Assessment of different geosynthetic clay liners in lysimeters

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ABSTRACT: Geosynthetic Clay Liners (GCL) are an established sealing product in the geoenvironmental industry. They are used in landfill caps and base liner applications under roads and railways as well as within various other containment structures such as dams, canals, ponds, rivers and lakes, even for waterproofing of buildings and other similar structures. Most published tests on the hydraulic conductivity of GCLs were carried out under laboratory conditions and do not cover complex effects as they occur under field conditions. For this reason several lysimeters with a diameter of two meters were built in Lemförde, Germany. One aim of this study is to document the performance of various systems with a GCL as single sealing element under changing climate conditions. Effects of changing water content of the bentonite on the GCL water permeability will be specially regarded. Furthermore it is intended to use the data for improving permeation modelling based on a modified HELP (Hydrologic Evaluation of Landfill Performance) programme. In this paper the test set-up, some data of the first year of investigation and some preliminary conclusions are presented.

1 INTRODUCTION

For geosynthetic clay liner applications tests are mainly concentrated on the performance of hydraulic conductivity. It is well known that bentonite can form an excellent hydraulic barrier. Daniel (1996) and Floss (1991, 1993) have tested the hydraulic properties related to varying confining stresses and hydraulic gradients.

In the late 80s and early 90s results of laboratory investigations were also published on the permeability behaviour under changing environmental conditions, such as wet-dry or freeze-thaw cycles, as well as strain and installation stresses. The water permeability of natural sodium bentonite remained unaffected by repeated wet-dry and freeze-thaw cycles. Permeability behaviour of strained material was mainly influenced by the geotextile components of the GCL. Furthermore such tests indicated that needlepunched GCL were by far superior to compacted clay liners in their ability to seal if the system is strained about 15%.

Until the mid-90s the authors are not aware of any results on field trials to determine the field behaviour of the GCL hydraulic conductivity. In general, it should be recognised that all GCL are based on a mineral layer of bentonite which show some permeation for water. This behaviour appears also for any compacted clay liner (CCL). According to Berger (2000) for a 0.5 m thick CCL covered by 1 m of silty and sandy soil a permeation rate between 150 to 15 mm/year can be expected.

Tests in Germany to measure the permeation rates through GCL under boundary conditions comparable to landfill covers in-situ are described by Maile (1997) and Schnatmayer (1998). In both cases permeation rates have been far lower than 150 mm/year as expected for CCLs. Some data of these tests are given in Table 1.

Summarising the data in Table 1, it is obvious that GCLs show a good performance (sealing efficiency of > 90 %) (Heerten et al. 1997). In order to obtain further knowledge and safety concerning predictions of the long term permeation behaviour of GCLs for low confining stress applications six lysimeters were built to perform a long-term experimental research programme.

Table 1. Summarised data from permeation testing of GCLs in two field trials

Sealing System	Drainage Layer	Thickness of Cover Soil [m]	Year of Installation	Year	Rainfall [mm]	Permeation [mm]	% of Rain
GCL 1	0.3 m gravel	1.0	1995	1996	700	1.5	0.2
				1997	1037	6.4	0.6
				1998 (until Sept.)	430	3.8	0.8
GCL 2	GDS	1.0 m	1994	94 -97*	2402	43.1	1.8

* incomplete monitoring

As the coefficient of water permeability, which is commonly used to indicate the permeability behaviour of clay is less useful for GCL this paper will only report values of the permeation rate, which means the volume of water permeating through a GCL related to the area and related to time.

Figure 1. View of soil protected lysimeters.

2 LYSIMETER SET-UP

The lysimeters were constructed in a similar way as described by Maile (1997) due to the fact that this design has shown its general ability within a longer testing programme and now seems to be an accepted system. The lysimeters were surrounded with soil to meet in-situ conditions better than with the free standing lysimeter type of Maile. This allowed a protection of the interior of the lysimeter against weather effects such as frost or temperature.

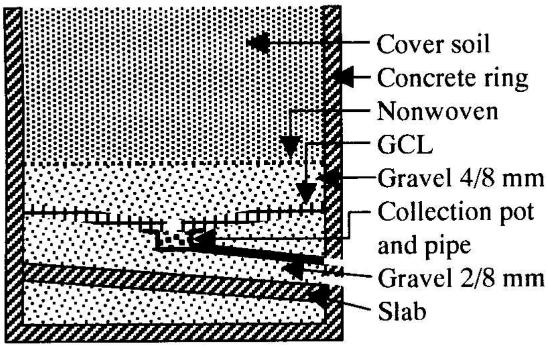

Figure 2. Lysimeter test set-up.

The lysimeters were built in a hill shaped soil body with a height of about three meters containing also equipment for measuring the different water discharge above and below the GCL (Figure 1). The concrete rings have a diameter of 2 m. The entire area of the lysimeter as well as the bottom slab was seal-coated in two layers. The connection between the slab and the ring wall was additionally reinforced with a woven to prevent a tearing of the coating. The bottom slab was constructed with an inclination of 20 (H) : 1 (V) towards the edge to allow the permeating water to run off. Prior to the filling of 30 cm of clean gravel 2/8 mm on top of the concrete slab a 5 cm diameter PVC pipe and the stainless steel collection pot was installed. To avoid movements during the filling process the pipe system was fixed. The stainless steel pot was additionally coated in the inside.

To prevent a clogging of the collection systems geosynthetic a drainage system (GDS) with needlepunched nonwovens was placed in the bottom of the collection pot (filled with 16/32 mm gravel).

The installed needlepunched GCLs were pre-cut with a diameter of 2 m and a 5 cm diameter hole in the middle so that water from above the GCL can flow into the collection pot. To allow a water flow towards the middle, where the drainage collection pot is located the GCL was installed with an 10 (H) : 1 (V) inclination. To avoid side wall leakage a 1.5 mm thick PVC strip (10 cm) overlapped the GCL and was fixed 20 cm above the GCL on to the concrete ring. An overlapping stainless steel bar was fixed on the PVC strip and additionally sealed on the top.

For the lysimeters nos. 1 to 3 a set-up was selected which simulates a landfill capping. The GCLs (see Table 2) were covered with 20 cm 4/8 mm gravel on which 1 m cover soil was placed and separated by a needle-punched PP nonwoven with a mass per unit area of 300 g/m². The lysimeters nos. 4 to 6 are not further investigated in this paper and therefore not described.

Table 2. Selected GCLs for lysimeter nos. 1 to 3.

	GCL 1	GCL 2	GCL 3
Lysimeter	1	2	3
Cover geotextile	Nonwoven 220 g/m²	Nonwoven 300 g/m², bentonite impregnated	Nonwoven 220 g/m²
Wyoming bentonite	4500 g/m²	5000 g/m²	4500 g/m²
Bottom geotextile	Woven, 110 g/m²	Woven, 200 g/m²	Woven, 110 g/m²
Bonding	Needle-punched	Needle-punched	Needle-punched

For monitoring temperature and water content of the cover soil and of the bentonite in the GCL several sensor systems have been installed. Some of these sensor systems are of a new type and shall be tested and calibrated within the frame of the programme. Furthermore it is planned later to perform some controlled drying tests with the liner system. Therefore some additional pipes were installed to allow the venting of air into the overlaying drainage layer.

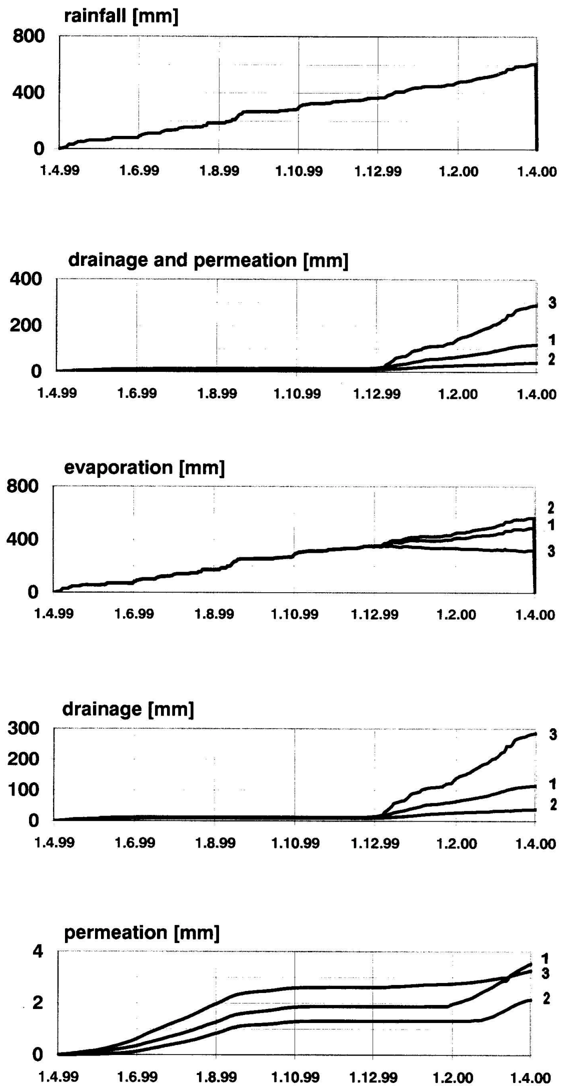

Figure 3. Cumulated data of rainfall, evaporation, drainage and permeation water for a period of one year of lysimeters nos. 1 to 3.

3 FIRST TEST RESULTS

The lysimeters have been installed at the site in Lemförde, Germany, in autumn 1998 without additional water saturation. Soil mechanical classification parameters of the cover soil have been determined. According to grain size distributions it contains mainly fine to medium sand, 15 to 20 % of silt and 3 to 10 % of gravel. The ignition loss is below 3 % and the content of carbonates below

1 %. The unit weight of grains is about 2.60 g/cm³ and the Proctor density was found to be in the range of 1.85 g/cm³ at a water content of about 12 %. The soil was placed into the lysimeters with a water content between 15 and 16 % and a density between 1.94 to 1.98 g/cm³. The field capacity of the soil was determined to 20.5 % and the wilting point is about 7%.

Collected data of the lysimeter test trials include temperature (average every 10 minutes), humidity (average every 10 minutes), wind velocity (average every 10 minutes), precipitation (average every 10 minutes), drainage water over the GCL (once daily on working days) and permeation water through the GCL (once daily on working days). Additionally two new measurement systems are included which may allow a measurement of the bentonite water content (every 4 hours) and the soil moisture (every 4 hours).

Since January 2000 the drainage water over the GCL and the permeation water through the GCL of lysimeter nos. 3 have been measured at the same frequency as the weather data (average every 10 minutes).

Cumulated data of the precipitation and permeation through the GCLs in lysimeter nos. 1 to 3 for the measuring period from April 1999 to the end of March 2000 are presented in Figure 3. These three lysimeters were selected for the first interpretation due to their similar test set-up (Figure 2) with 1 m cover soil. Related to the observation time of one year (April '99 to April 2000) only 0.3 to 0.5 % of the rain water has permeated through the different GCL. Concerning the permeation behaviour no significant difference has been found between the three GCL investigated up to now.

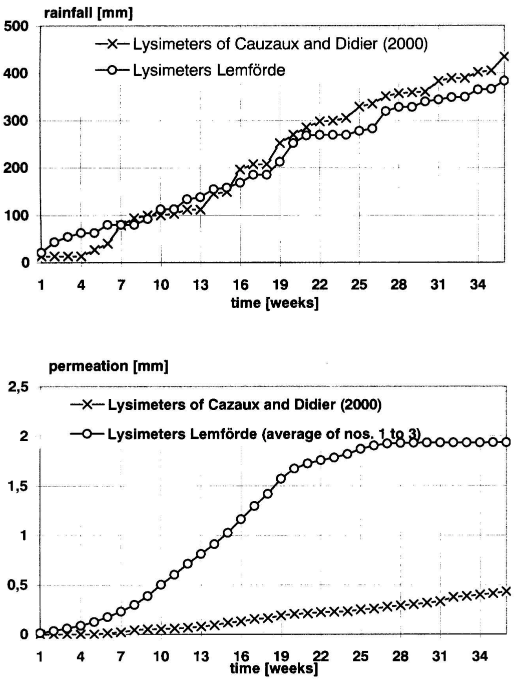

Figure 4. Comparison of GCL permeation data of different lysimeter investigations.

For general comparison purposes data published by Cazaux and Didier (2000), which have been obtained in large scale permeability tests of a similar needle-punched GCL with 5000 kg/m² bentonite filling covered by 0.4 to 0.8 m of soil are plotted together with the data collected from lysimeters nos. 1 – 3 for a time period of 36 weeks (Figure 4). In spite of differences in the test set-up the permeation rates are found to be in the same order of magnitude.

4 PRELIMINARY CONCLUSIONS

Larger scale testing simulating actual field conditions, is the most convincing way to prove the efficiency of a barrier system, and is more useful than a collection of laboratory tests modelling isolated and controlled conditions.

5 FINAL COMMENT

Geosynthetic Clay Liners have evolved and been successfully used on thousands of projects, constituting hundreds of millions of square meters, since the late 1980s. Numerous laboratory studies and in-situ field performance tests have shown that natural sodium bentonite is an excellent hydraulic and gas barrier with self healing characteristics.

Meanwhile GCLs have been approved by different national authorities and environmental agencies and have found their place in landfill and other geotechnical designs. They have become a common material for engineers to use in their lining applications. Continuous research activities and the development of test standards have enabled GCLs to become an acceptable alternative to other geotechnical liners. Nevertheless more information on the in-situ performance of GCLs in cover systems under varying climate conditions is required.

On-going long-term research data from lysimeters with GCLs involved show that the efficiency rate of GCLs lays in an acceptable range and is likely to outperform compacted clay liner systems.

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REFERENCES

Brandelik, A., Hübner, C. 1999. Long-term moisture monitoring under, in and over GCL liners. *Conference Proceedings Vol. 1, Geosynthetics '99.* Boston, USA.

Berger, K. 2000. Möglichkeiten und Grenzen der Anwendung des HELP-Modells. *Müll und Abfall 2/00.*

Cazaux, D., Didier, G. 2000. Field evaluation of hydraulic performances of geosynthetic clay liners by small and large-scale tests. *Geotextiles and geomembranes 18 (2000) 163-178.*

Daniel, D.E. 1996. Geosynthetic clay liners, part two: hydraulic properties. *Geotechnical Fabrics Report..*

Floss, R. 1991. Test Report on permeability behaviour dependent on the load of Bentofix. Munich, Germany.

Floss, R. 1993. Test Report Permeability behaviour dependent on consolidation and hydraulic gradient. Munich, Germany

Heerten, G., von Maubeuge, K. P., Reuter, E. 1997. Auswirkungen von Wassergehaltsschwankungen in vernadelten geosynthetischen Tondichtungsbahnen auf ihre Wirksamkeit als Dichtungselement. *geotechnik 20, Nr. 2*. pp. 109-116.

Maile, A. 1997. Leistungsfähigkeit von Oberflächenabdichtungssystemen zur Verminderung von Sickerwasser und Schadstoffemissionen bei Landschaftskörpern. *Studienreihe Abfall NOW, Band 15*. Stuttgart Reuter, E., Lükewille, W., Kruse, B. 1997. Wirksamkeitsvergleich von geosynthetischen Tondichtungsbahnen und mineralischen Tondichtungen. *5. Informationsveranstaltung über Kunststoffe in der Geotechnik.* Munich, Germany.

Reuter, E., Lükewille, W., Kruse, B. 1997. Wirksamkeitsvergleich von geosynthetischen Tondichtungsbahnen und mineralischen Tondichtungen. *5. Informationsveranstaltung über Kunststoffe in der Geotechnik.* Munich, Germany.

Schnatmeyer, C. 1998. Alternative Oberflächenabdichtungssysteme für Halden und Altstandorte am Beispiel einer Gichtstaubdeponie. *Trierer Geologische Arbeiten, Band 1.* Lehrstuhl für Geologie, Fachbereich VI, Geographie/Geowissenschaften, Universität Trier, Prof. Dr. Jean-Frank Wagner, Germany.