

High Compressive Resistance Drainage Geocomposites

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ABSTRACT: There are several typologies of drainage geocomposites available in the market which can be classified according to their structure as: cusped, monofilaments, geonets and those products formed by the combination of a draining blanket with a series of mini-pipes. Each one of them has its own range of compressive resistances. There are applications, such as are the new cells of landfills or mines and roads or railways over large embankments, where the pressure exerted on the geocomposite exceeds the compressive resistance of the majority of these typologies. For all these applications, besides providing an adequate flow capacity, it must be ensured that the chosen typology is able to withstand the required loadings without collapsing and guaranteeing an adequate factor of safety. This article will expose that, currently, the only typology of drainage geocomposites that can bear these loadings while maintaining its drainage properties is the triplanar geonet.

1 INTRODUCTION

Drainage geocomposites are of common use in civil works, building, mining, landfills, landscaping and any kind of construction or structure that requires an adequate management of infiltrating liquid or gas.

Amongst all the possible applications for drainage geocomposite there are those where the product must bear substantial loadings. This is the case of horizontal drainage in airports, roads, railways, trams, drainage under high embankments, tailings dams in the mining industry and new cells of landfills.

The requirements for drainage geocomposites in these applications should not be limited to their most used value, their flow capacity, but should also take into account the compressive resistance of the geocomposite in order to ensure its correct performance under such loadings.

There are many types of drainage geocomposites in the market, but not all of them can be used for this kind of applications.

2 CLASSIFICATION OF DRAINAGE GEOCOMPOSITES

Drainage geocomposites could be classified according to their geometry and structural configuration, their thickness, their raw material, their short-term

flow capacity, their creep behavior or any other considerations depending on the aim of the study.

In order to address the goal of this article, which is to explain which typology performs best under high pressures, they will be classified according to their geometry and structural configuration (which determines their compressive resistance). The different typologies are: cusped (Figure 1), monofilaments (Figure 2), geonets (Figures 3 and 4) and those products formed by the combination of a draining blanket with a series of mini-pipes that collect the fluid (Figure 5).

Each one of these typologies has its own range of compressive resistances depending on the configuration of its structure, its geometry, the specific production process of each manufacturer, etc. However, we may present values that, generically, mark the maximum compressive resistances that can be usually found in the market for each one of these structures.

It must be clarified that the goal of this study is not to test or to judge specific products or to state the exact maximum compressive resistances of any specific manufacturer. Nevertheless, the values presented are meant to give a general idea of the different products that can be found in the market with their most common range of values for crush resistance (Table 1).

Table 1. Classification of drainage geocomposites according to their configuration

Classification		Polymer of drainage core	Compressive resistance kPa
Cuspated	Simple cuspated	HDPE	125 – 400*
	Double cuspated	HDPE	125 – 400*
Monofilaments	Random filaments	PP	100 – 250
	Zig-zag filaments	PP	150 – 400
Geonets	Bi-planar	HDPE	600 – 850
	Tri-planar	HDPE	1.200 - 2.000
Combination of draining blanket with mini-pipes		PP blanket + HDPE pipes	400 – 700

* Specific products may reach a value of 700 kPa

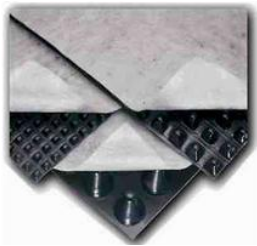


Figure 1 Cuspated



Figure 2 Monofilaments

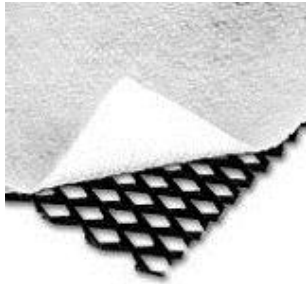


Figure 3 Bi-planar Geonet

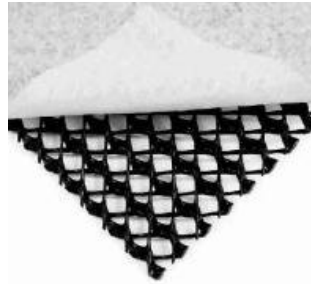


Figure 4 Tri-planar Geonet



Figure 5 Combination of a draining blanket with mini-pipes

3 COMPRESSIVE RESISTANCE

Compressive resistance for drainage geocomposites can be tested following either ISO 604 or ASTM D 6364. Crush resistance is defined by the yield point in a stress-strain graph (Figure 6).

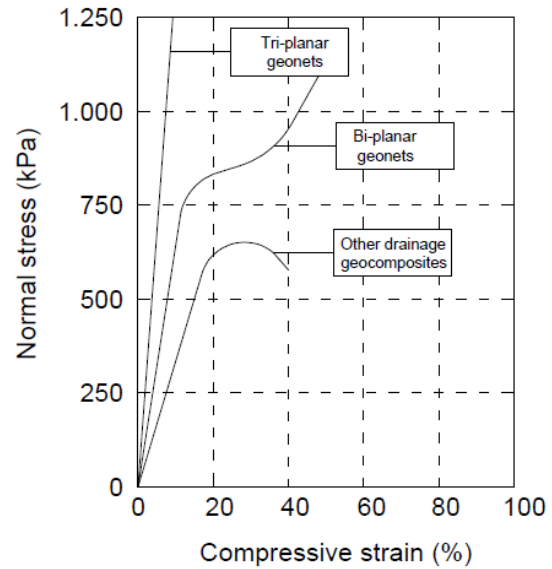


Figure 6 Conceptual compressive test results of various types of drainage geocomposites.

Most drainage geocomposites collapse under an increasing stress. On the other hand, bi-planar geonets have the tendency to lay-down or roll-over because their parallel sets of ribs are not exactly perpendicular to one another at their junctions; although, they are still able to convey liquid beyond this point (Koerner, 2012). Tri-planar geonets show no inflection point since the central and thicker set of ribs is perpendicular to the normal stress.

An important issue to consider is that these tests can only give the short-term compressive resistance. To establish the long-term behavior of a drainage geocomposite we must take creep into account. Creep, in materials science, is the tendency of a solid material to deform slowly and permanently as a result of a long-term exposure to high levels of stress that are below the yield stress of the material (Smith, 1993). Section 5 will give further information on this subject regarding geonets.

4 APPLICATIONS WITH HIGH COMPRESSIVE RESISTANCE REQUIREMENTS

Drainage geocomposites are meant to be installed as a high flow zones underneath layers of compacted soil, asphalt, etc. Thus, there will always be a Dead Load (σ_{DL}) over the geocomposite which is the summation of the specific weight of each one of the layers on top of it (γ_i) multiplied by the thickness of the layer (h_i), (Equation 1)

$$\sigma_{DL} = \sum_i \gamma_i \cdot h_i \quad (1)$$

And, of course, there will also be Live Loads (σ_{LL}), such as lane traffic in roads, and Construction Live Loads (σ_{CLL}). Indeed, if there are layers of compact-

ed soil on top of the geocomposite, construction and compacting equipment will have to ride on top of the geosynthetic. This Construction Live Load may easily reach values of 500 kPa. Recalling the values stated in Table 1, this fact alone eliminates the possibility of using several drainage geosynthetic products for many horizontal drainage applications because, even if they are able to bear service loads, they are not able to handle construction loads.

Regardless of this fact, there are applications where a drainage geocomposite must bear Dead or Live Loads that exceed those of common practice. This is the case of:

- Horizontal drainage in airports. Depending on the location of the airport, there must be drainage underneath the landing lanes exposed to high dynamic loads of airplanes landing. In this case, Live Loads are limiting.
- Horizontal drainage under high embankments (Figure 7). In this application Dead Loads are limiting. The drainage geocomposite “is not affected” by a road, a railway or an industrial area on top of the embankment. Just with the weight of the embankment itself, a high compressive resistance is required. As an example, a 30 m high embankment, built by compacting a 20 kN/m³ soil, without any loading on top exerts a load of 600 kPa on the drainage geocomposite beneath it.
- New cells of landfills
- Tailings dams in the mining industry



Figure 7 Green wall forming a 30 m high reinforced embankment in Bilbao, Spain

These last two applications are very similar to drainage under high embankments. In new cells of landfills and in tailings dams, drainage geocomposites are installed over (or between) waterproofing geocomposites (GCL, GM or combination of both) and a heavy load of waste or tailings is placed on top of these geocomposites. These loads can easily reach 700 kPa or even higher values. The main function of a drainage geocomposite in these applications is to

collect the leach residue to avoid its contact with the surrounding environment.

In all these applications, besides providing an adequate flow capacity, it must be ensured that the chosen typology is able to withstand, without collapsing and guaranteeing an adequate factor of safety, the loadings that it will be subjected to during the design life of the construction.

5 DESIGN METHODOLOGY

The short-term flow capacity of a drainage geosynthetic must be obtained through testing. Tests are performed with a transmissivity apparatus according to either ISO 12958 or ASTM D 4716. The reason why this flow capacity is referred as short-term is that the duration of the test is very limited in comparison with the design life of the geosynthetic (usually decades). Test durations are 100 hours if a reduction factor for intrusion is not considered in design (GRI GC8, 2001) or several minutes if this reduction factor is used.

The long-term flow capacity ($q_{long-term}$) is determined reducing the short-term tested flow capacity (q_{test}) by several reduction factors according to equation 2 (Koerner, 2012).

$$q_{Long-term} = \frac{q_{test}}{RF_{in} \cdot RF_{cr} \cdot RF_{bc} \cdot RF_{cc}} \quad (2)$$

This methodology considers four reduction factors: intrusion of the adjacent geosynthetics into the geonet's core space (RF_{in}), creep of the geonet and adjacent geosynthetics into the geonet's core space (RF_{cr}), chemical clogging or precipitation of chemical within the geonet's core space (RF_{cc}) and biological clogging within the geonet's core space (RF_{bc}).

As stated in section 3, creep is a key factor to consider in design. Creep tests should be performed in order to obtain the specific creep reduction factor of each geonet (Giraud et al., 2000).

Bi-planar geonets are formed by two sets of intersecting ribs at different angles and spacings (Figure 3) whereas tri-planar geonets have parallel central ribs with smaller sets of ribs above and beneath mainly for geometric stability (Figure 4). The unique configuration of tri-planar geonets allows them, not only to have higher compressive resistance and better creep behavior, but to have a much lower intrusion reduction factor even at pressures over 700 kPa (Zaho & Montanelli, 1999).

Once the long-term flow capacity is defined and the adequate geocomposite has been selected according to it, we must verify that this geosynthetics is capable to withstand the mechanical stresses to which it will be subjected to during its design life

(including the installation process as previously explained in section 4).

As a recommendation, an adequate factor of safety for compressive loads would be greater or equal to 2,5 (which would be, broadly speaking, equivalent to consider a 1,4 majoration factor for loads and a 1,8 minoration factor for compressive resistance according to the Load and Resistance Factor Design methodology of common use in structural engineering). This factor may be lower in installation as this is not a permanent situation.

We may now retake the example of section 4: a 30 m high embankment, built by compacting a 20 kN/m³ soil, without any loading on top. The pressure over the drainage geocomposite is 600 kPa, according to equation 1. Considering the recommended safety factor of 2,5, the adequate geocomposite for this application must have a compressive resistance greater or equal to 1.500 kPa. According to Table 1 only a tri-planar geonet is able to bear this kind of loading.

6 REAL APPLICATIONS OF HIGH COMPRESSIVE RESISTANCE GEOCOMPOSITES

6.1 *Chemical waste deposit for the decontamination of Flix's Reservoir (Spain)*

An out of control chemical waste deposit from mining operations was found next to Flix's reservoir in the Ebro River, Spain (Figure 8). Due to the obvious potential damage to the environment quick actions were carried. A large controlled landfill was designed in order to be able to remove all the mining waste from the river and store it safely.



Figure 8 Water reservoir in Flix. Note barrier to impede mixture and spreading of the chemical waste.

According to the EU regulations for chemical waste (1999/31/EC), several layers of drainage were designed (a total of 8 layers of high-density waste

(Figure 9) with a thickness of 3,5m per layer). The design also contemplates two waterproofing layers in the bottom of the cell with a leak detection drainage layer between them. All these drainage layers were built with drainage geocomposites which serve the purpose of collecting the generated leachate in order to be able to treat it properly.



Figure 9 High-density chemical waste

The pressure over the drainage geocomposite exceeds 600 kPa which requires a high compressive resistance 7mm thick tri-planar HDPE geonet. This tri-planar geonet has a 200 g/m² geotextile laminated on one side and a 200 g/m² Ultra Violet resistant geotextile on the exposed side. Over 150.000 m² of product were installed in 2012.

6.2 *New cell for Indaver LFS in Belgium*

The need to create a new cell for landfill in Belgium with a total height of 44 m of waste, with a specific weight of 16 kN/m³, required a drainage geocomposite for leachate collection with a compressive resistance around 700 kPa.

A 5mm high crush resistance tri-planar HDPE geonet with two 120 g/m² polypropylene geotextiles heat-bonded to it was selected by the designers.

40.000 m² of product were installed in 2011 with the purpose to collect leachate in the slopes and also in the base of new cell of the landfill, where at maximum loadings the product was installed with a 2% inclination ensuring an adequate performance.

The design life of the cell is 20 years, which indicates the need of a good creep behavior, such as the one offered by a tri-planar geonet, in order to ensure an optimum long-term performance.

One particularity of the project is that this new cell was not dug into the ground, but built above it as an "artificial mountain" (Figure 10).



Figure 10 New cell of landfill in Belgium

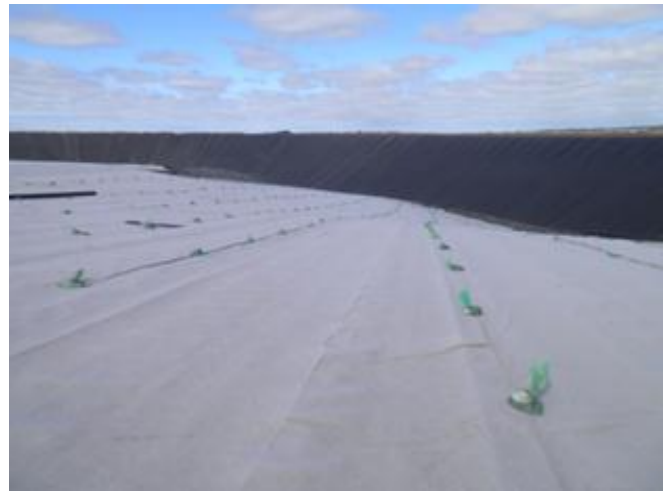


Figure 12 Installation of the leach residue collection layer in Kanmantoo's mine, Australia

6.3 Tailings dam in Kanmantoo's mine, Australia

Kanmantoo is a copper and gold mine located in Adelaide, Australia (Figure 11). To ensure an environmentally adequate operation of the mine it was necessary to build a new pond for the decantation of the mineral extracted in the mine.

The dam is around 40 m high. Considering a conservative density of 10 kN/m^3 for water with minerals in suspension, the pressure over the drainage geocomposite layer to installed is 400 kPa.



Figure 11 Construction of the tailings dam for Kanmantoo's mine located 25 km away from Mount Baker in the Adelaide Hills, Australia.

Leach collection and leak detection layers were installed by using a 5mm tri-planar HDPE geonet due to the great importance that designers gave to compressive resistance and creep behavior.

Over 150.000 m^2 of tri-planar drainage geocomposite were installed during 2011 as a leak detection layer and over 140.000 m^2 as the main collection layer for the leach residue (Figure 12).

6.4 Airport platform in Papua New Guinea

One of the biggest oil companies of the world, is currently building a huge plant of Liquefied Natural Gas (\$15,7 billion) in the area of the Hides in Papua New Guinea (Figure 13).

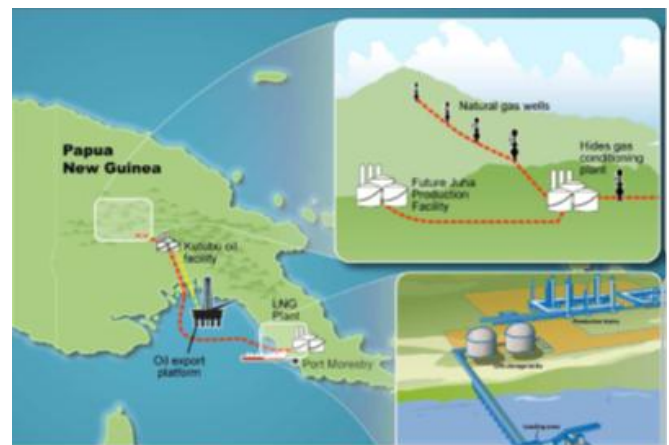


Figure 13 General conception of Papua New Guinea's Liquefied Natural Gas plant

The first intention was to build a road to access the site but this was found to be an unreasonable approach due to the huge distance and maintenance costs. Designers finally decided to build an airfield in Komo for their new plant (Figure 14).

Due to the remote location of the plant (in the Hides of Papua New Guinea) there wasn't enough quantity of adequate gravel to build the drainage layer of the airfield. Thus, designers decided to select a 5mm tri-planar HDPE geonet with two 120 g/m^2 polypropylene geotextiles heat-bonded to it. The surface drained in Komo's airfield is $260\,000 \text{ m}^2$.



Figure 14. Komos' airfield construction

There is no need to say that designers were looking for a special geocomposite with high compressive resistance and creep behavior in order to stand the dynamic loads of aircrafts during the takeoff and landing.

7 CONCLUSIONS

There are applications that have high requirements for compressive resistance, such as: horizontal drainage in airports, roads, railways, trams, drainage under high embankments, tailings dams in the mining industry and new cells of landfills.

Not all the available drainage geocomposites in the market are suitable for these applications due to their structural design that limits their compressive strength. In fact, only those geocomposites based on tri-planar geonets can perform adequately in the long-term under such demanding conditions.

Tri-planar geocomposites have been widely used around the world for these applications showing that not only a technical background but also the experience supports their use.

Engineers working in such projects should not limit requirements for drainage geocomposites to their flow capacity, but should also take into account their compressive resistance in order to ensure their correct long-term performance under such loading conditions

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