Influence of temperature and stress in the transmissivity of GCD used in landfills

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Abstract. Twenty-one transmissivity tests were performed in a double composite liner contaminant barrier for landfills. The secondary drainage system was tested with three geocomposite drains with different geonet core structures, biplanar, triplanar, and triaxial. Half of the tests were conducted under normal applied load of 250 kPa and varying temperatures of 30, 65, 75 and 85°C, to simulate different temperatures commonly found in the liner. The other half was performed at 30°C and varying applied stresses of 50, 150, 250 and 350 kPa, to simulate different heights of waste on top of the liner. The triaxial and triplanar GCDs presented similar but higher than the biplanar, rate of decrease in the flow rate with increasing temperature at 250 kPa. The highest the temperature of the liner, the smallest the flow rate of the geocomposite drain, but with a faster rate between 30-65°C than between 65-85°C.

1 Introduction

Contaminant barriers in solid waste landfills have the main goal of preventing the spread of contaminants from the waste to the surrounding environment. In jurisdictions with a good regulatory framework (e.g., New York State USA, Ontario Canada), a double composite liner system is generally required for large landfill cells. Double composite liner systems include a secondary leachate collection system (SLCS) between the primary and secondary liners as a contingency and leak detection system [1]. Gravel and geocomposite drains are the most common drainage materials used as the SLCS in double composite drains [2-7].

Geocomposite drains (GCDs) are geosynthetic materials produced specifically for drainage applications. They are often comprised of a geonet bonded to one or two geotextiles. The geotextiles' role is to act as a separation/filter, minimize intrusion and preventing the core from clogging, and the geonet core is responsible for allowing in-plane flow to a collection point (sump) in the drainage system. The transmissivity of GCDs can be measured in a transmissivity apparatus using ASTM D4716 both as a conformance test in quality control and as an index test for comparison of different GCDs [8].

While it is always desirable to assess the long-term performance of geosynthetics through case studies, there is not enough historical information available to make predictions of longevity for Municipal Solid Waste (MSW) landfills [9]. Thus, it is necessary to test the

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liner materials using simulators operating at elevated temperatures to allow extrapolation of the behaviour at higher temperatures to lower landfill temperatures.

The contaminant barrier is exposed to temperatures that can vary from 30-85ºC and different normal load conditions due to different phases of the landfill waste cell: construction, operation, and closure [10]. Therefore, the goal of this paper is to discuss the in-fluence of temperature and vertical stresses on the transmissivity of geocomposite drains with three different geonet core structures.

2 Materials

The geocomposite drains used in this research were from the same manufacturer, but with three different geonet core structures: biplanar, triplanar, and triaxial.

All three geocomposite drains had high density polyethylene (HDPE) geonet cores bonded thermally to two geotextiles. The geotextiles were grey, nonwoven, needle punched with poly-propylene fibres and a mass per unit area of 335 g/m² in the biplanar configuration and 200 g/m² in the triplanar and triaxial.

3 Transmissivity Tests

In this research, a total of 21 transmissivity tests [11] were performed in three geo-composite drains with different structures, biplanar, triplanar, and triaxial. All of them were conducted under the same top and bottom boundary conditions, varying the temperature and normal pressure applied in the composite liner, as shown in Table 1.

Table 1. Summary of tests performed.

Test #	Temperature (ºC)	Pressure (kPa)	Boundary Top	Drainage Material	Boundary Bottom
1	30	50	Sand + 1.5 mm GMB	GCD (Biplanar, Triplanar, Triaxial)	2.0 mm GMB + Sand
2	30	150			
3	30	250			
4	30	350			
5	65	250			
6	75	250			
7	85	250			

3.1 Equipment used

New equipment to test transmissivity was developed at Queen's University and used for the tests presented herein. The biggest innovation in this new equipment is the capacity to support high applied vertical stresses and high temperatures while measuring the transmissivity of the drainage material.

The device follows ASTM D4716 [11], and its normal load is applied using compressed air, to simplify the application of different load conditions. In addition, the new equipment has a heating system, comprised of two heating blankets around the transmissivity box, an insulation jacket, and a temperature controller, keeping the temperature constant.

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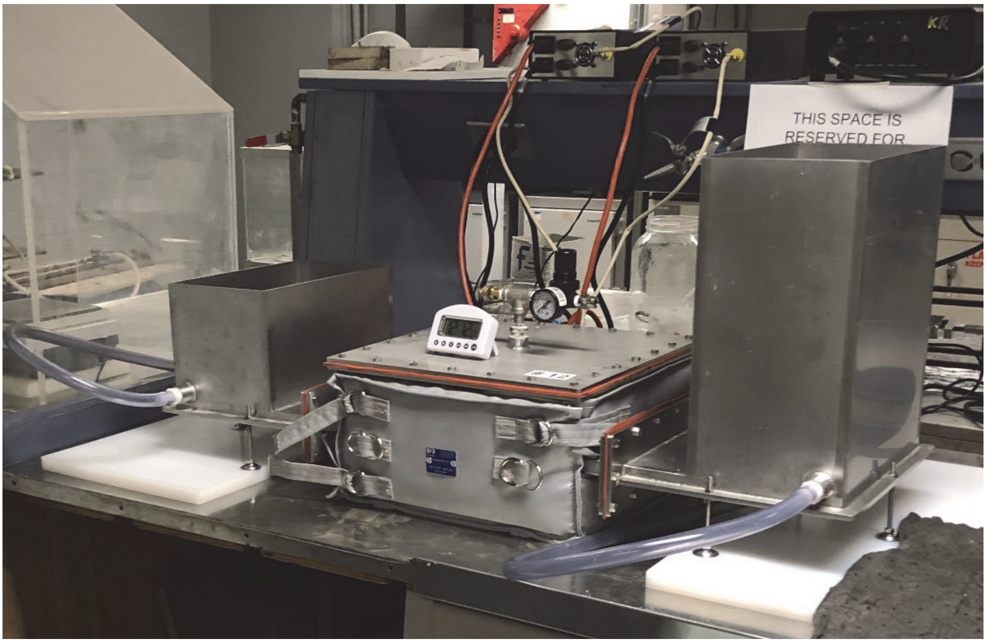

Fig. 1. Equipment developed at Queen's University.

3.2 Boundary conditions

The transmissivity test can be performed using steel plates above and below the drainage material, as top and bottom boundary conditions [11]. This may be suitable for conformance test but does not simulate field conditions. Thus, to more realistically simulate the use of GCD as a leak detection system in a landfill barrier, the test configuration was, from bottom to top: a layer of coarse silica sand compacted on optimal moisture content, acting as foundation soil; one 2.0 mm HDPE GMB; the GCD of interest; one 1.5 mm HDPE GMB; and another layer of compacted sand on top (Table 1).

The average temperature in the liner system for a normal active landfill is approximately 35-40°C, although temperatures between 85-100°C have been observed at the liner [10, 1, 12-15]. To represent the field temperature conditions, half of the transmissivity tests were conducted with the transmissivity cell at 250 kPa and four different temperatures at the liner system, 30, 65, 75 and 85°C.

The other half of the tests were performed at 30°C and varying applied vertical stresses of 50, 150, 250 and 350 kPa, to simulate different heights of waste on top of the liner as the different phases of the waste cell: construction, operation, and closure.

4 Results and Discussions

Figure 1 presents the results of transmissivity tests conducted at 30°C in four different load conditions: 50, 150, 250 and 350 kPa. As expected, geocomposite drains with triplanar and tri-axial geonet core structures presented a much higher flow rate than the biplanar geonet core. The triaxial geocomposite drain didn't show any significant changes in flow rate until 350 kPa since it is commonly used in high loads applications. Although the decreases in flow rate with an increase of pressure seem small, at 350 kPa they are 14% smaller than at 50 kPa for biplanar GCD and 5% for triplanar GCD.

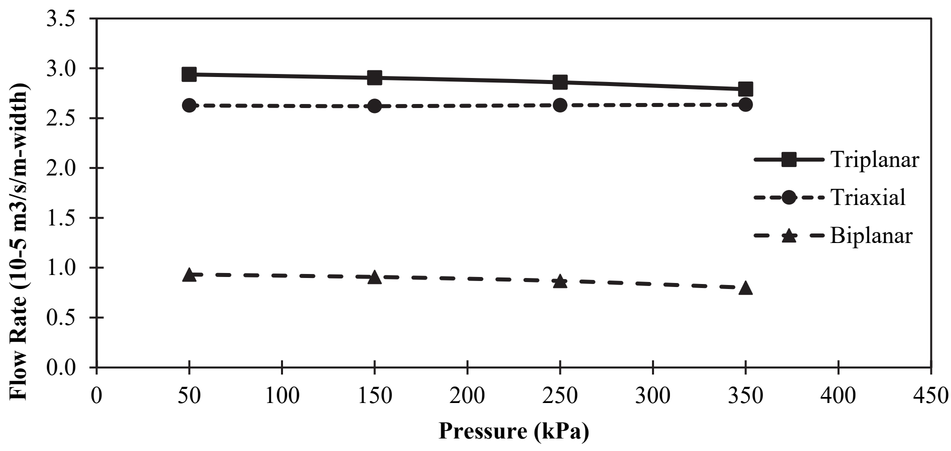

Fig. 1. Flow rate of geocomposite drains at 30ºC and varying pressures.

The influence of the temperature on the results of transmissivity tests conducted at 250 kPa is shown in Figure 2. In all three GCDs the flow rate decreases with the increase in temperature. Again, the triaxial GCD experienced the smallest relative decrease in flow rate with increasing temperature. The most affected structure was the triplanar GCD, with a 23% reduction in flow rate at 250 kPa and varying temperatures.
GCD and 5% for triplanar GCD.

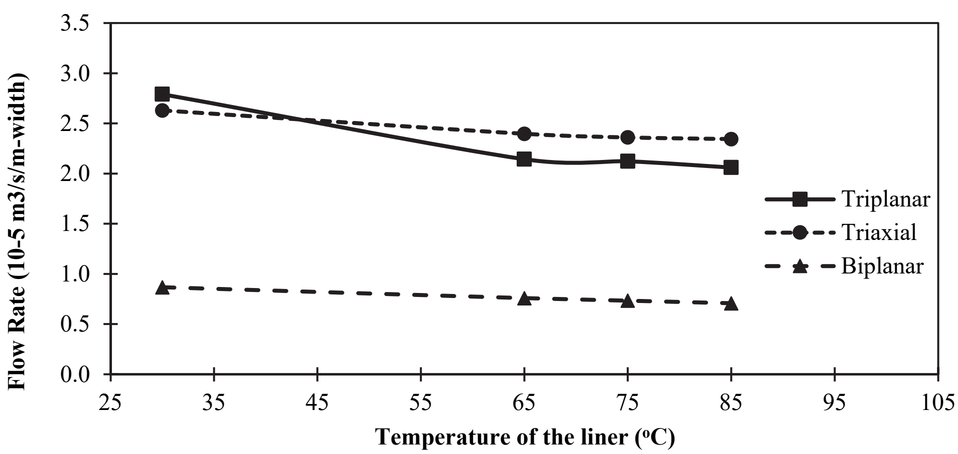

Fig. 2. Flow rate of geocomposite drains at 250 kPa and varying temperatures.

The reduction in flow in Figure 1 shows the normal reaction that can be expected from GCDs subjected to increasing confining pressure. Furthermore, comparing Figures 1 and 2, one could infer that in the short term, the elevated temperature has an additional influence in reducing the transmissive flow in three structures tested as a GCD core. Similar results were found when testing the transmissivity of five GCD structures at 25ºC and 70ºC with normal stresses varying from 30 to 500 kPa [16]. Moreover, the outcome of tests performed on a geonet confined between a pair of geomembranes under five increments of compressive stress, ranging from 25 to 400 kPa, presented a decrease in transmissivity with increase of load [8].

From this research, it can be inferred that the short-term transmissivity (<100h) in the geocomposite drain with triaxial geonet core was not influenced by the change in normal load and temperature, in the tested ranges of 50-350 kPa and 30-85°C.

5 Conclusions

Different structures of geonet cores will experience different impacts on the flow rate of the geocomposite drains due to temperature and normal load applied.

The higher the liner temperature, the smaller the flow rate of the geocomposite drain, but with a greater decrease in the flow rate between 30-65°C than between 65-85°C. Although the same reduction in flow rate is not evident when the temperature is kept constant and the applied stress is increased, with only a reduction of 14% in the flow rate in the biplanar GCD with increasing applied stress from 50 kPa to 350 kPa.

The tests presented herein represent a starting point for a long-term study. They were only conducted for up to 100h over a limited range of temperature and applied normal load. Ongoing research is considering the changes in the transmissivity of geocomposite drains aged under simulated landfill conditions over an extended period of time.

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