Closed-system investigation of GCL hydration from subsoil

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ABSTRACT
Hydration of various geosynthetic clay liners (GCL) from subsoil pore water in a closed-system (i.e. constant mass of moisture) is described. Several different GCLs were selected for hydration testing. Periodic sampling tests were conducted to investigate a spectrum of experimental variables and hydration behaviour. In these tests, the GCL was periodically removed, measured, weighed, and returned to the column to track the evolution of hydration with time (several months). A laser measurement technique was also employed to track the change in GCL thickness during hydration. Results indicated that the type of GCL and the interaction between the GCL and foundation soil plays an important role in hydration behaviour.

RÉSUMÉ
Hydratation de divers revêtements d'argile géosynthétique (GCL) de l'eau sous-sol dans un système fermé (c'est-à-dire d'une masse constante de la teneur en eau) est décrite. Plusieurs GCLs ont été sélectionnés pour les tests d'hydratation. Échantillonnage périodique essais ont été effectués pour enquêter sur un spectre expérimental de variables et d'hydratation comportement. Dans ces essais, le GCL est périodiquement enlevés, mesurés, pesés, puis a regagné la colonne de suivre l'évolution de l'hydratation avec le temps (plusieurs mois). Une technique de mesure laser a également été employées pour suivre l'évolution de GCL épaisseur au cours de l'hydratation. Les résultats indiquent que le type de GCL et l'interaction entre la GCL et le fondement du sol joue un rôle important dans l'hydratation comportement.

1 INTRODUCTION

Geosynthetic clay liners (GCLs) are most typically comprised of a layer of low permeability clay (bentonite) sandwiched between two layers of geotextile (a nonwoven cover geotextile and either a woven or nonwoven carrier geotextile) with the components being held together by needle-punching. GCLs are often used as part of composite liners with a geomembrane liner placed over the GCL. These composite liners have gained widespread acceptance for use in landfills and other liner applications.

GCLs have been shown to be highly effective in preventing groundwater contamination provided that they: (a) are adequately hydrated and (b) the overlap between the panels is maintained (Rowe, 2005). After placement, the GCL takes up water from the underlying soil and once it hydrates it becomes a very good barrier to contaminant transport (Rowe 2007). The performance of these GCLs as liners will depend in part on the hydration of the GCL and in order that engineering decisions can be made regarding likely GCL performance, data is required that will provided insight regarding the likely hydration behaviour of the GCL. However the rate of hydration when a dry GCL is placed on underlying subsoil has received very little examination. Daniel et al (1993) and Eberle and von Maubeuge (1997) have reported a limited amount of data for GCLs on sand. The former paper showed that, when placed on sand at 3% moisture content, an initially air dry GCL reached 88% moisture content after 40-45 days. The latter paper showed that when placed over sand with a moisture content of 8-10%, an initially air dry GCL reached a moisture content of 100% in less than 24 hours and 140% after 60 days. However it is not clear whether all GCLs exhibit the same hydration characterists for ths same subsoil and the rate of hydration for others soils (e.g. silty soils and claying soils) is presently unknown.

The speed of hydration is important in terms of assessing how fast the composite liner system must be covered with soil/waste if one aims to minimize damage due to wetting and drying cycles or to minimize the potential for desiccation cracking due to heat generated by the waste (Rowe, 2005). Thus, this paper seeks to investigate the rate of moisture uptake of GCLs from a silty-sand subgrade. The effect of GCL type and potential interaction between the GCL and the subsoil are examined.

2 MATERIAL PROPERTIES

2.1 Geosynthetic Clay Liners

Three different types of GCLs from two different manufacturers were examined. A summary of the GCL properties is given in Table 1. The selected GCLs had a mass per unit area of 4540-5460 g/m^2. All GCLs contained granular sodium bentonite.

Table 1: Description of selected GCLs

GCL	Mass/area (g/m^2)	Initial W/C (%)	Lower GT	Upper GT	Layer Connection	Symbol in paper
NSL	5460	7	W	NW	NPTT	GCL1
NWL	4540	7	SRNW	NW	NPTT	GCL2
DN	5360	8-10	NW	NW	NP	GCL3

W = Woven, NW = Nonwoven, SR = Scrim reinforced, NP = Needle punched, TT = thermally treated

2.2 Soil Characteristics

Soil from the Queen's composite geosynthetic liner experimental field site in Godfrey Ontario (Brachman et al, 2007) was used as foundation soil to compare the experimental results with the field data. The particle size distribution of the soil obtained using ASTM D 422 is given in Figure 1. This data indicates that the soil is a silty-sand with 35% passing the 0.075 mm sieve. These fines were found to be non-plastic. Standard Proctor compaction tests performed to characterize the soil properties (ASTM D 698) gave a maximum dry density of about 1.83 g/cm^3 and an optimum water content of 11.4% (Figure 2).

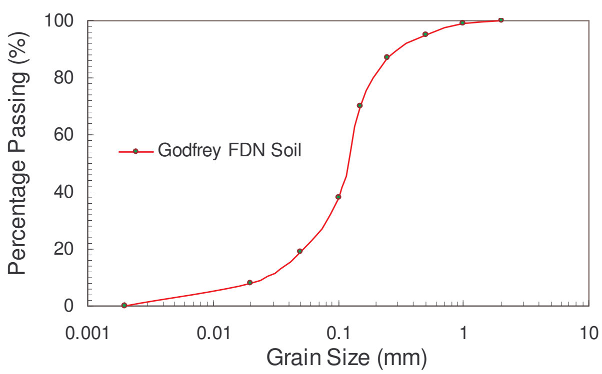

Figure 1. Grain size distribution of DN GCL and foundation soils

3 EXPERIMENTAL TESTING

Poly Vinyl Chloride (PVC) cells with a 150mm diameter and 500 mm high were constructed to investigate the closed-system (i.e. constant mass of moisture) hydration of various GCLs from subgrade pore water. Each cell was filled with a subgrade material at a known void ratio and moisture content, sealed, and allowed to come to moisture equilibrium. Immediately thereafter, a GCL sample was placed on top of the soil, and the system was sealed once again (with just enough headspace to allow for swelling).

The test cells were opened weekly and the GCL was periodically removed, measured, weighed, and returned to the column to track the evolution of hydration with time (several months). A laser measurement technique was also used to track the change in GCL thickness during hydration.

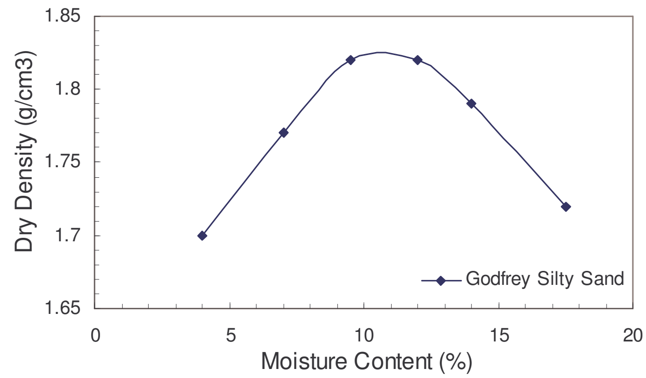

Figure 2. Compaction curve for Godfrey foundation soil

3.1 Sample Preparation

Bulk samples of Godfrey site soil were mixed with water to bring its water content to 16%, which corresponds to the average moisture content at the field site in Godfry when the GCL was placed there. After mixing was completed, the mixture was stored in air tight plastic bags and allowed to cure for 24 hours. This curing process produced a more even distribution of moisture throughout the soil. Specimens were prepared by tamping of the soil inside the cylindrical test cell to obtain the desired density (1.65 g/cm^3). The sub-soil was compacted in three layers. The uniformity of moisture content distribution along the height of the cells was controlled by tracking the soil water content through the sample. Figure 3 shows the moisture content profile of the soil after one day equilibration in three different cells. As it can be seen the soil is reasonably uniform prior to GCL installation.

The GCL samples were cut to a diameter of 150 mm and placed over the foundation soil in the cell. A thin layer of geomembrane was also placed on top of the GCL to simulate the field conditions and minimize potential evaporation into the headspace. In order to assure the contact between the GCL and the foundation soil, a seating block of 25 mm thickness was placed over the membrane to produce a stress of 2 kPa on the GCL for most tests. One series of tests was conducted without a surcharge to simulate the situation where there is a the wrinkle/gap between the geomembrane and the GCL so this effect on hydration of the GCL could be examined (Fig.4).

Table 3 shows the details of the GCL and the foundation soil for each test series. In all tests discussed in this paper, the soil density and moisture contents were kept similar, and the GCL types and the interaction between the GCL and sugbrade were studied.

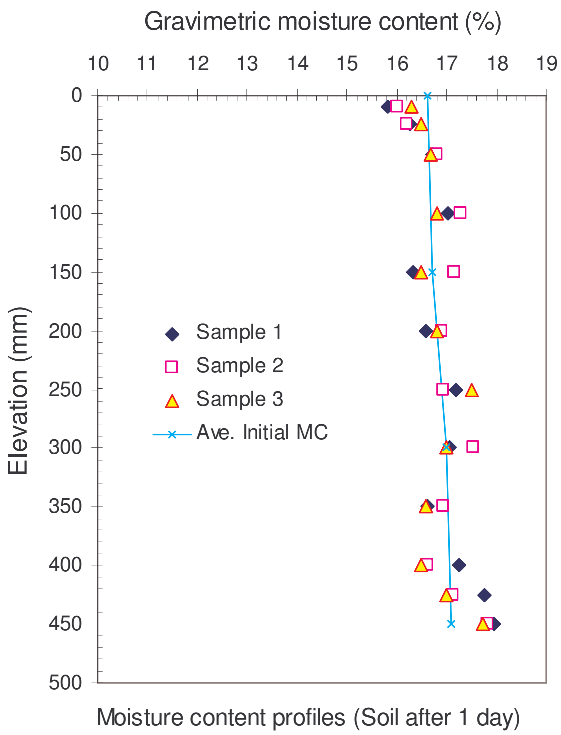

Figure 3. Variation in moisture content for soil samples after 1-day

Table 2: Experimental details of hydration tests

GCL type	GCL Thickness	Soil MC	Dry density (g/cm^3)	Load	Tests
GCL1	6.2 mm	16%	1.65	2 kPa	PM-5
GCL2	7.0 mm	16%	1.65	2 kPa	PM-3
GCL3	7.8 mm	16%	1.65	-	PM-1
GCL3	7.8 mm	16%	1.65	2 kPa	PM-2

3.2 Data Measurements

Two sets of data were collected from these tests. A laser measurement technique was used to measure the thickness variation of the GCL (Fig. 5). First, the GCL thickness was measured periodically by taking laser readings immediately befor and after the GCL was removed for weight measurement every week. Second, the mass of the GCL was measured to evaluate the change in moisture content. Variation of the GCL thickness and moisture content were plotted with time for each test series.

4 RESULTS

4.1 Moisture Uptake

Table 4 shows the initial moisture content and moisture uptake for all samples. GCL1 reached to the gravimetric moisture content of about 88% after 6 weeks on subgrade with water content of 16%. The moisture content of GCL2 increased from initial amount of 4.5 % to about 95% in 12 weeks, which is slightly less than that for GCL3 under the same conditions (PM-2). GCL3 moisture increased to 87% and 104 % in 12 weeks under zero and 2 kPa load, respectively. This increase in moisture content in PM-2 could be due to surcharge effect on hydration.

Figure 4: Test cell and GCL3 on top of subgrade

Figure 5: Laser technique for measuring elevation of soil and GCL in test cell

Free saturation moisture of all GCLs were also measured in water and included in Table 4. The maximum moisture uptake for GCL3 was measured about 170%, while the free saturation moisture for GCL1 and GCL2 were about 120 and 140%, respectively. This variation in free saturation moisture content is likely due to the method of manufacture of the GCL and, in particular, the restraint provided by the needle punching.

Table 4: Moisture uptake for different GCLs

GCL type	Initial MC	Free saturation	Moisture Content* (%)	Approximate Degree of saturation	Test
GCL1	7.0%	140%	88 (6 weeks)	60%	PM-5
GCL2	4.5%	120%	95.0	80%	PM-3
GCL3	8.5%	170%	87.0	50%	PM-1
GCL3	9.0%	170%	104.0	60%	PM-2

* after 12 weeks (84 days) hydration unless otherwise noted

4.2 Change in GCL Thickness

Table 5 presents the increase in GCL thickness after 12 weeks hydration. The initial thickness for the test GCL's varied from 6.2 mm to 7.8 mm. The thickness of GCL3 increased up to 8.6 mm in sample PM-2, while the final thickness for GCL2 was about 7.5 mm showing an increase of 0.5 mm after 12 weeks of hydration.

Table 5: Change in GCL thickness with 12 weeks hydration

GCL type	Initial thickness (g)	Thickness (mm)	Change in thickness (mm)	Tests
GCL2	7.0	7.5	0.5	PM-3
GCL3	7.8	8.3	0.6	PM-1
GCL3	7.8	8.6	0.8	PM-2

4.3 Effect of GCL Type on Hydration

Three samples with different GCLs were tested under similar test conditions to evaluate the effect of GCL manufacturing, bentonite type and geotextile configuration on hydration of the GCL from subsoil. All specimens were placed on top of the same foundation soil and similar loading of 2 kPa was placed on top of the GCL. Results show that the GCL type plays an important role in hydration of the GCL from subsoil (Figure 6). GCL1 showed similar moisture uptake as GCL2, which may be due to the same bentonite and same type thermal locking used for both GCL's. GCL3 demonstrated significantly higher moisture uptake than that for GCL2 under similar testing conditions. The rate of moisture uptake for GCL3, after 12 weeks of hydration, was about 104%, while the moisture uptake for GCL2 was about 95% at the same hydration time. However, it should be noted that higher water content of GCL is not necessarily provide better performance. The GCL needs to be near saturated to show low hydraulic conductivity. As it can be seen from Table 4 or Figure 7, GCL2 shows higher degree of saturation than GCL3.

4.4 Effect of Potential Wrinkle in Geomembrane on Hydration

Two test series with same the GCL (GCL3) but different loading conditions were compared to examine the effect of a potential wrinkle on hydration of GCL. In sample PM-1 the GCL was placed on top of the soil without any overburden pressure, while in PM-2 a seating block of 3.6 kg (stress of 2 kPa) was placed on top of the GCL to improve the interaction of the GCL and foundation soil. The results are depicted in Figure 8.

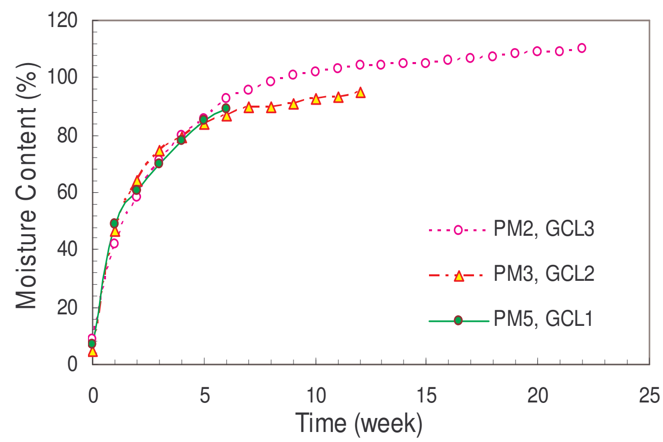

Figure 6: Effect of GCL type on hydration of GCL

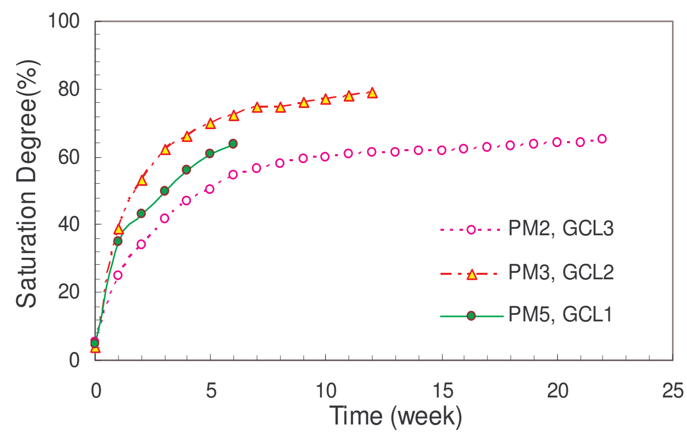

Figure 7: Degree of saturation versus hydration time for all GCLs

Applying a small load on top of the GCL appears to have significant effect on rate of moisture uptake from subgrade. The GCL in sample PM-2 demonstrated higher moisture content than that in sample PM-1. The difference in moisture uptake between two samples was about 10-20%.

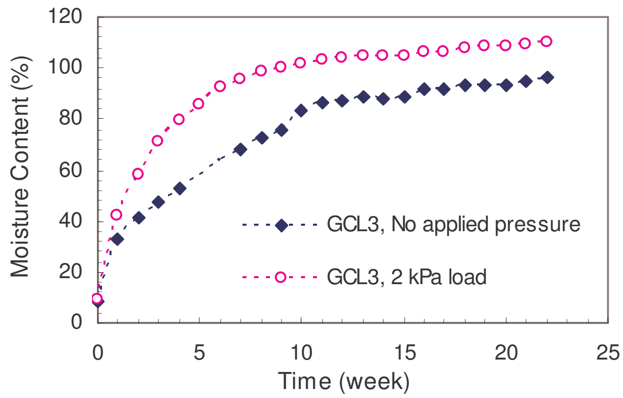

Figure 8: Effect of interaction of GCL and subsoil on hydration of GCL

5 SUMMARY

Hydration of different GCLs from subsoil pore water in a closed-system was investigated. Two different types of GCL with variations in initial water content, bentonite source, and needle-punch reinforcement were tested for hydration from a silty-sand subsoil. Two test series were also conducted to evaluate the effect of potential wrinkle in geomembrane on GCL hydration.

Results indicated that the GCL in all test series were hydrated from subsoil pore water. The GCL moisture content and consequently their thickness increased with hydration time due to moisture uptake from subsoil. Results also showed that the GCL manufacturing and the interaction between the GCL and foundation soil both affect the hydration behaviour.

Although the rate of hydration for GCL3 is higher than that for GCL1 and GCL2. However, this does not necessarily correspond to better performance of this GCL as a barrier system since the degree of saturation for GCL1 and GCL2 is higher than that for GCL3 and this could lead to lower permeability. Hydraulic conductivity tests are currently being performed on these GCLs after at different periods of moisture uptake to evaluate performance of GCLs at different stages of hydration.

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