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Water or gas flow through geosynthetic clay liners overlaps

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ABSTRACT: The Geosynthetic clay liners (GCLs) are usually used to realise seal barrier's when covering waste landfills. The principal functions of this barrier are to limit the water quantity infiltrated into the waste deposit and to minimise the inflow or the outflow of the gas through the cover. Many research works on the water or gas permeability of the current section of the GCLs has been done but little search has been done on the necessary overlap zones between panels of GCLs. For the assembly modes usually recommended during the installation of the GCLs, it is important to ensure that we have good continuity of the sealing on these zones. In order to test a representative overlap zone, we designed and carried out a special cell called Flow-Box of an area of 1 square meter and 0.2 m high (see figure 1). This cell allowed us to study the influence on the leak-flow at the overlap zone due to the variations of the following parameters : confining stress, hydraulic head or gas pressure, type of overlap zone treatment, nature of confining materials. We present the results of the tests done on overlaps of a needle punched GCL with various types of overlap zone treatment.

1 INTRODUCTION

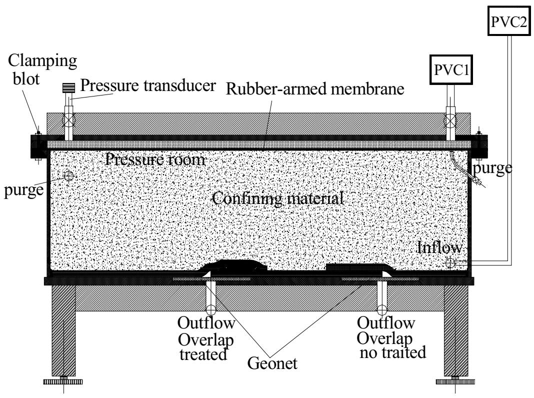
The installation of GCL obligatorily requires overlap zones between the panels. These zones are potential weak points and should be paid attention. To reinforce these zones, it is necessary to have a good knowledge of their behaviour when in use.
If there are many work researchs on the permeability with water or gas concerning GCL's current section, a few of them have been oriented on the necessary overlap zone between the GCL's panels. For assemblies' modes usually recommended at the GCL installation time, it is important to ensure that we have good sealing continuity at these levels.

It is in this context that our work research is situated. In this paper we present the results of several long duration tests devoted to study the GCL's hydraulic performance at the overlap level with water and gas. The tests were carried out in such a way that we can study and compare, for several phases of hydraulic head and gas pressure, water and gas flows of four overlap types. These overlaps contain one untreated and three other treated with bentonitic granulates, paste or powder. The geosynthetic clay liner (GCL) tested is a needle punched type. The results are presented for low normal confining stress (5-10 kPa) that is able to be met in capping waste landfills.

2 DESCRIPTION OF THE TEST CELL

The large test cell presented in figure 1 is a steel tank of 200 liters capacity (100×100×20 cm). This tank is provided by a steel cap and a rubber-armed membrane, the unit is completely tight. On the tank bottom, 2 lysimeters of 0.30 m² surface allow to compare the flow through a GCL's current part (no overlap zone) and a 0.8 m overlap zone length. They also allow to compare the flow through two overlap zones. These 2 lysimeters are hydraulically sealed by bentonite paste. Each lysimeter has two openings, one for outflow of liquid test, the other is used as a purge. The normal stress is transmitted to the GCL by a standard sand (2-5 mm) or a site's material. This tank allows :

- to test a representative sample of GCL,
- to vary the overlap's width (l) from 0.15 to 0.3 m (in our case l = 0.15 m),
- to follow the kinetics of swelling, absorption, then inflow and outflows of liquid under imposed hydraulic head and normal stress,
- to study the influence of the confining material nature in contact with the GCL on its hydraulic performances (on the overlap levels and in the current section). The space between the membrane and the cap (pressure room) is filled by water allowing :



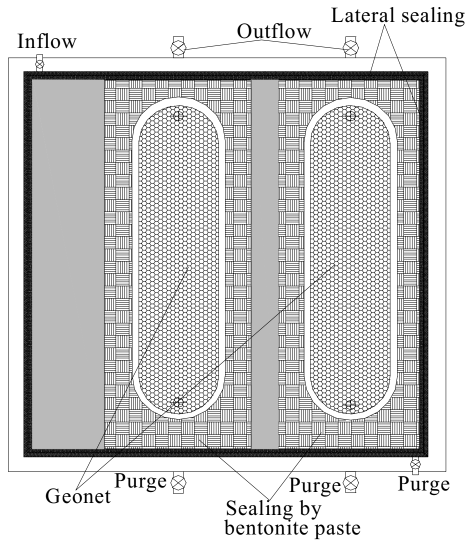


Figure 1. Diagram of the tank.

– to measure the swelling under imposed normal stress (by a controller pressure-volume whose the water level is measured by a sensor related to a acquisition computer that allows to know the water quantity entering or leaving the pressure room);
– to apply a normal stress (with an air pressure related to PVC1 (figure 1) for high stress);
– to control the water pressure by a sensor connected to the acquisition computer;
– to measure settlement due to variation of normal stress;

the constant hydraulic head is ensured by a controller pressure-volume.

3 CHARACTERISTICS OF THE OVERLAPS AND MATERIALS

The needle punched geosynthetic clay liner (GCL) contains a granular natural sodium bentonite (table 1).

Table 1: GCL Characteristics.

Mass per unit area (kg/m^2)		Initial water content	Thickness		Free swelling 2g
total	bentonite	W (%)	$E_{2\ kPa}$ (mm)	E_{20kPa} (mm)	(cm^3)
5.55	5.17	13.0	7.40	6.55	27

The GCL's bentonite is confined between two geotextiles, a woven one (90 g/m^2) and a non woven one (200 g/m^2). The woven and no woven geotextiles are in polypropylene. The confining material used is a siliceous sand of 2/5 mm. The tests are realised with tap water having a pH = 7.6 and a conductivity of 500 ms/cm.

The four types of overlap are studied, an untreated overlap and three other treated ones with 400 g/m additional bentonite dispersed on 8 cm width in the form of granulates, powder and paste with a water content of 300%. All the overlaps tested have 15 cm width and 80 cm length.

4 TESTING PROCEDURE

Each test was carried out in three principal phases : saturation phase, phase of water flow and phase of gas flow.

4.1 *Saturation phase*

During the saturation phase the tank is maintained horizontal with a low hydraulic head. The measurement of the vertical deformation is made by the controller pressure-volume PVC1 (see figure 1) connected to the pressure room. The entering water quantity (or outgoing) of the pressure room divided by the sample's surface gives the vertical deformation. This saturation phase of the sample can last more than two weeks. The results are exploited continuously. The saturation phase will be considered as completed when at least 90 % of final swelling for an infinite time (Δh_∞) are reached (standard project NFP 84706).

4.2 *Water flow phase*

As soon as the swelling of the GCL reaches at least 90% of its end value, the hydraulic head is increased until the desired value H_f after saturating the confining material. The normal stress is increased of a value of $\Delta\sigma = \gamma_\omega \times H_f$ in order to keep the effective normal stress constant. From time to time, we measure the outflows at the lysimeters level until these flows are stabilized.

4.3 *Gas flow phase*

As soon as the water flow phase is over, both the tank and the two lysimeters were completely drained from water and prepared for gas flow tests. Two methods were used to measure the gas outflow:

- the high outflow (between 0.1 and 5 l/min) were measured with constant gas pressure. Thus, a constant gas pressure was applied in the up-stream room (in the voids of the confining soil) and the gas outflow was measured at the level of each lysimeter independently with a flowmeter of rotameter type.
- the lower outflow (< 0.1 l/min) were measured with variable pressure where we applied a constant pressure in the up-stream room and we measure and record the variation of the pressure in each down-stream room (lysimeters). To realise this measurement we used three differential pressure sensors connected to an acquisition computer.

Principle of measurement of the flow with variable pressure

We remind that the tank is divided into two parts separated by the GCL's overlap having a length L and a width l (Figure 2). The higher (up-stream) part is fixed to a constant pressure gas; the lower part having a volume V_0 (down-stream) is initially fixed to the atmospheric pressure. This room will be closed after applying a constant gas pressure in the higher (up-stream) room. For a constant temperature, increasing of pressure (ΔP) in the down-stream room is a function of the gas volume having traversed the studied overlap. This volume (ΔV) is equal to $\Delta V = \Delta P . V_0 / P_0$.

During the measurement of the gas outflow going through the overlap, no gas outflow can cross the other overlap because the gate-valves are closed.

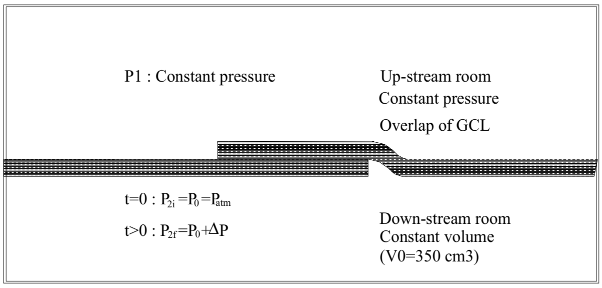


Figure 2 : Measurement principle.

5 RESULTS

5.1 *Saturation phase*

As an example we present in this paper the saturation phase of the test realized on the overlaps treated with bentonitic powder or paste, which was hydrated with water under a quasi null hydraulic head and under a normal stress of 10 kPa.

The evolution of absorptive volume and swelling versus time is shown in figure 3.

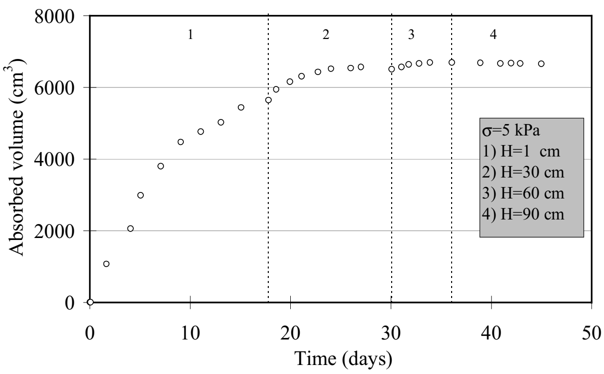


Figure 3. absorbed volume versus time.

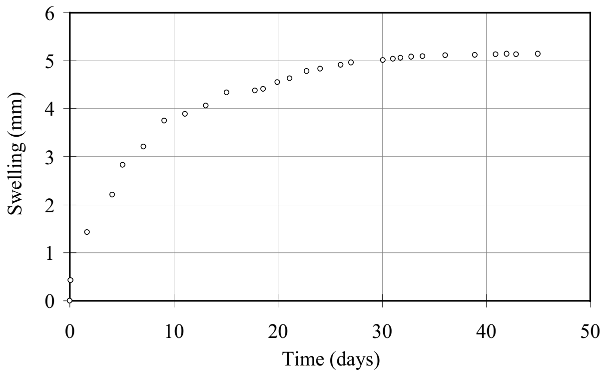


Figure 4. Swelling versus to time.

We observe that after a few days the kinetics of absorption and swelling obey hyperbolic laws, which allows us to estimate absorptive volume and swelling that we would have for an infinite time of saturation.

5.2 *Water flow phase*

As soon as the saturation phase is finished, we vary the hydraulic head for a given value of the normal stress.
For all the tests, increasing the hydraulic head generally leads to increase the leak-flow, in a quasi linear manner (Fig. 5).
With regards to the untreated overlap, outflow cannot be traced on the same figure because it is too high. For this reason we give its equation according to the hydraulic head :
$F = 5\times2710^{-8}H$ with F in $m^3/s/m$ if H in m. These flows allow to calculate the overlap zone transmissivity.

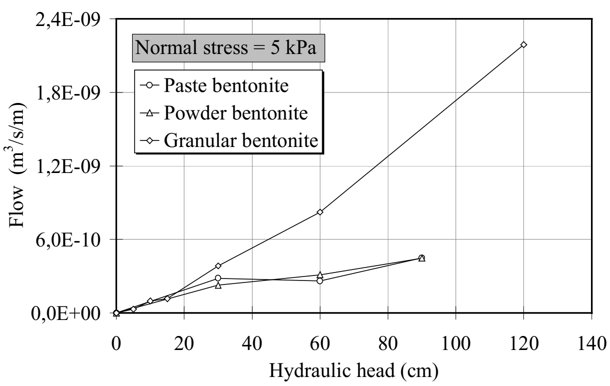


Figure 5. Flow versus hydraulic head.

This figure shows that under low normal stress the performances of the overlap treated by granular bentonite are the worst especially for hydraulic head higher than 20 cm. Probably the contact state at the level of the overlap between the granular bentonite and the non woven geotextile causes this difference, the granular bentonite will not succeed to fill the voids of the non woven. However, this difference in performance can be caused by the differences in quantity of extruded bentonite at the overlap's edges. Whatever is the reason of this difference in the performances, we have showed elsewhere that by increasing the normal stress, all the treatment types by bentonite evoked previously lead to overlaps having equivalent hydraulic performances.

By way of application of these results, we will place ourselves in the context of a capping waste landfills where a GCL is used like sealing barrier. We will consider a cover of a rack containing a current part of a surface 2500 m^2 and a total overlap length of 500 m. For low confining stress (between 5 and 10 kPa) and a hydraulic head of 1 cm (drained confining material), we calculated the water flows through the cover of this rack for several overlaps types for a saturated GCL (table 2).

Table 2: Water flow traversed a capping waste landfills.

Overlap type		Value of Transmissivity (m^2/s) $\times10^{-10}$	Outflow (liter/day/2500m^2) R	R+C*
ONT	Opened edges	7.76	2.2	13.0
	Closed edges	63.0	18.1	28.9
OTB	Opened edges	2.74	0.8	11.60
granular (400g/m)	Closed edges	9.6	2.8	13.6
OTB paste (138 g/m)		1.42	0.41	11.21
OTB powder (400g/m)		1.13	0.33	11.13

: O =overlap, T= Treated, N= No, B=Bentonite, C=Part current.

The flow crossing the current part is calculated for a permeability of 5.0×10^{-11} m/s, it is equal to 10.8 liter/day/2500m^2. This example shows that we have a very small total flow crossing a drained cover of waste landfills of 2500 m^2 whose sealing is ensured by geosynthetic clay liner.

The comparison of the flows crossing the treated overlaps shows that the best performances for a normal stress ranging between 5 and 10 kPa are for the overlap treated with bentonitic powder or paste. The comparison of the flows crossing the overlaps with opened or closed edges shows a 8 time decrease of the the flow crossing the untreated overlap and a 4 time decrease of the flow crossing the treated overlap with granular bentonite.

5.3 *Gas flow phase*

For the untreated overlaps and treated ones with granular bentonite, we varied the pressure P1 and measured the gas flow crossing the studied overlap. For a normal stress of 10 kPa, Fig 6 presents the evolutions of gas flows crossing the overlaps according to the gas pressure.

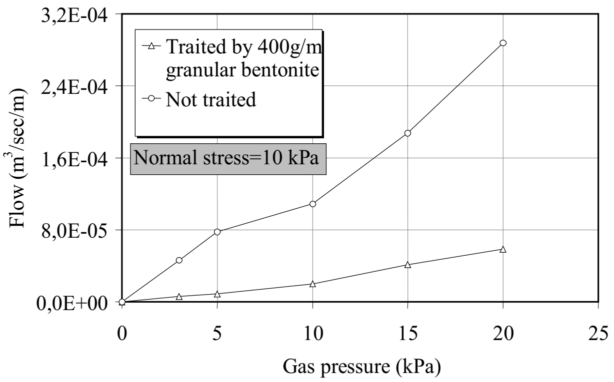


Figure 6 : Evolution of gas flows crossing overlaps versus to the applied gas pressure.

We note that the flow crossing the untreated overlap is 5 to 8 time bigger than the flow crossing the overlap treated with bentonite. Moreover, the difference between the two cases increases when the gas pressure increases. For the overlaps treated with bentonitic powder or paste, the gas flows are measured with variable pressure, they are calculated from the first slopes of the curves of the cumulated volumes in the down-stream room. Figure 7 presents the evolution of gas flows crossing the overlaps according to the gas pressure.

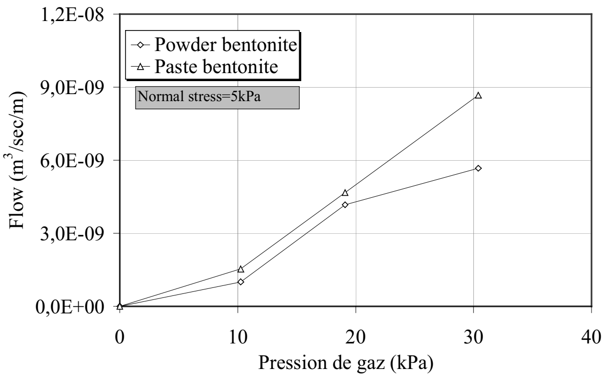


Figure 7: Evolution of gas flows crossing the overlaps versus to applied gas pressure.

As an application of these results, we will study the case of a waste landfill cap where a GCL is used like a sealing barrier. We consider a rack containing a current part having a surface of 2500 m^2 and an overlap of 500 m long et 15 cm wide. For normal stress between 5 and 10 kPa and biogas pressure of 10 kPa, we will calculate the gas flows crossing the saturated GCL in this rack and for several types of overlaps (table 3).

Table 3: Gas flow crossing a rack in a waste landfill cap.

Overlap type	Outflow (m^3/day/2500m^2)
Current part	0.0004
ONT	4700
OTB granular (400g/m)	862
OTB paste (138g/m)	0.08
OTB powder (400g/m)	0.05

O =Overlap, C= Current part.

This application shows that the gas flow crossing the saturated current part is completely negligible compared to that crossing the overlaps. Thus, we can consider that the flow crossing the rack passes completely through the overlap.

By comparing these overlaps, we find that the best performances are obtained for the overlaps treated with bentonitic powder or paste. For these two overlap types of 500 m length, the gas outflow is lower than 0.1 m^3/day/2500m^2 which is very low. If only one meter of overlap is not treated this outflow will be 100 to 200 times higher. That focuses the need of a serious and total control of the overlap treatment.

6 CONCLUSION AND PROSPECTS

The tests require a saturation phase of the GCL followed by a phase of water flow then a gas flow. For the saturation phase these tests showed that after a few days, the kinetics of absorption and of swelling of all the samples tests obey to a hyperbolic law that allows to calculate the swelling and absorption for a infinite time and to check that we reached the hydrous balance of the GCL.

These tests showed in the phase of water flow, the increase of the hydraulic head lead generally to a quasi linear increase of flow crossing the overlap and the current part. The comparison of the water outflows crossing the treated overlaps show that the best performances for normal stress ranging between 5 and 10 kPa are for the overlap treated with bentonitic powder or paste. If the sealing to gas is required, it is preferable to treat it with bentonitic powder instead of granular bentonite (for a same mass of 400 g bentonite placed on 1 m of overlap).

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