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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 either be 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 residents. It also damages the local road network that is not designed to handle heavy vehicles traffic. This paper presents the sizing and 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 roll length. 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 within the product and the specific fittings used to connect the product to the main collector pipe. The sizing of the geocomposite is done using laboratory tests and software to characterize the flow capacity and the head losses of the system. Multi-linear drainage geocomposites have been found to be efficient for both passive and active SSD systems.

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 and other naturally occurring elements 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.

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2 SUB-SLAB DEPRESSURIZATION SYSTEM

2.1 *General description*

Sub-slab depressurization (SSD) aims to reduce building occupants' exposure to toxic gases from the soil. A gas collection network is installed under the entire slab and connected to an exhaust pipe, typically 100 mm minimum diameter, installed vertically from below 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 one or several vents, 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.

2.2 *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°. The geocomposite provides the filtration/separation, gas collection and mechanical protection functions with a single product and a single installation.

The mini-pipe components of the geocomposite have a diameter of 25 mm and are typically spaced at 2 m on-center. With this configuration, it exhibits a long-term transmissivity superior or equal to 1×10^{-3} m^2/s. This value is measured as per ASTM D4716 or ISO 12958-2 standards, for a hydraulic gradient of 0.02, confined in soil under a normal load of 2400 kPa and a seating time of 1000 hours.

The main characteristic of Draintube multi-linear drainage geocomposites is that they maintain their drainage capacity over time, even under high load (Figure 1). They are not sensitive to creep in compression, nor geotextile intrusion (Blond *et al.* 2010).

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

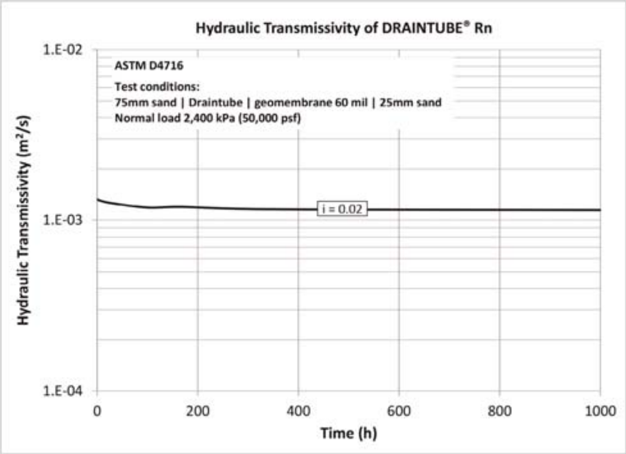

Figure 1. Geocomposite transmissivity under 2400 kPa for 1000 hours (ASTM D4716 / GRI GC15).

calculated using traditional flexible pipe design methodologies. The soil arching effect that applies to other flexible pipes also applies to this type of geocomposite.

2.3 *Gas suction pit*

The number and location of gas suction pits are determined according to the position of the header pipe, the gas concentration and the geometry of the building. Using an active SSD system with a venting layer under the overall surface of the building will decrease the number gas suction pits requiered.

2.4 *Vapor barrier*

A membrane is typically 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 membrane 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 vapor barrier can be installed directly on top of the multi-linear drainage geocomposite. Thanks to its geotextiles layers, the geocomposite mechanically protects the membrane from puncture of the underlying soil. The installation of a protective geotextile may also be required on the vapor barrier to prevent puncture by the overlying layers.

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

Membranes are efficient to prevent gas migration, but should not be used without the depressurization system underneath. Indeed, they exhibit a thickness generally lower than 1.0 mm and they are sensitive to puncture, especially during installation. Moreover, junctions between membrane rolls, and connections to the perimeter walls and any interior slab penetrations, such as columns, etc. are weak points and potential causes of leaks. It is crutial to keep the soil underneath the concrete slab at a pressure lower than inside the building with a gas venting layer like multi-linear drainage geocomposite. In case of leaks, the gas migration will then go from inside to ouside of the building where it is harmlessly vented to the atmosphere.

3 INSTALLATION

3.1 *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 2). Rolls are connected along the side with a minimum overlap of 100 mm 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 and the end of the next roll inserted into the opening. Mini-pipes are connected using snap coupler fitting.

In the case of columns or other interior slab penetrations, mini-pipes are diverted along the side of the penetration. If diversion is not possible, additional mini-pipe is positioned to redirect the flow to the next closest mini-pipe. Interior walls are addressed using drainage channels for the mini-pipes.

Figure 2. Installation of the geocomposite on the subgrade.

3.2 *Connection to the header pipe*

The gas venting layer is connected to one or more header pipes. This is a function of the geometry of the building, and the number of exhausts. These connections are achieved using quick connect connectors that allow the geocomposite mini-pipes to be mechanically attached to the header pipe. These quick connects prevent displacement of the mini-pipes during the installation of the upper layers and reduce the head losses at the connection between the venting layer and the exhaust pipe. This mechanical connection allows for single or double connections of the geocomposite to the header 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 3) to prevent intrusion into the thickness of the concrete slab.

Figure 3. Connection to the header pipe.

3.3 *Vapor barrier*

The vapor barrier is generally delivered in rolls that are unrolled and connected with a 300 mm overlap. Joints between rolls, around penetrations and against the walls are sealed to prevent unwanted gas migration. (Figure 4).

Figure 4. Vapor barrier and geotextile installation.

4 DESIGN AND PERFORMANCE

The aim of the gas venting layer is to migrate the gases to the header pipes and then outside of the building using the exhaust pipes. This exhaust system prevents 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.

4.1 *Design software*

A software for the hydraulic design of drainage geocomposite and granular drainage layers , named 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 Group and validated by large scale tests (Faure *et al*. 1995). It has been updated and improved with the contribution of the SAGEOS, CTT Group in Quebec, the CEGEP of Saint-Hyacinthe in Quebec, and the University of Saskatchewan in Alberta (Fourmont *et al*. 2023). The calculation module for gas collection using a multi-linear drainage geocomposite is based on the following flow conditions:

- Gas supply with a homogeneous flow distribution perpendicularly to the geocomposite,
- Horizontal or non-horizontal position of the drainage layer with the flow condition down or reverse to the slope α,

The fluid inside the drainage layer is assumed to flow perpendicular to the perforated mini-pipes. This hypothesis is conservative and reasonably good as the distance between the mini-pipes is 2 m maximum, provided the length of the mini-pipes is generally more than 10 m. The flow per unit area collected by the multi-linear drainage geocomposite is calculated with the software as a function of:

- distance between mini-pipes,
- transmissivity of the geotextile drainage layer itself,

- slope (if any),
- length of drainage (distance to the main collector),
- type of gas (density, dynamic viscosity),
- vacuum (negative pressure) applied to the system.

The software allows for SSD design in passive or active conditions. In passive conditions, the determination of the negative pressure applied to the system is based on the Barometric formula, which is a function of the height of the exhaust pipe.

4.2 *Performance of the geocomposite venting layer*

Figure 5 gives the collected flow rate per unit area as a function of the negative pressure applied, for several lengths of drainage, for a multi-linear drainage geocomposite with the mini-pipe components 25 mm diameter spaced at 2 m 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.

As an example, in the case of a passive SSD system under a two-storey building, the applied vacuum into the system is 0.070 kPa (6 m height exhaust pipe) and the multi-linear drainage geocomposite will collect a flow per unit area of 7×10^{-6} $m^3/s/m^2$ over a maximum length of 25 m to the header pipe. The collected flow is then 1.75×10^{-4} m^3/s per linear meter of header pipe.

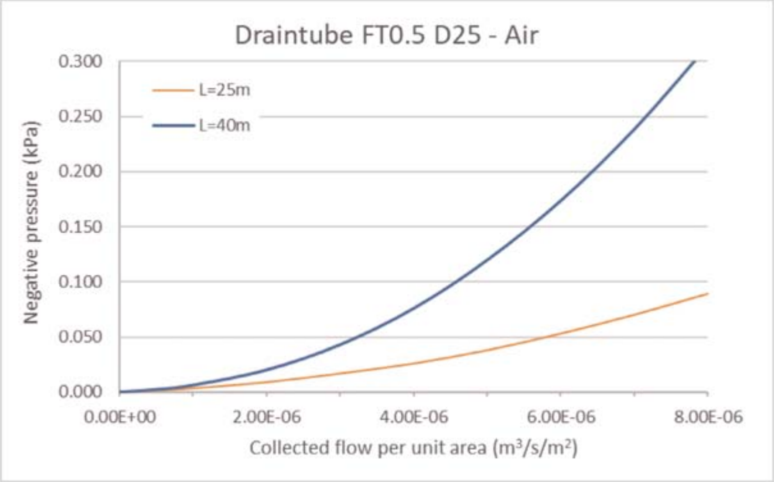

Figure 5. Collected flow per unit area.

As a function of the expected flow of gas to collect, and the vacuum 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, e.g. mini-pipes on 1 m centers instead of 2 m. The Lymphea software yields the size of the geocomposite based on the project's characteristics.

5 CONCLUSIONS

Draintube 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 provides 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 readily available labor without specialized skills. 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 is available to calculate the collected flow per unit area as a function of the negative pressure applied, the type of gas and the specific geometry of each project.

In replacement of a granular drainage layer and separation geotextiles, multi-linear drainage geocomposites aim to reduce the Green House Gas emissions while maintaining the same level of effectiveness. Geocomposites save up to 85% of CO_2 equivalent emissions, mostly due to less excavation being needed during installation compared to a granular drainage layer and lighter equipment used 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 disposal of the excavated polluted soil in a waste facility. It also avoids any problem of supply of granular materials and preserves these natural resources which are not renewable. 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 the duration of the works.

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