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An examination of the potential for internal erosion of GCLs placed directly over a geonet

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ABSTRACT: A fixed-ring hydraulic conductivity apparatus is used to examine the behaviour of three different GCLs placed directly over a geonet drainage layer. These GCLs incorporate different combinations and types of carrier and cover geotextile. The results demonstrate that for GCL's with a conventional woven or nonwoven carrier geotextile, high hydraulic gradients can cause internal erosion within the GCL that can result in an increase in hydraulic conductivity of at least one order of magnitude. It is shown that the method of GCL construction is important and that GCLs with a scrim-reinforced geotextile carrier layer performed better than those with a single light-weight geotextile carrier. The tests on GCLs with the scrim-reinforced geotextile carrier layer indicated that hydraulic gradients of up to 7000 (equivalent to about 70m of water head) could be sustained without measurable internal erosion for the cases examined.

1 INTRODUCTION

Geosynthetic clay liners (GCLs) are becoming increasingly popular as a replacement for traditional compacted clay liners in landfills with composite liners. In applications involving double composite liners, the primary composite liner may be underlain by a geonet which serves as a leak detection and secondary leachate collection system. In the event of a build up of leachate in the landfill, there is an increased potential for leakage through any holes or defects in the primary geomembrane. The GCL will serve to reduce that leakage, but its effectiveness in this capacity will depend on the hydraulic conductivity of the GCL.

Since GCLs are relatively thin (typically about 0.005-0.01m thick), the build-up of leachate in the primary collection system can result in high gradients. Thus, a 1 m leachate mound would imply a gradient of about 100–200 and a leachate head of 10 m would correspond to a gradient of 1000-2000. The combination of large hydraulic gradients and fine-grained soils that are inadequately filtered can lead to internal erosion and piping failure, a problem that has been primarily studied in dam applications (Meyer et al. 1994, Fenton & Griffiths 1997, Leonard & Deschamps 1998). Internal erosion involves the movement of fine particles into a coarser layer (e.g. an underlying geonet) and this local movement can lead to failure. The loss of bentonite from the GCL may not only affect its performance as a liner, but may also affect the barrier system as a whole. For example, bentonite could migrate from the GCL into the geonet collection system leading to a decrease in the hydraulic transmissivity of the collection layer and possible clogging (Giroud & Soderman 2000). Thus an important design consideration in this application is the potential for the bentonite in the GCL to erode into the geonet. This paper summarises the results from a number of laboratory tests developed to address this question.

2 MATERIALS

Tests on three different GCL types are reported herein. Table 1 lists the important GCL characteristics including the cover geotextile, core bentonite, carrier geotextile, total mass per unit area and bentonite moisture content. The GCLs were placed over a HDPE geonet with an opening size of 0.8 cm with a diagonal span of 1.2 cm. Table 2 lists the relevant properties of the geonet.

3 APPARATUS

Initial internal erosion tests were conducted using a computer controlled, constant flow rate, fixed ring hydraulic conductivity apparatus (Fernandez 1989) that has previously been used extensively for assessing clay-leachate compatibility of both compacted clays (Fernandez 1989) and GCLs (Petrov 1995). However, problems were encountered using the traditional fixed ring cells for the internal erosion testing of GCLs using a geonet subgrade and so a modified test cell was developed as described by Orsini & Rowe (2001). This modified cell was used to perform the tests reported herein.

4 TEST METHOD

The specimen preparation and installation procedures followed those described by Petrov et al (1997) who conducted hydraulic conductivity and compatibility tests on a number of GCLs. A 54 mm inner diameter circular steel cutting shoe was used to prepare the specimens for installation into the fixed ring cell. The cut specimen was weighed, the GCL reference mass per unit area calculated, and an initial bentonite moisture content was taken from the scrap material. The procedure adopted resulted in minimal bentonite losses.

Table 1. GCLs used in internal erosion tests

GCL	Core Sodium Bentonite	Polypropylene Carrier Geotextile	Total mass/unit area (g/m^2)
WD[1]	Granular 4340 g/m^2	Slit film woven 105 g/m^2	4645
BSNWD[2]	Powder 4700 g/m^2	Nonwoven (250 g/m^2) Slit film woven (100 g/m^2) composite	5350
NWD[3]	Granular 4800 g/m^2	Nonwoven 220 g/m^2	5100

[1] Bentofix NS, thermally locked and needle-punched
[2] Bentofix B4000, thermally locked and needle-punched
[3] Bentomat, needle-punched

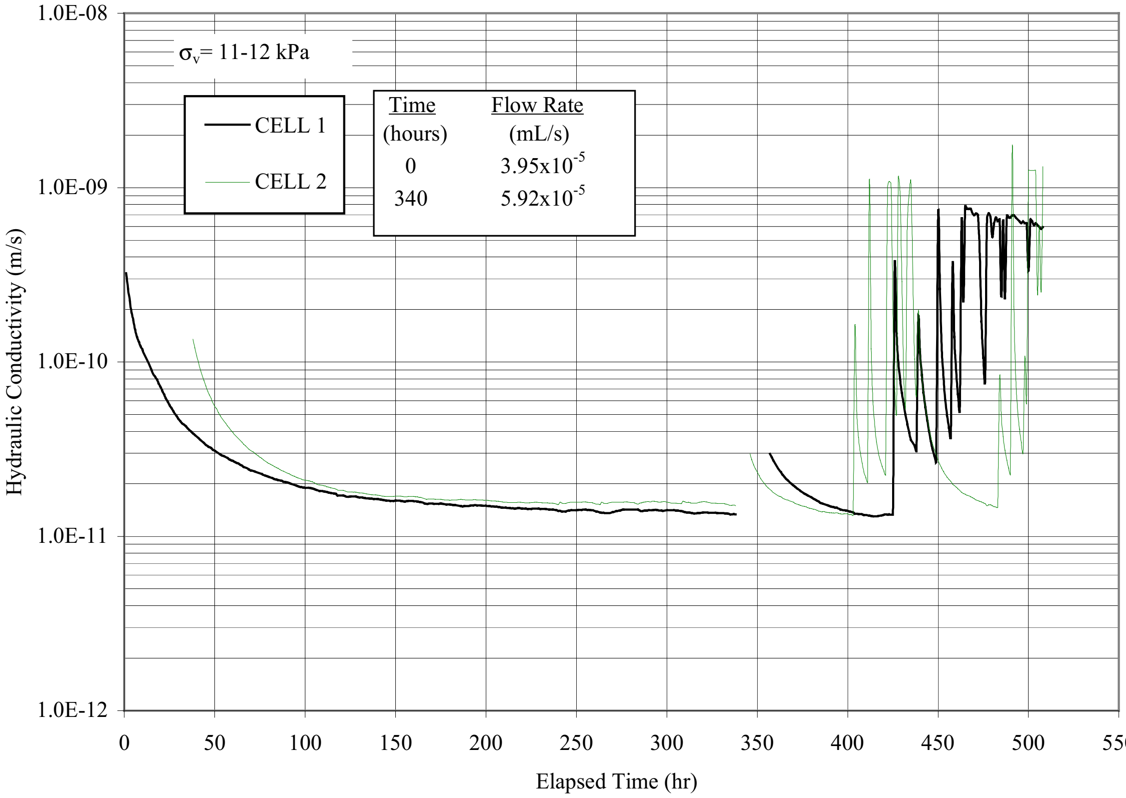

Figure 1 Hydraulic Conductivity with Time for WD GCL

Prior to cutting the GCL sample, the fixed ring cell was prepared by placing the geonet in the bottom of the cell and also putting a layer of silicon grease around the inner circumference of the cell wall to be in contact with the GCL. The GCL was then cut, weighed (as described above) and manually installed in the cell.

The initial height of the GCL was recorded prior to the addition of the confining stress and hydration. The GCL was hydrated with distilled, de-aired water under reservoir pressure heads of approximately 4-5 cm until further swelling with time was minimal. This typically took about 2 weeks. After the hydration was complete, the syringes used to force the constant flow through the samples were filled with distilled, de-aired water and permeation began. The GCL height was monitored throughout both hydration and permeation. The tests began at a flow rate of 3.95×10^{-5} *ml*/s and this flow rate was increased periodically if the hydraulic conductivity remained stable at a given flow rate. Tests were terminated if a failure was detected.

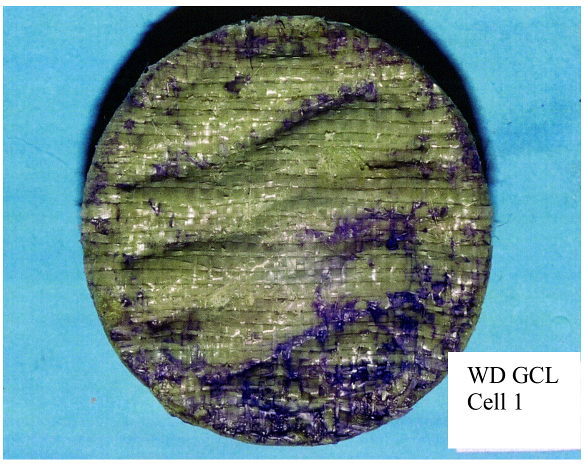

Figure 2. WD GCL after termination of test

Because of the constant flow rate, failure was characterised by a significant drop in pressure due to an increase in hydraulic conductivity. Prior to disassembly, permeation at the failure flow rate was conducted using a dye (Comassie Blue) to aid in specimen dissection and identification of the location where the failure occurred.

It should be noted that a significant difference between the tests in this study and those performed by others (e.g. Petrov et al. 1997a,b, Petrov & Rowe 1997) was the fact that rather than being placed on a porous plate as in the previous studies, here the samples were placed on a geonet.

5 RESULTS AND DISCUSSION

5.1 *WD GCL*

Two identical tests were performed for the WD GCL with a geonet subgrade. Flow began at a rate of 3.95×10^{-5} *ml*/s. The two test cells behaved very similarly throughout the duration of the tests. The hydraulic conductivity, k, (Figure 1) was relatively constant ranging between 1.3×10^{-11} m/s and 1.6×10^{-11} m/s for both test cells for the first two hundred hours. For this same time period, the hydraulic gradient, i, increased to 1950 (~12.5 m water) in Cell 1 and to 1750 (~11 m water) in Cell 2. At 340 hours the syringes were recharged and the flow rate was increased to 5.92×10^{-5} *ml*/s after which the hydraulic conductivity of Cell 2 decreased to 1.3×10^{-11} m/s and the hydraulic gradient reached a maximum of approximately 2950 (~19 m water). At this point the gradient experienced a large drop to near zero and the hydraulic conductivity increased to 1.1×10^{-9} m/s indicating a failure had occurred. Cell 1 followed a similar pattern (k = 1.3×10^{-11} m/s at a hydraulic gradient of 3000 or ~19.5 m water) with the failure occurring about 25 hours later. Once both tests had failed, dye was introduced and allowed to flow through until it was visible in the effluent. It should be noted that Cell 2

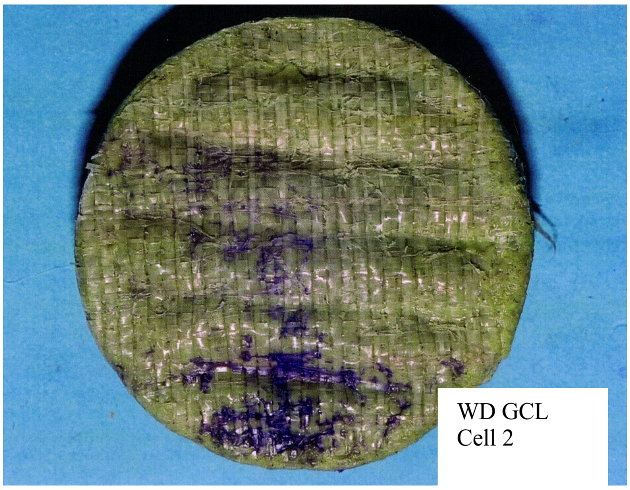

Figure 3. WD GCL after termination of test

showed signs of self healing as evidenced by the decrease in hydraulic conductivity to 1.5×10^{-11} m/s and increase in hydraulic gradient to approximately 2650 (~17 m water). These changes occurred after test failure and during dye permeation. However, the repair was short-lived since the GCL failed again at 480 hours. The test was terminated at 500 hours.

GCL WD had a woven carrier geotextile. Upon disassembly it was noted that the failures occurred in the area between geonet strands where the woven fibres of the carrier geotextile appeared to have moved slightly apart and allowed bentonite to escape, compromising the GCL's performance (Figures 2 & 3).

5.2 *BSNWD GCL*

Cells 3 & 4 contained identical samples of the BSNWD GCL over the geonet. Cell 3 showed some fluctuation in hydraulic conductivity at a flow rate of 3.95×10^{-5} *ml*/s between 100 hours and 200 hours, which stabilized at a steady value of 2×10^{-11} m/s. The hydraulic gradient showed similar fluctuations for the same time period, but eventually reached a high of 1400 (~11.5 m water) at 340 hours. The sample in Cell 4 exhibited a hydraulic conductivity of 2.1×10^{-11} m/s at a hydraulic gradient of about 1270 (~10 m water) at 340 hours. At this time the syringes were recharged and the flow rate was increased to 5.9×10^{-5} *ml*/s. Between 340 hours and 640 hours, Cell 3 maintained a steady hydraulic conductivity of 1.7×10^{-11} m/s at a hydraulic gradient of approximately 2400 (~20.5 m water), while Cell 4 had a hydraulic conductivity of 2×10^{-11} m/s at a hydraulic gradient of 1900 (~15 m water). At 670 hours, the flow rate was increased to 8.9×10^{-5} *ml*/s. The flow was stopped for syringe recharge at 800 hours and dye permeation began at 960 hours. The test was terminated at 1050 hours, even though neither test cell had failed at maximum hydraulic gradients of 6300 (~53.5 m water) and 4400 (~35 m water) for Cell 3 and 4 respectively.

Upon disassembly it was noted that there was no loose bentonite in the geonet or bottom cylinder, the bottom geotextile on the GCLs was completely intact and there was no sign of failure.

The BSNWD GCL has a composite scrim-reinforced, nonwoven carrier geotextile. The extra reinforcement in this bottom geotextile gave the GCL greater strength and ability to arch across the geonet openings without opening up the carrier geotextile compared to the other GCLs tested. This GCL performed very well with the geonet subgrade having survived hydraulic gradients of up to 6300 (~53.5 m of water).

5.3 *NWD GCL*

Cells 5 & 6 contained the NWD GCL over the geonet. At a flow rate of 3.95×10^{-5} *ml*/s, Cell 5 gave a minimum hydraulic conductivity of 9.4×10^{-12} m/s (Figure 4) at a gradient of 2750 (~20.5 m water) at 230 hours. The hydraulic conductivity then jumped to a value of 8.9×10^{-11} and the hydraulic gradient dropped to a value of about 290 (~2.2 m water). The results showed a continuing pattern of significant peaks and drops in both the hydraulic conductivity and hydraulic gradient after 230 hours.

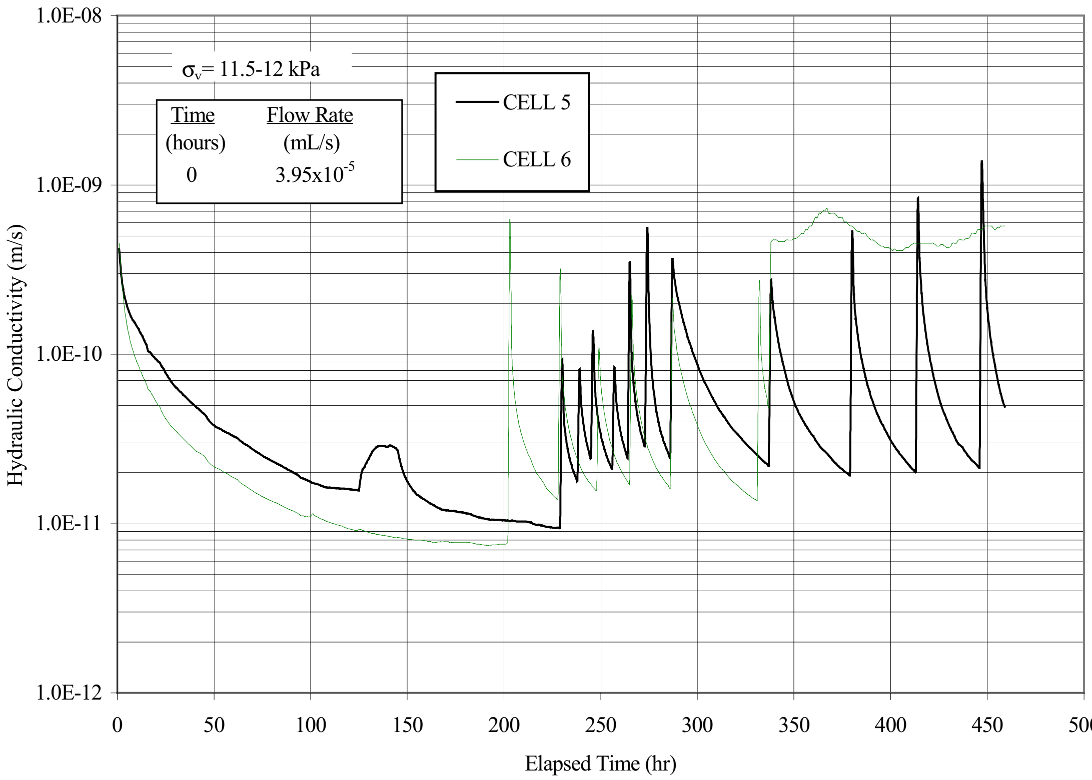

Figure 4. Hydraulic Conductivity with Time for NWD GCL

Cell 6 showed similar results with a minimum hydraulic conductivity of 7.5×10^{-12} m/s at a hydraulic gradient of 3500 (~30 m water). At 202 hours, the hydraulic conductivity jumped to 6×10^{-10} m/s and the hydraulic gradient dropped to almost zero. Like Cell 5, Cell 6 showed a continuing pattern of significant peaks and drops in both the hydraulic conductivity and hydraulic gradient after 202 hours.

The peak and drop pattern suggests a failure has occurred, but the GCL was attempting to heal itself at the times when the gradient was low. While the healing worked for a short time, the GCL could not sustain the gradient that began to develop after a short period of healing.

Table 2. Geonet Properties (from Serrot International, 2000)

Property	Test Method	Value[1]
Density (g/cm^3)	D1505	0.94
Carbon Black Content (%)	D4218	2.0
Thickness (mm)	D5199	5.1
Mass per Unit Area (kg/m^2)	D5261	0.79
Tensile Strength (kN/m) (Machine Direction)	D5035 Modified	7.9
Transmissivity[2] (m^2/s) @ Hydraulic Gradient & Confining Stress (kPa)	D4716	1×10^{-3} 1.0 718

[1] Minimum average test values for a typical roll.
[2] Measured in the machine direction between two steel plates one hour after application of the confining pressure

6 CONCLUSIONS

Two of the three GCLs tested (WD, NWD) on top of a geonet experienced an increase in hydraulic conductivity by at least one order of magnitude after being permeated with water at a head of about 19 to 20 m of water. However the BSNWD scrim-reinforced GCL with a total carrier geotextile mass per unit area of 350 g/m^2 performed very well on top of the geonet and no failure was observed at heads of 35-53 m of water. Thus, it would appear that careful consideration should be given to the potential for internal erosion of GCLs located directly above a geonet, although for the particular combination of GCLs and geonets examined here the problem was not manifest until a head of about 19m in the most critical case. It also appears that the problem can be mitigated by the use of an appropriate carrier geotextile as in the case of GCL BSNWD. Since the performance of these GCLs may be partly dependent on the geonet used, the conclusions should not be generalized, but rather used as a guide to the benefits arising from the choice of carrier geotextile and the need to perform tests similar to those reported herein when contemplating the use of a particular GCL over a particular geonet in a given landfill design.

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