GEOCELLS: THE WAY FORWARD WITH THE THREE DIMENSIONAL INNOVATION

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The geotechnical environment was completely revolutionised with the application of geosynthetics, starting with the humble non-woven to the more complex geo-composites. Most of these systems are two-dimensional. Cellular confinement systems add the third dimension to geosynthetics, which open up more avenues of applications, ranging from providing strength to geo-systems, to protection against erosion.

The System

Cellular Confinement Systems are popularly known as "Geocells". Geocells are strong, lightweight, three dimensional systems fabricated from ultrasonically-welded High Density Polyethylene (HDPE) strips that are expandable on-site to form a honeycomb-like structure (Fig. 1).Geocells are filled with compact non-cohesive soils which are confined within the cellular walls. The composite forms a rigid to semi-rigid structure. The depth of the geocells as well as the size of each cellular unit can vary as per design requirements.

Fig 1: Typical Geocell

Generally, the infill is sandy or gravelly material. However the infill may be plain concrete depending on the application such as erosion protection, water channel formation, etc.

The surface of the geocell is textured to increase soil-geocell wall friction. The geocell wall is punctured (Fig. 1) to assist in immediate dissipation of developed porewater pressures due to increased stresses within the infill of the individual cells.

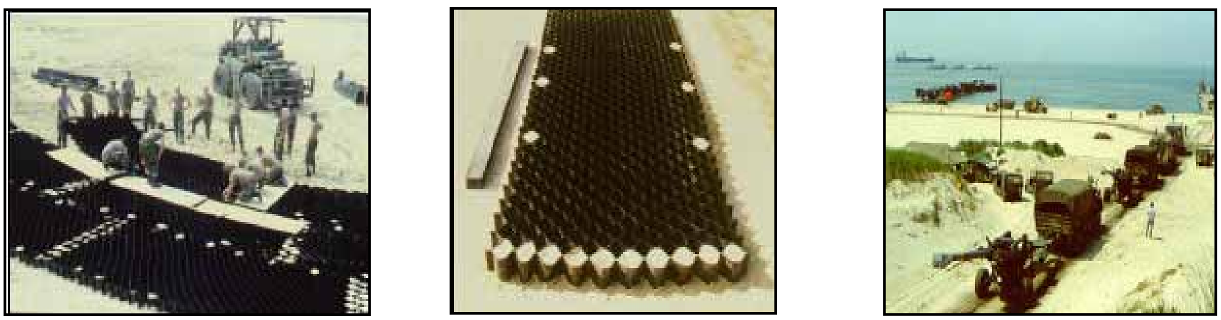
Geocells can be used to great advantage considering that:

1. Geocells are the only prefabricated three-dimensional geosynthetics with significant third dimension properties;
2. They are easily transported as flat strips welded width-wise at regular intervals, and logistics for large quantities is not a problem;
3. Geocells are easy to install and do not require skilled labour. They can be installed in any weather condition;
4. The in-fill has essentially to be non-cohesion material, however the material could be recycled material;

5. Solutions considering geocells as a solution for any civil engineering / geotechnical issue always proves to be cost effective with reduced and economic usage of valuable natural resources, including metal / aggregates, sand, cement, etc. the cost savings can be as substantial as much as 30% for road construction and the time saving can be as much as 50%;
6. When used for roads and pavements, geocells substantially reduce cost of maintenance by improving the longevity of the road / pavement;
7. Considering all of the above, geocells help reduce carbon foot-print; since carbon black is an essential ingredient of the HDPE, geocells indirectly foster carbon sequestration.

Genesis

The development of geocells has been credited to the US Corps of Engineers in 1975 to test the feasibility of constructing bridge approach roads over soft ground. Geocells were extensively used during the Vietnam War as well as the Gulf operations in the late 1980s (fig. 2).



Laying | Filling | Movement of heavy equipment

Fig. 2: US Army application

Civilian applications

In the civilian sector, 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:

1. Load support systems:
   a) Increase in load carrying capacity of foundation spread and strip footings, and grade slabs.
   b) Reinforcement and support systems for embankments on weak ground;
   c) Reduction in pavement sections for all types of roads, lay-down areas and parking lots.

2. Gravity walls for earth retention and surcharge load support.

3. Erosion control:
   a) Embankment slopes and natural slopes;
   b) Water channel and water pondage linings.

Roads

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. Geocells in-filled with sand / metal as subgrade improve the strength of the pavement, reducing settlements, formation of reflective crack and pot-holes. Besides, use of geocells not only reduces the thickness of the pavement section but also significantly reduces downtime due to maintenance.

Fig. 3 sequentially illustrates a case study of a road in Karnataka being rehabilitated using geocells. 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. The filled cells are compacted using a roller compactor. The filled geocells are then topped off with other layers as per designs.

Initial Site Conditions

Folded up geocells for transportation and storage

Spreading and anchoring the geocells

Geocells stapled and laid out

Placing of infill

Geocell reinforced road without topping

Fig. 3: Sequence of road rehabilitation

Load Support Systems

Geocells filled with cohesionless material form rigid mats capable of distributing imposed loads. The mechanics of geocells as a load carrying system is illustrated in Fig. 4.

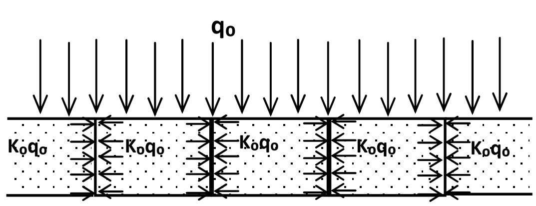


Fig. 4: The mechanics of geocells as load support systems

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_0q_0 where K_0 is the coefficient of earth pressure "at rest", i.e. (1-sinϕ) where ϕ 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.

This phenomenon of geocells is used to advantage in transferring relatively heavy vertical loads onto relatively weak soils by spreading the load over large areas. This includes use of geocells as basal reinforcement for earth embankments on soft foundations. Geocells can also be used below spread footings, strip footings, raft foundations and grade slabs on weak soils. Trials are underway in Tamil Nadu, using geocells within the ballast layer of railway track. The swelling characteristics of expansive soils can also be overcome by judicious use of geocells below foundations and roads.

Gravity walls for earth retention and surcharge load support

Geocells with granular infilling make ideal gravity walls (Fig 5). 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.

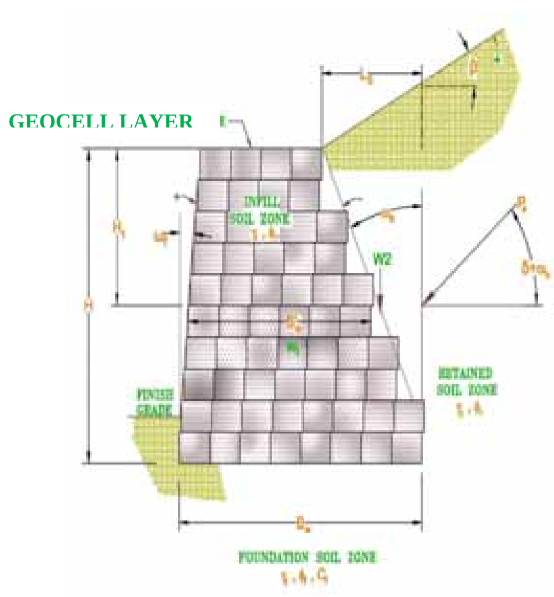


Fig. 5: Typical gravity wall of geocells

Such geocell walls have been tried out with success as sidewalls for storm water side drains along toll roads in Karnataka. Fig 6 shows the trial stretch at Karnataka along the six-laning project of NH 4.

Four layers of geocells to form gravity side wall for drain | The drain along the Highway | Trials with water

Fig. 6: Trial stretch of side storm water drain along NH-4

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. 7).

Take-off at pipe culverts | Finished geocell waterway down embankment slope

Fig. 7: Waterway along road embankment slope

Geocells can be effectively used to foster vegetation along slopes, which would provide further erosion protection. A typical solution is illustrated in Fig. 8 for the branded geocell "StrataWeb".

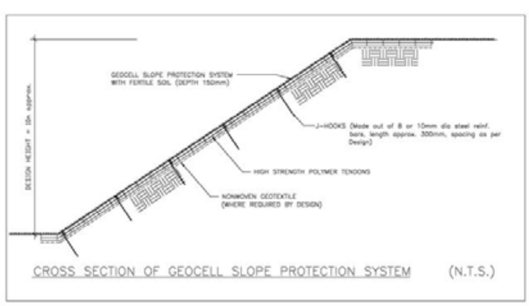


Fig. 8 Geocells with vegetation for slope protection

Geocells have also been effective to nurture grass on beach sand and prevent erosion of the sand.

Conclusion

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

Strata Geosystems (India) Pvt. Ltd. markets geocells as described above under the brand name “StrataWeb”.