Assessment of the Effect of Specimens Dimensions on the Measured Transmissivity of Planar Tubular Drainage Geocomposites

Eric Blond, eng., M.Sc.A., CTT GROUP / SAGEOS, Canada, eblond@gcttg.com
Pascal Saunier, eng., AFITEX-TEXEL, Canada, psaunier@afitex-texel.com
Tarik Daqoune, Eng, M.Sc.A., CTT GROUP / SAGEOS, Canada, tdaqoune@Gcttg.Com
Stephane Fourmont, AFITEX-TEXEL, Canada, stephane.fourmont@afitex.com

ABSTRACT
Transmissivity of drainage geocomposites can be measured using ASTM D4716. This method involves the use of relatively small scale specimens, typically 300 mm in length and 300 mm in width, which is a convenient approach to standardize the procedure and ensure repeatability of the test. One of the particularities of this method is that it imposes the use of square-shaped specimens, and that the specified dimensions are by far smaller than the size of the product which will be performing on real scale projects.

In order to estimate the effect of the shape and dimension on the transmissivity of planar drainage geocomposites, a large scale transmissivity apparatus was developed. This equipment was designed to permit evaluation of the transmissivity of geosynthetic products using several different shape factors. Tests per ASTM D4716 were also conducted in order to compare the measured properties to a standard reference.

A tubular drainage geocomposite was evaluated, using different number of pipes per meter. The tests were conducted with the geocomposite installed on a smooth HDPE geomembrane, covered by 100mm of sand, under a normal load of 100 kPa using several hydraulic gradients ranging from 0.005 to 1.0.

The results obtained are presented and discussed in this paper. It is shown that only the length of the specimen influences the measured transmissivity, and that the values obtained using the ASTM standard test method is conservative.

RÉSUMÉ
La transmissivité des géocomposites de drainage peut être mesurée selon ASTM D4716. Cette méthode utilise des spécimens relativement petits, typiquement 300 mm x 300 mm, ce qui est une approche simple pour standardiser la procédure et assurer la répétabilité des mesures. L'une des particularités de cette méthode est qu'elle impose l'utilisation de spécimens carrés, et que la dimension de ces spécimens est très largement inférieure à la dimension des produits qui seront installés sur site.

Afin de permettre d'estimer l'influence de la taille et de la dimension des spécimens de géocomposites de drainage tubulaires sur la transmissivité mesurée, un transmissivimètre de grande dimension a été développé. Cet équipement a été développé pour permettre l'évaluation de différentes dimensions de spécimens, et de différents rapports de forme (longueur versus largeur). Des essais selon ASTM D4716 ont aussi été ont aussi été réalisés pour permettre de comparer les observations avec des mesures standard utilisées en référence.

Un géocomposite de drainage a âme tubulaire a été évalué, en utilisant différent nombres du tubes par mètre de largeur. Ces essais ont été réalisés en instalent le produit sur une géomembrane lisse de PEHD, et en le recouvrant de 100 mm de sable, sous une contrainte normale de 100 kPa, et sous des gradients hydrauliques de 0.005 à 1.0.

Les résultats obtenus sont présentés et discutés dans ce document. Il est montré que seule la longueur des spécimens influence la transmissivité mesurée, et que les valeurs obtenues selon la norme ASTM D4716 sont conservatrices.

1 INTRODUCTION

Tubular drainage geocomposites are planar drainage geocomposites consisting of perforated tubes held between two geotextiles. The number of pipes per meter width as well as the diameter of the pipes can be modified to the needs of the projects on which they are aimed to be installed. As a consequence, the distance between two tubes can be either 250 mm, 500mm, 1000mm or 2000mm.

However, transmissivity measurements are typically conducted using either ASTM D4716 or ISO 12958 in an apparatus which has a maximum width of 300 mm. This dimension is sufficient to permit evaluation of the transmissivity of tubular drainage geocomposites with a maximum pipe spacing of 300mm. Assessing the transmissivity of tubular drainage geocomposites with pipe spacing greater than 300 mm thus requires assumptions, which are sometimes questioned by the end user.

In order to address these concerns and better understand the behavior of these products, a large apparatus was developed, which is capable to measure the transmissivity of tubular drainage geocomposites at a scale which is consistent with the size and structure of the product. It was used to run a series of tests to determine the relative transmissivity in a variety of configurations.

2 EXPERIMENTAL PROGRAM

2.1 Tested products

Properties of the tested product is summarized in Table 1.

Table 1: Material properties

Property	Unit	tubular drainage geocomposite
Total weight	(g/m²)	435
Total thickness	(mm)	4.6
Core structure	/	Pipe
Pipe diameter (in/out)	(mm)	D = 18.7 / 25
Weight of the core	(g/m²)	N/A
Type of geotextile	/	NW, PET
Geotextile weight - side 1 / side 2	(g/m²)	115 / 320
Geotextile thickness - side 1 / side 2	(mm)	1.5 / 3.9

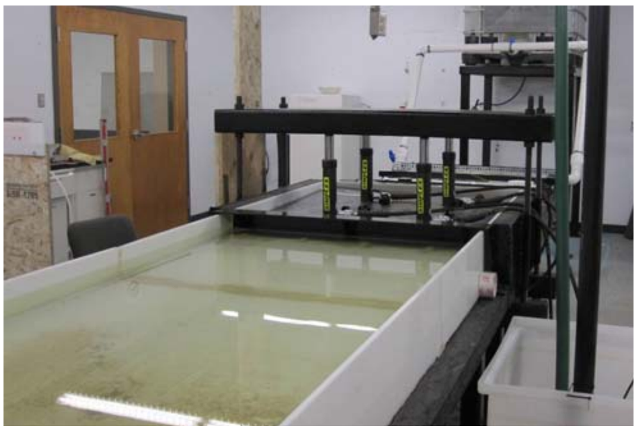

Figure 1 : LST as seen from the outflow weir, towards the upstream container

Figure 2 : Loading mechanism (load distribution layer not shown)

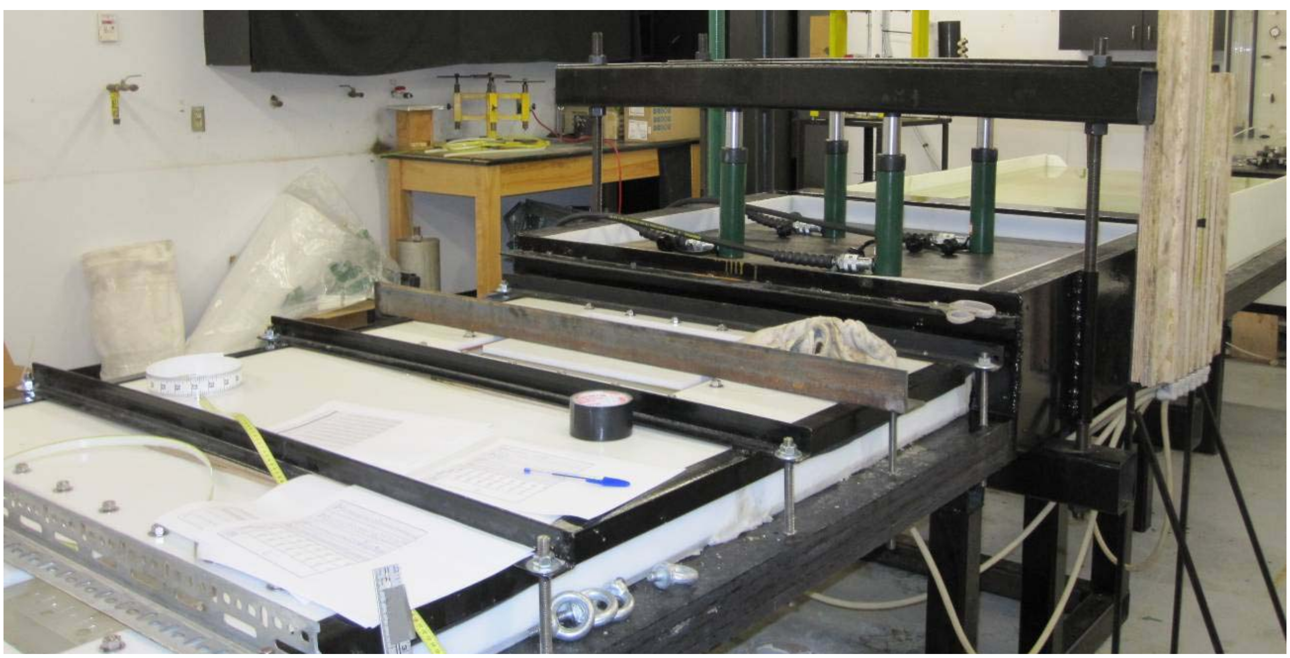

Figure 3 : LST seen from the inflow weir, looking at the loading mechanism and large hydraulic head measurement panel

2.2 Structure of the project

This project was articulated into steps:

- *Step 1: Validation of the apparatus*. In this step, measurements made in the Large Scale Transmissivity (LST) apparatus are compared to those obtained using the Standard (Std) apparatus conforming to ASTM D4716 and ISO 12958 on the same specimens (300 x 300 mm).
- *Step 2: Influence of the scale*. After verification of the transmissivity measurements conducted within Step 1, results obtained on 1, 2 or 4 pipes per meter width installed in large 1000 mm x 1000 mm specimens were compared to observe proportionality of the transmissivity.
- *Step 3: Influence of the width / length ratio (shape factor)*. Once the influence of the size of the specimen has been observed within Step 2, an investigation of the effect of the geometry (width / length ratio) of the specimen was conducted in step 3.

3 APPARATUS

The 'Standard' (Std) apparatus used as a reference was purchased to conform to both ASTM D4716 and ISO 12958 and is used on a routine basis for conformance testing. On the other hand, the 'Large Scale Transmissivity' (LST) apparatus was developed in order to be able to conduct transmissivity tests on specimens as large as 1.0m x 1.0m. The key components are presented on figures 1 to 3. Among the key features of the apparatus:

- Maximum surface of the specimen: 1.0 m x 1.0 m = 1.0 m²;
- Length of the upstream and downstream weirs: 1.90 meters each;
- Upstream weir fully confined to minimize volumes of water involved;
- Base structure built over 4 layers of 3/4" thick plywood, lined with a 6 mm thick polyethylene sheet;
- Compression applied through a system composed of a rigid, 1" thick cellular steel plate confined between 2 layers of 3 mm thick steel plates, on which 4 hydraulic pistons apply a normal stress.

3.1 Test method

The tests were conducted according to ASTM D4716 and ISO 12958, with the following precisions / modifications:

- Size, and for Step 3, geometry of the specimens
- The tubular drainage geocomposite was installed on a 25 mm (1") thick foundation layer of fine sand
- The tubular drainage geocomposite was covered by 75 mm (3") of fine sand
- One test specimen was tested instead of 2 (for ASTM D4716) or 3 (ISO 12958)
- Measurements were conducted after a seating time of at least 15 minutes. The deviation from the required seating time of 6 minutes in ISO 12958 was not considered to be a concern given the lack of sensitivity of the product to normal load nor seating time in this configuration, according to Saunier et al (2010).
- The precision of the loading mechanism has been estimated to be in the range of 5 to 10%, however, it was also shown by Saunier et al. (2010) that normal stress does not affect the hydraulic transmissivity of Draintube when tested in the above configuration.

As a consequence, the tests were considered to be in general accordance with both ASTM D4716 and ISO 12958 except for the shape and dimension of the specimens.

3.2 Test conditions

The retained test conditions were as follows:

- Compression stress: 20, 100 and 200 kPa
- Hydraulic gradients: 0.005, 0.02, 0.1 and 1.0
- Seating time (following both application of stress and initiation of flow at a given gradient): 15 minutes

The gradient of 0.005 was used only for tests conducted on specimens with specimen lengths of 500 and 1000 mm to ensure a reasonable precision of the measurements.

3.3 Test set-up

Figures 6 to 17 describe the installation of the test specimens in the apparatus.

4 TEST RESULTS

4.1 Step 1: Validation of the apparatus

The tests were conducted under a compressive load of 100 kPa. Results are summarized in Table 2 and on Figure 16.

It can be observed that the measurements obtained on the 250 x 300 mm wide specimen were identical, whether they were measured in the large apparatus or the standard apparatus. On the other hand, transmissivity values calculated based on the measurements made on 1000 mm x 1000 mm specimens are larger than the ones calculated from 250 mm x 300 mm specimens.

Based on these results, it can be concluded that:

- The particular geometry of the LST does not influence the measurements, or influences them in a similar way than the standard D4716 / ISO 12958 apparatus does with a 250 mm x 300 mm specimen;
- The transmissivity determined based on measurements made on large 1000 mm x 1000 mm specimens is higher than the one obtained on small specimens. Because f the consistency of the measurements obtained on a small specimen tested in both standard and large scale apparatus, This was

considered to be a result of the size of the specimen, and not a deviation caused by the apparatus itself.

- As a consequence, results obtained in a standard apparatus can be considered to be conservative if the size of the product is larger than 1000 mm x 1000 mm.

Table 2: Tests conducted within Step 1 (Validation of the apparatus)

LST, 1000 x 1000 4 pipes / 1000 mm		**LST (*), 250 x 300 1 pipe / 250 mm**		**Standard apparatus (*), 250 x 300 1 pipe / 250 mm**	
Hydraulic gradient	**Transmissivity (cm^2/s)**	**Hydraulic gradient**	**Transmissivity (cm^2/s)**	**Hydraulic gradient**	**Transmissivity (cm^2/s)**
0.006	2.66E-02	0.020	8.38E-03	0.006	1.45E-02
0.013	1.61E-02	0.037	5.80E-03	0.010	1.14E-02
0.02	1.34E-02	0.070	4.16E-03	0.020	7.95E-03
0.05	8.08E-03	0.177	2.56E-03	0.050	5.20E-03
0.099	5.84E-03	0.347	1.85E-03	0.099	3.64E-03
0.203	4.18E-03	0.680	1.32E-03	0.200	2.60E-03
0.498	2.69E-03	1.697	8.36E-04	0.500	1.66E-03
1.000	1.87E-03	3.283	6.04E-04	0.999	1.17E-03

(*) : The same specimen was evaluated in both Standard (Std) and Large Scale (LST) Transmissivity apparatuses

Figure 4 : 25mm layer of sand (confined in a thin plastic sheet) installed as a foundation layer in the LST

Figure 5 : Draintube covered by sand. The cover geotextile was wrapped around the sand to contain it

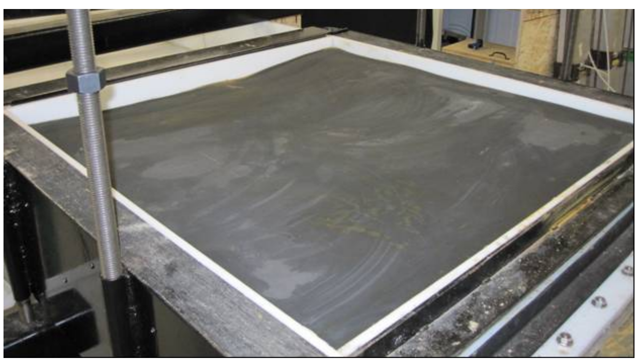

Figure 6 : Closed cell foam installed between two layers of 6mm thick steel to seal the edges

Figure 7 : 250 mm x 300 mm specimen installed in the LST

Figure 8 : 1000 mm x 500 mm specimen installed in the LST

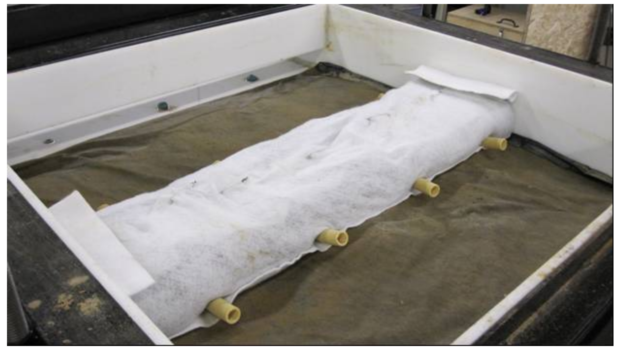

Figure 9 : 1000 mm x 250 mm specimen with 4 x 25mm pipes installed in the LST

Figure 10 : 1000 mm x 250 mm specimen with 2 x 25mm pipes installed in the LST

Figure 11 : 1000 mm x 250 mm specimen with 1 x 25mm pipe installed in the LST

Figure 12 : 500 mm x 1000 mm specimen installed in the LST

Figure 13 : 500 mm x 1000 mm specimen with 2 x 25mm pipes installed in the LST

Figure 14 : 250 mm x 1000 mm specimen installed in the LST

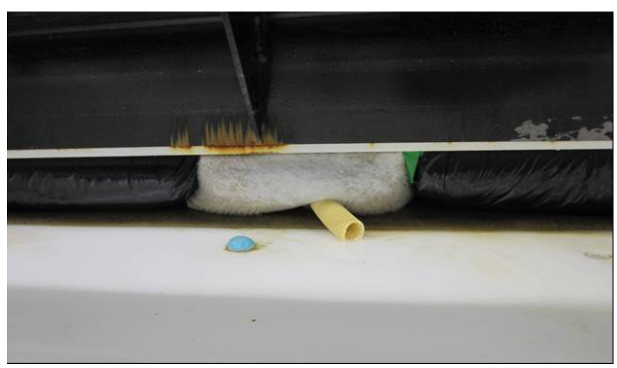

Figure 15 : 250 mm x 1000 mm specimen with one 25mm pipe installed in the LST

4.2 Step 2: Influence of the scale

The aim of this step was to confirm if a test conducted on one single pipe, permitting determination of a “flow rate per pipe”, could be used to extrapolate the transmissivity of products involving one or multiple pipes per meter. To do so, the transmissivity of the tubular drainage geocomposite was determined using a specimen width of one meter and different configurations (1, 2 or 4 pipes per meter). The results obtained were compared to observe proportionality. The observations are summarized in Table 3 and Figure 17.

It can be observed that the transmissivity measured on a sample containing 4 pipes per meter is 2 times larger than the transmissivity measured on a product containing 2 pipes per meter, and 4 times larger than the transmissivity measured on a product containing 1 pipe per meter.

Based on these results, it was concluded that:

- The transmissivity of tubular drainage geocomposites is proportional to the number of pipes per unit width.

Step 3: Influence of the shape factor

Various configurations were tested to evaluate the effect of length and width on the measured transmissivity. Overall, the same hydraulic gradient was applied on specimens with different lengths and widths, in order to observe the effect of the shape factor on the measured transmissivity. The results are summarized on Table 4 and Figures 18 to 20.

It can be observed that under the same gradient and normal stress and for a constant number of pipes per unit width, the transmissivity of tubular drainage geocomposites increases as the length of the sample increases. On the other hand, a change of width does not affect the measured transmissivity. On the other hand, the proportionality between the number of pipes per unit width observed within Step 2 was also verified considering different widths of specimens.

Based on these results, it was concluded that:

- The width of the specimen does not influence the measured transmissivity per unit width.
- The length of the specimen was positively correlated to the measured transmissivity.

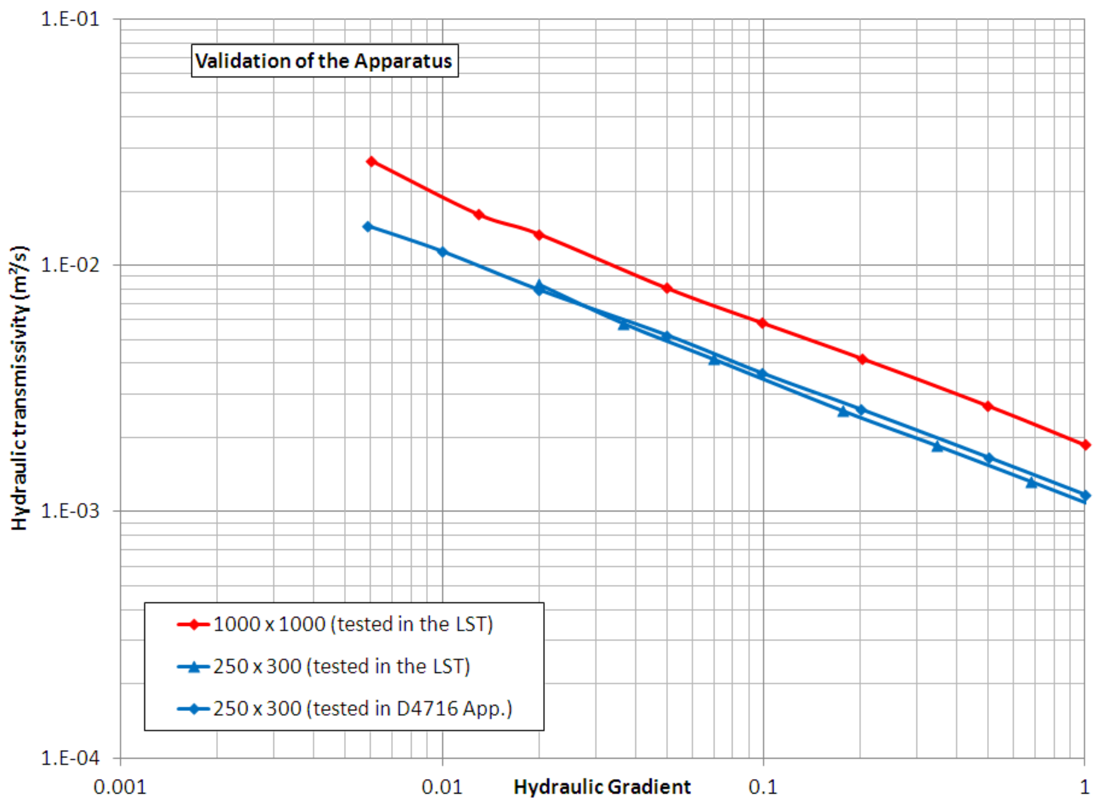

Figure 16 : Validation of the apparatus

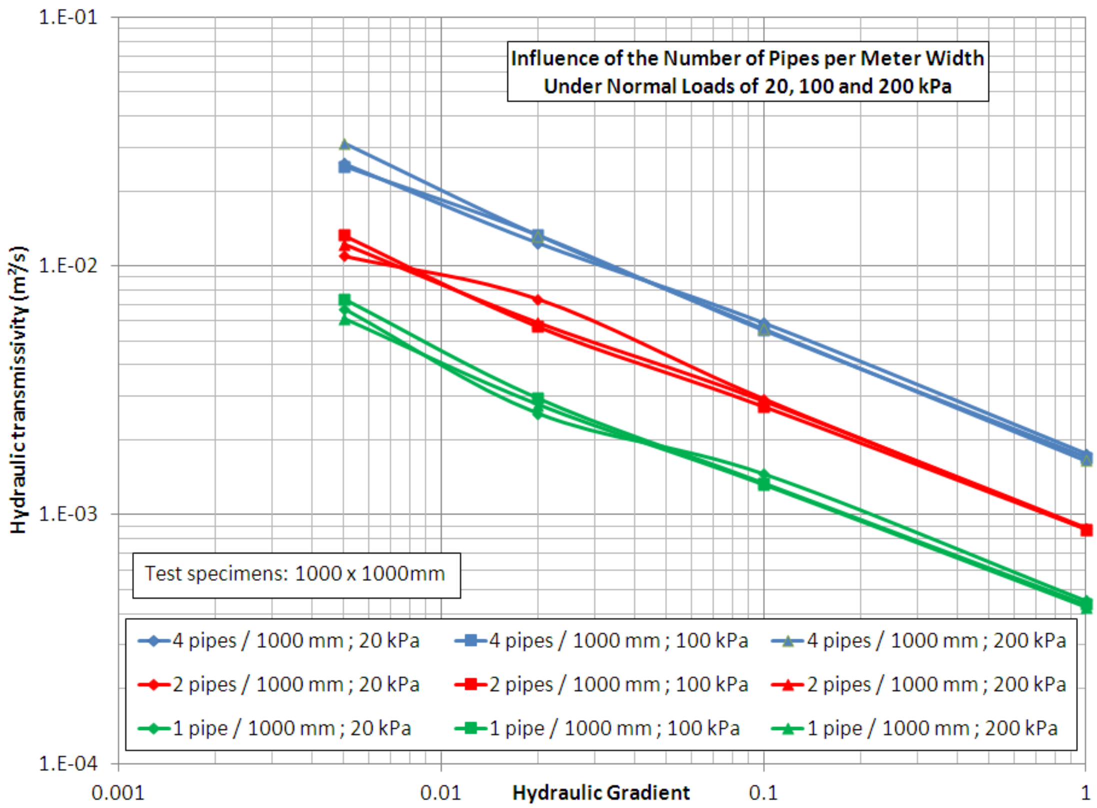

Figure 17 : 1, 2 and 4 pipes per 1000 mm, tested in the 1000 x 1000 mm apparatus

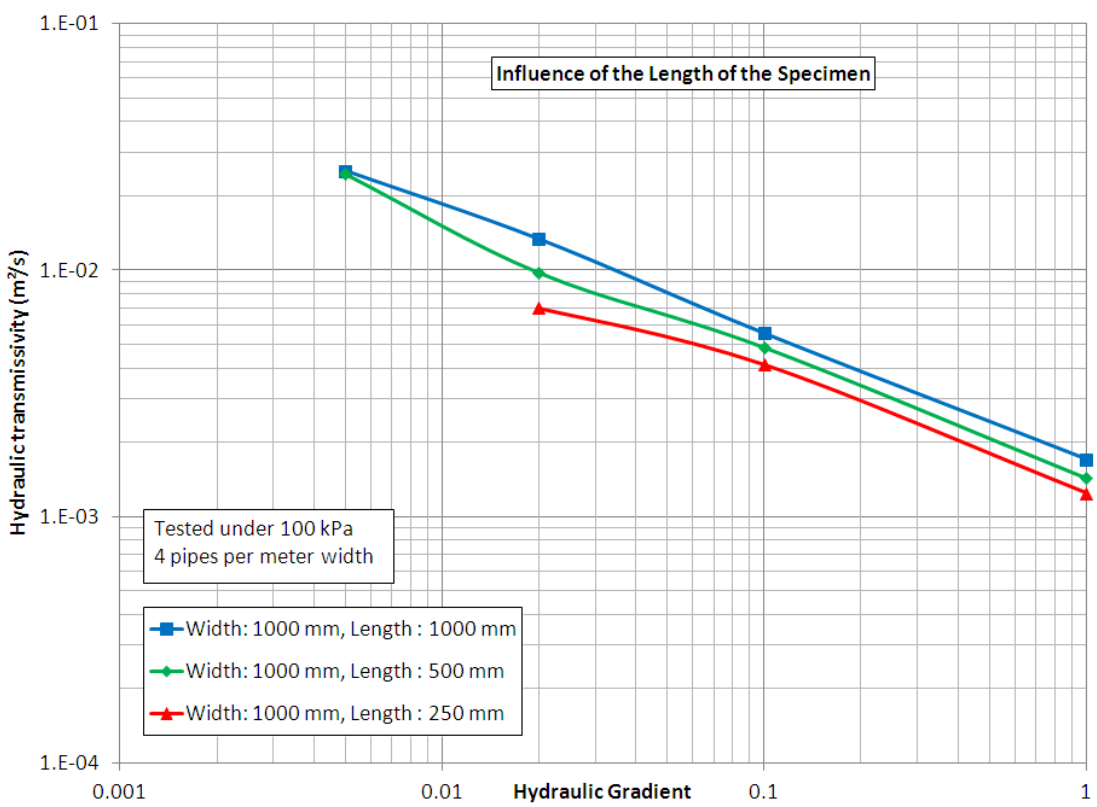

Figure 18 : Influence of the length, for a fixed width of 1000 mm and 4 pipes / 1000 mm

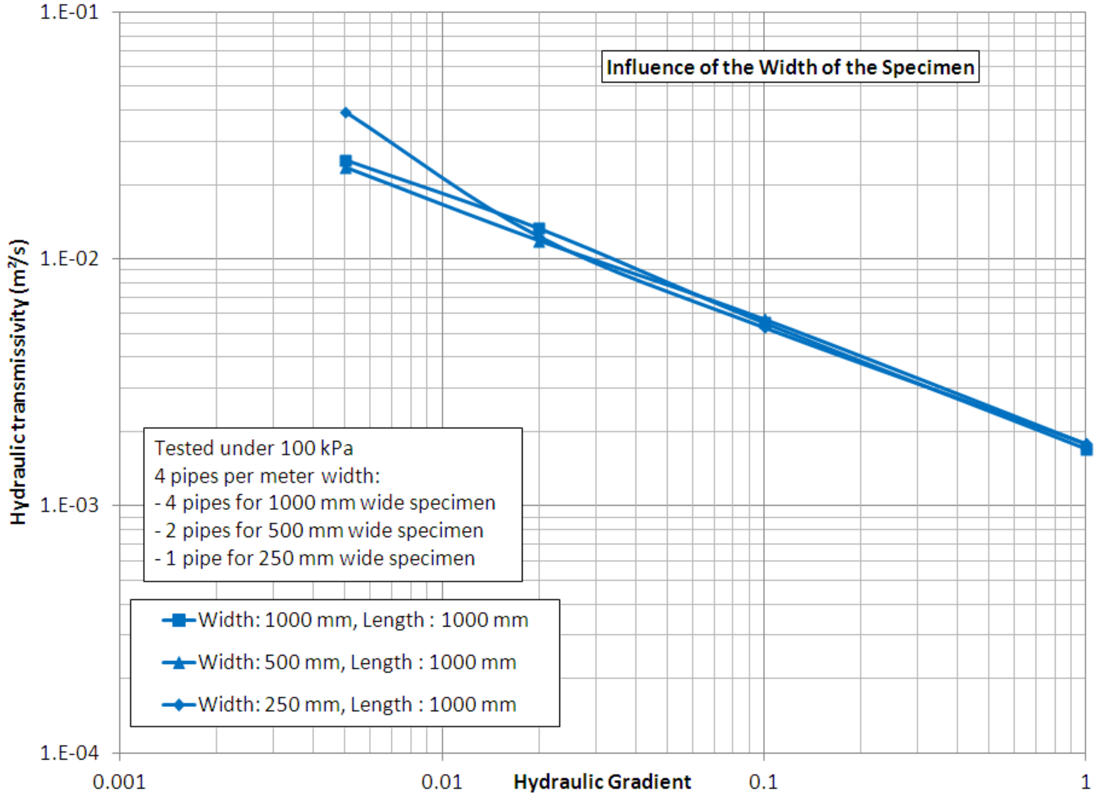

Figure 19 : Influence of the width, for a fixed length of 1000 mm and 4 pipes / 1000 mm

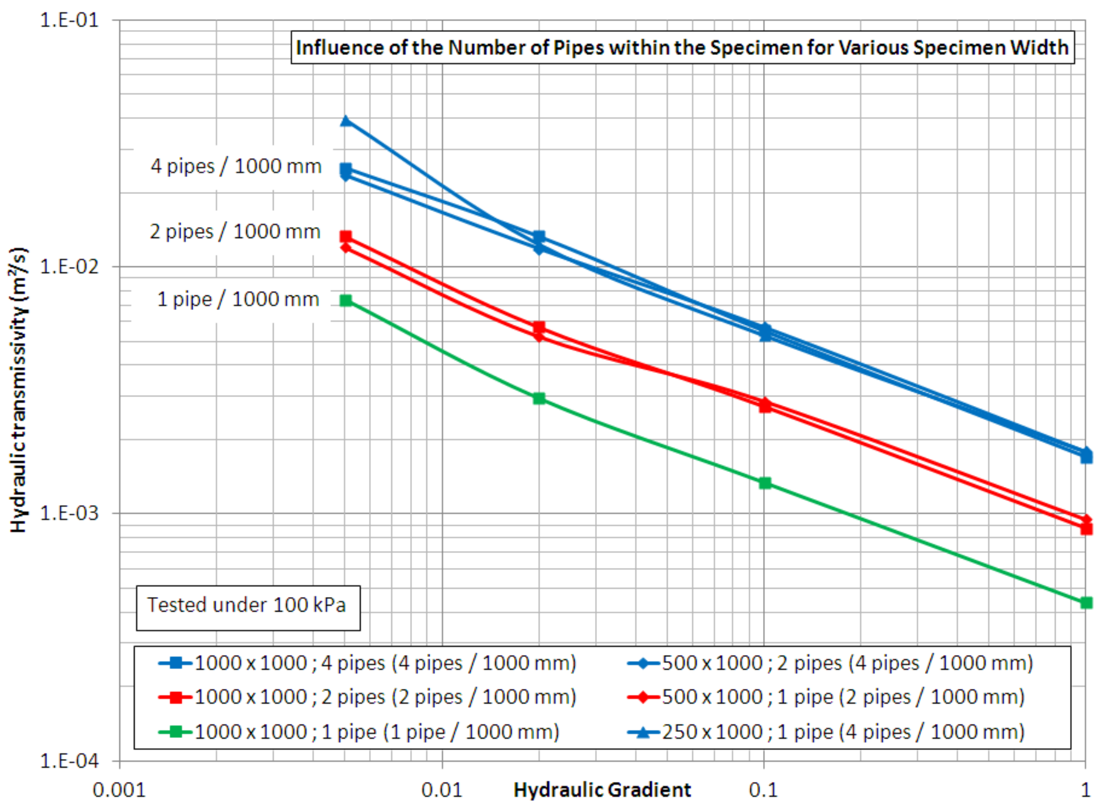

Figure 20 : Influence of the width of the test specimen for a fixed length of 1000 mm and 1, 2 or 4 pipes / 1000 mm

Table 3: Results of Step 2 (influence of the scale)

Configuration	**Specimen size**	**Compressive stress**	**Gradient i=0.005**	**Gradient i=0.02**	**Gradient i=0.1**	**Gradient i=1.0**
4 pipes / 1000mm	Width: 1000 mm Length: 1000 mm	20 kPa	2.59E-02	1.24E-02	5.91E-03	1.76E-03
		100 kPa	2.52E-02	1.33E-02	5.52E-03	1.70E-03
		200 kPa	3.11E-02	1.33E-02	5.60E-03	1.66E-03
2 pipes / 1000mm	Width: 1000 mm Length: 1000 mm	20 kPa	1.10E-02	7.37E-03	2.92E-03	8.82E-04
		100 kPa	1.33E-02	5.71E-03	2.72E-03	8.73E-04
		200 kPa	1.22E-02	5.90E-03	2.86E-03	8.75E-04
1 pipe / 1000mm	Width: 250 mm Length: 300 mm	20 kPa	6.72E-03	2.55E-03	1.46E-03	4.52E-04
		100 kPa	7.36E-03	2.94E-03	1.34E-03	4.36E-04
		200 kPa	6.14E-03	2.77E-03	1.32E-03	4.26E-04

Table 4: Influence of the shape factor

Configuration	Width	Length	Compressive stress	Gradient i=0.005	Gradient i=0.02	Gradient i=0.1	Gradient i=1.0
Influence of the length of the specimen							
4 pipes / 1000 mm	1000	1000	100 kPa	2.52E-02	1.33E-02	5.52E-03	1.70E-03
		500		2.45E-02	9.72E-03	4.84E-03	1.42E-03
		250		--	7.00E-03	4.13E-03	1.24E-03
2 pipes / 1000 mm	1000	1000	100 kPa	1.33E-02	5.71E-03	2.72E-03	8.73E-04
		500		1.41E-02	4.73E-03	2.33E-03	7.77E-04
		250		--	3.77E-03	1.87E-03	6.49E-04
1 pipe / 1000 mm	1000	1000	100 kPa	7.36E-03	2.94E-03	1.34E-03	4.36E-04
		500		4.07E-03	2.38E-03	1.18E-03	4.29E-04
		250		--	2.05E-03	9.50E-04	3.52E-04
Influence of the width of the specimen							
4 pipes / 1000 mm	1000	1000	100 kPa	2.52E-02	1.33E-02	5.52E-03	1.70E-03
	500			2.35E-02	1.19E-02	5.71E-03	1.79E-03
	250			3.94E-02	1.23E-02	5.28E-03	1.78E-03
2 pipes / 1000 mm	1000	1000	100 kPa	1.33E-02	5.71E-03	2.72E-03	8.73E-04
	500			1.20E-02	5.23E-03	2.86E-03	9.50E-04

5 CONCLUSIONS

Based on the results gathered within this project, it was possible to conclude that for a tubular drainage geocomposites confined in soil:

- The transmissivity is proportional to the number of pipes per unit width. The properties measured on a single pipe and calculated for a unit width of one meter can be multiplied by 2 if there are 2 pipes per meter, or by 4 if there are 4 pipes per meter.
- Transmissivity measured on a 300 mm long specimen according to a ASTM D4716 or ISO 12956 is smaller than transmissivity measured on larger specimens, such as 500 or 1000 mm. As a consequence, a property reported per either ASTM D4716 or ISO 12956 can be considered to be conservative for drainage lengths of 1.0 m or more.

6 REFERENCES

Saunier P., Ragen W., Blond E. (2010). Assesment of the resistance of Draintube drainage geocomposites to high compressive loads. *9th International Conference on Geosynthetics*, Brazil.

ISO 12958 (2010). Geotextiles and geotextile-related products — Determination of water flow capacity in their plane

ASTM D4716. Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head