting traffic movement. Geocell has improved the performance of recycled asphalt pavement (RAP) bases over weak subgrade as compared with the unreinforced base section and Geocell significantly increased the percentage of resilient deformation of the RAP base. The Geocell reinforcement reduced the vertical stresses transferred to the subgrade by distributing the load over a wider area. Studies shows about the bearing capacity improvement of gravel base layers in road constructions using Geocell and concluded that Geocell layer placed within the gravel base layer of an asphalt paved construction reduced the vertical stresses on subgrade during vehicle crossing about 30 per cent and increased the layer modulus of the gravel base layers compared to an unreinforced layer. As a result the measured deflection on the asphalt surface were also reduced. Besides, use of Geocells not only reduces the thickness of the pavement section but also significantly reduces downtime due to maintenance.

As shown above, the surface is dressed and compacted. Geocells are spread over the dressed surface by manual labour. Adjoining sections of Geocells are interconnected using pneumatic staplers or ties. The Geocells are spread open and anchored in position using metal anchors or wooden stakes. The Geocells are then in- filled using a loader or similar equipment, topping over by 50mm. Geocells filled with cohesionless material form rigid mats capable of distributing imposed loads. The filled cells are compacted using a roller compactor. The filled Geocells are then topped off with other layers as per designs.

5.3 In Foundation
Various test results clearly demonstrate that Geocell mattress can substantially increase the bearing capacity and reduce settlement of the clay subgrade with void. Provision of Geocell reinforcement in the overlying sand layer improves the load carrying capacity of circular foundation and reduces the surface heaving of the foundation bed substantially. The performance improvement increases with increase in the width of the Geocell layer up to b=D of 5 beyond which it is negligible. Good improvement in the load carrying capacity of the foundation bed can be obtained even with Geocell mattress of width almost equal to the diameter of the footing.

5.4 Gravity walls for earth retention and surcharge load support
Geocells with granular infilling make ideal gravity walls (Fig 8). Multiple layers of Geocells filled with granular material are stacked atop each other. The principal of design is similar to conventional gravity walls. The perforations ensure that hydrostatic pressures behind the wall are dissipated. The Geocell system allows flexibility at site which need not be dressed to perfection prior to laying. The consecutive layers of Geocells are laid to a batter and the horizontal exposed surfaces of the Geocells could be put to use for turfing or any appropriate vegetation.

Fig 8 typical strataweb gravity wall section
5.5 Erosion control

Geocells with soil or concrete infilling provide an effective erosion protection system. Geocells filled with concrete can be shaped to form waterways to route storm water along slopes and embankments to prevent formation of gullies and ruts which can weaken the earth structure (Fig. 9). Geocells can be effectively used to foster vegetation along slopes, which would provide further erosion protection. A typical solution is illustrated in Fig. 10 for the branded Geocell “StrataWeb”. Geocells have also been effective to nurture grass on beach sand and prevent erosion of the sand.

![Fig. 9: Waterway along road embankment slope](image)

![Fig. 10 Geocells with vegetation for slope protection](image)

5.6 Miscellaneous applications

Such Geocell walls have been tried out with success as sidewalls for storm water side drains along toll roads in Karnataka. Fig 11 shows the trial stretch at Karnataka along the six-laning project of NH 4. Four layers of Geocells to form gravity side The drain along the Highway Trials with water wall for drain

![Fig. 11: Trial stretch of side storm water drain along NH-4](image)

6. Conclusion

From the various studies conducted by many previous researchers, discussed in this paper we can conclude that Geocell is a soil reinforcement technique which is proved to be a versatile method in terms of its cost effectiveness and it provides all round confinement to the materials hence it prevents the lateral spreading of soil on the application of load. So the use of Geocell reinforcement increases the strength and stiffness property of the soft soil. Its application in civil engineering field are numerous such as slope protection, earth reinforcement, road or highway load support, channel protection, improving bearing capacity of soft soil to support footing etc. Still there are other applications which are yet to be discovered. In addition, overall behavior of the Geocell reinforced soil is of interest for future research. To conclude, Geocells is an innovation that has several applications as structural and protective geosystems. These applications include, but are not limited to:

- Urban and rural roads
- National and state highways and expressways
• Service roads
• Road shoulders
• Haul roads for:
  • Mines
    • Construction sites
    • Oil fields
• Railway track stabilization
• Foundations on weak soil
• Basal reinforcement for embankments on weak soils
• Container yards
• Landfills
• Tank farms
• Channel embankments and levees
• Slope erosion control
• Wind farms and solar power units
• Retaining walls
**Annexure**

**Material properties of Geocell:**

<table>
<thead>
<tr>
<th>Material</th>
<th>High Density Polyethylene (HDPE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer density</td>
<td>0.935-0.965 g/cm$^3$</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>1.5% (± 3%)</td>
</tr>
<tr>
<td>Nominal Sheet Thickness</td>
<td>Minimum 1.3mm</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td>Polyethylene strip consists of a multiple rhomboidal indentations, over the entire strip area on both sides of the strip. The indentations have a surface density of 22 to 32 per cm$^2$.</td>
</tr>
<tr>
<td><strong>Perforations</strong></td>
<td>Polyethylene strip is perforated with horizontal rows of maximum 10 mm diameter holes. Cell perforations area is less than 12% of cell surface area.</td>
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**Cell properties**:  

| Weld spacing (± 3%)             | 356mm                                             |
| Cell depth (± 3%)               | 150mm                                             |
| Expanded cell size (± 10%)      | 259 X 224 mm                                     |
| Expanded cell area (± 10%)      | 290 cm$^2$                                        |
| Nominal expanded section width  | 2.59 mts                                          |
| Nominal expanded section length | 6.50 mts                                          |
| Nominal expanded section area   | 16.8 m$^2$                                        |
| Seam strength                   | 2130 N                                            |

*The depth of the Geocell as well as the size of each cellular unit can vary as per design requirements.*