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Design and use of multi-linear drainage geocomposites for gas collection layers

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Abstract. Pore pressures generated by gas underneath a geomembrane can affect its integrity and the entire lining system. It can create whales/hippos in a surface impoundment, significantly reduce normal stress on the lower interface and create a veneer instability on final landfill cover. The membrane is lifted by the pressure of the gas trapped beneath it. The solution to avoid such occurrences is to install a permeable material that collects and transmits the gas outside the lining system. It can be vented to the atmosphere in the case of impoundments or collected in a gas collection network for valorization in case of landfills, for example. A sand layer is certainly possible, but drainage geocomposites offer an efficient and economical alternative. Depending on the application, the drainage geocomposite is designed to act as a passive system (no mechanical vacuum applied) or active. This paper presents the use of multi-linear drainage geocomposite for gas collection and its hydraulic behavior to collect and evacuate the gas. A case study is also given with the use of geocomposite as venting layer under a lined pond.

1 Introduction

There are a number of phenomena that can lead to the presence and accumulation of gas under a waterproofing system. In the case of ponds, the installation of the geomembrane on the soil prevents exchanges between the soil and the atmosphere. Indeed, most soils naturally contain air in the voids between the grains, in equilibrium with the atmosphere. A fermentation of the organic part of the soil occurs when the geomembrane is applied, which can lead to significant gas production depending on the organic matter content. Another cause is the presence of a water table beneath the pond. Indeed, the level variation of the water table, that is a function of rainfall and/or seasonality, can compress the gas into the soil between the free surface of the water table and the geomembrane, even if the maximum water table level remains below the level of the basin floor.

These phenomena lead to uplift of the geomembrane. Ballasting the geomembrane can minimize this phenomenon, but will not necessarily prevent it. As a result, geomembrane uplift is regularly observed in water-filled basins where the weight of the water on the geomembrane is insufficient to compensate for the gas pressure.

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In the case of final landfill covers, the degradation of the waste leads to the generation of biogas, which accumulates under the impermeable cover, creating pressure beneath the geomembrane and reducing the angle of friction at the interfaces. This can cause landslides on slopes. The quantity of biogas generated is generally important, and it is crucial to properly design the biogas collection layer under the geomembrane, in addition to vertical gas collection wells. Indeed, due to the heterogeneity of the waste mass and its limited zone of influence, biogas collection wells need to be complemented by a biogas collection layer under the geomembrane cover.

The gas collection layer can be composed of free draining granular materials and protected underneath with a separator and filter geotextile. A more technically and economically optimized solution is to use a drainage geocomposite.

2 Multi-linear drainage geocomposites

Draintube multi-linear drainage geocomposites (terminology as per ASTM D4439 [1]) are commonly used for gas collection under liner systems as they provide high flow capacity and a connection technology that minimizes head pressure losses. The geocomposite is composed of non-woven geotextiles that are needle-punched together with perforated, corrugated polypropylene mini-pipes regularly spaced inside and running the length of the roll. The mini-pipes have two perforations per corrugation at 180˚ and alternating at 90˚ (Figure 1). It combines the filtration, separation, gas collection and mechanical protection functions with a single product and a single installation.

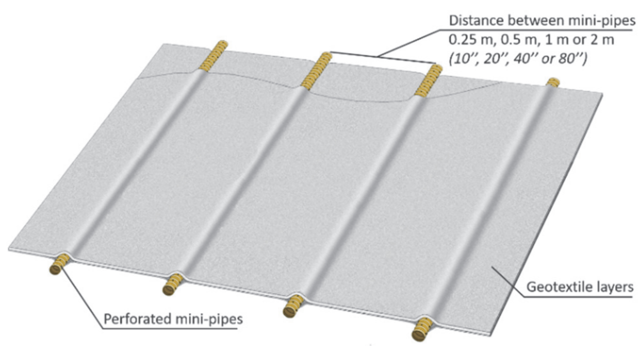

Fig. 1. Draintube geocomposite description.

The distance between the mini-pipes in the multi-linear geocomposite ranges, from 2 m to 0.25 m, and is based on the flow of gas to be collected. Indeed, the drainage capacity of the geocomposite (Transmissivity as per ASTM D4716 [2]) is driven by the number of mini-pipes within the product. There is a linear relationship between the spacing of the mini-pipes and the transmissivity of the overall product (Blond et al. [3] and GRI GC15 [4]).

2.1 Long term hydraulic behavior

The main characteristic of the product is that it keeps its drainage capacity over time even under high load. Figure 2 shows the transmissivity of the product measured for loads between 24 kPa (500 psf) and 2,400 kPa (50,000 psf) at several gradients. It can be observed that the product is not load sensitive when confined between a geomembrane and a soil layer.

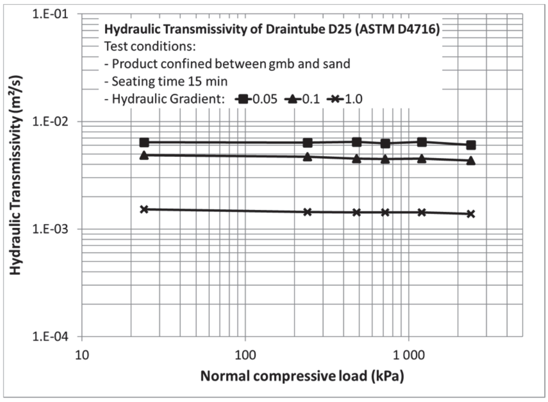

Fig. 2. Hydraulic transmissivity of the Draintube multi-linear drainage geocomposite for several loads.

Figure 3 presents the variation over time of the transmissivity of the geocomposite under 2,400 kPa (50,000 psf) for 1,000 hours. Again, no variation of the transmissivity is observed. Unlike other geocomposites, the multi-linear geocomposite is not sensitive to creep in compression when confined between a geomembrane and a soil layer.

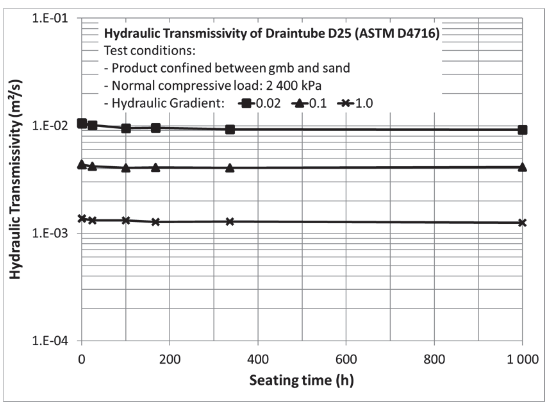

Fig. 3. Hydraulic transmissivity of the Draintube multi-linear drainage geocomposite under load and over time.

This resistance to creep in compression is specific to this multi-linear geocomposite. It is documented by Saunier et al. [5] and in the ASTM D7931 [6] Standard Guide for specifying drainage geocomposites.

2.2 Connection technology

At the end of the drainage system, the geocomposite is be connected to a collector drain in order to evacuate the gas outside the liner system. This connection can induce significant head losses and limit the gas extraction capacity of the entire system.

The multi-linear drainage geocomposite can be connected to the header pipe using quick connectors that allow the geocomposite mini-pipes to be mechanically plugged directly into the header. This prevents displacement during installation of the upper layers and allows for better vacuum distribution throughout the system. Figures 4 & 5 show a typical cross section and an illustration of the connections.

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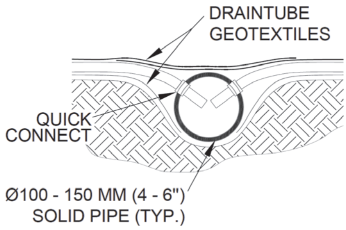

Fig. 4 & 5. Connection using the quick connect system.

3 Venting layer under ponds

3.1 Main requirements

The use of drainage layers under lined ponds and impoundments prevents gas from building up pressure under the geomembrane. Gas coming from the ground is generally evacuated around the perimeter of the pond. Depending on the gas flow rate to be collected, the drainage geocomposite can be installed over the entire surface of the pond or just part of it (e.g. 50% of the surface). Anticipated gas flow rates are typically of the order of 10^{-6} $m^3/s/m^2$ (10^{-4} $scfm/ft^2$), although this typical value can vary by up to an order of magnitude. Figures 6 show examples of full-surface and partial-surface drainage geocomposite installation.

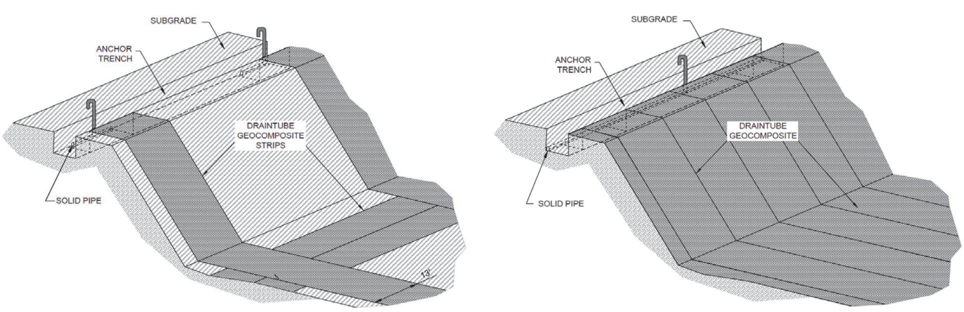

Fig. 6. Installation of the geocomposite on partial-surface or full-surface.

The gas collection under the pond is a passive system, i.e. no mechanical ventilation is installed. The drainage geocomposite must be designed to evacuate the pressurized gas under the geomembrane. It must be designed to maintain a pressure under the geomembrane at all times lower than the load of the ballast (water or soil) on the geomembrane.

3.2 Design considerations

This section describes the various issues to consider when selecting a drainage geocomposite for gas drainage under a geomembrane in a pond or impoundment. Is the bottom of the pond below the maximum water table height? If yes, a groundwater drainage system must also be considered. The venting layer and groundwater drainage system can be achieved using the same geocomposite, because water and gas won't be simultaneously drained, but dedicated collectors need to be constructed and measures must be taken to avoid any accumulation of water in the gas collection system.

What is the minimum load on the geomembrane? Given by the soil protection layer or the minimum water level in the pond. In some case, the geomembrane is left exposed. Although this is not generally recommended (particularly with regard to U.V. resistance), the gas drainage system must be sized accordingly. In this case, a vacuum and air circulation under the geomembrane is preferred.

What is the expected amount of gas to be collected? This amount is generally unknown unless the gas is generated by the degradation of waste. In that case, literature gives formula to estimate the gas generation. Without any information, a flow per unit area of 10^{-6} - 10^{-5} $m^3/s/m^2$ (10^{-4} - 10^{-3} $scfm/ft^2$) can be considered.

How many vents should be installed? The frequency of vents to be placed is about 1 vent every 15 lm of berm. This distance can be increased with the use of quick connect connectors to a peripheral solid pipe.

4 Case study

4.1 Project presentation

The project presented in this paragraph was completed in 2014 and inspected in 2016 by G. Koerner (Koerner [7]). At the site of a 100-year-old petroleum refinery currently being repurposed, two surface impoundments were constructed using a 1.5mm (60 mil) HDPE geomembrane. Pond 1, 60 m x 20 m (200 ft x 65 ft), has a non-woven geotextile under the geomembrane for puncture protection. Pond 2, 90 m x 45 m (295 ft x 148 ft), has a multi-linear drainage geocomposite under the geomembrane for puncture protection and gas venting. 16 vents were installed on the perimeter of the pond; one every 15 m. Figure 7 shows the 2 ponds. Both ponds were built to keep a minimum load on the geomembrane: a minimum water level of 300 mm (approx. 3 kPa) maintained in the pond 1, and a 75 mm thick aggregate layer (approx. 1.5 kPa) in the pond 2.

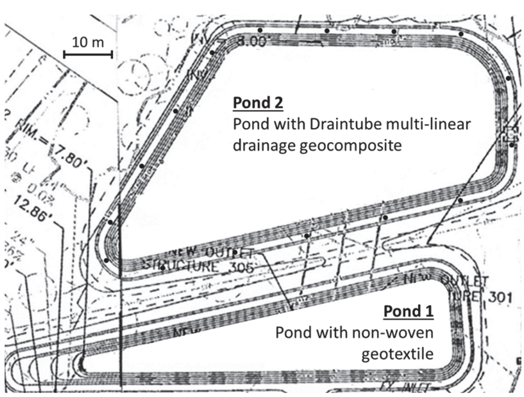

Fig. 7. Ponds view.

4.2 Performance of the multi-linear drainage geocomposite

The multi-linear drainage geocomposite is composed of a series of 25 mm diameter perforated mini-pipes between the non-woven geotextile layers and spaced every 2 m. On the most unfavorable section, the multi-linear drainage geocomposite collects a flow a gas greater than $3x10^{-5}$ $m^3/s/m^2$ with a gas pressure under the geomembrane limited to 1.5 kPa.

The calculation has been achieved using the hydraulic design software, Lymphea. Figure 8 presents the calculation sheet.

The Lymphea software allows the designer to determine the maximum gas pressure below the geomembrane and the type of multi-linear drainage geocomposite. The software is based on a previous model developed with LIRIGM university research laboratory at the University of Grenoble (France) and CEREMA (formerly Laboratoire Regional des Ponts et Chaussées de Nancy). It has been updated and improved with the contribution of the SAGEOS (CTT Group, Quebec), the CEGEP of Saint-Hyacinthe (Quebec), and the University of Saskatchewan (USASK) in Alberta (Fourmont et al. [8]).

Calculations have been performed without any vacuum applied to the system, only the pressure of the gas under the geomembrane is considered to generate a hydraulic gradient. In fact, the difference of elevation between the geocomposite at the bottom of the pond and the vents on top of the slopes induces a barometric variation that creates a vacuum into the system and increases the flow of gas collected by the geocomposite. This type of calculation was previously explained by Fourmont et al. [9].

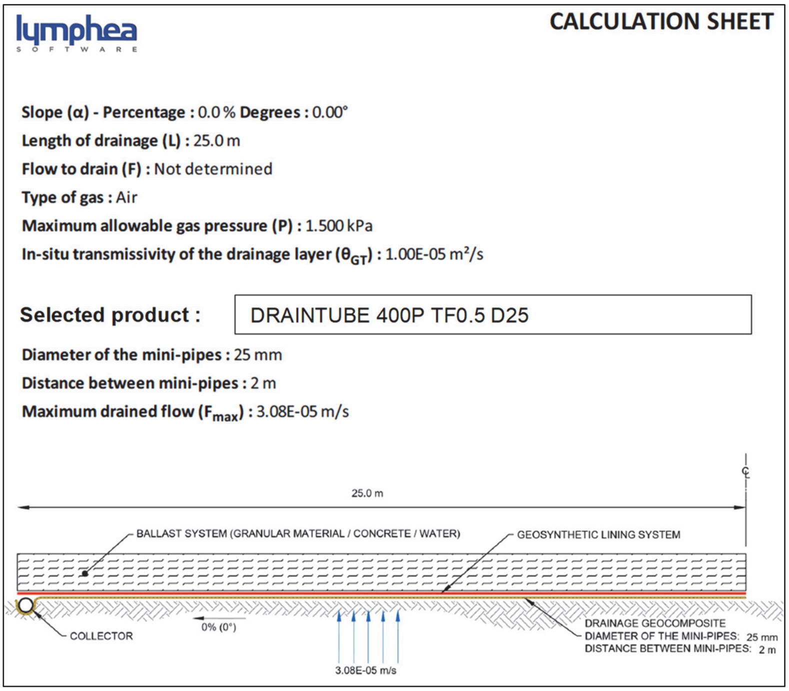

Fig. 8. Lymphea calculation sheet.

4.3 Operation of the ponds

Within a few months after the construction of the ponds, many whales and hippos appeared on the pond 1, as seen in Figure 9. Remediation measures were implemented on Pond 1. A 220 mm thick gravel layer (approx. 4.5 kPa) was placed over the geomembrane, and vents were built on the perimeter at the top of the slope. The gas in the whales and hippos was gradually forced out and the geomembrane returned to its original horizontal position. Their future occurrence is unknown at present.

Fig. 9. Geomembrane uplifts in Pond 1.

On the contrary, Pond 2 drained with the geocomposite had no whales or hippos (Figure 10).

Fig. 10. View of the Pond 2.

Further investigations on the ponds showed presence Volatile Organic Compounds (VOCs) in the soil. Measurement of the concentration of the VOCs was carried out on each vent of the Pond 2. Measured values are reported on the Figure 11. The first six low values occurred where a former building was located and the 10 high values were formerly undeveloped land with assumed, but unknown, hydrocarbon disposal.

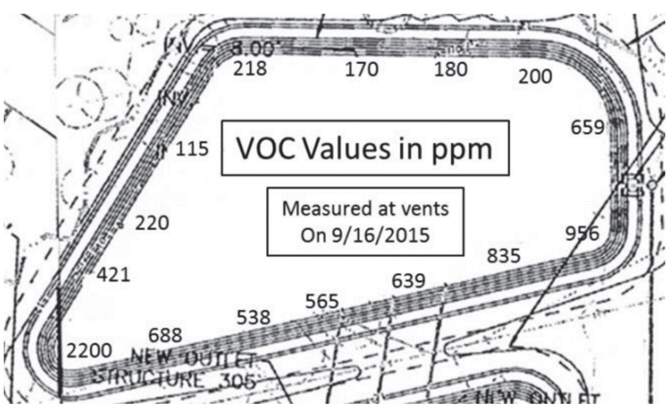

Fig. 11. VOC measurements in Pond 2.

5 Conclusions

The installation of a gas collection layer under a lining system is crucial to protect the geomembrane against gas pressures coming from the soil or from waste degradation. Draintube multi-linear drainage geocomposites are commonly used as a gas collection layer as they provide a high flow capacity even under high loads and reduce the head losses into the system, particularly at the connection with the header pipe with the use of quick connect connectors. The geocomposite is designed, using the hydraulic software Lymphea, to maintain a pressure under the geomembrane at all times lower than the load of the ballast (water or soil) on the geomembrane.

The case study presented in the paper shows that the rising gas under the liner can be caused not only by degradation of subsurface organic material, or rising water table levels from adjacent sources, but also by rising volatile organic compounds (VOCs). A non-woven geotextile for puncture protection under the geomembrane and a limited load on the geomembrane is not always sufficient to prevent uplift of the geomembrane, even on small ponds. It seems to the authors that drainage geocomposites and venting networks should always be used for geomembrane-lined surface impoundments.

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