Leachate drainage by technical geocomposite at Sofa sanitary landfill

E. Tardif
Afitexinov, 15 rue Louis Blériot, 28300 Champhol, France
J. Khamisse
Afitex Middle East, Jdeidet El metn, Lebanon
P. Gendrin
Georoute, 15 rue Louis Blériot, 28300 Champhol, France
P. Gendrin
Afitexinov, 15 rue Louis Blériot, 28300 Champhol, France

ABSTRACT: In 2018, the Municipal Development and Lending Fund of Palestine started the construction of Sofa sanitary landfill at Al Fukhkhary. The lining system of the bottom was initially constituted of a 2mm-thick HDPE geomembrane, a protective geotextile and a 0.45m-thick gravel draining layer, on a surface of around 60000m2. A design has been made to propose a drainage geocomposite with mini-pipes Draintube, able to have the same hydraulic properties as the draining layer. The choice of the product considered the whole geometry of the project (waste thickness, geometry of the bottom…) as well as the project requirements (mechanical specifications, etc.), as it also provides a mechanical protection of the lining system. Using geocomposite with mini-pipes allowed to save 27000m3 of draining gravel. In addition, the technology of this geocomposite with mini-pipes avoids biological clogging and thus guarantees its efficiency through time. In order to create a prefilter between the geocomposite with mini-pipes and the waste, a 0.15m-thick protective layer has been installed. By calculating the retention criteria, it has been shown the adequation between the opening size of the filter of the geocomposite and the sieve analysis of the protective layer.

1 INTRODUCTION

In a need to improve the solid waste management in Gaza strip, the Gaza Solid Waste Management Project (GSWMP) launched the construction of a sanitary landfill at Al Fukhkhary. This project is a part of a complete change in the way of managing the solid waste system. Its aims are to decrease the environmental impact of waste management alongside with improving it. Indeed, this is first landfill in Gaza strip designed with a real drainage and lining system at the bottom. This Sofa sanitary landfill will serve almost half of the population of the Gaza strip, in the southern and central areas. This project is led by the Municipal Development and Lending Fund (MDLF). The engineering team is a joint venture composed of Antea Group, ENGECON and EMCC and the contractor is also a joint venture of MACC and Mesogéos. With a cost of more than 8M€, it has been financed with the help of the World Bank Group (AFD), the French Development Agency (AFD) and the European Union (UE). The landfill is in Al Fukhkhary, in the south of the Gaza strip (Figure 1). This article is focused on the construction of the first cell (initially divided into two parts: cell 1A and cell 1B). This cell will have a total waste storage capacity of 2 200 000m^3, for 40m-high waste. More particularly, the drainage and lining system installed at the bottom of the cell is the main subject developed here.

Figure 1. Location of the project in the southern area of Gaza strip. Google maps picture.

2 CONTEXT OF THE STUDY

To have a better understanding of the project in terms of drainage and lining system, a focus is made on the geometry of the cell as well as on the technical requirements regarding the said system.

2.1. *Structure of the bottom of the cell*

As mentioned in the introduction, the cell was supposed to be divided into two parts, each one having its own draining and lining system. In the very end of the project, the two parts have been reunited to create a big one. During the whole design process, the two-parts geometry has been the one used. Both cells are rectangular-shaped. Cell 1A is 200m by 145m and cell 1B is 200m by 155m.

For each cell, the slopes of the bottom are following the network of leachate collection. This system is a herringbone drainage, made of a main pipe which is collecting leachates from a secondary pipe network. The main collector is running from the north west corner towards a leachate sump at the south east corner. It is a HDPE perforated pipe of diameter 110mm. The secondary ones are all going towards the main collector, starting either from the west or the north border of the cell. They are HDPE perforated pipes of diameter 90mm. Leachates of cell 1B are collected in a sump box, which is linked to the main evacuation thanks to a solid HDPE pipe of diameter 110mm. The main evacuation is located at the south east corner of cell 1A (Figure 2). Thus, this evacuation collects leachates from both cells and bring them thanks to a solid HDPE pipe of diameter 610mm to a leachate treatment facility outside of the cells. The main collector has a slope of 2% towards the leachate sump, as well as the secondary network.

2.2. *Technical requirements for the drainage and lining system*

The creation of a landfill cell requires to do an appropriate preparation of the subgrade. This preparation is linked to the regulation, which is different according to the geographic area. In this case, the subgrade is prepared with a layer of 0.50m of compacted local soil with a permeability lower than 10^{-9} m/s, which can be assimilated to clay. On top of it, a geotextile of 300g/m^2 is used to protect the liner. Then, the lining system is a 2mm HDPE geomembrane. The advantage of using such a material is that HDPE is chemically inert. Then it will not be damaged by all the chemicals that are inside of the leachates. The geomembrane needs to be protected also on the top, here by a geotextile of 800g/m^2. Finally, the draining layer is a 0.45m-

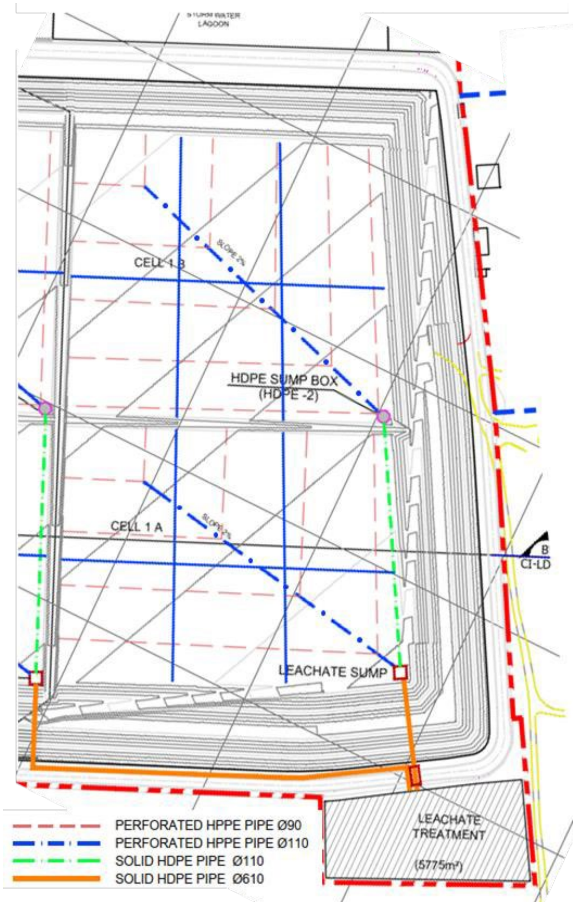

Figure 2. View of the botto... ...ell) and cell 1B (upper cell). The different pipes are represented, as well as the leachate treatment facility at the south east of cell 1A.

thick gravel layer, in which HDPE pipes are inserted to collect leachates. This material is type 20/40. The characteristics of this draining layer are meant to allow the evacuation of leachates, with a given daily maximum leachate production of $50m^3$/day per cell.

The aim of the process is to propose a drainage geocomposite which will be able to act as an anti-puncturing and which will have equivalent or better hydraulic properties than the granular draining layer.

3 PROTECTION AND DRAINAGE GEOCOMPOSITE

The chosen geocomposite presents some specific characteristics that are presented in this section.

3.1. *Anti-biological clogging property of the filter*

The drainage and protection geocomposite must combine several functions in order to fit the specific medium that are bottoms of landfills. One of these functions is to be able to keep its draining properties through time, to avoid clogging caused by the biomass.

The drainage and protection geocomposite Draintube ABC 800 FT1 D25 (ABC: Anti-Biological Clogging) chosen for this project is composed of a filter layer treated against biological clogging, a draining and anti-puncturing layer in polypropylene and mini-pipes regularly perforated according to a 90° alternated dual axis, in polypropylene as well, of diameter 25mm and spaced of 1m (Figure 3). The components are associated together by needle-punching in order to keep the hydraulic and mechanical characteristics of the geotextiles.

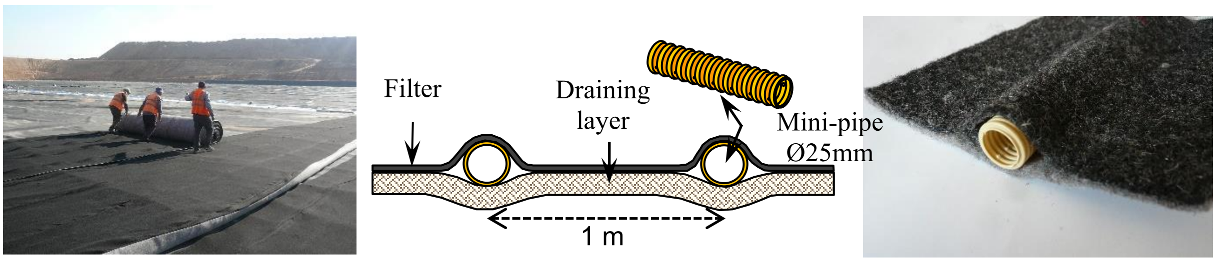

Figure 3. Structure of draining and protection geocomposite.

The filter is treated against biological clogging. The fibers contains a small amount of silver, magnesium, aluminium and phosphorus but does not release any component and thus remains chemically inert. Thanks to these chemical components, the fibers radiate an ionic field which neutralises the biomass (Figure 4). This biomass, thus electrically destabilized, does attach itself to the fiber and goes through the filter to be evacuated. The electrical "discharge" received

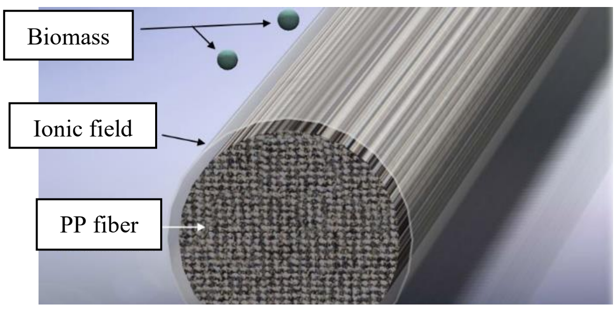

Figure 4. Illustration of a fiber treated against biological clogging.

by the biomass is enough to neutralize it. Treatment is carried out on the fibers in order to ensure a fully functionalized filter, with no release of these particles in the drained leachate.

3.2. *Studies of the filter with different types of leachates*

Two different studies have been carried out in order to validate the behaviour of the geocomposite with mini-pipes when submitted to leachates. The aim of realizing two experimentations is to be able to choose sites which will propose leachates of several constitutions. Indeed, according to the area in the world, leachates have different pH, viscosity or chemical aggressivity. In 2011, the first study has been done on French leachates, from non-hazardous landfill of class 2. Leachates were pumped directly from the bottom of nine cells and then injected inside of apparatus constituted of geocomposite and granular material. The system was made in such a way that the operating conditions in the tests were the same as inside of the landfill.

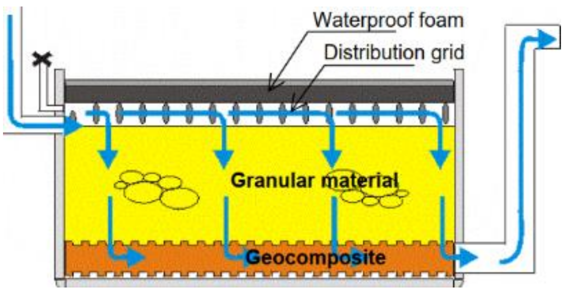

Figure 5. Scheme of one cell of 0.25m-wide. A pressure of 100kPa is applied. A distribution grid forces the leachate to spread heavenly in the cell and the top of the system is maintained completely waterproof. The tests are done in anaerobic conditions.

The leachate flow was monitored in both layers for 18 months. Finally, the clogging index has been evaluated in the different configurations and is presented in Figure 6.

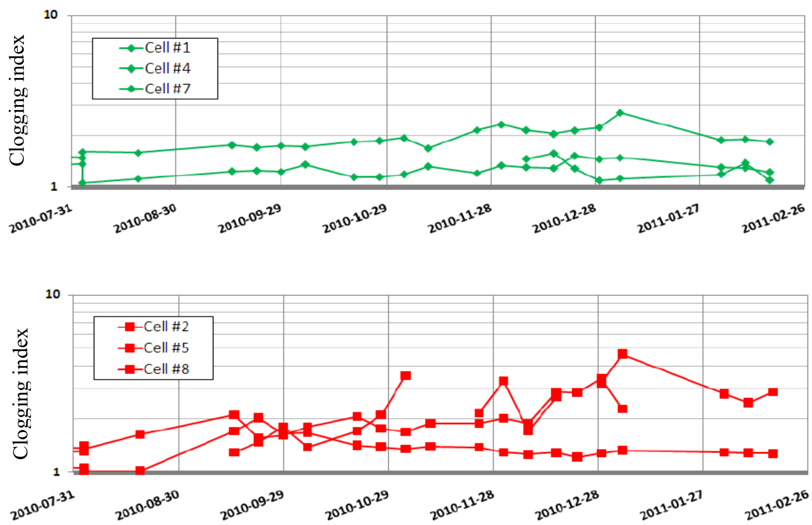

Figure 6. Representation of the clogging index through time. The upper graph presents this index for the geocomposite layer and the lower one is for gravel. For each, 3 samples were tested ('cell #X').

These results show that after a year and a half of exposition to "real" leachate, the geocomposite with a treated filter did not show any signs of biological clogging that could suggest a loss of functionality. Then, this geocomposite offers a similar performance as the gravel layer.

In 2014, the same tests have been performed in Morocco in collaboration with the CSD-CRB, the University Mohammed Premier in Oujda and a French Laboratory (LPEE). By doing a similar experimentation to the one in France, it has been found out that the conclusions were also the same.

4 CALCULATIONS TO JUSTIFY THE CHOICE OF THE GEOCOMPOSITE

The geocomposite aims at replacing the protective geotextile and the draining granular layer as well as the secondary pipe network. Then, it means than it needs to be resistant enough puncturing-wise in order to provide a good mechanical protection of the geomembrane from the upper layers. It also must get a draining function sufficient to collect leachates produced by the waste.

4.1. *Hydraulic calculation*

The hydraulic calculation is done in order to validate that the geocomposite has the same hydraulic properties than the gravel one, but also to compare the flow drained to the amount of leachate produced by the cells. The system of drainage of a geocomposite with mini-pipes consists in collecting the fluid in the draining mat and bringing them towards the closest mini-pipe. The fluid (whether it is water, or gas, or leachate) passes through the filter and saturates the draining mat. This phenomenon puts the draining mat under pressure and thus creates a hydraulic gradient, allowing the evacuation of the fluid towards the mini-pipes.

Regarding the disposition of the main collector (Figure 7), the maximal length of drainage, which is the maximum distance that leachate will have to go the reach a pipe, is going to be the entire width of the cell; that is to say 200m. The calculation is made with Lymphea^{TM} software. This software has been created and validated by the French Road Authorities and the French laboratory LIRIGM. Based on Darcy law, it allows to calculate the flow drained by a given geocomposite according to the geometry of the site. In addition to the geometry of the subgrade (slope, length), it also considers the load, brought by the height of waste. This parameter appears through the transmissivity of the draining layer of the geocomposite (geotextile part only), which represents the hydraulic behavior of the draining mat when submitted to a load.

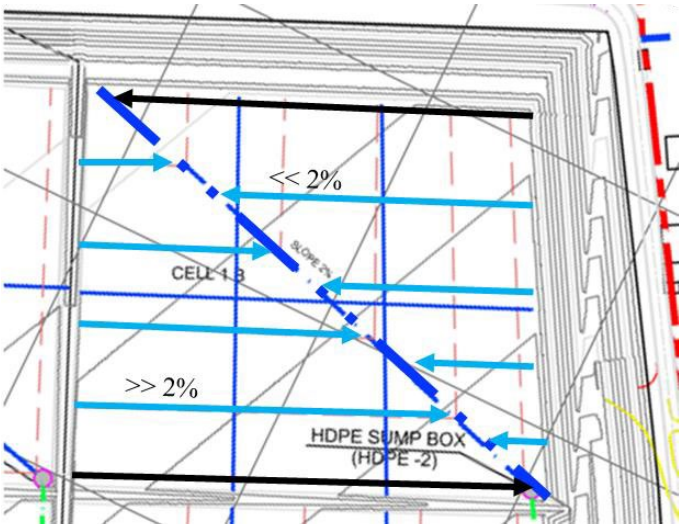

Figure 7. Scheme of the geometry used for the hydraulic calculation. The main collector is represented by the diagonal dotted line. The arrows represent the direction of drainage (direction of mini-pipes). The longest arrows (at the very top and at the very bottom) are the maximal lengths of drainage, 200m.

With the mentioned parameters, linked to the geometrical properties of the site, the flow drained by the geocomposite with mini-pipes F if the following one:

$$F = 3.80 \times 10^{-7} \text{m}^3/\text{s}/\text{m}^2 \quad (1)$$

With a hydraulic pressure of 0.03m.

This flow represents the amount of leachate that the geocomposite drains in a square of 1m per 1m ib one second.

Considering a length of drainage L of 200m, the flow rate Q is:

$$Q = F \times L = 7.60 \times 10^{-5} \mathrm{m}^3/\mathrm{s}/\mathrm{m} \ (2)$$

This flow rate is the amount of leachate drained along the maximum length of drainage.

Thanks to the result of (2), it is possible to calculate the equivalent amount of leachate. Considering the dimensions of cell 1B, the bottom surface S is 31000m^2. So, the flow rate Q_{1B} for the whole bottom is:

$$Q_{1B} = Q \times S = 0.0114 \ \mathrm{m}^3/\mathrm{s} = 985 \ \mathrm{m}^3/\mathrm{day} \ (3)$$

(3) means that the geocomposite with mini-pipes can evacuate a flow of leachate of 0.0114m^3/s. The value announced for this landfill was of 50m^3/day, which is almost 20 times lower than what the geocomposite can drain.

The comparison between the geocomposite and the granular layer is done in terms of transmissivity. To do so, an equivalent transmissivity θ_{GCP} is calculated for the geocomposite. This value depends on the flow rate Q and on the hydraulic gradient i; i being assimilated to the ratio between the slope h of 2% and the length of drainage L.

$$i = h/L = 0.02 \ (4)$$

$$\theta_{GCP} = Q/i = 3.80 \times 10^{-3} \mathrm{m}^2/\mathrm{s} \ (5)$$

The calculation is done also to obtain the transmissivity of the draining layer θ_{gravel}, which depends on the permeability of the gravel K and on its thickness e, equal to 0.45m. In this project, the permeability must be taken as a hypothesis. It has been chosen to take the value usually used in the French landfill projects, that is to say K=10^{-4}m/s.

$$\theta_{gravel} = K \times e = 4.5 \times 10^{-5} \mathrm{m}^2/\mathrm{s} \ (6)$$

By doing the ration between the two transmissivities:

$$\theta_{GCP}/\theta_{gravel} = 84 \ (7)$$

Finally, the geocomposite with mini-pipes is able to evacuate the expected leachate flow rate and also has way better hydraulic performances than the granular draining layer.

As the aim is to remove the secondary network and then to keep only one main collector, it is necessary to check the design of the diameter of this main collector with the new calculated flow. By using the Manning equation, a diameter 200mm is calculated, which is a bit bigger than the planned one.

4.2. *Mechanical verifications*

Regarding the protection of the geomembrane, it is asked to provide an 800g/sqm product. Without a specific request regarding mechanical values, the capacity of the geocomposite to ensure the anti-puncturing function has been checked by comparison to the French habits. In France, the "strongest" products are from 1000g/sqm to 1200g/sqm. Other masses per unit are installed too; the "low-end" ones being around 800g/sqm. The project has then specified a enough protection of the lining system.

Another mechanical aspect which could be asked is the creep resistance of the mini-pipes of the geocomposite. A study has been carried out to quantify this phenomenon, based on the arching effect that is developed when a load is applied (Figure 8).

To do so, it has been assumed that a creep effect in the mini-pipe would lead to a modification of its shape, having an effect on the transmissivity. A geocomposite with mini-pipes has been placed between a geomembrane and a layer of sand and then submitted to different loads, from 25kPa to 2500kPa. Each load is applied during 15 minutes and the load 2500kPa is extended to 100 hours. The aim of this installation was then to place the product in real conditions. The results of this study have shown that the transmissivity is not affected to high loads, as sand is providing a suitable confinement. Up to 2500kPa, it is considered that there is no creep appearing in the geocomposite with mini-pipes.

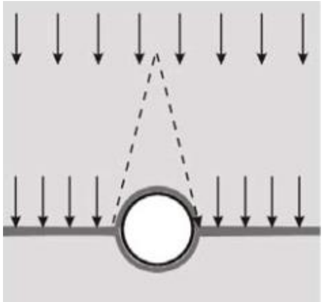

Figure 8. Illustration of arching effect, done by a proper confinement of the mini-pipe with the soil.

5 INSTALLATION OF THE DRAINAGE AND LINING SYSTEM

A study office has been mandated to validate the installation of the drainage and lining system at the bottom on the Sofa site. The objective was to verify the installation of the lining system (control of the state of the subgrade, size of the trenches, etc.), as well as the good installation of the geocomposite with mini-pipes. The geocomposite is made in rolls. The longitudinal connection between two rolls (side by side) is done by simple overlaps, that are heated to be maintained in place (Figure 8). The transversal connection is done by peeling the filter from a first stripe and then insert the second stripe inside of the first one. To ensure the hydraulic continuity between the two rolls, the mini-pipe of each roll are put side by side on 10 to 20cm (Figure 9).

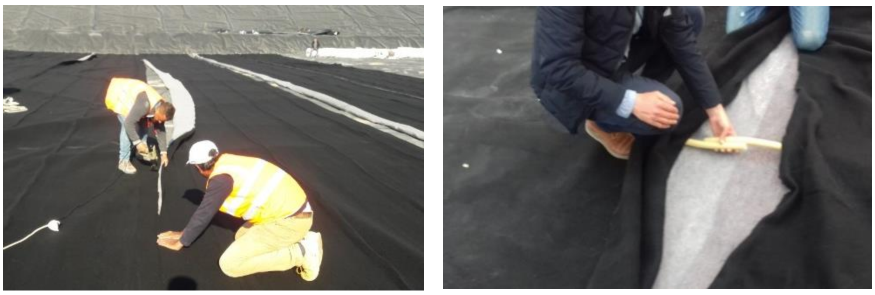

Figure 9. Connection between the rolls. On the left, the longitudinal connection by overlap and fixing by hot point. On the right, the transversal connection by putting the mini-pipe side by side.

These missions on site were also a way to check the installation regarding the new disposition that had been decided at the last moment. Indeed, the whole design has been made considering two cells, with a evacuation made by a pipe in each cell; pipe placed diagonally (Figure 9). Due to a lack of time, this geometry changed at the beginning of the works. Finally, it is only one big cell that has been built, with only one main collector. For the hydraulic design, the calculations done initially were considering the most unfavourable case (the length of drainage being the whole width of the cell) so the new configuration did not change this design and is even on a safety side.

6 CONCLUSION

The use of a technical geocomposite for Sofa sanitary landfill allowed to create an extra space of waste storage, by replacing the 0.45m-thick gravel layer. It is also a cost-effective solution, whether this is for not using gravel but also by saving time of work. Indeed, the installation is fast and does not require any specific material nor a lot of workers. This geocomposite with mini-pipes has succeeded in proving that it was a good choice for this project. Its filter treated against biological clogging was a very important condition to ensure its efficiency through time, as well as its duration regarding the height of waste by no creeping. Finally, the hydraulic design showed the adequacy between the requirements (amount of leachate to drain) and the chose geocomposite.

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