Tubular Drainage and Lining Geocomposite for Mine Tailings and Heap Leach Pads

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ABSTRACT

In the last decade Afitex developed the Draintube™ geocomposite, which provides simultaneous drainage and waterproofing functions. This new type of drain tubes planar geocomposites (DTPG) differs from other geocomposites as the drainage core is composed of multiple corrugated and perforated pipes instead of biaxial or triaxial nets. It is furthermore associated with needle-punch stitched layers of non-woven geotextiles, which act either as capillary mediums or as filters.

In this paper, the structure of the Draintube™ drainage composite is presented along with its key properties and the drainage mechanism associated with its particular structure.

The relevance of this kind of structure is then reviewed based on past and current laboratory bench evaluations and field installations for mining applications such as the covering of acid rock drainage (ARD) tailings for the Central Manitoba Mine (Canada) site-rehabilitation; and as a pregnant solution collection layer in heap leach pads.

Some of the demonstrated critical advantages of Draintube™ in the mining industry are as follows:

- reduction of the thickness, hence lower volume of granular drain layers
- improvement of fluid and gas collection and reduction of the hydraulic load
- reduction of secondary collector network
- mechanical protection of the sealing membrane
- fast and economical installation of interlifts
- stability under extreme conditions (compression, temperature, pH)
- increased stability of entire covering system and reinforcement of protection of dykes
- filtration of the covered material
- customised drainage
- positive connection of the geocomposite to collector pipes
- enable leaks detection (using a conductive textile layer) with an electrical test.

INTRODUCTION

The use of geomembranes in mining applications has been widely documented. However, geocomposites, and particularly drain tubes planar geocomposites (DTPG), compatibility studies with mined material are scarce and very limited information is available despite the evident advantages of such products. The functions of geocomposites are:

- drainage – to remove water/gas flows
- filtration – by their structure, to prevent fine particles passing while remaining permeable
- separation – placed between two layers of different materials, to prevent mixing under the effect of mechanical stress
- mechanical protection – placed between a geomembrane and the subgrade or embankment, it absorbs the localised stress and protects the liner from puncturing and perforations
- sealing – associated with a membrane, it creates a fluid and gases impermeable barrier.

When compared to traditional solutions (ie granular media such as sand or crushed rock), geocomposites also provide superior:

- quality controls (eg constant quality controlled at factory and on site, uniformity of materials, controlled and stable properties such as permeability)
- cost control (eg little variability in costs – depending on site proximity, stable cost due to resource and stock availability all year long)
- environmental footprint reduction.

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A study by Smith and Zhao (2004) clearly shows that drainage geocomposites lead to improved service and cost reduction in heap leaching. Gulec, Benson and Edil (2005) indicated there were no major changes in the hydraulic and mechanical properties of polypropylene geotextiles after immersion in acid mine drainage for 22 months. Similar results were reported by Grubb *et al* (2001) and Jeon (2006). That is why geocomposites are used in landfills for collecting leachate. Budka *et al* (2007) and more recently Nan and Saunier (2014) proved that geocomposites, and specially DTPGs, can advantageously replace a part of the granular layer (0.20 m of gravel or 0.50 m of sand respectively).

In this paper, we synthetise technical evidence of the superior capability of DTPGs compared to traditional solution (granular media) and other geocomposites (ie biaxial or triaxial nets) for drainage applications in the mining industry through two different case studies:

1. the cover of the ARD tailings of the Central Manitoba Mine (Canada) site-rehabilitation
2. the use as a pregnant solution collection layer in heap leach pads.

DESCRIPTION OF DRAINTUBE™ GEOCOMPOSITE

Primarily used in the construction industry for environmental and civil engineering applications (landfills, infrastructures, etc), DTPGs are now also used for mining applications due to their unique structure and technical characteristics demonstrating their long-term viability as a drainage solution. Among them, Afitex Draintube™ has been the object of various certifications (AFAQ ISO 9001, CE, ASQUAL, IDRRIM, CSTB) to allow its deployment in the highly competitive and regulated European and North American regions.

Technology

Afitex Draintube™ DTPG differs from other geocomposite as the drainage core is composed of multiple corrugated and perforated polypropylene pipes spaced at regular intervals (1–4 m width – see Figure 1) instead of biaxial or triaxial nets. These perforated pipes provide most of the drainage capability of the product. It is furthermore associated to non-woven polyethylene/polyester geotextiles needle-punch together, which act either as capillary mediums or as filters (Figure 1), the latter, thicker, also acting as a cushion to protect an underlying geo-membrane.

Hydraulic functioning

The multidirectional flow associated with the DTP geocomposites is illustrated in Figure 2 and its characteristics are as follows:

- the fluid is intercepted by the mini-drains and is discharged to the collector trenches (Figure 2c)
- the waters (or gas) are drained from the supporting soil or rocks or water precipitation
- the flow length in the drainage layer is half the distance between the mini-drains and is independent of the total length of drainage
- the geocomposite offers an efficient drainage with a limited hydraulic pressure even with a zero slope.

This structure is more efficient than the simple flow in a homogeneous layer (direction of the slope – Figure 2a) of traditional geocomposites.

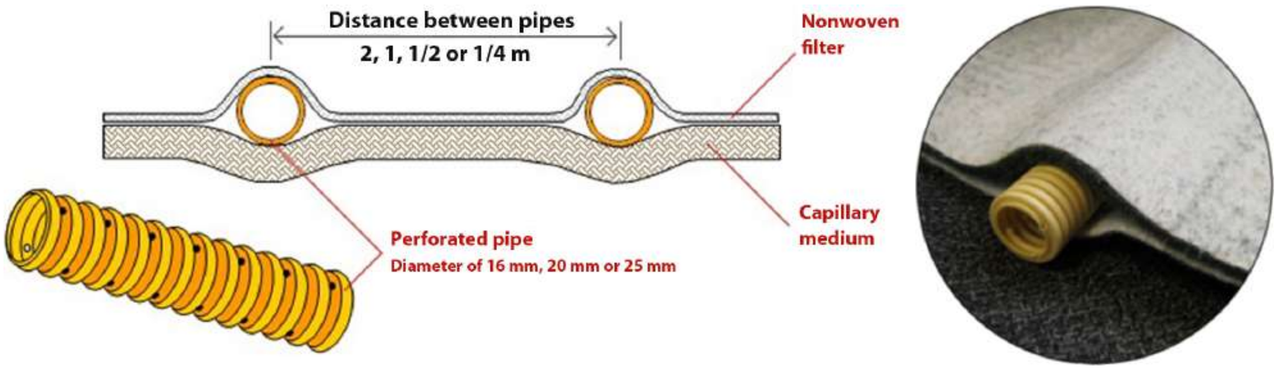


FIG 1 – Afitex Draintube™ geocomposite: a schematic of the structure (left) and photo of the Draintube™ (right).

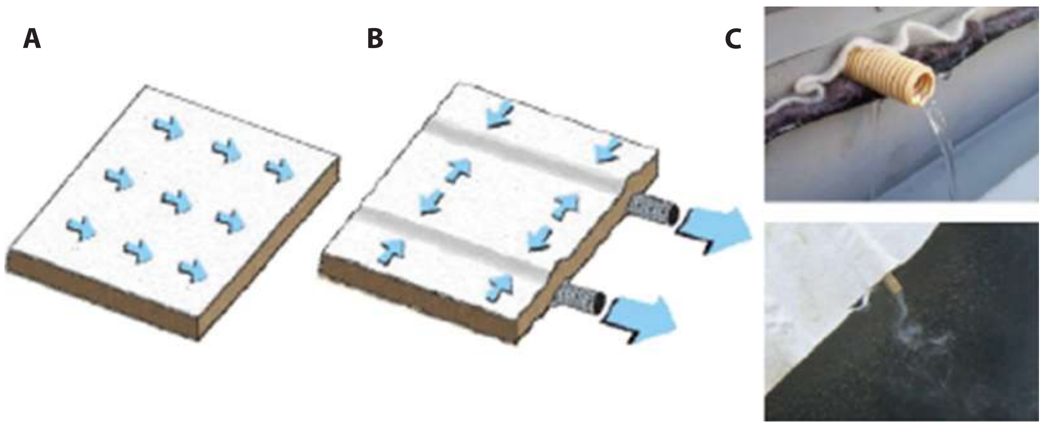


FIG 2 – Hydraulic functioning of the Draintube™: (A) flow in a homogeneous layer (direction of the slope); (B) flows in the Draintube™ geocomposite (mini drains direction); (C) photos of field installation of Draintube™ geocomposite with fluids discharge.

One key character of the DTPGs is that their structure and performance can be designed to the specifics of the site taking into account parameters such as the maximum length of drainage, the slope, the maximum load on the geocomposite, the spacing and diameter of the perforated mini-pipes into the product, and the transmissivity of the geotextile drainage layer. The Lymphea software (Arab and Gendrin, 2007) is used for Draintube™ to integrate all those parameters.

An environmental more responsible approach (drain tubes planar geocomposites versus gravel/sand)

Natural materials have been used for centuries as drainage layers in almost all civil, environmental and mining applications. Those materials were easy to be found and to use.

Natural materials are now more and more difficult to be found at a reasonable price. Furthermore, the protection of the environment, by limiting the greenhouse gas effect, plays an important role in decisions related to the choice of material in designs. According to Durkheim and Fourmont (2002), geosynthetic materials and in particular drainage geocomposites offer a constructive alternative to traditional solutions. In this period of global awareness of the need to protect the environment for future generations, it has become a matter of urgency to evaluate the impact of geosynthetic materials especially where the emission of greenhouses gases (GHG) is concerned. The use of geocomposite instead of granular layer permits to save up to 87 per cent of equivalent CO_2 emissions for equivalent hydraulic performances. Table 1 shows the different amount of positive contribution of DTPG on GHG effects in the construction industry.

Long-term hydraulic performance (drain tubes planar geocomposites versus geonets)

For geosynthetic materials, compression creep phenomenon includes three stages, as described in Figure 3. The first stage, or primary creep, consists in a rapid deformation of the product while the load is applied. The second stage, or secondary creep, consists of a slow deformation of the product, which is related to a molecular reorganisation of material, and which can occur over extended time and displacements. The third stage, or tertiary creep, precedes a brutal failure, and can occur only if the normal load is higher than some threshold value (Saunier, Ragen and Blond, 2010).

Moreover, if creep occurs, the geometry of the product will be modified (ie thickness reduction for geonet geocomposites, or ovalisation for pipes). This change in geometrical property will reduce either the flow surface or the hydraulic radius of the flow path, which, in both cases, will reduce the hydraulic transmissivity. As a consequence, if a change in geometry occurs, it will be detected by a change in transmissivity, which is easily measurable in the lab. It is, however, largely documented that DTPGs are not exposed to creep nor geotextile intrusion. Indeed, when confined, it has been shown that arching soil works around the pipe and therefore keeps it from collapse even under an important compressive load (up to 50 000 psf). Therefore, DTPGs are considered to have a Reduction Factor for Creep of 1.0 (Figure 4) in comparison with other geocomposites using a geonet which has a higher factor to be applied (refer to GRI-GC8 for data in Narejo and Richardson, 2003).

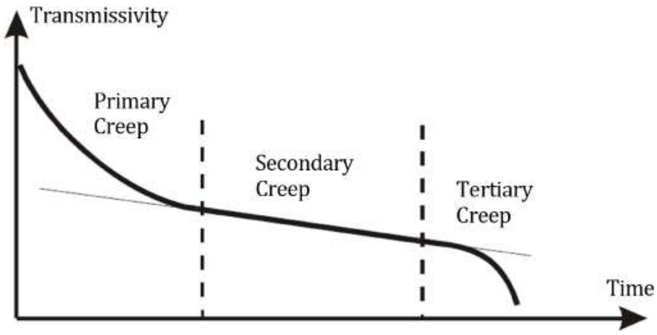


FIG 3 – Creep behaviour of planar drainage geosynthetics (Saunier and Blond, 2010).

Mining applications and designs

Based on the important advantages DTPGs are offering in comparison with natural materials and compressive drainage materials that are using geonet cores, DTPGs are more and more considered as a long-term high-performance solution.

Design schematics of the Draintube™ main applications for mining are presented in Figures 5 to 7 for covering of tailings, base of heap leach pads and dry tailing barriers respectively. The advantages of Draintube™ for each of those three applications over the traditional solutions are outlined below.

For covering of tailings (Figure 5):

- filtration of the covered ground
- efficient drainage of rain water
- mechanical protection of the geomembrane against possible puncturing
- improvement of sealing performance by reducing the hydraulic load on this element
- conservation of the mechanical properties of the confinement layer

TABLE 1

Emission of CO_2 equivalent and contribution of Drain Tubes Planar Geocomposites (DTPG) (after Durkheim and Fourmont, 2002).

Application	Description		Emission (eq. CO_2)	Emission reduction
Drainage under concrete paving	Traditional solution	0.50 m drainage materials + geotextile filter + polyethylene film	24.28 kg (CO_2/m^2)	87%
	Geocomposite solution	Geocomposite only	3.23 kg (CO_2/m^2)	
Drainage under embankment	Traditional solution	0.50 m drainage materials + geotextile filter	15.85 kg (CO_2/m^2)	80%
	Geocomposite solution	Geocomposite only	3.15 kg (CO_2/m^2)	
Drainage screen along roadside	Traditional solution	Drainage material trench, width 0.50 m and depth 0.80 m	40.69 kg (CO_2/ml)	69%
	Geocomposite solution	0.30 m drainage material + geocomposite	12.79 kg (CO_2/ml)	
Drainage under waste disposal landfill	Traditional solution	0.50 m drainage material + anti-puncture geotexture	21.55 kg (CO_2/m^2)	26%
	Geocomposite solution	0.30 m drainage material + geocomposite	16.01 kg (CO_2/m^2)	

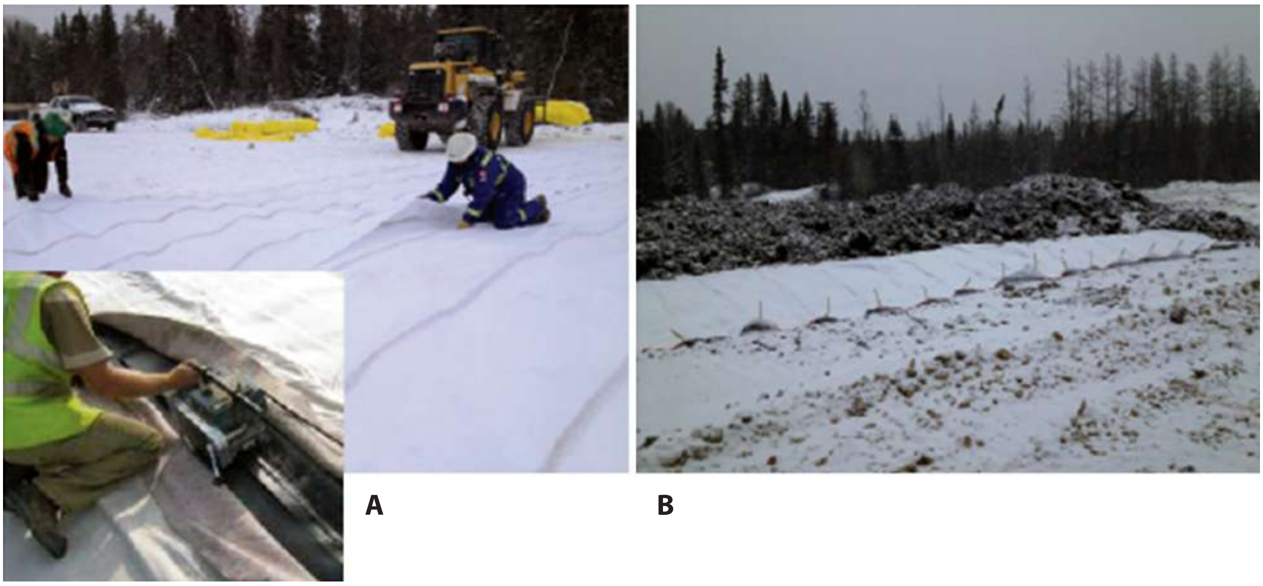


FIG 4 – Central Manitoba Mine (Canada) abandoned tailing rehabilitation site: (A) deployment and installation of Draintube™ ensuring overlap between drainage tube liners. Insert – sealing of drainage tube liner together; (B) deployed drainage tube liner with peat overlain.

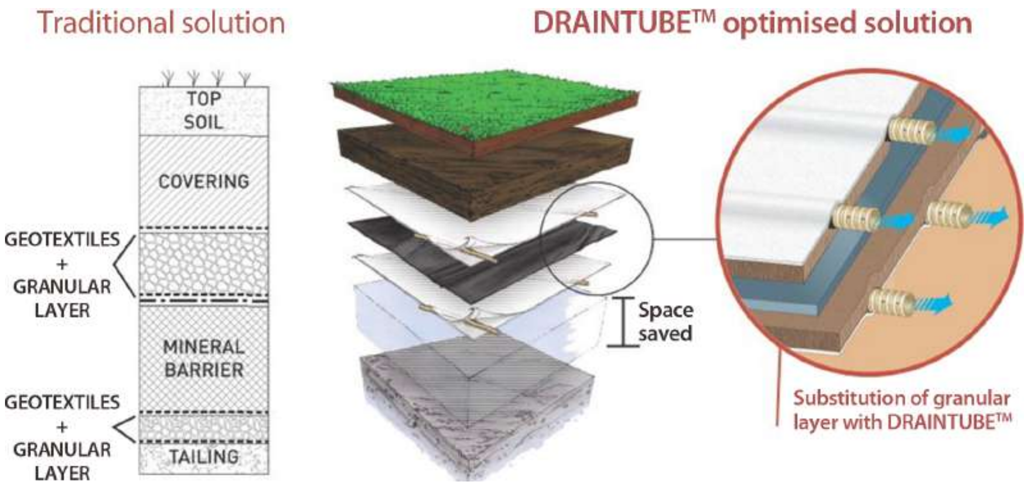


FIG 5 – Design schematic of the Draintube™ for covering of tailings.

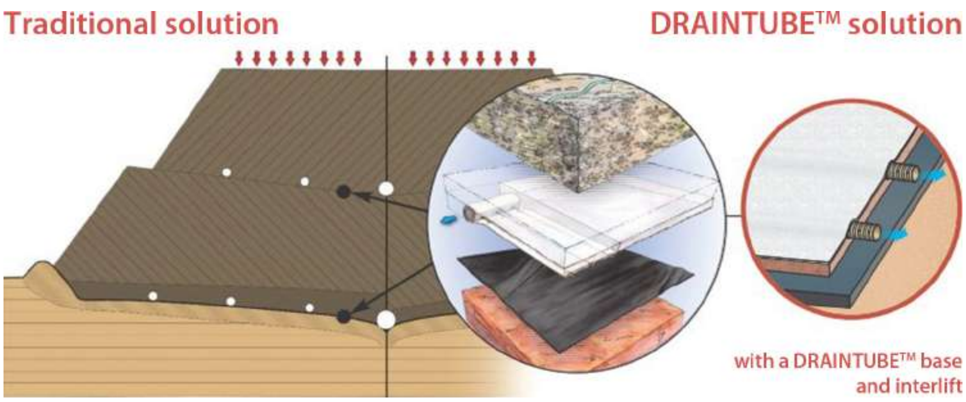


FIG 6 – Design schematic of the Draintube™ for heap leach pads.

- increased stability of the entire covering system.

For heap leach pads (Figure 6):

- reduction of the granular drain layer
- improvement of solution collection and reduction of the hydraulic load
- reduction of secondary collectors network; mechanical protection of the sealing geomembrane
- fast and economical installation of an interlift
- proven stability under extreme conditions (P, T, pH).

For dry tailing barriers (Figure 7):

- placed within the dyke to allow lowering of perched groundwater level and global stability of the structure
- replace the trenches (gravel, pipes)

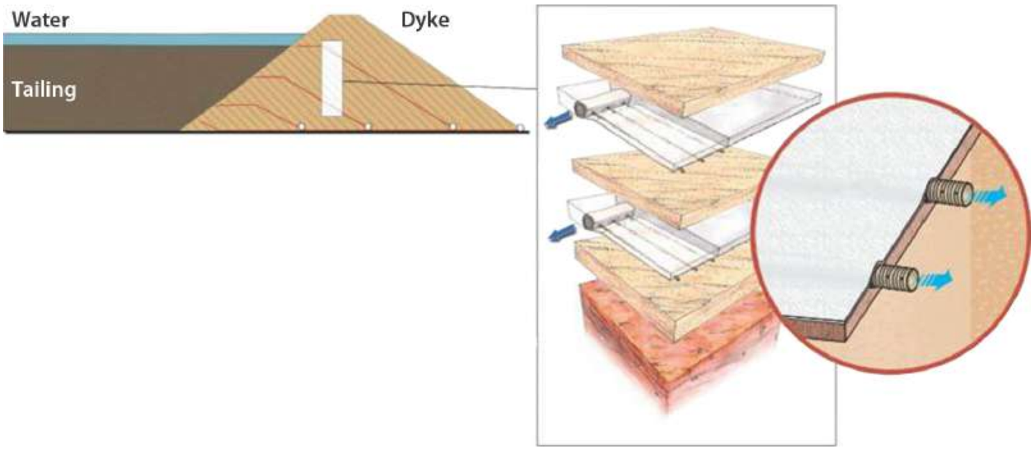


FIG 7 – Design schematic of the Draintube™ as a barrier for dry tailing of mining waste materials.

- quick connect system (Ameglio, Durkheim and Saunier, 2014) allows no need of trenches; reinforced protection of the dyke.

CASE STUDIES

In this section of the paper we will only emphasise the salient results and findings of applications of Draintube™ DTPG to the covering of mine tailings, and heap leach pads.

Mine tailing cover

From 1927 to 1937, Central Manitoba Mine extracted 5000 t of gold (using cyanide) from 480 000 t of ore. The site was closed and orphaned. An AMEC engineering office was then chosen to rehabilitate the site. Originally, a 500 mm sand layer was planned to collect percolated water and reduce the risk of leachate production (see Figure 8, left profile). Instead, Draintube™ (a 400P FT1 D25 type exactly) was chosen to replace the sand layer (50 cm – see Figure 8, right profile). Because of the distance from the pit to the mine, the sand was both impractical and expensive. Using Draintube™ to replace the sand layer also offered other advantages, such as:

- reducing the overall cost and construction time of the project
- higher tailing (equivalent to the 50 cm of sand layer) than conventional lining
- reducing 90 per cent of the truck traffic in the area related to the transport of the sand drainage layer, thus reducing the environmental footprint of the project
- site-specific designed drainage layer characteristics using Lymphéa© Drainage software (Figure 9).

Illustration of the site installation in 2013 is presented in Figure 9.

Subsequent monitoring of the site is ongoing to analyse the *in situ* long-term effectiveness of the soil cover composed of topsoil, overlying sandy clay, and the drainage layer in which the sand was replaced with the geosynthetic. Results are not yet available. In the meantime, a sensitivity analysis for the hydrology of the cover was undertaken to examine the behaviour of the soil cover system with changing drainage layer effectiveness, including constraints and complexities associated with the fill (natural) materials, and also in particular, the geosynthetic (synthetic) materials that are part of the cover. Detailed methodology and results of the study have already been published by Nan and Saunier (2014). Hereafter, we emphasise the main conclusions of Nan and Saunier (2014) with respect to the long-term performance of the Central Manitoba Mine tailing cover and how it could be impacted by changes in the expected hydrological conditions

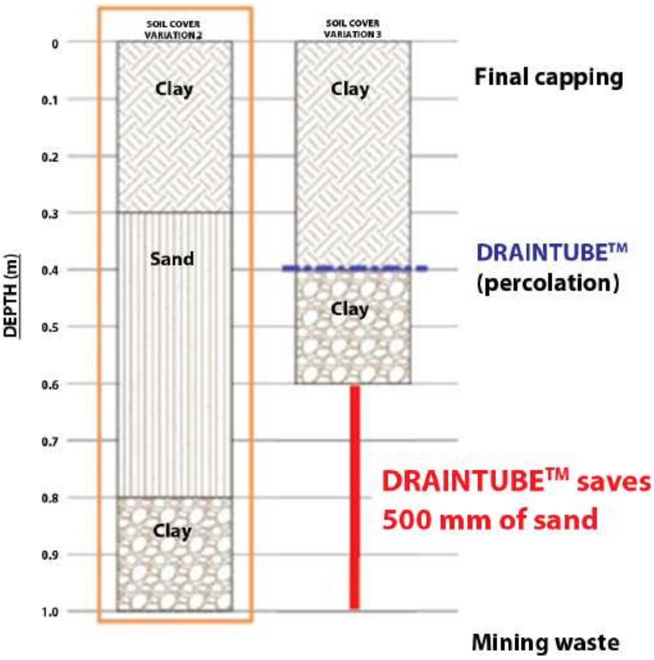
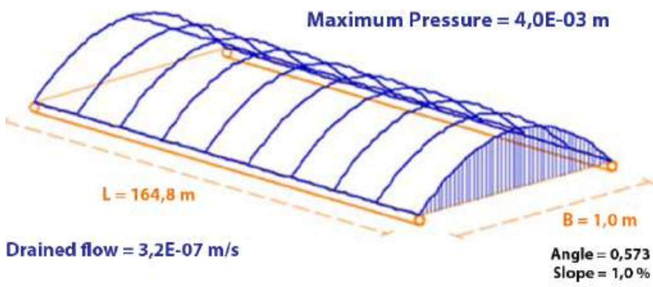


FIG 8 – Profiles of soil cover geometries (AMEC, 2011) over the Central Manitoba Mine, Canada, abandoned tailing. Left profile: traditional approach with sand used as drainage material. Right column: Draintube™ replacing the sand material.



Overall Infiltration rate		Safety factor	Value used in design
Value	Unit		
1000	mm / year	SF > 10,00	10000
2,00E-08	m3/s/m2		3,17E-07

FIG 9 – Typical data coming from Lymphéa© drainage design software.

and/or man-made material properties or performance. The modelling performed with SVFlux version 2.1.19 (developed by Soil Vision Systems Ltd), showed increasing flow trends over time as the hydraulic conductivity was reduced. The software results illustrated that the least desirable case and most extreme case showed that if the drainage system were to fail by becoming completely clogged in the long term, more than 50 per cent of the drainage layer would be saturated and an increasing trend over 20 years could increase water percolation rates into the tailings. However, the system displays some level of flexibility in terms of drainage-layer clogging. Even with a 50 per cent clogging of the drainage layer, the cover system would still be performing as designed, with a minor increase in saturation levels and a limited increase in percolation rates. From this perspective the system was designed, with a design safety factor higher than ten on the planar drainage geocomposite, has a built-in safety factor that allows good long-term performance and should perform according to original requirements such as limiting erosion, limiting direct human exposure to tailings, shedding water away, and supporting the vegetative cover.

Heap leach pads

Heap leaching is a mineral processing technique in which piles of mineral-rich crushed ore are leached with solutions to extract metals. The stack of ore in HLPs can range from 40 to 230 m high (see Breitenbach and Thiel, 2005; Thiel and Smith, 2004). The critical components of HLPs structures are the liner system and the drainage system at their base. The appropriate design of HLPs lining and drainage systems allow for efficient recovery of the metals-rich pregnant solution over the full design period of the structure and global stability of the heap in term of easy recovery of the pregnant solution with reduced economic and environmental costs and liabilities. The traditional solution for the drainage at the base of HLPs is made of a granular media (ie crushed rock or gravels) and embedded perforated pipes, installed above the liner system and below the ore heap. DTPGs are, however, increasingly used in environmental applications such as leachate drainage systems of waste disposal areas (see Budka *et al*, 2007; Arab, Cherifi and Loudjani, 2009) and constitute an ideal replacement candidate of natural rock for the drainage of HLPs.

Laboratory evaluations of the applicability of the Draintube™ DTPG for the HLP application have been performed (Blond and Saunier, 2014) via:

- long-term flow tests with typical crushed ore from a copper mine with the aim of evaluating the filtration capabilities of two different filters
- a transmissivity test, conducted with the aim of assessing how the flow rate is affected in the long run by extreme normal loads.

Details of the methodology and results of those two evaluations are developed in Blond and Saunier (2014). The present paper only emphasises the salient conclusions of Blond and Saunier (2014), and also other technical evaluation of the Draintube™ performances, to address the recurrent industry practical questions about Draintube™ geocomposite effectiveness such as:

- flow rate pattern, hence clogging effect
- 'survival' or integrity of the geocomposite when exposed to acid circulation
- behaviour under high compressive load.

Flow rate stability against clogging

In order to confirm (and extend to the HLP industry) the results largely documented (Faure *et al*, 2006), Blond and Saunier (2014) long-term flow tests were conducted over ninety days. The tests involved acid circulation through the DTPG overlined by crushed copper ore and under a nominal confining stress of 100 kPa (see Figure 10a). Characteristics of the inlet acid solution (20 g/L sulfuric acid solution with a pH of 1.4) and the pregnant solution (99–200 ppm Cu) are also indicted in Figure 10a. As shown in Figure 10b, hydraulic properties were not significantly affected (flow rate remains relatively constant over time) despite the filtration of suspended particles, load and acid condition.

Integrity of the geocomposite

From the same test conditions described in the above paragraph and in Figure 10a, Blond and Saunier (2014) also reported, after ninety days of percolation, a quantity of 80 g m^2 of particles on average in the upper geotextile, while only 10 g/m^2 were found on the lower geotextile. On the other hand, the perforated drainage pipe was found to be completely free of particles (see photos in Figure 10c, right). After the 90 days period, a reduction of only ten per cent of the permittivity of the textile was measured (Blond and Saunier, 2014).

Behaviour under high compressive load

With an ore density between 1.5 and 1.8, the compressive load on the drainage layer can reach 2 MPa (Thiel and Smith, 2004; Castillo *et al*, 2005). For traditional planar geocomposites involving a planar drainage core (such as biplanar or triplanar geonet), it has been shown by several authors that the hydraulic properties of these geosynthetics are adversely affected by such high compression stresses. However, DTPG geocomposites are not exposed to such long-term loss of performance problems according to Saunier and Blond (2010) (see Figure 11).

CONCLUSIONS

The robustness and effectiveness of the DTPG as drainage solution is now well established, technically illustrated and documented in various conditions, based on theoretical prospective as well as laboratory evaluations and field installations. Various levels of professional certifications further emphasise its superior long-term hydraulic properties, soil retention, and chemical resistance, to quote a few key parameters, when compared to granular media and other biaxial or triaxial geotextile nets traditionally used. The Afitex Draintube™ DTPG also offer the additional benefits of:

- increased volume capacity of a heap pad or a tailing
- improved and easier design and building of secondary collector network
- fast and economical installation
- customised drainage to site specifics
- being environmental friendly.

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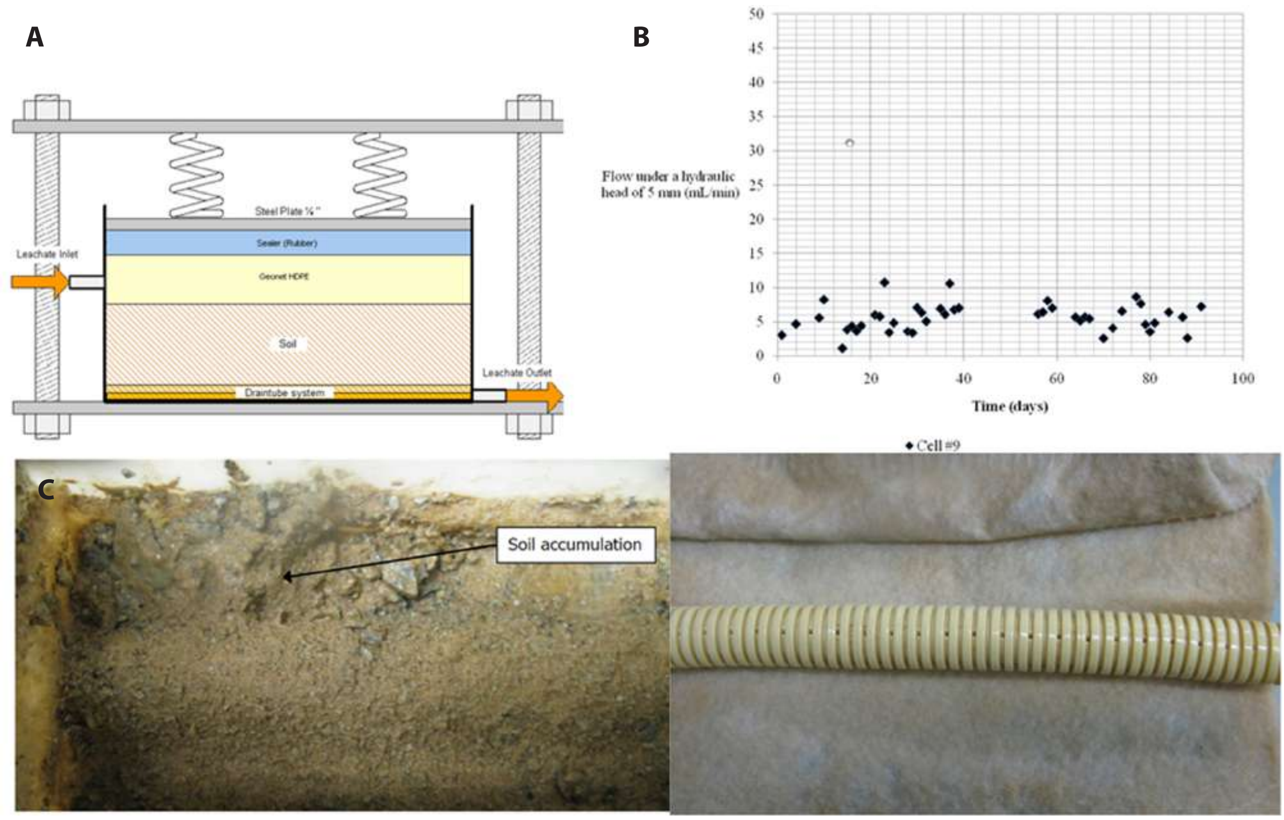

FIG 10 – Draintube™ geocomposite behaviour during long-term flow test with copper ore (after Blond and Saunier, 2014): (A) schematic cross-section of the experimental leaching cell design; (B) flow rates evolution over time under a hydraulic head of 5 mm (see Blond and Saunier, 2014); (C) external (left) and internal (right) view of the geocomposite after three months of sulfuric acid percolation.

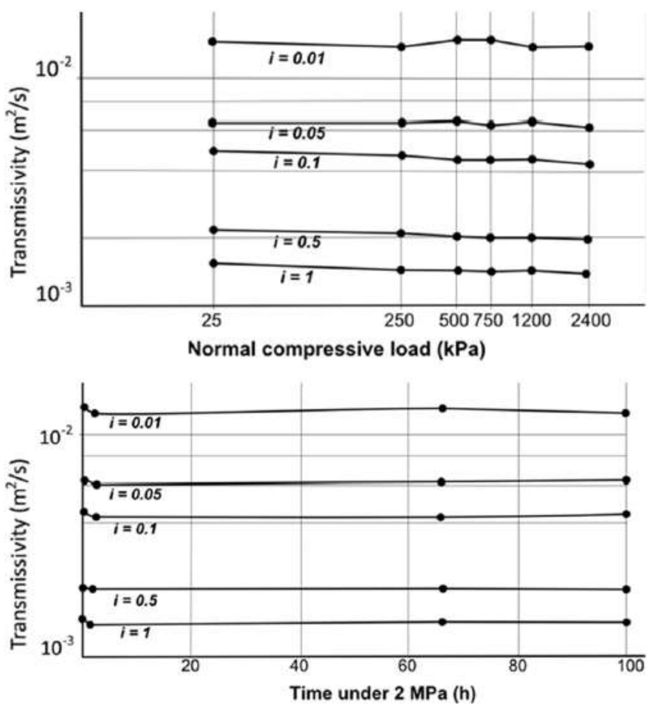

FIG 11 – Draintube™ geocomposite behaviour under high compressive load (after Saunier and Blond, 2010).

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