Multi-linear drainage geocomposite for Sub-slab Depressurization and radon mitigation

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ABSTRACT
Sub-slab Depressurization (SSD) aims to reduce building occupants' exposure to toxic gases from the soil. These gases can be either generated from contaminated soils (like volatile organic compounds or landfill gas) or naturally present in the soil (like radon). The SSD system is composed from the bottom to the top of a separator geotextile, a drainage layer, and a vapor barrier. One or more gas pits are located according to the gas concentration in the area and to the geometry of the building. Because most of the SSD systems are constructed in high-density population areas (e.g. new construction in old industrial zones), the truck traffic and the noise resulting from the excavation works and the transportation of granular material is a nuisance for local residents. It also damages the local road network that is not designed to handle heavy vehicles traffic. This paper presents the use of multi-linear drainage geocomposite as part of the SSD system providing separation and gas collection functions. The geocomposite is composed of non-woven geotextile layers incorporating perforated mini-pipes regularly spaced and running the length of the roll. It is connected to a collector pipe and to the gas pit. It collects the soil gas and reduces the head losses thanks to the high-density network of perforated mini-pipes into the product and the specific fittings used to connect the product to the main collector pipe. Multi-linear drainage geocomposite has been found efficient for both passive and active SSD systems.

RÉSUMÉ
Le système de dépressurisation sous la dalle de plancher vise à réduire l'exposition des occupants d'un bâtiment aux gaz toxiques présents dans le sol. Ces gaz peuvent être soit générés par des sols contaminés (comme les composés organiques volatils ou les biogaz), soit présents naturellement dans le sol (comme le radon). Le système de dépressurisation est composé, de bas en haut, d'un géotextile séparateur, d'une couche de drainage et d'un pare-vapeur. Une ou plusieurs fosses de retenues sont positionnées en fonction de la concentration de gaz dans la zone et de la géométrie du bâtiment. Comme la plupart des systèmes de dépressurisation est construite dans des zones à forte densité de population (par exemple, de nouvelles constructions dans d'anciennes zones industrielles), la circulation des camions et le bruit résultant des travaux d'excavation et du transport du matériau granulaire constituent une nuisance pour les résidents locaux. Ils endommagent également le réseau routier local qui n'est pas conçu pour supporter le trafic de véhicules lourds. Cet article présente l'utilisation d'un géocomposite de drainage multi-linéaire comme élément du système de dépressurisation assurant les fonctions de séparation et de collecte des gaz. Le géocomposite est composé de géotextiles non-tissés aiguilletés incorporant des mini-drains perforés régulièrement espacés dans le produit. Il est relié à un tuyau collecteur et d'évacuation. Il permet de collecter les gaz du sol et de réduire les pertes de charge grâce au réseau dense de mini-drains perforés dans le produit et aux raccords spécifiques utilisés pour connecter le produit au tuyau collecteur principal. Le géocomposite de drainage multi-linéaire est efficace pour les systèmes de dépressurisation passifs et actifs.

1 INTRODUCTION

The reclamation of industrial brownfield sites or former waste deposit sites for new developments is already common practice in various parts of the world. The infiltration of underground gases poses a serious threat to the safety of the occupants of these reclaimed sites. Gases generated by both waste products (biogas) and contaminated soils (such as volatile organic compounds VOC), and even natural gases like radon produced by the natural decay of uranium, are commonly detected in affected areas. Sub-slab gas collection systems, using a natural permeable layer such as crushed stones paired with draining pipes and vents, are frequently used to prevent gas infiltration into new developments. However, geosynthetic products such as multi-linear drainage geocomposites present an excellent alternative for both passive and active sub-slab gas collection systems.

This technical paper aims to present a comprehensive overview of the installation and performance of such systems, while demonstrating their benefits over conventional approaches to underground gas collection.

2 UNDERGROUND GASES

Underground gases that can infiltrate buildings and have an effect on the inhabitants are usually the result of either site pollution (contaminated soils, etc.) or site geology (gases naturally present in the soil and sublayers).

2.1 Landfill gas (LFG)

LFG is produced during the decomposition of putrescible materials in landfills and the breakdown of organic materials in soils by microorganisms. LFG is typically 40 to 60 percent methane (CH_4), with the remainder consisting of carbon dioxide (CO_2) with limited amounts of nitrogen, oxygen, and other compounds.

2.2 Volatile Organic Compounds (VOCs)

VOC's are organic compounds containing one or more carbon atoms that have high vapor pressures and therefore evaporate readily to the atmosphere. There are thousands of compounds that meet this definition. Some, such as benzene and formaldehyde, are considered toxic and can affect health.

A major source of man-made VOCs are solvents that are used in paints and protective coatings. VOCs come from human activities such as the production, storage, transport, processing, use and combustion of natural gas, coal and petroleum and its sub-products.

2.3 Radon

Radon is a radioactive gas found naturally in the environment. It is produced by the decay of uranium found in soil, rock or water. Radon is invisible, odourless, and tasteless and emits ionizing radiation.

When radon escapes from the earth into the atmosphere, it is diluted to such low concentrations that it poses a negligible threat to health. However, when radon is confined to enclosed or poorly ventilated spaces like buildings, it can accumulate to high levels and may pose a health risk.

3 SUB-SLAB DEPRESSURIZATION SYSTEM

3.1 General description

Sub-slab depressurization (SSD) aims to reduce building occupants' exposure to toxic gases from the soil. To do so, a gas collection network is installed under the entire slab and connected to an exhaust pipe, 100 mm (4 in.) minimum diameter, installed vertically through the floor to the roof.

In order to prevent subsurface vapors from entering homes and other buildings, mitigation solutions can be achieved by passive or active SSD. In a passive SSD system, the gas is collected from under the slab by the drainage system to a collector pipe connected to a vent, which extracts the gas from the building by natural draft. An active SSD system is created by adding a fan to the drain vent of a passive system to increase the negative pressure applied to the system.

3.2 Gas Venting layer

The gas venting layer is constructed using the Draintube multi-linear drainage geocomposite (terminology as per ASTM D4439). It is composed of non-woven geotextiles that are needle-punched together with perforated, corrugated Polypropylene (PP) 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 provides the filtration/separation, gas collection and mechanical protection functions with a single product and a single installation.

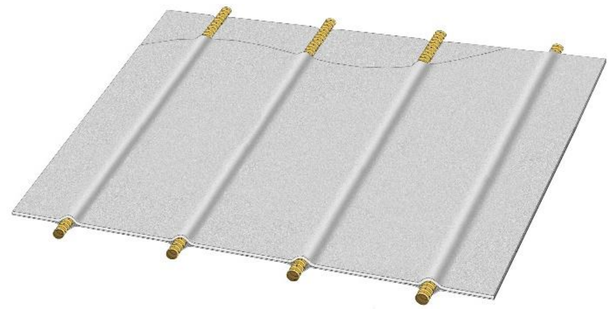

Figure 1. Drainage geocomposite description

The mini-pipe components of the geocomposite have a diameter of 25 mm (1 in) and are typically spaced at 2 m (80 in) centers. With this configuration, it exhibits a long-term transmissivity superior or equal to $1x10^{-3}$ m^2/s. This value is measured as per ASTM D4716 standard, for a hydraulic gradient of 0.02, confined in soil under a normal load of 2,400 kPa (50,000 psf) and a seating time of 1,000 hours.

The main characteristic of the product is that it keeps its drainage capacity over time even under high load (Figure 2). It is not sensible to creep in compression, nor geotextile intrusion (Blond et al., 2010).

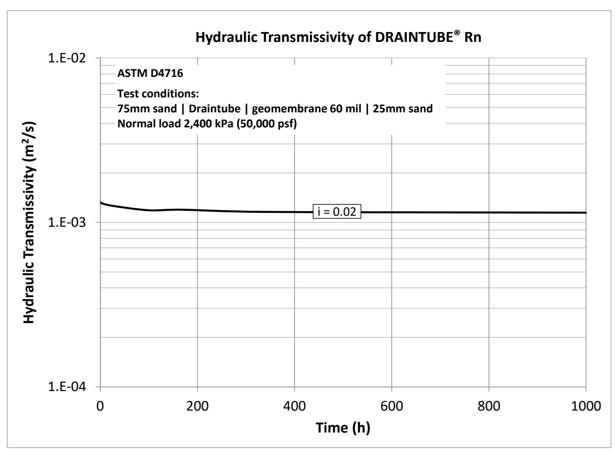

Figure 2. Geocomposite Transmissivity under 2,400 kPa after 1,000 hours (ASTM D4716 / GRI GC15)

Unlike other planar geocomposites, the load transfer mechanism between the overlying and underlying material is only a fraction of the normal load. The mini-pipe component of multi-linear drainage geocomposite is confined by the surrounding soil, thus loads are calculated using traditional flexible pipe design methodologies. The soil arching effect that applies to other flexible pipes applies to this type of geocomposite as well (Figure 3).

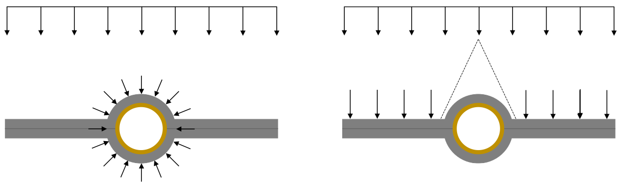

Figure 3. Load transfer mechanism

3.3 Gas suction pit

The gas suction pits are centrally located, according to the gas concentration and the geometry of the building. One gas suction pit per 5,000 to 10,000 m^2 (50,000 to 100,000 ft^2) generally results in an effective SSD system.

3.4 Vapor barrier

A geomembrane is to be placed under the concrete slab. It prevents contamination of the underlying layers when the concrete is cast and limits the gas migration through the floor. The performance of the geomembrane layer is dependent on the composition and thickness of the material, but also on its installation (joints between panels, connection to the walls, etc.).

The geomembrane may require a protective geotextile before pouring the concrete slab on it.

Two typical cross sections for the SSD system are presented on Figure 4, with and without granular fill.

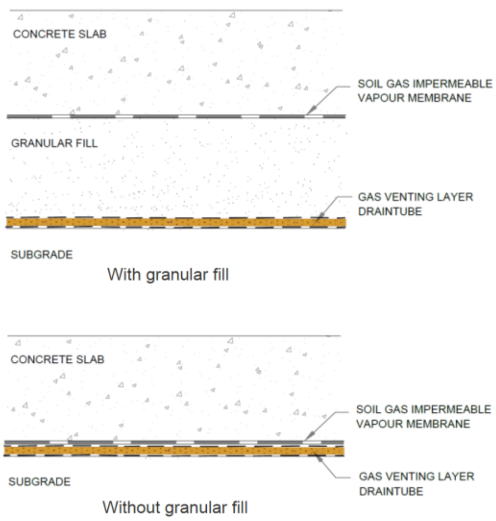

Figure 4. Typical cross-sections for SSD systems

Multi-layers true gas barrier geomembranes with an ethylene vinyl alcohol (EVOH) core co-extruded between polyethylene (PE) layers are recommended especially in presence of VOCs. These types of geomembrane exhibit much lower gas permeability characteristics with an order of magnitude of 10^3 to 10^4 compared to high density polyethylene (HDPE) geomembranes (Kelsey, 2014).

4 INSTALLATION

4.1 Gas Venting layer

The installation of the gas venting layer is achieved by unrolling the multi-linear drainage geocomposite on the subgrade such that the mini-pipe components are oriented with the intended flow direction and perpendicular to the main header pipe (Figure 5).

Figure 5. Installation of the geocomposite on the subgrade

Rolls are connected along the side with a minimum overlap of 100 mm (4 in) and secured using seams, welds, or additional overlap. The connection at the terminating edge of the roll is overlapped such that the upper geotextile layer can be rolled back 150 mm (6 inches) and the end of the next roll inserted into the opening (Figure 6). Mini-pipes are connected using snap coupler fitting.

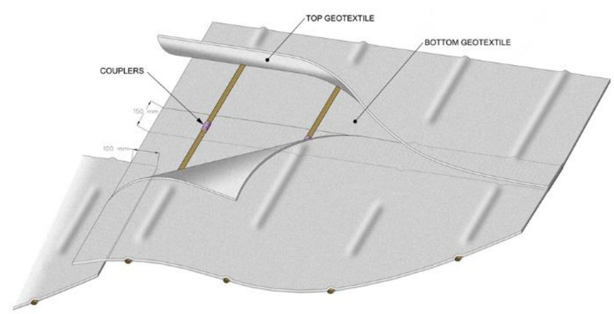

Figure 6. Geocomposite overlaps

In the case of posts, mini-pipes are diverted along the side of the post. If not possible, additional mini-pipe is positioned to redirect the flow to the next closest mini-pipe. Cross walls are passed using drainage channels for the mini-pipes (Figure 7).

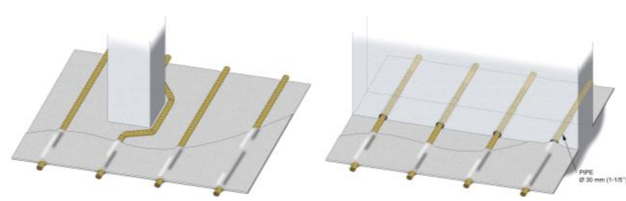

Figure 7. Passing post

4.2 Connection to the header pipe

The gas venting layer is connected to one or more header pipes, function of the geometry of the building, and the number of exhausts.

The connection is achieved using quick connect connectors that allow the geocomposite mini-pipes to be mechanically attached to the header pipe. It prevents displacement during the installation of the upper layers and reduces the head losses at the connection between the venting layer and the exhaust pipe.

Depending on the cross section of the SSD (with or without granular fill), the header pipe may need to be placed in a trench (Figure 8).

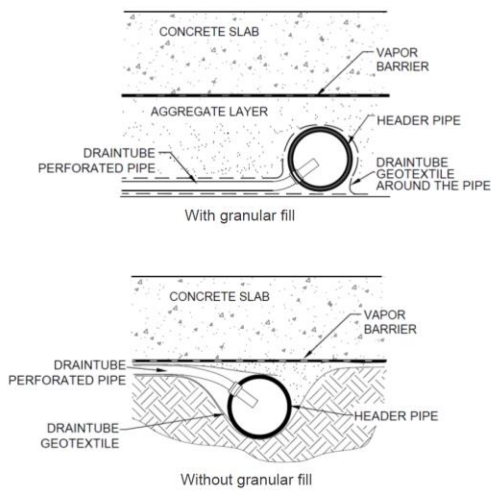

Figure 8. Connection to the header pipe

This mechanical connection allows for single or double connections of the geocomposite to the header pipe (Figure 9).


Figure 9. Single connection to the header pipe


Figure 10. Double connection to the header pipe

4.3 Vapor Barrier

The vapor barrier is generally delivered in rolls that are unrolled and connected with a 300 mm (12 in) overlap. Joints between rolls, around penetrations and against the walls are sealed to prevent gas migration.

The installation of a protective geotextile may be required on the vapor barrier to prevent puncture by the overlying layers (Figure 11).

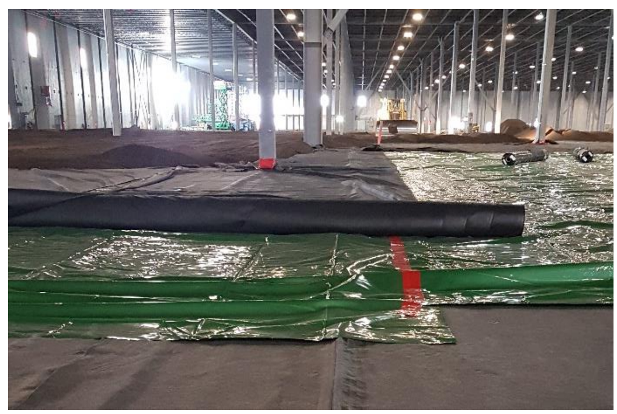
Figure 11. Vapor barrier and geotextile installation

5 DESIGN / PERFORMANCE

The aim of the gas venting layer is to migrate the gases to the header pipes and then outside the building using the exhaust pipes. This exhaust system avoids the accumulation of gas under the slab that could eventually infiltrate into the building.

The multi-linear drainage geocomposite is compatible with passive and active SSD.

5.1 Design software

A design software, Lymphea, has been developed by LIRIGM (Laboratoire Interdisciplinaire de Recherche Impliquant la Géologie et la Mécanique) at the University of Grenoble (France) in collaboration with Afitex and validated by large scale tests (Faure et al., 1995). It has been recently updated with the contribution of the CCT Group.

Equations governing the gas collection in the software have been explained by Steinhauser et al., 2015. The gas discharge capacity of the mini-pipes of the geocomposite is expressed using the Equation 1.

$$\left(q_p\right)_g = \alpha\left(i_g\right)^n \quad [1]$$

Where:
$(q_p)_g$ = gas discharge capacity
i_g = gradient
n,α = constants function of the type of gas and the mini-pipe

The design software combines Equation 1 with the drainage capacity of the geotextile layer itself to calculate the head loss in the entire geocomposite function of the flow to evacuate, the geometry of the project (drainage length, slope, loads applied, distance between collectors, etc.), the characteristics of the gas (density, dynamic viscosity, etc.).

Figure 12 shows the home page of the software for the SSD system application.

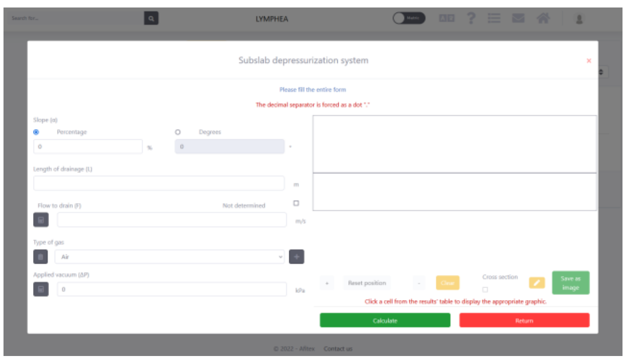

Figure 12. SSD system application in Lymphea software

The software allows for SSD design in passive or active conditions. (Figure13). The determination of the negative pressure applied in passive condition is based on the Barometric formula, function of the height of the exhaust pipe.

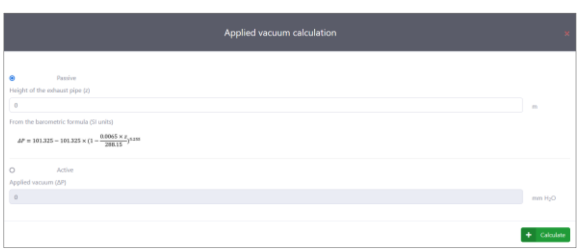

Figure 13. Applied vacuum calculation

5.2 Performance of the geocomposite venting layer

Figure 14 gives the collected flow rate per unit area function of the negative pressure applied, for several length of drainage, for a multi-linear drainage geocomposite with the mini-pipe components 25 mm (1 in) diameter spaced at 2 m (80 in) centers into the product.

Calculations have been conducted using air but can also be done for other gas like methane, radon, or any gas mix.

The length of drainage is the maximum drainage length to the header pipe, or the half distance between two header pipes in case the geocomposite is connected at both ends.

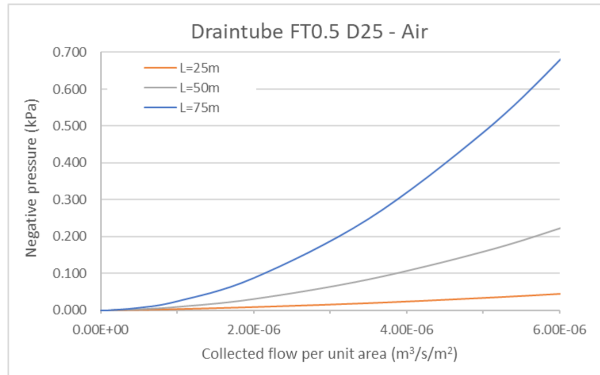

Figure 14. Collected flow per unit area

Figure 15 shows the same calculation displayed per unit length of header pipe.

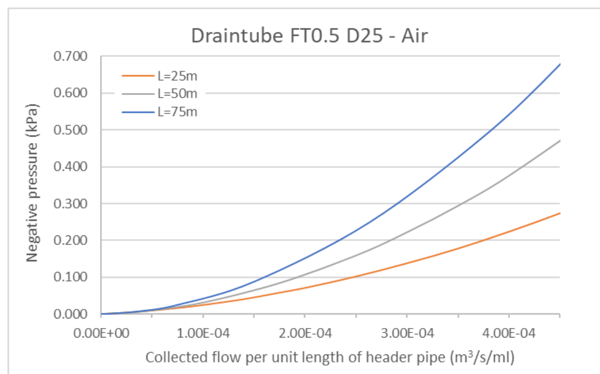

Figure 15. Collected flow per unit length of header pipe

Function of the expected flow of gas to collect, and the negative pressure that can be applied into the system, additional header pipes can be installed (to reduce the maximum length of drainage) or the use of a multi-linear drainage geocomposite with a higher density of mini-pipes inside, eg. mini-pipes on 1m (40 in) centers instead of 2 m (80 in.).

The Lymphea software allows to size the geocomposite based on the project's characteristics.

6 ENVIRONMENTAL AND SOCIAL FOOTPRINT

In replacement of a granular drainage layer and separation geotextiles, multi-linear drainage geocomposites aims to reduce the Green House Gas emissions for the same performances.

Geocomposites save up to 85% of emissions, mostly due to less excavation being needed during installation compared to a granular drainage layer and less heavy vehicle use in evacuating soil and transporting gravel (Durkheim et al, 2010).

The geocomposite solution reduces drastically the related costs because there is no soil excavation needed compared to a gravel layer and so no fees for placement of the excavated polluted soil in a waste facility.

Because SSD systems are most often required in high-density population areas (e.g. new construction in old industrial zones), the use of a multi-linear drainage geocomposite reduces the social impact on neighboring populations by limiting construction traffic and reducing works duration.

7 CONCLUSIONS

The multi-linear drainage geocomposite is an effective solution as a gas venting layer in the SSD system. Its dense network of perforated mini-pipes and its mechanical connection to the header pipe permits to get a uniform negative pressure under the overall slab of the building.

Compared to granular drainage material, the installation of the geocomposite is simple, requiring less excavation works and relatively low skilled work. Additionally, in terms of greenhouse gas emission, social acceptability and economic competitiveness, the system has more positive assets than its conventional counterpart. Multi-linear drainage geocomposites can be used for passive or active sub-slab depressurization systems.

A dedicated software has been developed to calculate the collected flow per unit area function of the negative pressure applied, the type of gas and the specific geometry of each project.

8 REFERENCES

ASTM D4439. Standard Terminology for Geosynthetics, *American Society for Testing and Materials*, West Conshohocken, PA, USA

ASTM D4716. Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head, *American Society for Testing and Materials*, West Conshohocken, PA, USA

GRI Test Method GC15. Determining the Flow Rate per Unit Width of Drainage Geocomposites with Discrete High Flow Components, *Geosynthetic Institute, Folsom*, PA USA

Durkheim Y. and Fourmont S. (2010). Drainage geocomposites: a considerable potential for the reduction of greenhouse gas emission, *9th International Conference on Geosynthetics*, Guaruja, Brazil

Faure Y.H. and Auvin G. (1995). Gas drainage by geocomposites, Rencontres 95, Beaunes, France

Kelsey C. (2014). *Advances in barrier geosynthetics, Civil and Structural Engineer magazine*, January 2014 edition

Saunier, P., Ragen, W. and Blond, E. (2010). Assessment of the resistance of drain tube planar drainage geocomposites to high compressive loads, *9th International Conference on Geosynthetics, Guarujá, Brazil*, Vol3

Steinhauser E., Fourmont S. (2015). Innovative approach to landfill gas collection and control, *Geosynthetics 2015*, Portland, OR, USA, pp 283-290