The state of the art and new tri-planar drainage composite for landfill cappings

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ABSTRACT: There are several typologies of drainage geocomposites available in the market which can be classified according to their core structure as: dimpled, monofilaments and geonets. Each one of them has its own range of compressive resistances as well as specific applications where some of them perform better than the others. Geonets have been typically considered as the best option to provide adequate flow capacity when the load to withstand is medium, high or very high. But for low pressure applications, such as landfill cappings, traditional geonets were not able to give an adequate and cost-effective solution, where many times monofilament-based composites where chosen instead. While thinner and lighter bi-planar geonets were not capable of giving a high flow rate when needed, the heavy tri-planar geonets appeared as very expensive solutions. For those areas where intense episodes of rainfall are expected, or in landfills with high extension and long slopes, a high flow capacity geonet was needed. Trying to join the benefits of the tri-planar structure with a light product, a new cutting edge lightweight tri-planar geonet has been designed and developed to give response to the projects where cost-effectiveness and high performance are a must. This paper will expose the characteristics, benefits and range of applications of these new geonets.

Keywords: geonets, drainage composites, compression, creep, landfill, capping

1 INTRODUCTION

The Council Directive 1999/31/EC of 26 April 1999 regulates the operational and technical requirements on the waste and landfills. The main objective of this Directive is to provide measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air. In order to do so, the Directive provides us with general requirements for all classes of landfills, focusing its attention in: location, water control and leachate management, protection of soil and water, gas control, nuisances and hazards, stability, and barriers.

When it comes to water control, it is written that “appropriate measures shall be taken, with respect to the characteristics of the landfill and the meteorological conditions, in order to control water from precipitations entering into the landfill body, and prevent surface water and/or groundwater from entering into the landfilled waste”.

With regard to gas control, the Directive says that “appropriate measures shall be taken in order to control the accumulation and migration of landfill gas; landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used; the collection, treatment and use of landfill gas shall be carried on in a manner which minimises damage to or deterioration of the environment and risk to human health”.

Traditionally, gravels have been used for gas and water drainage, while polymer-based composites have been used in the last decades due to their advantages in terms of environmental impact, cost-effectiveness, installation performance, etc…

2 DRAINAGE COMPOSITES IN THE MARKET

Polymer-based composites are normally manufactured in HDPE or PP. The choice of the polymer and the drainage core structure depends very much on the final applications and the real needs of the site, and several types are generally accepted in the market by all landfills operators worldwide. It must be mentioned that all engineered landfills should be focused on the technical parameters of the composite (both mechanical and hydraulic), regardless what raw material is used for its production.

Both mechanical and hydraulic properties of the composite will depend mostly on their geometry and structural configuration. According to this, composites can be classified as: dimpled or cuspated (Figure 1), entangled or monofilament-type (Figure 2) and geonets (Figures 3 and 4).


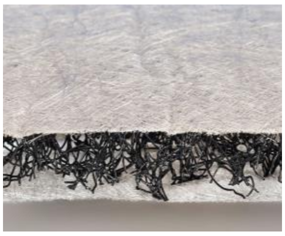
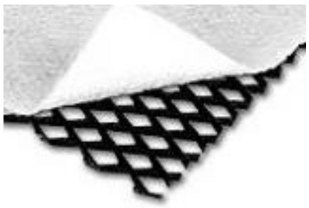


Figure 1 Dimpled   Figure 2 Monofilaments   Figure 3 Bi-planar Geonet   Figure 4 Tri-planar Geonet

Figure 5 shows us a first qualitative approach to the compressive resistance of all these types of drainage composites. It is clear that geonet-based composites show the highest compressive resistance, while the other sheet drains are supposed to have higher flow-rate capacity but only for low pressure applications. In addition, it must be mentioned that a unique non-woven geotextile should never be considered as a drainage layer (see Figure 6).

In the analysis made in Figures 5 and 6, the new lightweight tri-planar did not exist. In next points we will show how this product compares and what his position is. We will understand how this new lightweight tri-planar composites are top flow rate performers, with good compressive strength and excellent creep behaviour.

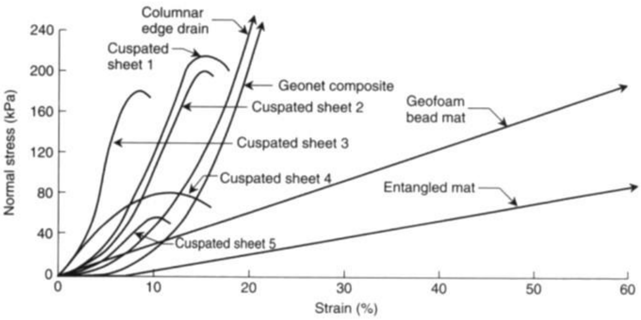

Figure 5 Compressive strength of main composites types (Koerner, R. M., 2012)

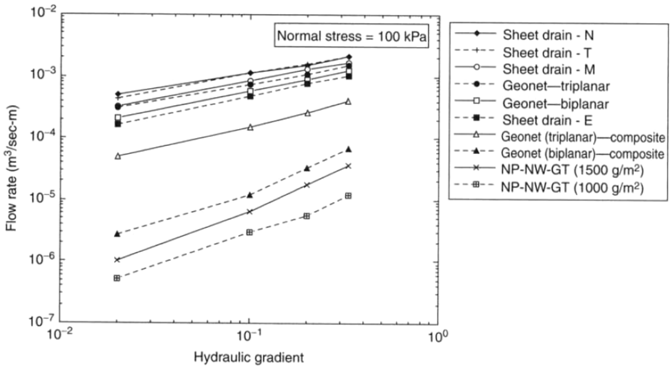

Figure 6 Index flow rate of various drainage composites and thick geotextiles (Koerner, R. M., 2012)

3 DRAINAGE NECESSITIES IN A LANDFILL CAPPING

When designing a capping lining system, the real on-site conditions must be assessed. It is very important to choose the proper product for each application, so that the most cost-effective solution is always considered. In a MSW (municipal solid waste) landfill capping we will typically find a cross section as it is shown in figure 7.

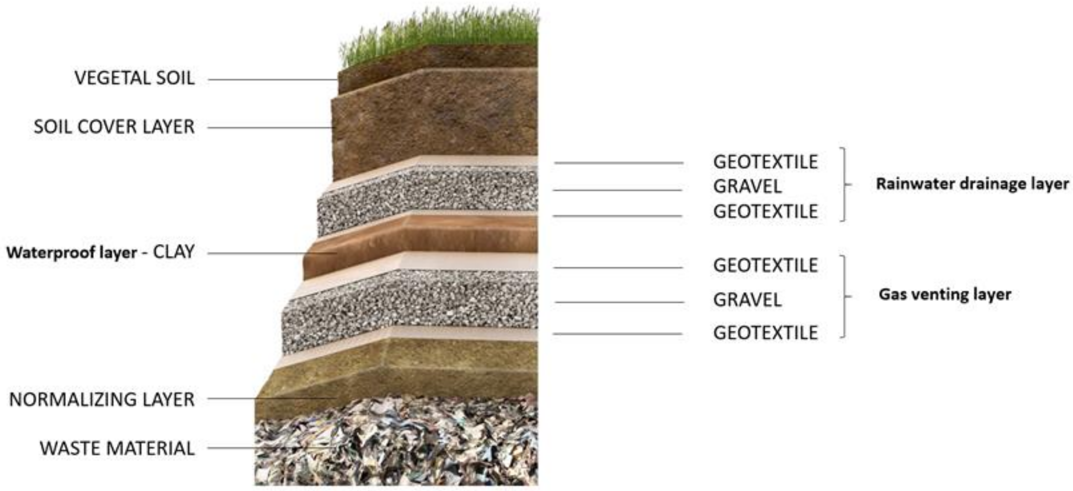

Figure 7 Typical cross section of a MSW landfill capping

3.1 *Main functions of drainage layers in landfill cappings*

The first drainage layer from top to bottom is the one that will help us to avoid the entrance of water in the landfill body, as mentioned in the introduction. This is a must in order to stop the production of leachate, but additionally this layer will comply with another critical function, that is to ensure stability of the veneer cover soil. In this case, the drainage layer serves for eliminating the static pressure on the soil above (also called seepage forces), in order to avoid slides and lack of stability (Koerner and Soong, 1998: Analysis and Design of veneer cover soils. Paragraph 3.3 Page 12).

Below the rainwater drainage layer, a waterproofing system must be installed. Normally natural clay has been used for this purpose, but the lack of raw materials, their prices and logistics troubles have created the need for finding synthetic products. For such application Geosynthetic Clay Liners (GCL) and/or Geomembranes (GM) are currently used instead of clay.

The second drainage layer is needed for the evacuation of Landfill Gas (LFG). In the landfill body, anaerobic bacteria decompose organic waste to produce a mixture of gas, being methane the main compound. Not only because they may be hazardous, but they can be profitable as well, these gases are collected when the landfill life span is finished. If not burnt, they can be sent to a cogeneration plant close to the landfill.

3.2 *Requirements for drainage composites in landfill cappings*

Gravels are non-compressible and inert, while drainage composites are polymer-based products. Therefore, their mechanical and chemical behaviour must be evaluated when they are used in landfills. In the case of cappings, special attention must be put on the following aspects:

3.2.1 *Transmissivity*

This is the main purpose of the composite. Short-term flow capacity (equal to transmissivity multiplied “gradient” times) is measured in accordance with either ISO 12958 or ASTM D4716. These tests are performed simulating real on-site conditions: pressure on the composite, gradient and boundary conditions. In our case, a small constant load is expected, normally 20kPa (corresponding to 1m of soil 20kN/m^3), gradients will vary very much from flat areas to slopes, and boundary conditions will be normally Hard-Soft (Hard for both GM/GCL and Soft for soil and normalizing layers).

Afterwards, long-term flow capacity is calculated following GRI-GC8 “Determination of the Allowable Flow Rate of a Drainage Geocomposite”. After 100 years the flow capacity of the composite will be reduced, mainly due to four basic factors: damages during installation, chemical clogging, biological clogging and creep. It is not our scope to discuss about this topic, widely discussed by many authors, but the creep behaviour will appear later due to its importance in the performance of the drainage composite.

3.2.2 *Compressive resistance*

This parameter is to be assessed by either ASTM D6364 or ISO 25619-2. While dead loads are expected to be low (<20kPa), even if constant, live loads may be higher if the main recommendations are not followed during the construction process. It is well known that no machines should be driven directly over the composite, but in the site, it is not unlikely to find vehicles driving directly over it. In these cases, the geonet is the best option to withstand such loads.

3.2.3 *Creep behaviour*

In accordance with either ASTM D7361 or ISO 25619-1, it is important to know how our composite is going to behave under a constant load in the long-term (one of GRI-GC8 reduction factors depends on this property). Both standards give us the reduction in thickness after a certain period of time, but the American Standard gives us 10.000h while the ISO norm only gives us 1.000h. Therefore, ASTM D7361 will be more suitable for us because we can extrapolate the result to 1.000.000h, which is our final target. Moreover, the American Standard is an accelerated method and therefore the most adequate one to use for this specific property.

Once this behaviour is evaluated, we must apply GRI-GC8 methodology to obtain the value of the Reduction Factor due to Creep. This formula to obtain RFcr was proposed by Giroud, Zhao and Richardson (2000), and depends on sample thickness in different temporal moments and the porosity of the polymer. By applying this method, we will know in the following points the RFcr that applies to current available drainage composites.

The constant load will be low, expectedly <20kPa, but some products may appear as inadequate once they are tested according to the abovementioned test.

3.2.4 *Long-term protection efficiency*

To be tested in accordance with ISO 13719, long-term protection efficiency is especially important when the chosen waterproofing layer is a Geomembrane. Preventing puncture in the GM is mandatory and this subject must be evaluated. Consequently, the drainage composite must bring enough protection so that it prevents the GM from being damaged.

3.2.5 *Ply adhesion*

Normally tested under ASTM D7005, this parameter can be critical in very steep slopes. There have been many attempts to find a relationship between internal ply adhesion of composites and interface shearing resistance of the respective materials determined per ASTM D5321, but unfortunately with no successful results to date.

4 THE NEW CAPDRAIN

This new lightweight tri-planar geonet has the main advantages of a typical heavy tri-planar geonet (higher flow rate due to its preferred flow orientation and its lower intrusion) but with a lower weight (see figures 8 and 9).

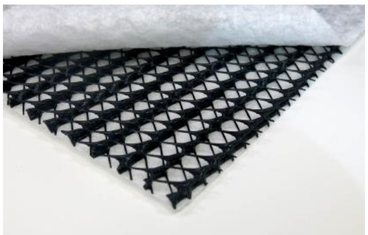

Figure 8 New tri-planar geonet

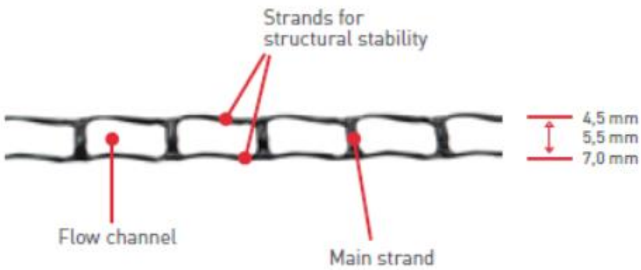

Figure 9 Cross section of the geonet and range of thicknesses

Especially designed for landfill cappings, this new product can be manufactured in three different thicknesses, as shown in Figure 9.

Regarding the first and main property, transmissivity, this new tri-planar geocomposite can be considered as a top performer. If plotted against the other types that have been mentioned until now, it would be drawn in the upper part of the graph in Figure 6. Doing such an exercise gives us the drawing as per Figure 10.

In this figure, typical drainage composites have been considered. In all the cases the composite is formed by a drainage core and two non-woven geotextiles laminated to both sides, except the dimpled type, with only one geotextile. Equivalent products in core weight have been used (light tri-planar, standard bi-planar and dimpled are 550gr/m^2, monofilament type is 600gr/m^2 and standard tri-planar is 800gr/m^2, the minimum known weight in the market).

Standard tri-planar geocomposite is not able to reach high flow rates, even if the product will be much less competitive with a 45% more in average weight compared to the others. No need to say that this statement is not valid for higher loads, where the arguments are totally different and only heavy tri-planar geonets are advisable. In Figure 11 it is shown how the main drainage composites behave when the normal load is increased under a constant gradient.

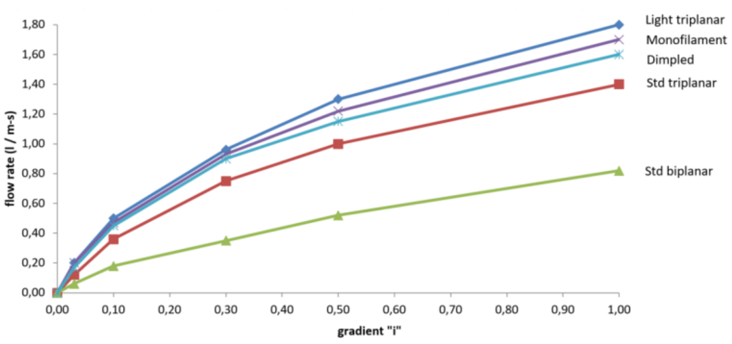

Figure 10 Comparison of short-term flow capacity for various drainage composites, under 20kpa and Hard-Soft boundary conditions, in accordance with ISO 12958

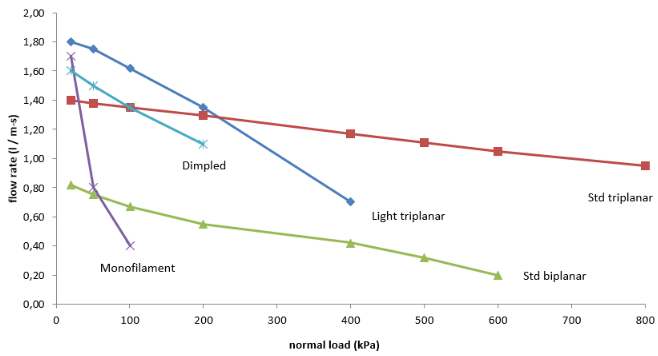

Figure 11 Comparison of short-term flow capacity for various drainage composites, gradient i=1 and Hard-Soft boundary conditions, in accordance with ISO 12958

The second parameter that has been highlighted is compressive resistance in the short-term. In other words, the point in which the product is supposed to break or collapse. In the case of geosynthetics, it is often very difficult to reach such a yield point, thus it is always important to know the deformation for the given value. The new tri-planar geonet reaches values higher than 400kPa at a 20% strain, and therefore it can be easily placed within the geonet range. Consequently, the new light tri-planar geonet has a similar compressive strength to basic geonets but much higher than the other types of composites (Figure 5).

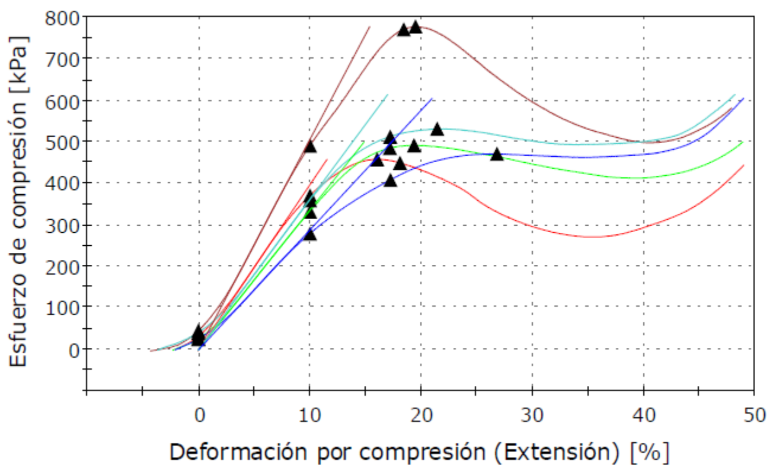

Figure 12. Compressive test results for a 550gr/m^2 tri-planar geonet

Even if the long-term constant load will be only around 20kPa, it has been mentioned before that very often vehicles or machines may ride over the composite, even if it is not recommended. In such a case, an instant pressure of circa 440kPa can be easily exerted on the composite (20x20cm tyre footprint in a 7Tn 4-wheel excavator), and this is the reason why it is so important to ensure a certain compressive strength of the composite, also in landfill cappings.

Regarding creep behaviour, taking for granted that the composite has survived the live loads during installation, even if 20kPa is not a critical value for the short-term compressive strength, the situation can be different if we analyse the flow capacity after 100years. A small constant load over the composite can entail a thickness reduction that cannot be obviated. Figure 13 shows the behaviour of high flow capacity drainage cores under constant loads of 20, 50 and 100kPa, in accordance with ASTM D7361 stepped isothermal method, after 1.000.000hours.

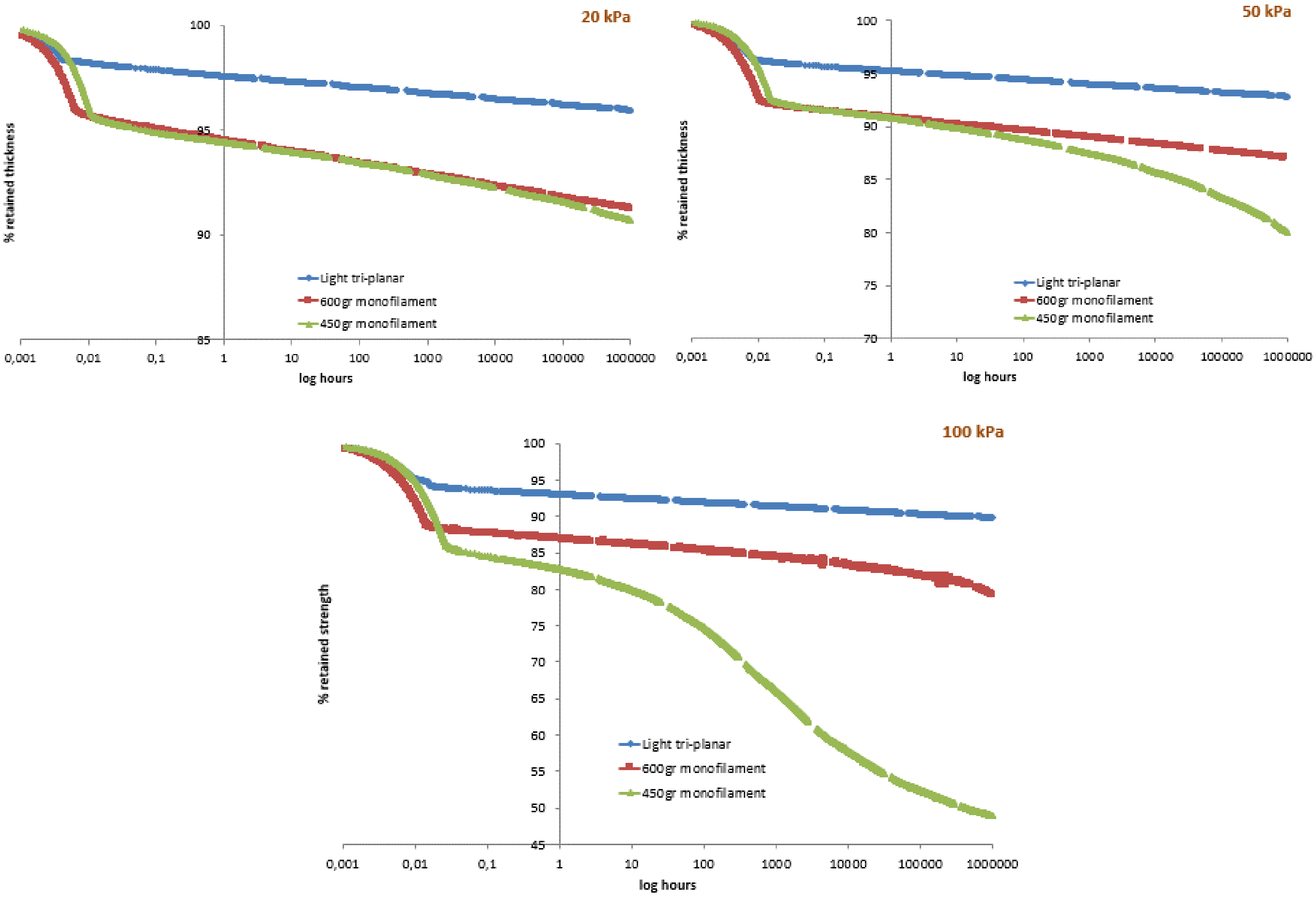

Figure 13. Comparison of creep behaviour under 20, 50 and 100kpa, in accordance with ASTM D7361

The new light tri-planar geonet shows an excellent behaviour when the data is extrapolated to 1.000.000 hours. The differences are important especially beyond 50kPa, which is not a typical situation, but it reflects the performance of each type of product.

Finally, with regard to long-term protection efficiency and ply adhesion, the new tri-planar geocomposite shows a similar performance than any other composite based on geonet. Both parameters can be customized depending on the job necessities and in both the geotextile weight plays an important role.

5 CONCLUSIONS

Drainage composites bring important advantages when compared to traditional solutions with gravels. Up to date, in the case of landfill cappings, the existing range of products in the market did not include a high flow capacity cost-effective geonet-based composite. This paper has exposed the experience with a new light product that is able to join the mechanical benefits of geonets with the hydraulic performance of soft core composites. These two advantages together, the new light tri-planar geonet becomes the most suitable solution for the drainage of gas and water in landfill cappings during the whole life span of the installation.

REFERENCES

ASTM D4716, 2008. Standard Test Method for Deter-mining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

ASTM D5321 – 08. Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

ASTM D6364, 2011. Standard Test Method for Deter-mining Short-Term Compression Behaviour of Geosynthetics

ASTM D7005 – 08. Standard Test Method for Determining the Bond Strength (Ply Adhesion) of Geocomposites

ASTM D7361 – 07. Standard Test Method for Accelerated Compressive Creep of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method

Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste

Giroud, J. P., Zhao, A., and Richarson, G. N., 2000. Ef-fect of Thickness reduction on Geosynthetic Hydraulic Transmissivity. Geosinthetic International, Vol.7 Nos. 4-5, pp.

GRI Standard GC8, 2008. Standard Guide for Determination of the Allowable Flow Rate of a Drainage Geocomposite. Geosynthetic Institute

ISO 12958, 2010. Geotextiles and geotextile-related products -- Determination of water flow capacity in their plane

ISO 13719, 2003. Determination of the long-term protection efficiency of geotextiles in contact with geosynthetic barriers

ISO 25619-1, 2008. Determination of compression behaviour -- Part 1: Compressive creep properties

ISO 25619-2, 2008. Determination of compression behaviour -- Part 2: Determination of short-term compression behaviour

Koerner and Soong, 1998: Analysis and Design of veneer cover soils. Paragraph 3.3 Page 12

Koerner, R. M., 2012. Designing with geosynthetics. 6th Edition.