Method for direct measurements of the long-term water flow capacity of drainage geocomposites under soft bedding conditions

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ABSTRACT: For the design of drainage geocomposites (GCDs) the relevant property is the long-term water flow capacity. Different methods have been used to calculate or to simulate this property. First design recommendations were made to calculate the "long-term water flow capacity" by using reduction factors for local deformations and for compressive creep behaviour. Others simulated the "long-term water flow capacity" by short-term water flow capacity tests under soft bedding but under elevated compressive stress – representative for the "long-term thickness" of the core under the identical normal stress. The variety of combinations of different core types and geotextile filters in GCDs are high. And not all effects like compressive creep of the core and the initial deformation together with the time dependent deformation of the filter at various normal stresses will be taken into account by following the above mentioned methods.
A new method by using direct measurements of the "long-term water flow capacity" of GCDs after long-term compressive loading with soft bedding shows that real decrease in water flow capacity can be much higher than taken into account by short-term generated reduction factors. With typical commercially used GCDs, long-term compressive creep tests with soft bedding and different loads have been carried out in two laboratories. These "measured long-term water flow capacities" will be compared with "calculated" and with "simulated long-term water flow capacities".

1 INTRODUCTION

GCDs are used in environmentally sensitive applications such as landfills. In such applications, the GCDs can be subjected to compressive stresses over long periods of time. Of concern is the effect of creep on the long-term water flow capacity of the drainage systems besides ageing effects. The long-term water flow capacity is influenced by magnitude of applied load, gradient, contact surface, creep of filter geotextile.

Drainage reduction factors include chemical clogging, biological clogging, intrusion of the geotextile into the drainage core and compressive creep of the drainage core. Creep values are sensitive to the core structure and to the density of the resin used. Koerner (2005) has recommended reduction factor values for GCDs in landfill cover. For creep RF_{CR} = 1.1-1.4 and for elastic deformation or intrusion of geotextile into geonet core RF_{IN} = 1.3-1.5. Zanzinger & Gartung (1999) have shown that based on compressive creep tests, the reduction factor RF_{CR} can come up to 3.0 for certain GCDs at 20 kPa confining pressure. Jarousseau & Gallo (2004) found reduction factors for creep between 1.1 and 4.2 for different types of drainage cores with confining pressures between 50 kPa and 200 kPa.

Müller et al. (2008), Jarousseau & Gallo (2004) have determined the long-term water flow capacity indirectly by measuring the residual thickness of the GCD after a defined period and extrapolated to the required service life. The water flow capacity related to that thickness is measured at virgin samples.

In this paper, we report on the method for the direct measurement of the long-term water flow capacity of GCD that is subjected to compressive creep in a specially designed compressive creep test box. Bedding conditions e.g. hard/hard or soft/soft or hard/soft conditions can be simulated in the box simultaneously.

2 TEST PROGRAM AND TEST MATERIALS

The GCDs have been installed in a specially designed compressive creep test box. Böttcher (2006) has already presented this method. The box is placed in a room with controlled environment i.e. 20 °C and 65% relative humidity. The specimens are loaded by means of pressure bags which are on the top and bottom part of the box. In the test program, the specimens are subjected to air pressure loading of 20 kPa and 50 kPa. The specimens are encircled by a frame of same material so that it hinders the free movement of the drainage core in the transverse direction.

Figure 1. Compressive creep test box

The compressive creep test box ensures long-term loading of the core and filter geotextiles. A soft bedding condition is realized by direct contact of the specimen with a soft rubber membrane, a hard bedding condition is realized by metal plates placed between the specimen and the membrane. In the drain tester, a soft bedding condition is realized by foam plates placed between the load plate and the specimen. Soil pressure against geotextile was simulated by using a foam plate.

GCDs can be tested for creep with conventional method according to ISO 25619-1 or accelerated method e.g. SIM acc. to ASTM D7361. In conventional creep method, tests are performed at ambient temperature of around 20 °C or any other site-specific temperature. In accelerated procedure, the testing is performed at several elevated temperatures and the resulting data is then extrapolated to the ambient temperature through time-temperature superposition. The advantage of the accelerated testing over conventional methods is that the required information can be obtained within hours versus months required by the conventional tests.

Various types of commercially available GCDs are tested. They differ in core structure (i.e. geomat, geonet), type of geotextile (i.e. mechanically or thermally bonded), bonding of geocomposite elements (i.e. thermally bonded or stitch bonded). Ten GCDs that were tested are given in Table 1.

Table 1. GCDs used in the test program

GCD code	Drainage core	Geotextile
MVM-1, MVM-2,	Geomat, V-shaped monofilaments	Two mechanically bonded nonwoven geotextiles
TVT-1, TVT-2	Geomat, V-shaped monofilaments	Two thermally bonded non woven geotextiles
TRT-1, TRT-4 TRT-5	Geomat, Random array of filaments	Two thermally bonded nonwoven geotextiles
MNM-1, MNM-3, MNM-4	Geonet, bi-planar	Two mechanically bonded nonwoven geotextiles

The water flow capacity in the plane is determined acc. to ISO 12958. The specimens have a dimension of 20 cm x 30 cm. The specimen dimensions are optimal for testing in the drain tester and for the installation in the compressive creep test box. To determine the residual water flow capacity, the specimens are taken out at regular intervals and tested in the drain tester at the same load and bedding conditions as they are present in the compressive creep test box.

3 RESULTS AND DISCUSSION

3.1 Direct method: Comparison of test results of lab 1 and lab 2

The determination of long-term water flow capacity at lab 1 and lab 2 is according to the method described in this paper.

Figures 2 and 3 shows the influence of loading on TVT-1, TVT-2 respectively at hard/soft bedding condition. The water flow capacity at hard/hard is higher than at hard/soft. It is usual because the foam plate presses the filter geotextile into the drainage core and therefore less water flow capacity is measured. The results show a very good correlation between the two labs.

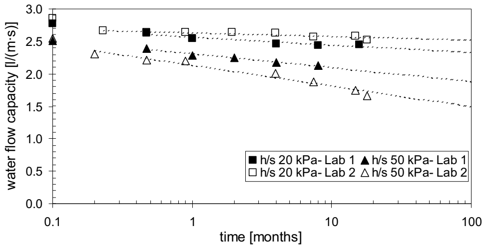

Figure 2. Comparison of results of TVT-1 at different loading and same bedding conditions

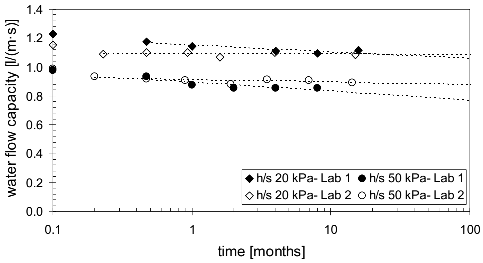

Figure 3. Comparison of results of TVT-2 at different loading and same bedding conditions

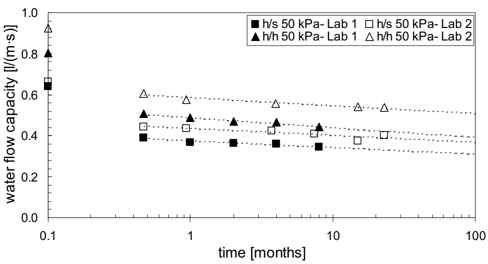

Figure 4. Comparison of results of TRT-1 at different bedding conditions and same loading

Figure 4 shows the influence of bedding conditions on TRT-1 at 50 kPa loading. The test results show a very good correlation between the two labs. The water flow capacity of TRT-1 measured by lab 1 at the delivery state is little less compared to the value measured by lab 2. The material has variations and also specimens were taken from different samples. The curves are almost parallel.

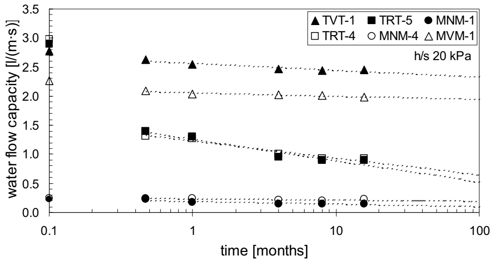

Figure 5. Water flow capacity of GCDs with different core structures

Figure 5 shows the water flow capacity of GCDs with different core structures at 20 kPa loading and hard/soft bedding conditions. Bi-planar geonets MNM-1 and MNM-4, which have high compression resistance show a negligible change in the water flow capacity during the whole test period. TRT-4 and TRT-5 have a drainage core with random array of monofilaments. They have a rapid decrease in the water flow capacity during the first few weeks of the testing period. The random filaments are compressed and there is a considerable reduction in the thickness of the product. TVT-1 and MVM-1 have a V-shaped drainage core with different geotexiles and densities of resin.

3.2 *Direct and indirect methods: Comparison of test results of lab 1 and lab 3*

Lab 1 determined the long-term water flow capacity by direct method and extrapolated to 100 years (Figures 6 and 7) whereas lab 3 used the indirect method (Müller et al. 2008). The residual thickness of the GCD after 100 years was extrapolated from creep curves measured over a period of one year. The water flow capacity related to that thickness is measured at virgin samples.

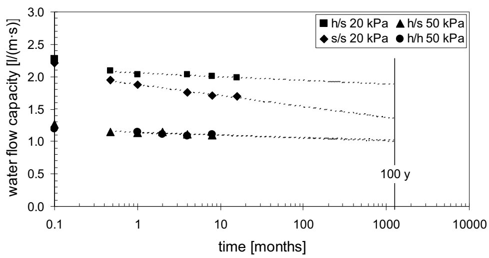

Figure 6. Water flow capacity of MVM-1 at different bedding conditions and loading

Figure 6 shows the water flow capacity of MVM-1 at different bedding conditions and loading. As expected the water flow capacity at 20 kPa loading with hard/soft is higher than at soft/soft. Figure 7 shows the water flow capacity of MVM-2 and MNM-3. A comparison of test results of three types of GCDs is given in Table 2.

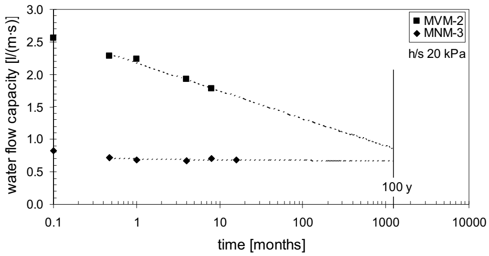

Figure 7. Water flow capacity of MVM-2 and MNM-3 at 20 kPa loading

Table 2. Comparison of results of two methods used by lab 1 and lab 3

GCD code	Bedding condition	Load [kPa]	Long-term water flow capacity [l/(m·s)]	
			Lab 1	Lab 3
MVM-1	h/s	20	1.88	1.5
	s/s	20	1.36	1.5
	h/h	50	1.09	1.2
	h/s	50	1.01	1.2
MVM-2	h/s	20	0.86	0.88
MNM-3	h/s	20	0.67	0.66

The extrapolated values of MVM-2 and MNM-3 till 100 years have shown good agreement. The water flow capacity of MVM-1 at hard/soft bedding and 20 kPa loading show slight deviation whereas it is almost identical for hard/soft and hard/hard bedding conditions at 50 kPa loading. For the extrapolation, it is considered that the ageing does not have an effect on mechanical properties of drainage core and no collapse occur in the period of extrapolation.

4 CONCLUSIONS

The long-term water flow capacity of various GCDs was evaluated by direct method using compressive creep test box. The actual insitu conditions can be simulated with this box. Direct measurement of long-term flow capacity is more precise but time consuming. The method is used to determine the influence of bedding conditions on water flow capacity. Indirect method can be performed quickly if accelerated creep testing via SIM is included. The indirect method cannot differentiate between the bedding conditions.

GCDs with high compression resistance show negligible change in the water flow capacity at 20 kPa and 50 kPa loading whereas drainage cores with random array of monofilaments showed a considerable decrease in the water flow capacity due to reduction of core thickness over time. The test results have shown a very good comparison between the laboratories. The tested specimens were taken from different samples and therefore material to material variation resulted in small deviations in the comparison.

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