Applying Geocell Confinement to the Built Environment

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Abstract

The use of geocells have become common in civil engineering. Dating back to the 1970's where geocells were used extensively for military roads, the US Army Corps developed geocells from aluminum and later polymer materials to traverse difficult terrain with armored vehicles. Geocells generally termed as 3D honey-comb matrices were then developed and produced around the world by multiple manufacturers and are contrived from different materials such as High-Density polyethylene (HDPE) or Polypropylene.

This paper will highlight the different available geocells on the market today and its current uses. The paper will also go into detail on the manufacture, testing and uses in the civil engineering industry. The paper will aim to increase the awareness of geocells and its various uses in today's built environment in many sectors, including pavement optimization, erosion control, reinforcement and hydraulic applications. The information here should be treated as an introductory guide to the usage of geocells as an alternative construction material.

Keywords: *Geocells, Optimization, Reinforcement, Erosion control, Stabilization, Hydraulic*

1 Introduction

Geocells are a versatile addition to the engineering basket and have many different applications in today's construction field. Utilized to achieve cost savings or faster construction speeds on site. Geocells have been designed and modelled in the past and have a rich history supporting them. The paper will illustrate the different kinds of geocells available on the market today. Highlighting the different polymers used to manufacture the geocells and the cost that separate them in the market. As well as indicating some of the testing procedures geocells are put through. After identifying the nature of the problem, the designer can choose a geocell based on its polymer abilities.

2 Geocell Compositions and Cost Relations

2.1 High- Density polyethylene (HDPE)

High-Density polyethylene (HDPE) is a thermoplastic polymer produced from the monomer ethylene. It has a high strength-to-density ratio and is used for piping, geomembranes and other end products. HDPE is commonly used as a chemical-resistant barriers on one spectrum and on the other being outdoor chairs, bottle crates etc.

2.2 Polypropylene

Polypropylene is a thermoplastic polymer produced from the chain-growth polymerization from the monomer propylene, its properties are similar to polyethylene and is a mechanically rugged material with a high chemical resistance. Manufacturing with polypropylene is achieved via extrusion and molding and used for piping, plastic containers, bags and manufacturing of carpets and synthetic fibers.

2.3 Polyester

Polyester is a category of polymers that contain the ester functional group in every repeat unit of their main chain. Polyesters include natural occurring chemicals found in plants and insects, as well as synthetics such as polybutyrate. Depending on the chemical structure polyesters can be thermoplastic or thermoset. The applications are vast and range from knitted or woven fabrics to making bottles, sails and products in the film industry.

2.4 Novel Polymeric Alloy (NPA)

A polymeric alloy composed of polyolefin and thermo plastic engineering polymer. NPA was developed for the use in geosynthetics and is mainly used as polymeric strips in cellular confinement systems. It offers a high tensile strength and stiffness and is manufactured by co-extrusion and in multi-layer strips. The novel polymeric alloy was mainly developed for high-modulus geosynthetics and is used for geocells, geogrids and geomembranes.

2.5 Aluminium

Aluminium is a chemical element with the symbol Al and atomic number 13. It resembles Silver and its great ability to reflect light. It is soft, non-magnetic and ductile and has one stable isotope. It is also the twelfth most common element in the universe. Major uses for aluminium are currently in the transportation, packaging, building and construction as well as a wide range of household items.

2.6 Cost Relations

Table 1: Costs at time of writing

Polymer	Cost p/kg
Polypropylene	R14
Polyester	R11.12
Ethylene	R14.41
Recycled Polyester	R10.53
Aluminum	R34.38

Novel Polymeric Alloy prices could not be attained as this is a proprietary material.

The prices stated above were taken at time of writing from the market exchange rates and could differ. It does however show the differences relating to cost in the different manufactured goods. The quality difference will also come in to account but we should take note that different geocells are manufactured with specific applications in mind. Testing is undergone to ensure stringent quality control for these geocells to function as designed for.

3 Uses for Geocells

Fig 1. Channel lining

3.1 Channel Lining/Canal Protection

Geocells are used all over the world as a concrete shuttering system or as a soil containing system. The cell walls allow high flow systems to be filled with concrete and act as reinforcement replacement for steel mesh and rebar. Geocells having individual pockets and perforated strips allow for vegetation to thrive, thus reducing erosion on channel slopes and beds. The perforations in the strips allow for relief caused to the system by hydrostatic pressure. Maintenance could be noted as easy when earth is used to fill the cells, making it a cost effective solution opposed to standard concrete.

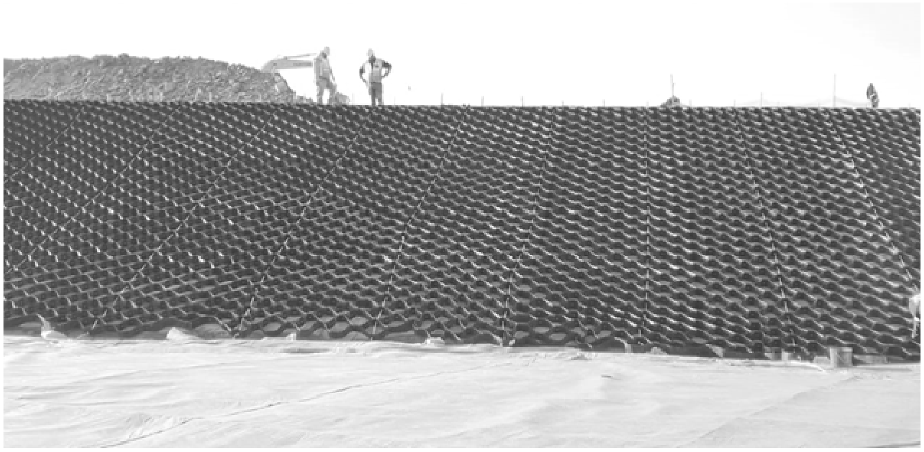

Fig 2. Slope protection

3.2 Slope Protection/Erosion Control

Geocells are mostly designed in such a way that they can be infilled with topsoil for vegetative purposes or concrete for harder finishes. The main advantage of geocells on slopes is to increase a soils natural angle of repose, thus increasing space for platforms. Other important functions include the mitigation of erosion by confining the soil to a pocket.

Fig 3. Geocell infilled with concrete for a road

3.3 Load Support and Concrete Roads

Geocells strengthen soils by containing and creating an apparent cohesion to cohesion less soils. The individual hoop strength of each cell prevents the lateral displacement of the soil and can thus decrease deflection and settlement, in weak or poor subgrades, allowing for stable bases for road layers. Geocells make for perfect load support systems over areas of CBR's less than 3%.

4 Geocell Manufacture and Testing Procedures

Geocells are typically manufactured in a honeycomb structure from different parent materials. In the case of polymers such as polyester and polypropylene, strips of coated woven tape are stitched together to form three dimensional diamond shape cells. When HDPE is involved, we notice that extruded sheets are used that are welded together to create the joints. In all these manufacturing techniques stringent testing is undergone to make sure that the manufactured geocells are optimal for the application. The next segment will highlight the testing undergone.

4.1 Material Properties

All geocell manufacturers provide data sheets stating which polymers were used to manufacture the product. This will also in most cases determine the application of the geocell. Most manufacturers do specify applications for usage.

TECHNICAL DATA SHEET

Product Name

Reference No: DS ERSN 0501-09/2013 Rev1

Date of Issue 31 July 2014

Description A polymeric homogenous sheet bonded to form four-sided cells in a diamond shaped lattice pattern bordered by an external tensioning frame, Patent No. 2003/3945

Mass / panel	Height	75 mm	kg	4.5	SANS 10221
		100 mm		6.5	
		150 mm		9.5	
		200 mm		13.5	
Parent product	Laminated polypropylene slit-film woven tape				
	Thickness		mm	0.65	SANS 10221
Tensile Strength	Parent	Strength	kN/m	26	SANS 10221
		Elongation	%	21	
	Seam	Strength	kN/m	4	
		Elongation	%	12	

Fig 4. Data sheets

4.2 Weld Strength or Seam Strength

The weld or seam strength is normally used for quality control purposes but is not always a factor in engineering design as in the case of perforated geocell strips, the strip will fail before the seam or weld. ISO 13426-1 is used for testing the weld/seam strength. To simulate 90º forces, an X-shaped sample from the geocell is wrapped around two rollers in a jig apparatus and clamped to a tensile test strength machine. The test is conducted at a rate of 100mm/m until a split failure of the welds occurs.

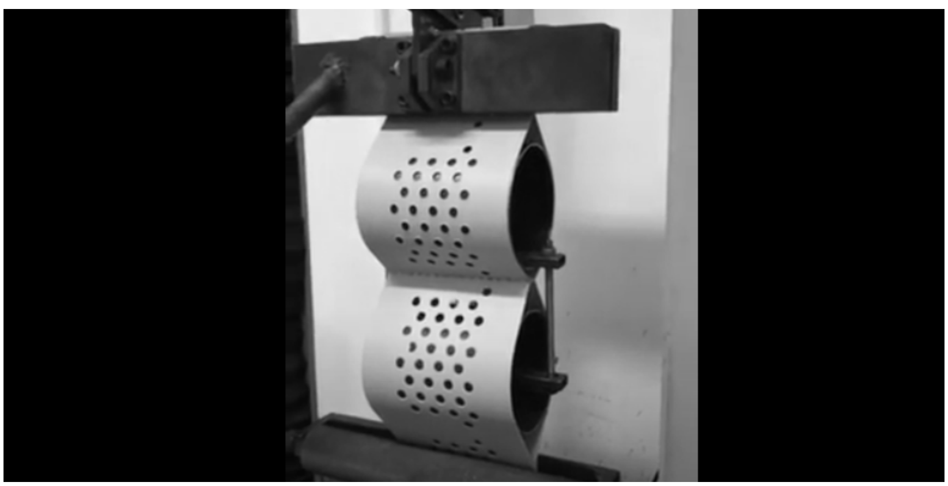

Fig 5. Weld/seam strength test

4.3 Tensile Strength

Material tensile strengths are tested with the ISO 10319:2015 method. South Africa adopts SANS 10221. This involves clamping a 200mm section strip on each side and placed under constant strain until the specimen ruptures. Measurement is performed by an extensometer and strain at maximum load is recorded.

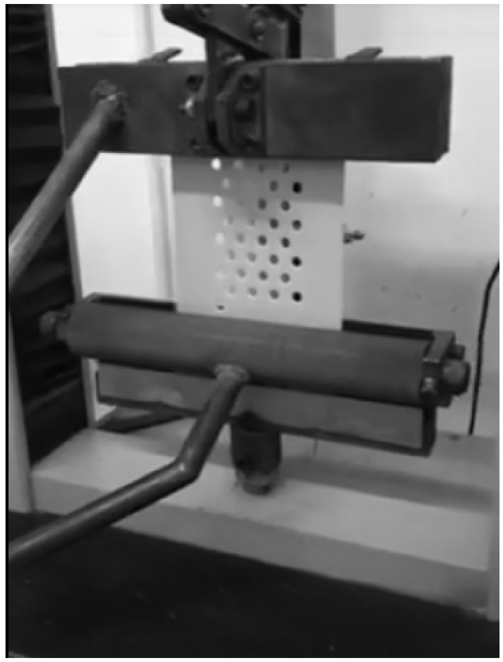

Fig 6. Tensile strength test

4.4 Other Testing Procedures

Geocells today are commonly made from polymers. These polymers are subjected to stringent tests and quality controls to make sure that products supplied to meet the needs of an engineered design. Such tests include UV stability tests. These are done by using xenon arc weathering. The tests generate visible UV and infrared light which closely replicates sunlight. By using different filters the heat levels can be adjusted to achieve the desired effect close to that of site.

6 Case Studies, History

6.1 History

Geocells were first introduced by the Army Corps of Engineers in September 1975 when they were researching confinement systems in opposition to conventional aggregate systems when crossing soft soils. These geocells were constructed from aluminium as polymers currently used were most likely not available at the time. Currently geocells are made from a few different polymers and are much more cost effective. Geocells have been used in multiple different applications and then developed through trial and error and thereafter scientific testing and research in terms of stability.

Fig 7. Side by side aluminum and plastic geocells

6.2 Case Studies

For the benefit of the paper a few published case studies have been chosen from across the world to showcase the different applications as well as benefits in using the technology.

6.2.2 Erosion Control Slope Stabilization Ballito

The contractor (Mono-Block) approached a well-known supplier/manufacturer to assist in an erosion control issue that an embankment was facing. The site was the Santorini Holiday Apartments in Ballito Bay. The embankment comprised of very unstable dune sands which faced the effects of wash away. They opted for the 100mm profile MULTI-CELL system, not only for its ability to protect and stabilize the slope but also because it's lightweight and easy to handle nature on extremely steep slopes. The MULTI-CELL was anchored at the top of the slope in a small sub-soil drain while at the bottom of the slope it was anchored into a Gabion Basket. Each individual 5m x 10m cell was staked with steel at designed spaces. It was quite critical that the soil within the cells be properly compacted to avoid further scour during heavy rain.

Fig 8. Multicell layout

Fig 9. Multicell infilled

6.2.3 Fochville Canal Reinforcement

The Merafong City Municipality had approved a roads and storm water construction project at an informal settlement. In order to cope with an increase in surface water run-off from the surrounding hardened area, an existing trapezoidal canal running parallel to the township required an extension. The solution was to stabilize the slopes of the canal, Multi-Cell® was specified. Along both crests parallel to the canal, trenches were excavated into which the Multi-Cell® was anchored. Once installed, they were filled with pre-mix concrete to cope with the higher velocity.

Fig 10. Canal prep

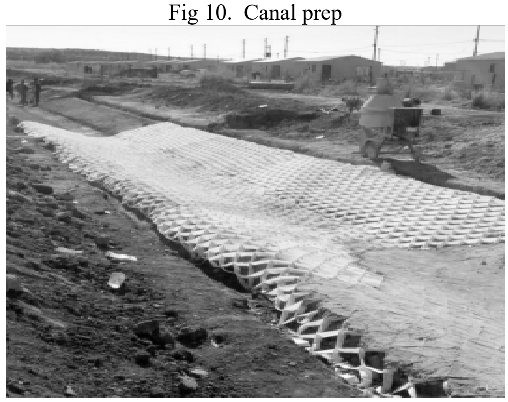

Fig 11. Multicell laid down

Fig 12. Premix concrete infill

6.2.4 Geocell for Flexible Pavement

The client turned to geocells to strengthen the internal roads of their manufacturing facility of wind turbine towers. The site consisted of weak clayey soils with a CBR (California bearing ratio) of 15% which needed to be strengthened for traffic movement and to minimize the effects of ruts due to vehicular passes. The manufacturers' team of geotechnical experts suggested removing a layer of the road crust and adding a layer of StrataWeb® geocell. Introducing StrataWeb® in the granular base or sub-base not only improves the longevity of the pavement but also economizes the overall crust thickness. StrataWeb® helps in confining the soil due to its three-dimensional structure. It helps in distributing the load to a wider area thereby reducing stresses on the overall crust thickness. It also helps in increasing the pavement life by reinforcing soil within. StrataWeb® enabled the use of locally available aggregate.

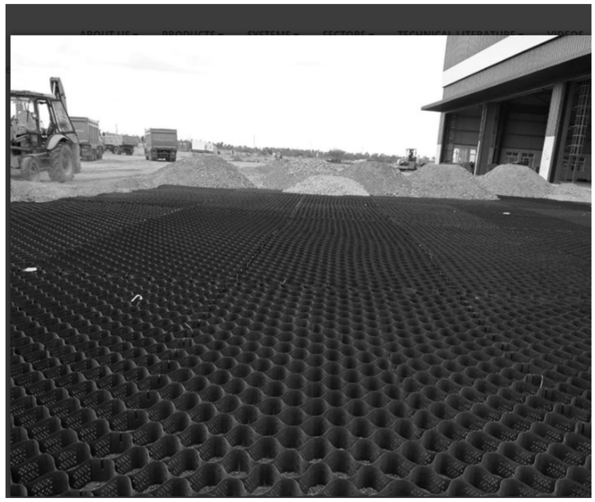

Fig 13. Strataweb® laid down for the sub base.

Fig 14. Strataweb® filled with local aggregate

7 Alternative Uses in South Africa

Applications in South Africa are mainly noted in erosion control applications, basal applications but are rapidly increasing in the field of waste containment. The cells are infilled with either a soil-cement mixture or concrete and placed over liners that a susceptible to UV exposure. Being so versatile and finding its place in the built environment, they have been noted as a cost saving alternative to conventional materials.

One such case is shown in the above application (Fig 11.), where a road is reinforced by using geocells and local fill was used. This allows cost savings to be achieved by cutting down on required importation of material, as well as a decreased carbon footprint. The following examples will show how geocells could be used in other applications to achieve greater project efficiency and cost savings when alternative methods are considered.

7.1 Retaining Walls Using Geocells as Facings

Geocells can be used as reinforcement and facings in retaining or gravity wall structures to secure soil in place as the 3D honeycomb structure contains the soil in the pockets. This action reinforces the soil placed inside them. This can allow for structures to be built in environments where shuttering is of concern as well as tie-back lengths when using geogrid reinforcement. Images below depict this type of construction.

Fig 15. Earth retaining wall using geocells.

7.2 Check Dam Construction

With the versatility shown using geocells, structures can also be completed by reinforcing fill placed within the honeycomb structure. In the case of the Check Dam, an earth bund could not be used as the structure was washed away within the first rain season. The geocells contained the soil and allowed for a reasonable water-tight structure with cement infill on the upstream side of the construction. The benefits found was that sitewon fill could be used and an enviromentally friendly solution could be attained

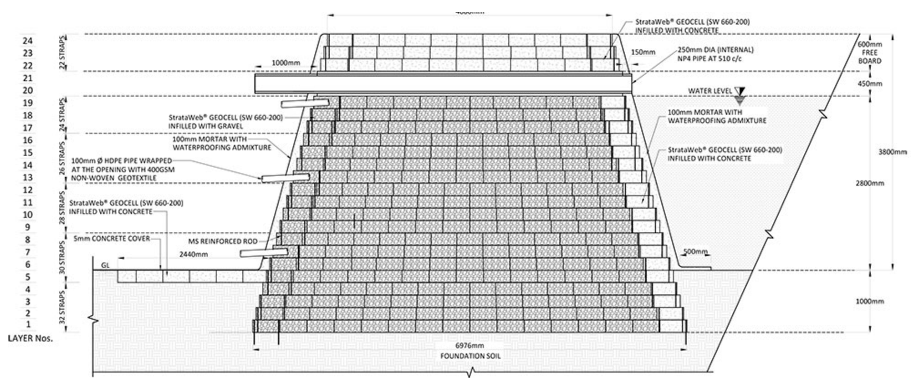

Fig 16. Check dam design

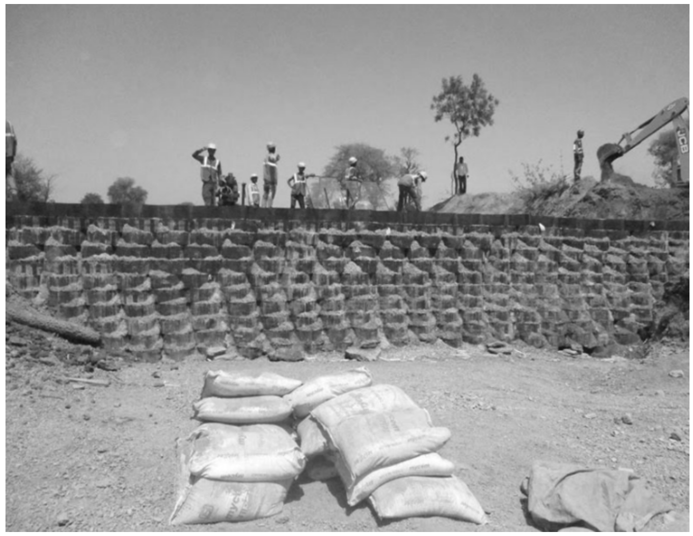

Fig 17. Check dam design

Conclusion

The paper cycles through history, manufacture, testing and actual usage on site. The aim of the paper was to highlight that geocells is not new technology but rather a technology that is continuously advancing as research continues in the built environment. The vast majority of stable polymers has now made geocells cost effective to be used all over the globe. Extensive testing when manufacturing has seen confidence grow in design engineers to actively include them as the new conventional material.

Rising costs of raw materials has seen many countries shelve projects thus seeing a downward spiral in economic growth. It should be our responsibility to seek alternative methods of design and materials to ensure projects move forward in a cost effective manner.

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