Lateral and Capping Landfills Drainage with Geocomposites

Rabah Arab[1], Stéphane Fourmont[1]; Pierre Gendrin[2]

[1] *Afitex, France*
[2] *Géoroute Ingénierie France*

ABSTRACT: The authors present two waste landfill (WL) drainage systems using a geocomposite. The first is used for capping system drainage to limit the volume of water entering the landfill. The second is used for drainage of leachate and water on slope.

1. 1 INTRODUCTION

Nowadays, drainage geocomposites are widely used in waste landfills management, particularly in capping system and on slopes. The most of the landfill capping systems contain in their structure a drainage system, particularly in semi permeable capping. The function of the drainage is to limit the infiltration of water inside the landfill. The last decade we developed a geocomposite which assures simultaneously the drainage and the waterproofing of the landfill capping. This solution was applied in several landfills capping system. Another application is the drainage on slope. Traditionally, we use a coarse material, now days we use a drainage géocomposite wich is resistant to UV rays and assures also the protection of the liner. This solution is widely used in westearn European. The drainage geocomposites need to be designed taking into account all the project characteristics. For this purpose, we use Lymphea Software (Arab and al. 2002). In our communication, we will present two case histories dealing with capping drainage and slope drainage. We will also present how the design is conducted with Lymphea software.

2. 2 DRAINAGE AND WATERPROOFING OF LANDFILL CAPPING

1. 2.1 Materials Used

At the end of using a Landfill Waste Storage (LWS), the manager has to ensure the closure of the storage units. The covering of a LWS must reach performance objectives in accordance with the chosen design. Those objectives are mainly control on liquid flux (collection and treatment), control on gazes flux (collection and treatment), revegetation of the site and its reintegration to landscape. To achieve the aims whatever the chosen covering concept, the technical solutions take into account the nature of waste (domestic waste, non-hazardous industrial waste, etc.) , the covering geometry (slope, rampant lengh, etc.), the climatic conditions (precipitations, erosion, frost, etc.), and the site enhancement

On landfill cover for domestic waste, the semi-permeable layer is traditionally composed of 1 m of Compacted Clay Layer (CCL) or a Geosynthetic Clay Liner (GCL) under a drainage layer (figure 1)

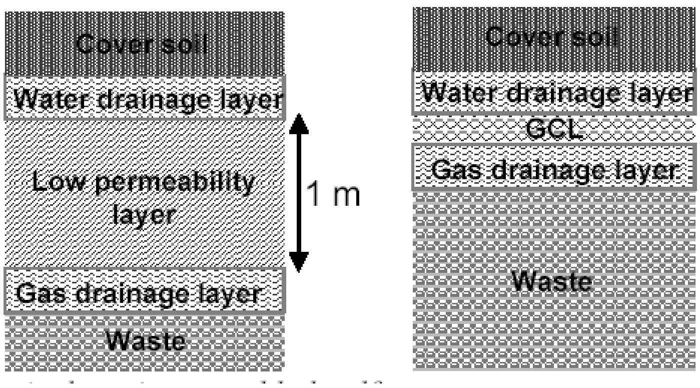

Figure 1. Typical semi-permeable landfill cover with low permeability layer or GCL.

This cover allows an amount of water to go into the waste and permits to control the leachate

production. The infiltration rate depends on the drainage efficiency and the permeability of the low permeability layer.
For Satolas project, the operator has chosen not to use a compacted clay layer or Geosynthetic Clay Liner (GCL) to seal the landfill. However to limit the infiltration of water inside the landfill, the solution retained was the DRAINTUBE FT/PE500 witch is a waterproof and drainage geocomposite whose structure is illustrated in figure 2.

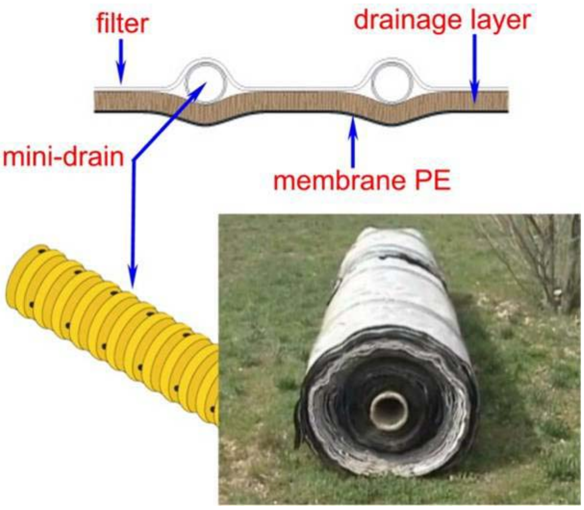

Figure 2. Geocomposite Draintube FT/PE structure

It is composed of (from the bottom to the top) :

- a membrane made with PolyEthylene (PE), 0,5 mm thick.
- a non woven needle punched drainage layer made with polypropylene ;
- 1 polypropylene (PP) mini-drain per metre, regularly perforated according a 90° dual alternated axis ;
- a non woven needle punched filter made with polypropylene (PP) ;

Filter, mini-drains and drainage web are factory combined by needle punched process. The fixation of the PE membrane to the drainage geocomposite is made with a patented process which preserves the hydraulic properties of the drainage geocomposite.
The infiltrations through a cover drained by impermeable geocomposite occur at the joints between the rolls. There are two types of joints : transversal overlap (downstream end of the roll) and longitudinal overlap (parallel to the slope). Infiltrations through transversal joints depend on the height of water in the geocomposite. With a sufficient overlap length and a small height of water in the geocomposite, they can be prevented (Faure & Meydiot, 2002). However, the infiltrations through longitudinal overlaps cannot be prevented as transversal overlaps. Tests have been carried out using an inclinable cell plane 2.5 m long and 2.0 m wide on the same cover structure drained by an impermeable geocomposite (Fourmont & Arab, 2005). The results have shown that the landfill capping drained with geocomposite draintube FT/PE500 highly reduces infiltrations into the waste. The density of mini-pipes into the drainage map slightly affects the infiltration rate.
For drainage of the dome area, the geocomposite is placed on a 30 cm thick closing material (figure 3). The system is dimensioned to obtain a maximum pressure between mini-pipes of less than 1 cm. This very low water pressure does not affect the top soil to geocomposite layer interface characteristics and therefore guarantees the correct hold of the top soil.

The following factors are taken into account when calculating the percentage of water infiltrating inside the landfill :
the flow of the geocomposite drainage layer,
the perpendicular permeability of the geocomposite,
the permeability of the surface sealing material.
An infiltration percentage of around 0, 2% is thus obtained, which enables correct decomposition of waste while limiting the volume of leachate.
The water collection system is shown on figure 4.

Figure 3. Installation of the geocomposite ant the top soil

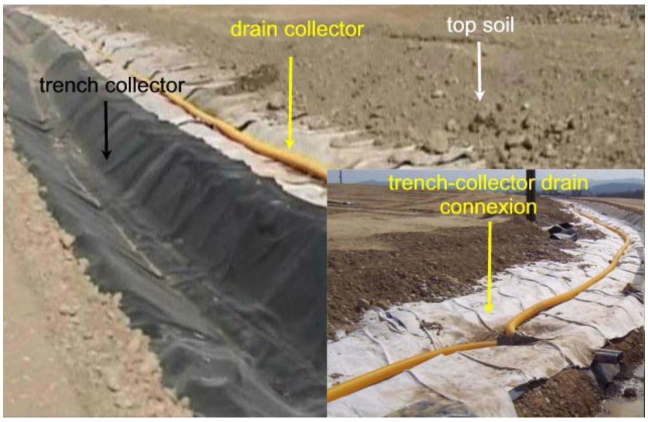

Figure 4. Water collection system

3. LANDFILL LATERAL DRAINAGE OF WATER AND LEACHATE

When operating a domestic waste landfill, a leachate drainage system is obligatory before their treatment. Drainage generally takes place in the sump of the landfill via a 30 to 50 cm thick layer composed of granular material. The use of a drainage geocomposite on the embankments enables fast drainage to the sump with a drainage layer gain in storage volume. Nowadays the most wide-spread solution used for lateral landfill drainage is the installation on the liner of a drainage geocomposite then an anti puncture geotextile witch is resistant to UV rays. This solution presents the inconvenience of a stake in work in two stages and the anti puncture reduction efficiency of the geotextile because it is not directly in contact with the liner.

The DRAINTUBE FT UV is a geocomposite which allows in a single installation to operate the drainage of leachate and the mechanical protection of the liner.

Drainage on embankment permits to collect rapidly the leachate at the bottom of the landfill and also reduces the hydraulic pressure on the geomembrane.

The hydraulic design of the product is done taking into account the flow of leachate to drain. It is estimated from the type of waste and also from the rainfall on the site and the type of capping.

The height of water in the geocomposite has to be calculated with the maximum load on it (i.e. landfill full of waste). This height of water must not be superior to a few centimetres to keep the efficiency of the lining system.

The mechanical design is done both for protection of the geomembrane (CBR resistance NF EN ISO 12236, mass per unit area NF EN 9864) and product resistance during installation of waste (tensile strength and elongation at break, NF EN ISO 10319).

On embankments the geocomposite will be exposed to Ultra Violet rays during the operating of the landfill (figure 5). The geotextile filter of the DRAINTUBE FT UV is UV resistant. This resistance is obtained from the standard ISO 4892. This standard ensures that at the time limit, the geotextile will keep at least 50% of its tensile strength.

For Villeparisis project near Paris, the designed geocomposite was a Draintube 700PP FT 1 D16 UV 2 GREEN to drain leachate and protect the geomembrane on slope. Its structure is shown on the figure 6.

Figure 5. Damage to the geotextile filter caused by UV rays

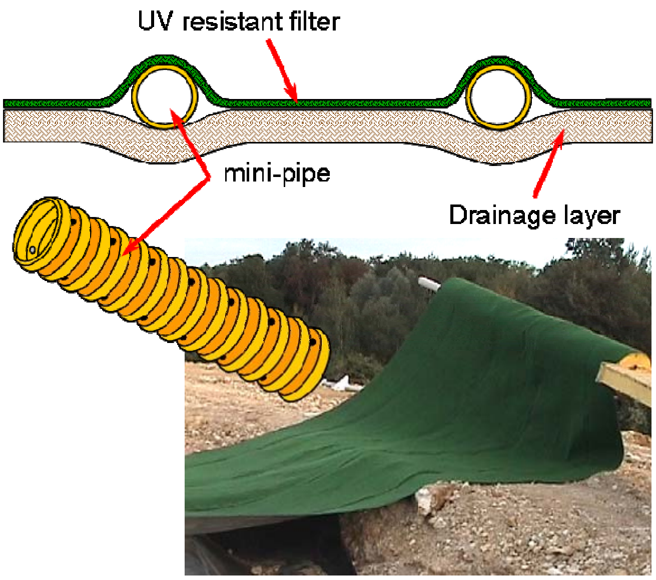

Figure 6. Geocomposite DRAINTUBE 700PP FT 1 D16 UV 2 GREEN

The geocomposite has 1 mini-pipe per meter width of product to drain the leachate. For the protection of the geomembrane, its total mass per unit area is 700 g/m² (NF EN 9864) and its CBR puncture resistance is 5 kN (NF EN ISO 12236).

Considering the slope of 1H/1V and the maximum height of waste of 25 m, the tensile strength of the geocomposite equal to 30 kN/m (NF EN ISO 10319) offers a coefficient of safety superior to 5.

To follow the settlements of the waste in long term, the geocomposite has an elongation at break superior to 80% (NF EN ISO 10319).

The operator of the landfill wanted to have a product U.V resistant up to 2 years. Samples have been tested after 18 months of exposition. The figure 7 compares the degradation curve of the geocomposite and its theoretical behaviour by the time of exposition to the U.V rays.

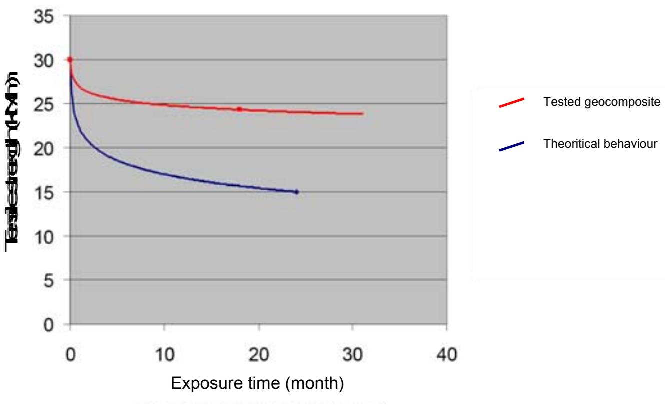

Figure 7. Loss tensile strength of the geocomposite installed in Villeparisis versus exposure time

The figure 7 shows that after 18 month of exposition to U.V. Rays, the geocomposite has a tensile strength superior to the one demanded by the standard ISO 4892.
Several explanations must be considered:
The 2 years U.V. guarantee is only the filter, because of the protected reinforced draining layer under it, the overall geocomposite keep a better tensile strength by the time,
The orientation of the product to the sun change the energy per unit area received by the geocomposite, the most unfavourable orientation is to the south at 45°,
The last requirement of this project was the landscape insertion of the landfill during the operating. The color of the filter was green (figure 8).

Figure 8. View of the slope of the landfill

4. DESIGN METHOD : LYMPHEA SOFTWARE

The software design LYMPHEA has been developed in cooperation with the Laboratoire Interdisciplinaire de Recherche Impliquant la Géologie et la Mécanique (Lirigm) of the Joseph Fourier university in Grenoble and validated together with the Laboratoire Régional des Ponts et Chaussées (LRPC) of Nancy . The "LYMPHEA" calculation code enables dimensioning of drainage geocomposites for the draining of both water and gaz (Faure et Auvin, 1994)

Two flow conditions are considered:

– Water supply under a constant hydraulic head through a soil layer;
– Water supply with homogenous velocity distribution perpendicularly to the product.

The water inside the drainage layer is supposed to flow perpenducalarly to the mini-drains (figure 9)

Figure 9. the flow in the draining mat is perpendicular to the mini-drains

LYMPHEA software takes the following parameters into consideration :

– the transmissivity of the drainage layer under compression,
– the flow length in the mini-drains,
– the flow slope in the mini-drains,
– the distance between mini-drains,
– the flow conditions in the mini-drains (saturated, partially saturated or not saturated)

The software allows to design the appropriate product with limiting the pressure (water head) in the product.
It also allows visualizing the piezometric curves in the drainage product (homogenous or heterogeneous one).
The theoretical approaches of the flow computed in LYMPHEA software are given bellow.

4.1 Supply by a constant homogeneous flow

The flow in the soil is assumed to be perpendicular to the plane of the drainage geocomposite with a constant speed V. the head loss in each element of the geocomposite is computed according to the flow conditions into the mini-drains.

4.1.1 Mini-drains unsaturated

The mini-drains of the geocomposite may remain unsaturated when the slope is relatively steep, the length L0 of the mini-drains short enough, the incoming-flow velocity V from the soil not too high and the distance between the mini-drains in the geocomposite relatively short.
These conditions are encountered when the balance between these parameters is :

$$L_o < \frac{\alpha(\sin\beta)^{n+1}}{VB} \tag{1}$$

The pressure is maximum between mini-drains and is equal to :

$$\left(\frac{u}{\gamma_w}\right)_{\max} = \frac{VB^2}{8\theta} + a\left(\frac{VB}{2}\right)^b \tag{2}$$

4.1.2 Mini-drains saturated

This will occur, for instance, in the case of a negative slope (as under an embankment, where the central point is beneath the outlets because of differential settlements) or in the case of slope that is too small, according to the length of the mini-drains.
The mini-drains are saturated all along their length L, the only relevant parameter controlling the flow being the altitude difference between the ends considered.
With positive slope, the mini-drains will be fully saturated for :

$$L > \frac{\alpha}{VB}\left(\frac{n+2}{n+1}\sin\beta\right)^{n+1} \tag{3a}$$

And the maximum pressure between mini-drains is :

$$\frac{u}{\gamma_w} = \frac{VB^2}{8\theta} + a\left(\frac{VB}{2}\right)^b + \left(\frac{n+1}{n+2}\right)\left(\frac{VB}{\alpha}\right)^{1/n+1} L^{(n+2)/(n+1)} - L.\sin(\beta) \tag{3.b}$$

When the slope β is negative or zero, the hydraulic pressure expressed in water height unit above the outlet is given by :

$$\frac{u}{\gamma_w} = \frac{VB^2}{8\theta} + a\left(\frac{VB}{2}\right)^b + \left(\frac{n+1}{n+2}\right)\left(\frac{VB}{\alpha}\right)^{1/n+1} L^{(n+2)/(n+1)} \tag{3.c}$$

4.2 Supply with a constant head trough a soil layer

This situation represents, for example, the drainage of a large foundation bearing on a low - permeability soil layer of thickness D, under the water-table level.
The mini-drains are considered saturated and horizontal in the theoretical approach with a length L.
Under these conditions, the incoming flow velocity distribution into the geocomposite is not uniform but a function of the head loss through the drainage layer between the mini-drains and along the mini-drains.
With h0 being the water-head supply, the maximum pressure in the centre between the mini-drains in the drainage layer is given by :

$$\left(\frac{u}{\gamma_w}\right)_{\max} = h_0\left[1 - \frac{1}{\cosh\left(\sqrt{\chi}\,L\right)} \times \frac{1}{\cosh\left(\frac{B}{2}\sqrt{\frac{k}{\theta D}}\right)}\right] \tag{4 a}$$

With $\chi = \frac{2}{q_d}\sqrt{\frac{k\theta}{D}}\tanh\left(\frac{B}{2}\sqrt{\frac{k\theta}{D}}\right)$

The discharge capacity of the mini-drains is assumed to be constant and is computed from the flow at the outlet, where the flow rate is a maximum, and hence the discharge capacity is a minimum.
The flow rate in each mini-drains is :

$$Q_2(s = L) = q_d h_0 \sqrt{\chi}\tanh\left(\sqrt{\chi}\;L\right) \tag{4 b}$$

Notations

V : incoming – flow velocity from the soil (m/s)
B : half distance between mini-drains (m)
L : flow length (m)
a : experimental constant
b : experimental constant
θ : transmissivity of the drainage layer (m²/s)
α : experimental constant
n : experimental constant
β : slope (°)
h : hydraulic head or maximum pressure (m)
q_d : discharge capacity (m^3/s)
k : soil permeability (m/s)
D : soil thickness (m)

5. CONCLUSION

Drainage geocomposites were used successfully. Comparatively to the traditional solutions they offers great guarantee on regularity performance, rapidity on execution and saving earthwork.
These applications have enables:

- the development of protective drainage geocomposite resistant to UV rays,

- the limitation of water infiltration into the cell using a drainage and waterproofing geocomposite,
- etc.

REFERENCES

Arab R., Gendrin P., Durkheim Y. 2002. Landfill Drainage Systems, *7IGS, Nice (France), pp. 745 –748.*

Faure Y.H., Auvin G. 1994. Performance and Design of Geocomposites for Drainage of Gaz. *Fifth International Conference on Geotextiles, Geomembranes and Related Products, pp. 833-836*.

Faure Y. H., Meydiot V. (2002) – Secondary function of a complete drainage system: waterproofing,Geosynthetics *7th ICG, pp 549-553*

Fourmont S.; Arab R. 2005. Cover landfill drainage systems - Drainage and waterproofing for semi-permeable landfill capping. *International Workshop « Hydro-Physico-Mechanics of Landfills » Grenoble 1 University (France) 21-22 March.*

.