Evaluation of GCLs overlaps hydraulic performances

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ABSTRACT: In order to qualify the overlap zone of geosynthetic clay liners (GCL), we have developed a large flow box allowing the study of the main parameters influencing the outflow of this overlap zone. The confining stress, Hydraulic head, Confining material, Liquid used for saturation and testing and Overlap width are the parameters which can be studied by the box.

1 INTRODUCTION

Installation of Geosynthetic Clay Liners (GCLs) needs making overlaps between panels whatever its application. Overlapping zone are potentially leaking points, so a particular attention must be taken on it. Final hydraulic performances of the sealing system depend on the quality of interface between two consecutive panels and on the additional raw material at the interface. Estornell and Daniel (1992), Cooley and Daniel (1995) have shown that overlapping get a self-sealing potential if installation rules have been meticulously respected. Their researches have been carried out in large tank or flow box. Cooley and Daniel have estimated leakage flow of defected overlapped and proved that they can be of several magnitudes higher than a typical flow through a good overlap. Omission of additional material can be considered as a defect. The results presented in this paper are focused on three different overlap configurations: with our without additional bentonite at the overlap interface and welded overlap. The later is made by heating with a blowlamp the upper and lower geotextiles at the interface. All three configurations have a width of overlap equal to 15 cm.

2 TESTING DEVICE

The large flow box used for this research is a powder coated steel tank of 200 liters capacity allowing testing 1 m² specimen. Cover of the tank consists in a rubber-armed membrane and a steel cap (figure 1). Two lysimeters are positioned on the bottom of the tank and are used to compare flow through a plain section of GCL or through an overlap of 0,8 m length. Both lysimeters are hydraulically independent with a sealant tape (bentonite paste). Each lysimeters are connected to two ports: one for liquid outlet, the other for purge. Normal confining stress is transmitted to the GCL with standard coarse sand (2-5 mm) or a specified soil.

The tank is designed to test a representative sample of GCL with various overlap widths (from 0.15 to 0.30 m). Swelling and absorption kinetics can be followed during saturation stage. Inflow and outflow can be measured through various conditions of hydraulic head and confining stress. Since the scale of the tank is 1 m², this allows studying influence of various confining materials on hydraulic performances of GCL in the plain section or in the overlap zone.

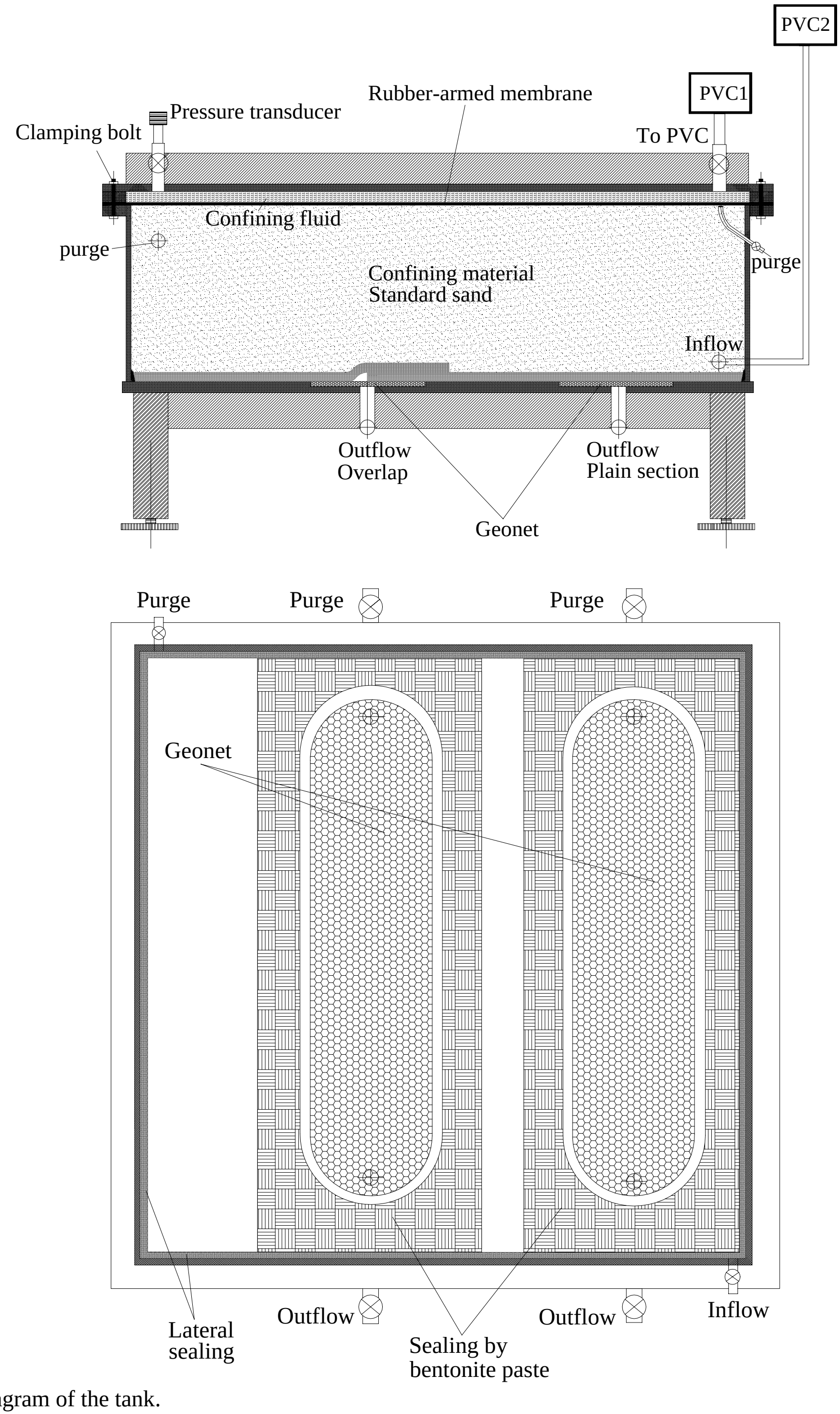


Figure 1. Diagram of the tank.

The thin chamber between rubber membrane and tank cap is filled with water. The chamber is connected to a pressure volume controller. This allows the monitoring of swelling under specific confining stress. Evolution of water volume in the chamber is used for determination of swelling. After saturation stage, the chamber is pressurized to increase confining stress on the GCL. The pressure is controlled with a transducer and monitored via a data acquisition system. The settlement can also be deduced from evolution of pressure evolution.

3 TESTING PROCEDURE

3.1 *Saturation stage*

During saturation stage, the hydraulic head is remained low, about one centimeter. Control of vertical deformation is made with the pressure volume controller connected to the chamber. The amount of inflow or outflow from the chamber gives the vertical deformation by dividing this amount by the surface area of the GCL specimen. The saturation stage may take more than two weeks. The saturation stage is stopped when more than 90% of final swelling for an infinite time is reached.

3.2 *Flux measurement*

When the swelling has reached 90%, the hydraulic head is increased to a given value Hf. The increasing of H must be done carefully to saturate the confining sand layer. The normal stress is increased to keep the same value of effective normal stress. The outflows are recorded for both lysimeters until stabilization is reached.

4 SAMPLE AND TESTING DATA

The GCL tested in this paper is a needle-punched GCL with a granular natural sodium bentonite. Two types of GCL have been tested:

GCL1 has been tested without and with additional bentonite at the overlap (400 g per meter). The woven geotextile is 90 g/m² and non-woven one is 200 g/m².

GCL2 has been tested with a welded overlap of 6 cm width. The upper geotextile is a combination of a woven (90g) and non-woven (270 g/m²); the lower one is a non-woven geotextile of 270 g/m².

Table 1. GCLs main characteristics

GCL	GCL1	GCL2
Total mass per unit area (kg/m²)	5.65	5.36
Mass per unit area of bentonite (kg/m²)	5.25	4.73
Moisture (%)	16.0	12.0
Thickness under 2 kPa (mm)	7.40	10.27
Thickness under 20 kPa (mm)	6.60	9.10
Free swell 2 g (cm^3)	27	27

The confining material used in this study is siliceous sand of 2/5 mm. The tests has been carried out with tap water (pH = 7.6, conductivity 500 µs/cm).

The flow have been measured for various configuration:

- plain section
- overlap without additional bentonite
- overlap with 400 g additional bentonite dispersed on 8 cm width
- welded overlap on 6 cm width

All overlaps have a width of 15 cm.

5 RESULTS

5.1 *Saturation stage*

The example presented below corresponds to the case of a welded overlap hydrated under 1 cm hydraulic head and 10 kPa confining stress. Figure 2 shows evolution of absorbed volume and swelling versus time for this specimen.

After a few days, both absorption and swelling kinetics follow hyperbolic laws. This allows the estimation of absorbed volume and swelling at an infinite saturation time.

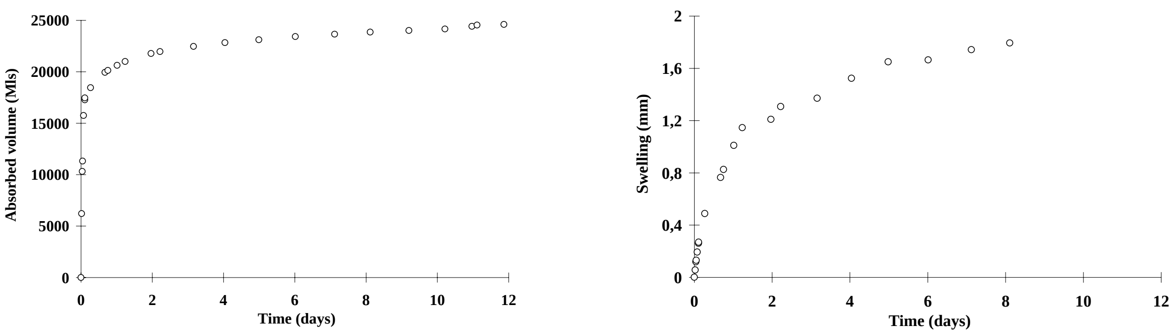


Figure 2. Absorbed volume and swelling against time.

5.2 *Permeability stage*

As soon as the saturation stage is stopped, the hydraulic head is increased step by step for a given confining stress. Comparatively, the confining stress will be increased for a given hydraulic head to study influence parameters.

5.2.1 *Increasing of hydraulic head*

For all tests, the increasing of hydraulic head gives a linear increasing of outflow. Table 2 gives the equations giving the flux (F) as a function of the hydraulic head (H) for a given confining stress of 5 kPa.

Table 2. Equations of straight lines

	Flux q ($m^3/s/m$) function of H (m)
Plain part (q in m/s)	$q = 1.10^{-8} \times H$
With bentonite	$q = 2.10^{-9} \times H$
Without bentonite	$q = 5.10^{-8} \times H$
Welded	$q = 3.10^{-9} \times H$

Figure 3 shows the influence of hydraulic head on transmissivity of overlaps.

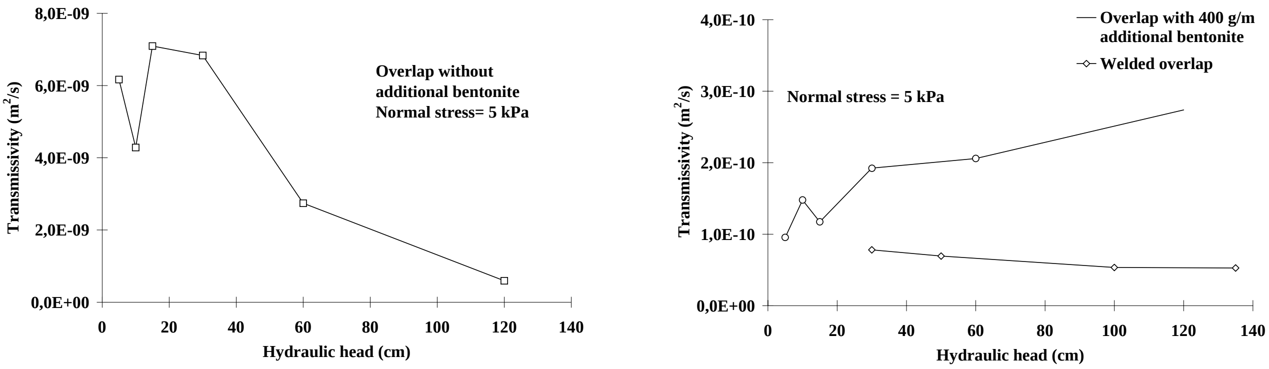


Figure 3. Influence of hydraulic head on the transmissivity.

For the overlap with additional bentonite, we can observe an increasing of transmissivity with increasing of hydraulic head under a low confining stress. The increasing of hydraulic head can lead to migration of bentonite at the interface with the non-woven geotextile.

For the welded overlap, increasing of hydraulic head tends to reduce the transmissivity.

5.2.2 *Increasing of normal stress*

The increasing of normal stress reduce the flow through the overlap except for the welded overlap. This reduction is due to a smaller thickness of flow through the overlap. Increasing of stress tends to make the bentonite extruding from the edge of overlap. This allows a healing of the overlap. For the welded overlap, increasing of confining stress reduces the flow until 20 kPa and then tends to increase the flow. Figure 4 shows the evolution of flux as a function of confining stress for the three test configurations.

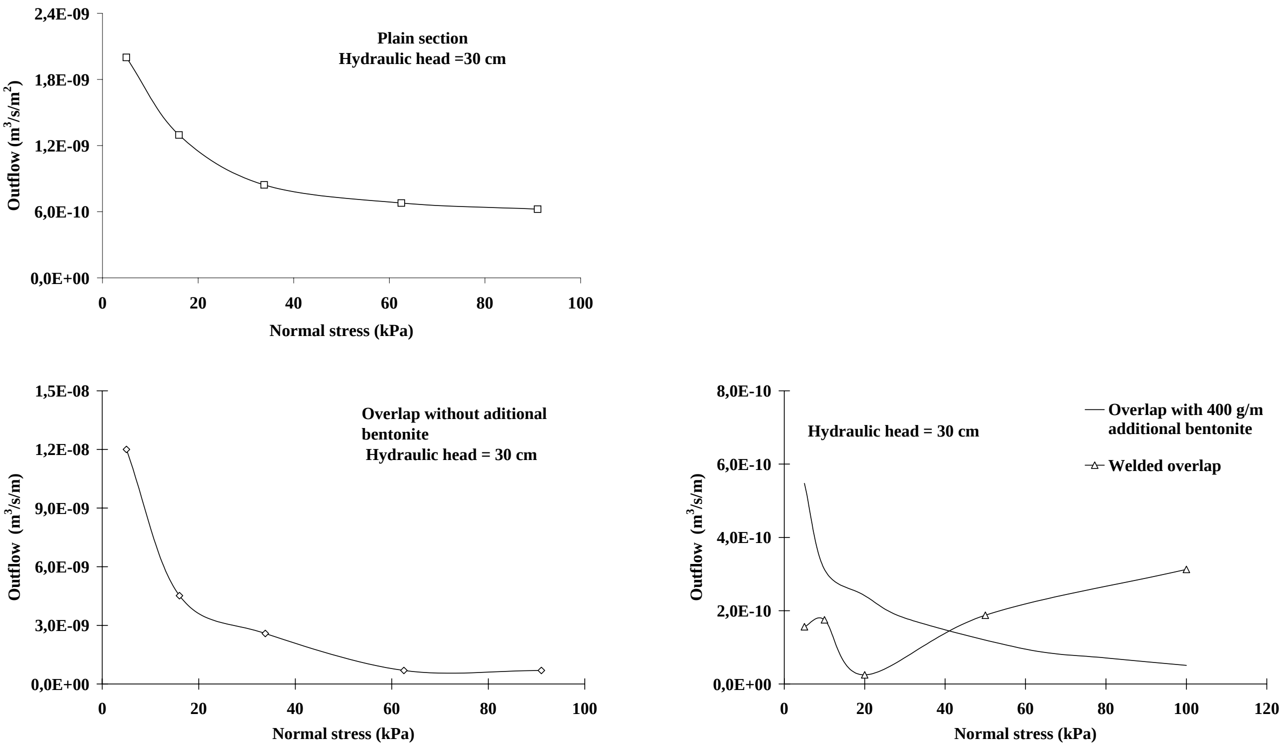
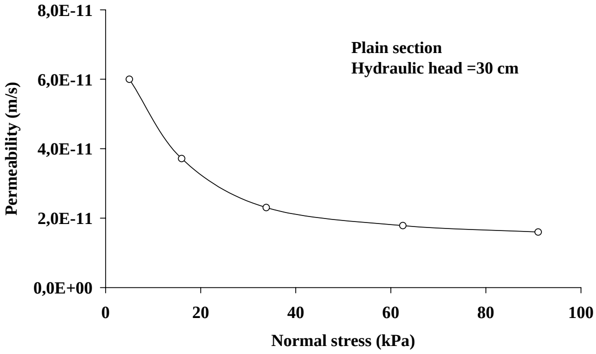


Figure 4. Influence of normal stress on outflow.

The transmissivity decreases with the normal stress with or without additional bentonite in the overlap. For the welded overlap, the transmissivity decreases until a value of confining stress and then increases. For the plain section, the permeability decreases according to confining stress (figure 5).



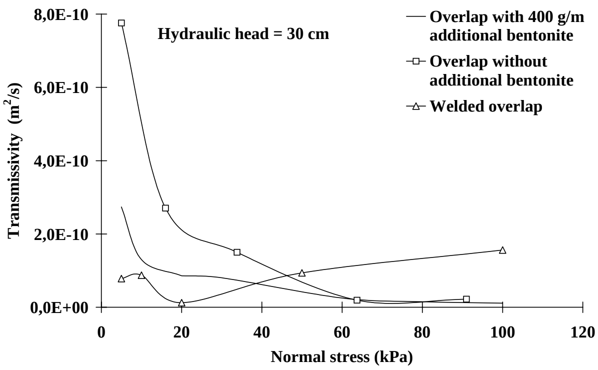


Figure 5. Influence of normal stress on transmissivity and permeability.

6 CONCLUSIONS

Tables 3 and 4 give the values of flux and transmissivity for the three test configurations and for two confining stress (5 to 20 kPa):

Table 3. Values of outflow and transmissivity for 5 kPa normal stress and 30 cm hydraulic head

	Flux ($\times 10^{-10}$ $m^3/s/m$)	Transmissivity ($\times 10^{-10}$ m^2/s)
Without bentonite	136.6	68.3
With bentonite	3.85	1.92
welded	2.89	1.45

Table 4. Values of outflow and transmissivity for 20 kPa normal stress and 30 cm hydraulic head

	Flux ($\times 10^{-10}$ $m^3/s/m$)	Transmissivity ($\times 10^{-10}$ m^2/s)
Without bentonite	42.6	17.2
With bentonite	2.4	1.2
welded	0.25	0.13

The following comments can be made:

For a normal stress of 5 kPa, the welded overlap shows the best hydraulic performance with a flux value of 2,9;10-10 m3/s. The overlap with additional bentonite is 30 % higher and the overlap without additional bentonite 47 times higher than welded one. The same remarks can be made for the transmissivity since the hydraulic head is remained constant.

A normal stress of 20 kPa leads to a decreasing of outflow whatever the type of overlap.

The welded overlap shows the best performance again with a flux of 2.5.10-11 m/s. The bentonite treated overlap is 10 times higher and the simple overlap 170 times higher.

The confining stress of 20 kPa appears to be the critical stress of the welded overlap because the increasing of stress over this value creates fractures within welding. This increases transmissivity and leakage flow.

The welded overlap shows the best performance until 20 kPa of confining stress. The overlap without bentonite shows high leakage flow mainly for low confining stress. These results show that it is necessary to put additional bentonite to get continuity in the sealing of overlaps. A combined welding and additional bentonite should show much better performances.

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