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Evaluating Tubular Drainage Geocomposites for use in Lined Landfill Leachate Collection Systems

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Abstract**:** Cost-effective, efficient, and effective leachate collection systems are critical to the operation, maintenance, and regulatory compliance of a well-run landfill. Geonet drainage geocomposites are commonly used in leachate collection systems to help meet regulatory requirements for leachate travel time, limit the head of leachate above the geomembrane, and reduce the number of leachate collection conveyance pipes. The long-term performance of geonet drainage geocomposites is limited by several factors including intrusion of the geotextile and biological clogging. Tubular drainage geocomposites offer the advantage of better long-term hydraulic performance and its ease of installation make it an ideal material to increase the performance of landfill leachate collection systems and reduce the overall construction cost.

This paper/presentation discusses the hydraulic laboratory testing associated with the design of drainage geocomposites for lined landfill leachate collection systems, presents the results of recent biological and hydraulic conductivity testing on tubular drainage geocomposites, and presents recommendations for designing landfill leachate collection systems at North American landfills.

Keywords: tubular drainage geocomposite, leachate, landfill.

1. Introduction

Proper management of leachate within a lined landfill is essential. Solid waste regulations limit the head of leachate that is allowed above a landfill liner system, and the failure to efficiently remove leachate could lead to stability concerns. The current state of the practice is to use a granular material that exhibits a high hydraulic conductivity (e.g., sand, gravel, or fine aggregate), a geosynthetic drainage material that exhibits a high transmissivity, or a combination of both. The selection of the leachate drainage layer materials is based on many considerations including the landfill configuration, climate, and available materials. Often, a combination soil/geosynthetic layer is used, in which the soil layer also serves as the protective layer between the waste and the underlying geomembrane liner. In addition to the hydraulic considerations, landfill designers must also consider protecting the geomembrane liner from puncture of the overlying drainage/protective cover soil under the anticipated load during construction and throughout the life of the landfill.

Because of the aforementioned regulatory and design considerations, geosynthetic drainage geocomposites are commonly used. These materials are capable of providing both the desired hydraulic characteristics as well as the puncture protection. To date geonet drainage geocomposites (i.e., a geocomposite comprised of a geonet core sandwiched between two nonwoven geotextiles heated bonded to the core) have been used mostly in North America. However, in Europe and Africa more than 10 millions of square meters of tubular drainage composites (e.g., a perforated small diameter tube spaced between two nonwoven geotextiles needle-punched together) have been installed since 1992 for gas or liquid drainage in building, roadwork, environmental and mining applications (Figures 1 and 2).

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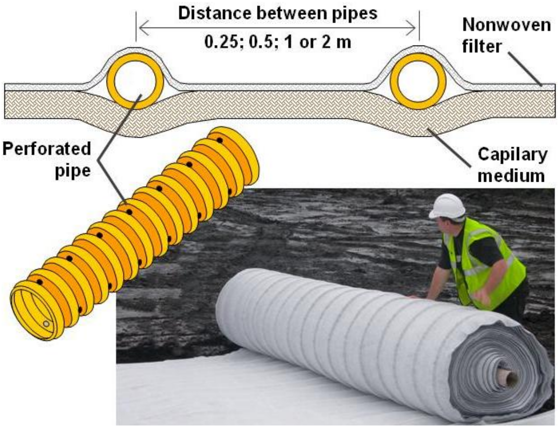

Figure 1. Roll of tubular drainage geocomposite

Figure 2. Leachate drainage at the bottom of land-fill

An important characteristic of tubular drainage geocomposites is that they maintain their transmissivity (the volumetric flow rate per unit width of specimen per unit gradient in a direction parallel to the plane of the specimen; see ASTM D4716 [ASTM, 2013]) under significant normal stresses (Saunier, et. al., 2010) in large part because they do not experience geotextile intrusion into the primary high-flow component. Therefore, for most of the applications, the applied combined reduction factors (intrusion of the geotextile into the drainage core RF_{IN}, creep of the drainage core RF_{CR}, chemical clogging of the drainage core RF_{CC} and biological clogging of the drainage core RF_{BC}) for tubular drainage geocomposite are almost half of those applied to standard geonet geocomposites (Maier, et. al., 2013). Figure 3 present a scheme of a transmissivity testing device. Figure 4 provides transmissivity test results for a tubular drainage geocomposite with four equally spaced, 25-mm diameter pipes per meter width of product.

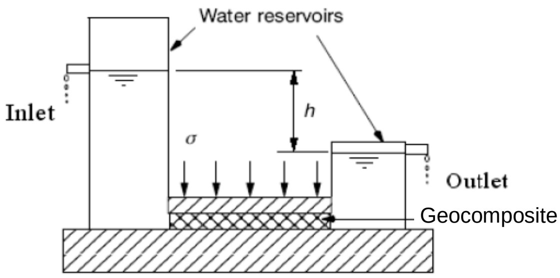

Figure 3. Transmissivity test device scheme

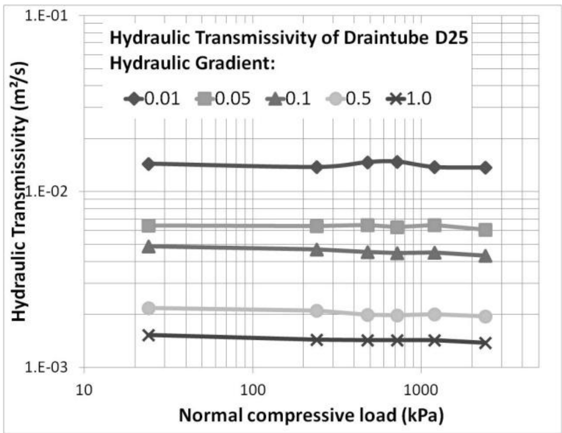

Figure 4. Transmissivity test results for a tubular drainage geocomposite with four, 25-mm diameter pipes per meter width.

The case for considering tubular drainage composites in leachate collection layers is presented below, based on an evaluation of laboratory testing of the two types of geocomposite drainage materials.

2. Laboratory Testing

2.1 Background

The design of drainage geocomposites for leachate collection layers for lined landfills considers several factors including the capacity of the geocomposite to transmit the liquid and the ability of the geotextile component of the geocomposite to protect the underlying geomembrane from puncture from the overlying granular material. These two functions are related because the mass of the nonwoven geotextile has a direct effect on the hydraulic characteristics of the geocomposite. According to GRI Standard GC8 (Geosynthetic Institute 2013), the design standard for the liquid conveyance performance of the drainage geocomposite is based on a 100-hour transmissivity test performed in accordance with ASTM D4716 (ASTM, 2013).

For design purposes, the results of ASTM D4716 are modified (i.e., reduced) to account for anticipated flow reductions. Recommended reduction factors are presented in GRI Standard GC8 (Geosynthetic Institute 2013) and Part III of GSI White Paper #4 (Geosynthetic Institute, 2007). Because the aforementioned reduction factors do not address the geotextile component (other than its intrusion into the geonet core), reduction of the geotextile component as outlined in Part II of GSI White Paper #4 should also be applied.

Designers must be aware that the hydraulic testing of the drainage geocomposite should be performed using the nonwoven geotextile components selected to protect the underlying geomembrane from puncture due to the overlying granular soil. The procedure to select the required mass of the geotextile component of a drainage geocomposite should follow the steps defined in GSI White Paper #14 (Geosynthetic Institute, 2008), which is based on an extensive testing program. In this procedure, the mass of the geotextile (the presence of the drainage core is not considered) may be calculated from the anticipated loads applied to the geomembrane (reduced by a factor of safety) (i.e., allowable pressure) in consideration of the protrusion height of the granular soil (i.e., portion of the granular soil likely to exert a puncturing effect on the geotextile). In additional, there are several modification and reduction factors that should be applied. The modification factors address the shape, density, and arching characteristics associated with the granular soil. The reduction factors address long-term chemical/biological clogging and long-term creep. GSI White Paper #14 provides recommended modification and reduction factors and specifically indicates conditions (i.e., geotextile mass-protrusion height combinations) that are not recommended.

Based on the above, and to avoid unnecessary design iterations, it is clear that designers should first identify the mass of the geotextile components of the drainage geocomposite then evaluate the hydraulic characteristics of the geocomposite.

One should expect that the results of ASTM D4716 testing will vary depending on the thickness and matrix of the geonet core as well as the mass of the nonwoven geotextiles. Also, because the GRI Standard GC8 assumes the use of a geonet drainage geocomposite, it is possible to avoid, or at least greatly reduce, the above reduction factors by using a tubular drainage geocomposite.

The results of ASTM D4716 are typically based on tests performed using water, not leachate. While clogging studies relative to geotextiles have been performed, it is not practical to specifically define a reduction factor for a specific project and leachate types.

2.2 Hydraulic Testing of Tubular Drainage Geocomposites

It is acknowledged that tubular drainage geocomposites are not used in landfill leachate collection systems in the US. However, these materials are used in Africa and Europe. Because of concerns relative to biological and chemical clogging, a testing program to assess the performance of tubular drainage geocomposites under anaerobic conditions (to simulate the atmosphere of a liner system) was developed for two non-hazardous landfills – one in France and the other in Morocco (Blond, 2014 and Riot, 2013, respectfully). For both sites, a tubular drainage geocomposite that included an anti-bacterial nonwoven geotextile (composed of special fibers including silver ions in their formulation as a biocide agent) as the upper layer was evaluated with site-specific leachate.

The apparatus used to test the tubular drainage geocomposite is shown in Figure 5 and an illustration of the apparatus is presented as Figure 6.

Figure 5. View of the test apparatus

In order to evaluate the clogging potential of both the nonwoven geotextile and perforated pipes of the geocomposite, the following testing conditions were established:

- Constant normal load of 100 kPa on the geocomposite;
- Anaerobic conditions (cells always saturated with leachate);
- Fresh leachate directly pumped from a sump in the cell;
- Temperature maintained above 22°C (72°F);
- Same amount of leachate injected into each cell (about 5.5 m^3 in 18 month, equivalent to a flow of 2 10^{-6} $m^3/s/m^2$ to evacuate); and
- Each configuration was replicated 3 times.

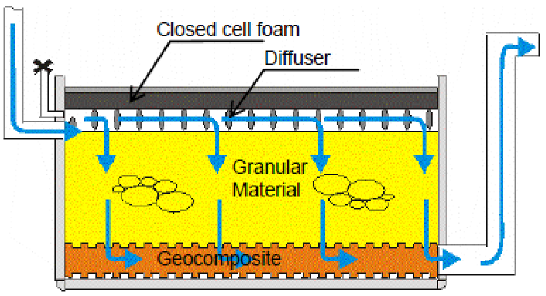

Figure 6. Cross section of a test cell

For comparison, test cells filled with crushed gravel (20 - 40 mm [0.8 to 1.6 inch] diameter) were also included in the test program.

During the 18-month testing program the equivalent hydraulic conductivity of the material (velocity of the water into the cell under an average head of 0.15 m) in each test cell was measured over the time. Figure 4 shows the relative changes in hydraulic conductivity of the tubular drainage geocomposite compared to the gravel. Values greater than 0 percent indicates that the geocomposite exhibited a better hydraulic behavior compared to the gravel.

As indicated in Figure 7, there was no significant decrease of drainage capacity of the tubular drainage composite compared to the gravel layer. Both systems have the same behavior over the time and neither the geotextile filter nor the tube clogged during the 18-month test program.

2.3 Geosynthetic Research Institute (USA)

Currently, another series of hydraulic conductivity tests are being performed at the Geosynthetic Research Institute (GRI) in Pennsylvania. For this testing program, tubular drainage geocomposites, with different geotextile components, are being evaluated and compared with geonet drainage geocomposites. Like the testing programs performed in Morocco and France, the GRI test program is using fresh leachate; however, the geocomposites are not always under anaerobic conditions. Rather, the cells are allowed to empty before being re-filled, and as such, the materials tested are replicating the aerobic-anaerobic environments that portions of a liner system may encounter.

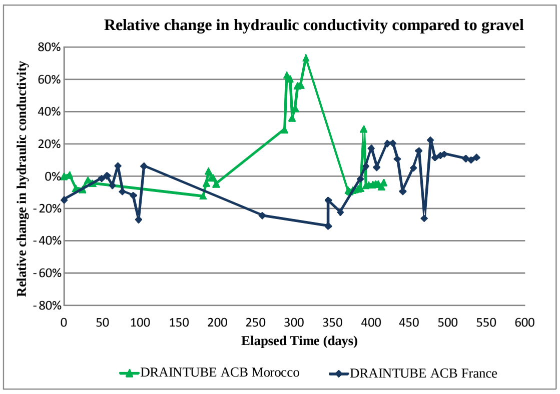

Figure 7. Relative change in permeability between tubular drainage composite and crushed gravel, results from France and Morocco testing programs

During the test program, the behavior of the entire geocomposite (geotextile layer and drainage core [geonet or tube]) will be monitored. The box configuration is similar to those used in Morocco and France with geocomposite placed at the bottom of the cell under a 150-mm (6-inch) thick layer of sand.

Figure 8 shows the relative changes in permeability of two tubular drainage geocomposites with anti-biological geotextile components (one being the same as tested in France and Morocco) compared to a geonet geocomposite with a 7.6 mm (300-mil) thick, biplanar geonet core heat bonded to two nonwoven geotextiles.

As indicated in Figure 8, after a year of testing, the results indicate that the tubular drainage geocomposites with anti-biological geotextiles exhibit about two times more residual drainage capacity than the geonet drainage geocomposite tested.

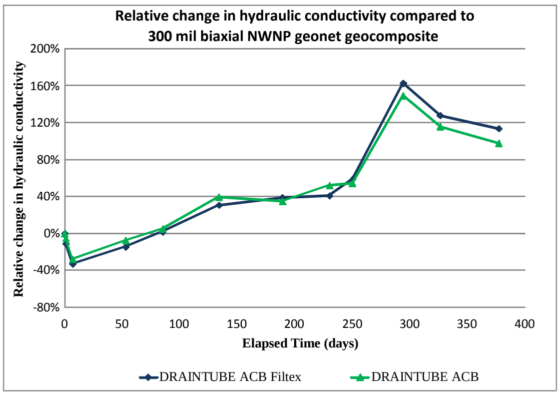

Figure 8. Preliminary results from the GRI test program

3. Design Considerations for Leachate Collection Layers

For drainage geocomposites, the performance of the geotextile component is critical. Leachate has to pass through the geotextile in order to reach either the geonet core or the perforated tube. From GSI White Paper #4, the reduction factor for biological clogging (RF_{BC}) ranges from 2 to 5 and higher for the geotextile component and from 1.5 to 2 for the geonet drainage core.

Considering that the results of the hydraulic testing on tubular drainage geocomposites do not indicate significant reductions over time when anti-biological geotextile components are used, it is possible reduce the RF_{BC} values as they apply to the geotextile. Also, by using tubular drainage geocomposites it is possible to reduce the reduction factors associated with the geonet core (i.e., RF_{IN}, RF_{CR}, RF_{CC}, and RF_{BC}). From the hydraulic testing performed in France and Morocco, considering both the geotextile and tube components, an overall reduction of 2 (the same as for gravel) was calculated.

Because tubular drainage geocomposites require smaller reduction factor values, especially when anti-biological geotextile components are used, and because the overall transmissivity of tubular drainage geocomposites does not decrease with normal load, tubular drainage geocomposites are a valid alternative to geonet drainage composites in landfill leachate collection systems.

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