Assessment of long term water flow capacity of geocomposites

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ABSTRACT: In France, to design drainage geocomposites into drainage and filtration systems, we have a new standard NF G38-061 (Afnor 2017). A major part of this standard is derived from a guide edited by the French Chapter of IGS (Comité Français des Géosynthétiques 2014). To design drainage geocomposites on the long term, the standard NF G38-061 (Afnor 2017) takes into account the decrease over time of geocomposite in-plane water flow capacity due to normal stress. Two phenomena are considered: the reduction of the composites thickness (compression of the drainage core) and simultaneously the intrusion of the geotextile filter into the drainage core in the case of soft boundary interface conditions. These two phenomena are assessed following two reduction factors that have to be applied to the in-plane water flow capacity of geocomposite measured following the standard NF EN ISO 12958 (Afnor 2010). There are current discussion in ISO TC 221 WG4 in the framework of the creation of the NF EN ISO 12958 part 2 – performance test, especially about the time of compression of the specimen in the cell before the in-plane water flow capacity measurement. This paper deals with the methods to assess the long term in-plane water flow capacity of geocomposites and discusses the time of compression of the specimen in the cell before the in-plane water flow capacity measurement is performed.

Keywords: water flow capacity, contact surfaces, compressive creep, intrusion, thickness reduction

1 INTRODUCTION

1.1 *General Framework*

The in-plane water flow capacity q (or transmissivity θ which is the volumetric flow rate per unit of width of specimen and per unit gradient in the plane of the product following NF EN ISO 10318 (Afnor 2015) of drainage composites (or simply geocomposites in this paper) is subjected to decrease along time due to several actions: (i) normal stress that leads to a reduction of the composites thickness (compression of the drainage core) and simultaneously to the intrusion of the geotextile filters into the drainage core in the case of soft boundary interface conditions (Figure 1); (ii) chemical and biological actions that lead to a clogging of the drainage core; (iii) physical actions that can also lead to a clogging of the drainage core (intrusion of fines particles into the drainage core for example).

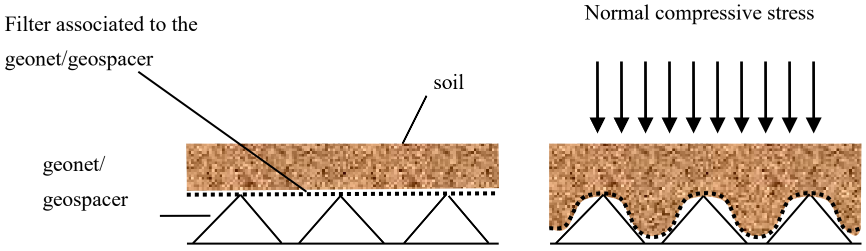

Figure 1. Intrusion phenomenon of the filter layer into the drainage core (from Touze-Foltz et al. 2014).

Giroud et al. (2000) dealt with all the mechanisms that induce a decrease of the geocomposite hydraulic performance and suggested a general equation to assess the long term transmissivity of drainage composites from a measurement made in a laboratory test at which is applied several reduction factors:

$$\theta_{LTIS} = \frac{\theta_{measured}}{\prod(RF)} = \frac{\theta_{measured}}{RF_{IMCO} \times RF_{IMIN} \times RF_{CR} \times RF_{IN} \times RF_{CD} \times RF_{PC} \times RF_{CC} \times RF_{BC}} \tag{1}$$

where, following Giroud et al. (2000): θ_{LTIS} is the long-term-in-soil hydraulic transmissivity of the considered geocomposite, i.e. the minimum hydraulic transmissivity calculated for the geosynthetic subjected to the maximum stress anticipated in the soil during the design life of the liquid collection layer and subjected to all mechanisms likely to reduce its hydraulic transmissivity; $\theta_{measured}$ is the value of hydraulic transmissivity measured in a laboratory test; Π(RF) is the product of all reduction factors; RF_{IMCO} is the reduction factor for immediate compression, i.e. decrease of hydraulic transmissivity due to compression of the transmissive core immediately following the application of stress; R_{FIMIN} is the reduction factor for immediate intrusion, i.e. decrease of hydraulic transmissivity due to geotextile intrusion into the transmissive core immediately following the application of stress; RF_{CR} is the reduction factor for creep, i.e. time-dependent hydraulic transmissivity reduction due to creep of the transmissive core under the applied stress; RF_{IN} is the reduction factor for delayed intrusion, i.e. decrease of hydraulic transmissivity over time due to geotextile intrusion into the transmissive core resulting from time-dependent deformation of the geotextile; RF_{CD} is the reduction factor for chemical degradation, i.e. decrease of hydraulic transmissivity due to chemical degradation of the polymeric compound(s) used to make the geocomposite; RF_{PC} is the reduction factor for particulate clogging, i.e. decrease of hydraulic transmissivity due to clogging by particles migrating into the transmissive core; RF_{CC} is the reduction factor for chemical clogging, i.e. decrease of hydraulic transmissivity due to chemical clogging of the transmissive core; and RF_{BC} is the reduction factor for biological clogging, i.e. decrease of hydraulic transmissivity due to biological clogging of the transmissive core.

This kind of approach suggested by Giroud et al. (2000) can also be found in Koerner (2005). It is also used in the project of guide ISO TR 18228-4 which ISO TC 221 WG6 is currently working on. Laslty, the standard NF G38-061 (Afnor 2017) also uses this approach. There are some differences between each design methods. To completely design the drainage geocomposite, Giroud et al. (2000) suggested to use a factor of safety FS (values such as 2 or 3) on the hydraulic transmissivity to take into account possible uncertainties. Some other factors of safety can be applied, for example on the maximum liquid thickness. In the project of guide ISO TR 18228-4, a supplementary reduction factor can be used for overall uncertainties on laboratory data and field conditions and after a final factor of safety FS_G can also be used.

In the standard NF G38-061 (Afnor 2017), $q_{measured}$ (corresponding to $\theta_{measured}$ in equation 1) is the value of hydraulic transmissivity measured in a laboratory test following NF EN ISO 12958 (Afnor 2010). Following this standard, the time during which the stress is applied before the flow rate (from which the in-plane water flow capacity is derived) is measured (called by Giroud et al. (2000) the "seating time") is equal to 8 min. In such condition, RF_{IMCO} and RF_{IMIN} is equal to one. Moreover, the field application of the standard NF G38-061 (Afnor 2017) excludes waste water, leachate and situations where physico-chemical phenomena can occur so RF_{CC} and RF_{BC} are equal to one. In a specific note, it is state that the drainage core of the geocomposite must evacuate fines particles that go through the geotextile filter, so RF_{PC} is equal to one. Concerning the durability, the design of the geocomposite must follow the recommendation in the standard NF EN 13252+A1 (Afnor 2015); so RF_{CD} is equal to one. Finally, in the standard NF G38-061 (Afnor 2017), equation (1) is expressed as follow (using the in-plane water flow capacity q instead of the transmissivity θ):

$$\frac{q_{GSY}(t)}{\prod(RF)} = \frac{q_{12958}(t = 8min)}{RF_{CR}(t - t = 8\text{min}) \times RF_{IN}(t - t = 8\text{min})} \tag{2}$$

with q_{GSY} (t) the long term water flow capacity used to design a geocomposite during the time t; q_{12958} (t=8min) is the measurement of the in-plane water flow capacity following NF EN ISO 12958 (Afnor, 2010) at an hydraulic gradient i, a normal stress σ with a seating time of 8 minutes and with Rigid/Foam (R/F) or Foam/Foam (F/F) as usual boundary conditions, Rigid/Rigid (R/R) boundary conditions being only relevant for leakage detection in landfills between two rigid geomembranes or for drainage between shotcrete and structural arch in tunnels.

To assess the long term water flow capacity of the geocomposite, the main challenge is to determine the reduction factor RF_{CR} (t – t = 8 min) and RF_{IN} (t – t = 8 min).

1.2 *Assessment of the reduction factor RFCR and RFIN*

There are several methods to assess the reduction factor RF_{CR} (t – t = 8 min) and RF_{IN} (t – t = 8 min) described above.

The first method, suggested by NF G38-061 (Afnor 2017), is to assess simultaneously these two parameters, by performing a long term laboratory test with the appropriate boundary conditions. This approach requires either a specific hydraulic device to measure over the long term the decrease of the water flow capacity of the tested specimen compressed at a specific normal load and for a specific hydraulic gradient, or for very long term test (i.e. several years), compressive creep boxes applying appropriate boundary conditions in parallel with the usual water flow capacity test device in accordance with NF EN ISO 12958.

The second method consists in assessing separately the two reduction factors RF_{CR}(t – t = 8min) and RF_{IN} (t-t=8min). To assess the reduction factor only linked to the compression creep of the drainage core RF_{CR}(t – t = 8min), three main methods can be applied:

- Measuring over time the water flow capacity of a specimen compressed in the water discharge capacity cell with Rigid/Rigid boundary conditions (Touze-Foltz et al. 2014);
- Performing a compressive creep tests (according to NF EN ISO 25619-1 (Afnor 2009 for example) and measuring at various times the water flow capacity with R/R boundary conditions (Böttcher 2006);
- (#1) Performing a complete compressive creep tests, according to NF EN ISO 25619-1 (Afnor 2009) in order to determine the long term thickness of the geocomposite from the compressive creep curve of the geocomposite; (#2) determine the short term compressive curve of the geocomposite according to NF EN ISO 9863-1 (Afnor 2016) and from this curve determine the compressive stress corresponding to the long term thickness; (#3) determine the long term water flow capacity for R/R boundary conditions at the compressive stress determined in #2; this method is described in Müller and Saathoff (2015); if F/F boundary conditions are used in #3, this takes into account only the immediate effect of intrusion phenomenon; other authors applied some variant of this method like Jarousseau and Gallo (2004).

To assess the reduction factor only linked to the intrusion phenomenon in the drainage core RF_{IN}(t – t = 8min), two main methods can be applied:

- Measuring over time the water flow capacity of a specimen compressed in the water discharge capacity cell with F/F boundary condition and compare these measurements with those of another specimen tested in R/R boundary condition (Touze-Foltz et al. 2014);
- Performing a compressive creep test according to NF EN ISO 25619-1 (Afnor 2009) for example and measuring at various times the water flow capacity with appropriate boundary conditions; then compare measurements between specimen with R/R boundary condition and specimen with F/F boundary condition (Böttcher 2006; Stoltz and Hérault 2016).

1.3 *Questions raised about the seating time in NF EN ISO 12958 (Afnor 2010)*

There are current discussion in ISO TC 221 WG4 in the framework of the creation of a second part in the NF EN ISO 12958 (Afnor 2010) standard corresponding to a performance test. Many discussions are raised about this new performance test and especially whereas the seating time in the discharge capacity cell should be more than 8 min. From some experimental data previously presented in Touze-Foltz et al. (2014), a discussion is done about the relevance of an increase of this seating time.

2 EXPERIMENTAL PROGRAM

2.1 *Testing apparatus*

The equipment used fulfils the requirements of NF EN ISO 12958 (Afnor 2010). The water flow rate can be determined either by measurements of volume or directly by a gauge. Figure 2 shows a picture of the equipment.

Figure 2. In-plane flow capacity measurement device (Irstea).

2.2 *Geocomposites tested*

The drainage structures (geospacers) of the drainage geocomposites tested are as follows:

- Three-dimensional monofilament structure between two thermobonded nonwoven filters with a seam in the central part of the specimen,
- Cuspated structure covered (not bonded) on both sides by a thermobonded nonwoven filter,
- Symmetrical thermoformed sheet covered (not bonded) on both sides by a thermobonded nonwoven filter, and
- Bi-axial geonet bonded on both sides to a thermobonded nonwoven filter.

2.3 *Testing conditions*

For each geocomposite, two tests are performed using the testing equipment of NF EN ISO 12958 (Afnor 2010): (1) a test between two rigid plates (called rigid-rigid in the following), and (2) a test between two layers of foam (called foam-foam in the following). New layers of foam are used for each test. A single test was performed on a specimen of each drainage geocomposite.

The normal compressive stress applied was equal to 200 kPa and the hydraulic gradient was equal to one in all tests.

Measurements of the flow rate were performed at 8, 15, 30, 60 minutes, 2, 6, 24 hours, 2, 3, 4 and 7 days.

3 RESULTS

3.1 *Flow rate reduction over time*

Figure 3 to 6 show the evolution with time of the flow rate reduction for the four tested geocomposites.

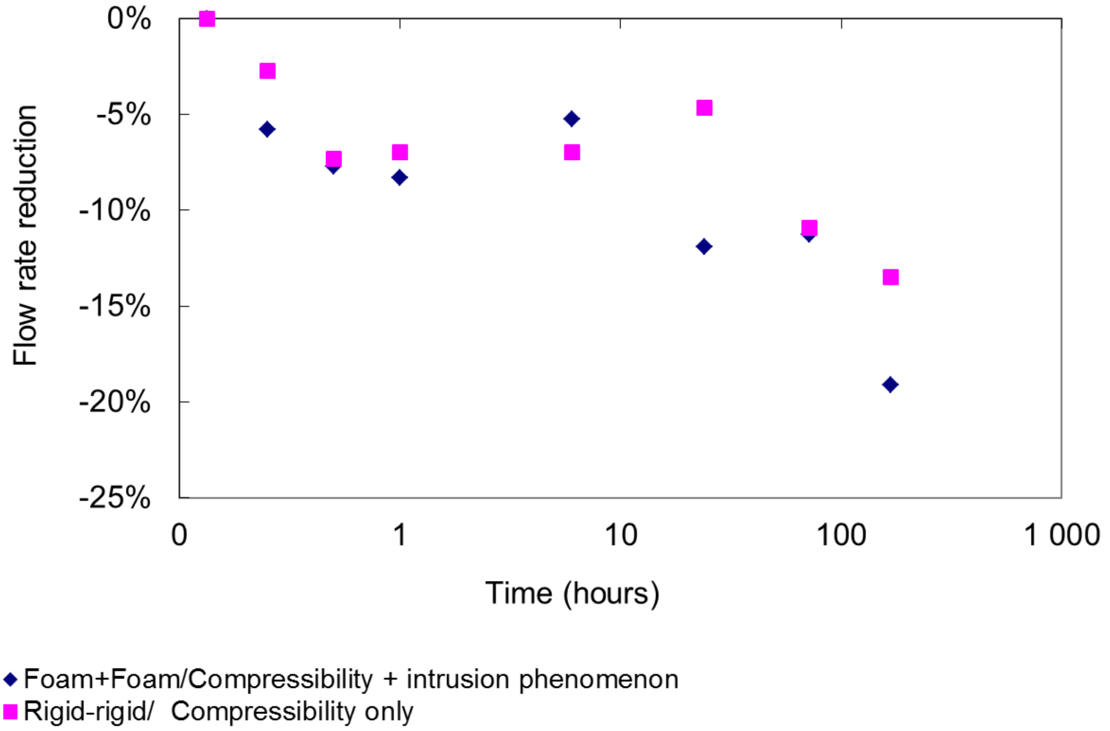

Figure 3. Results obtained with the three-dimensional monofilament structure between two filters with a seam in the central part of the specimen.

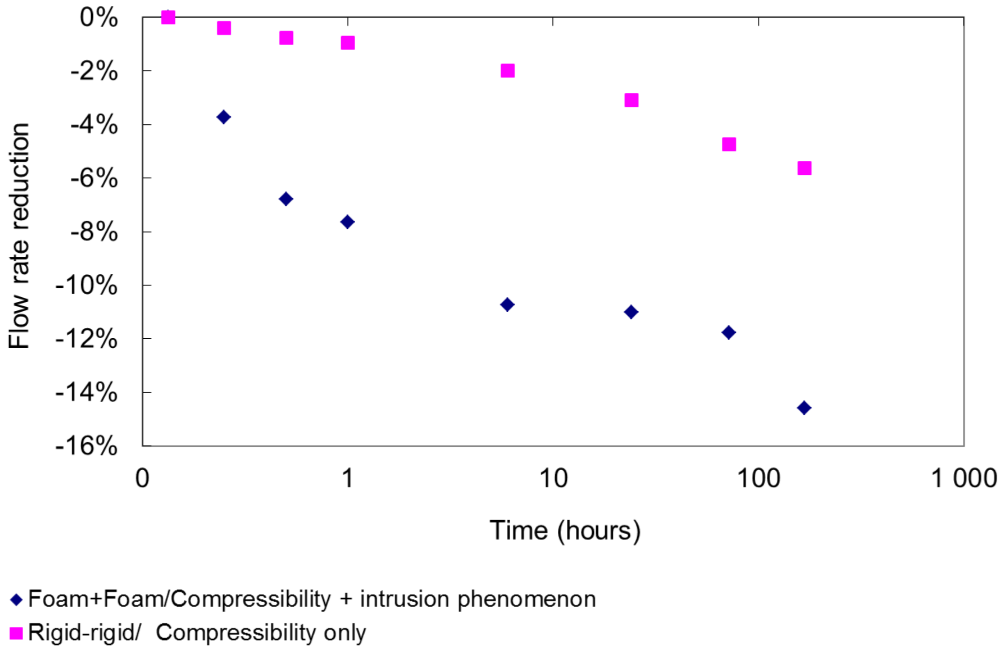

Figure 4. Results obtained with the cuspated structure covered (not bonded) on both sides by a filter.

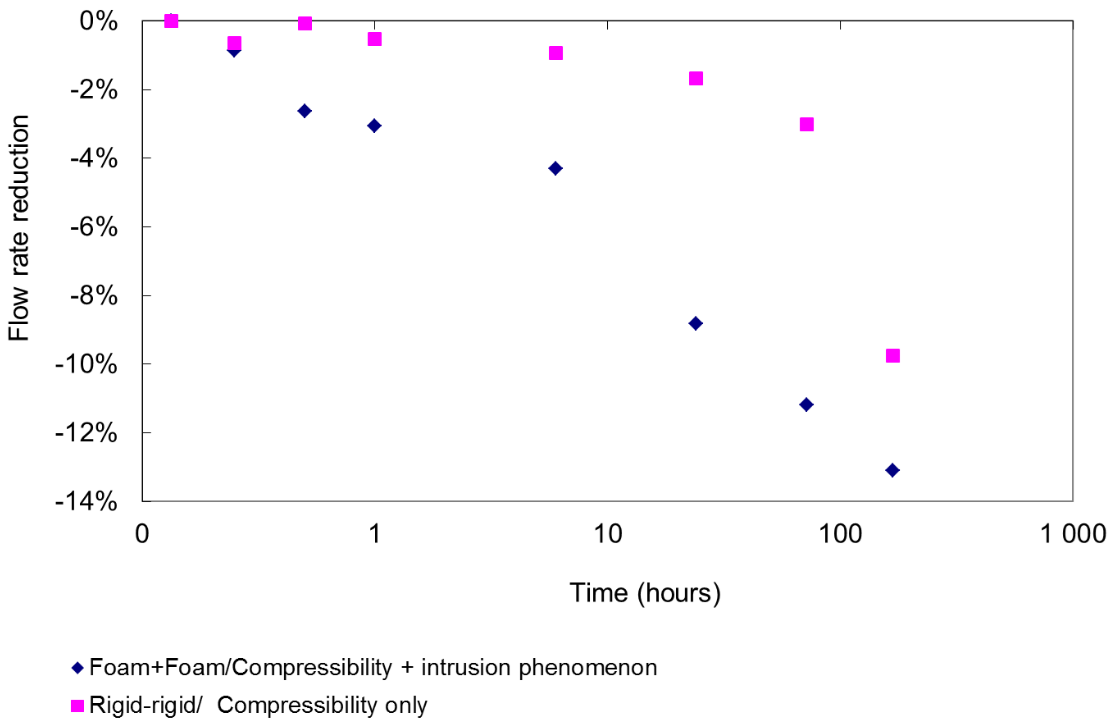

Figure 5. Results obtained with the symmetrical thermoformed sheet covered (not bonded) on both sides by a filter

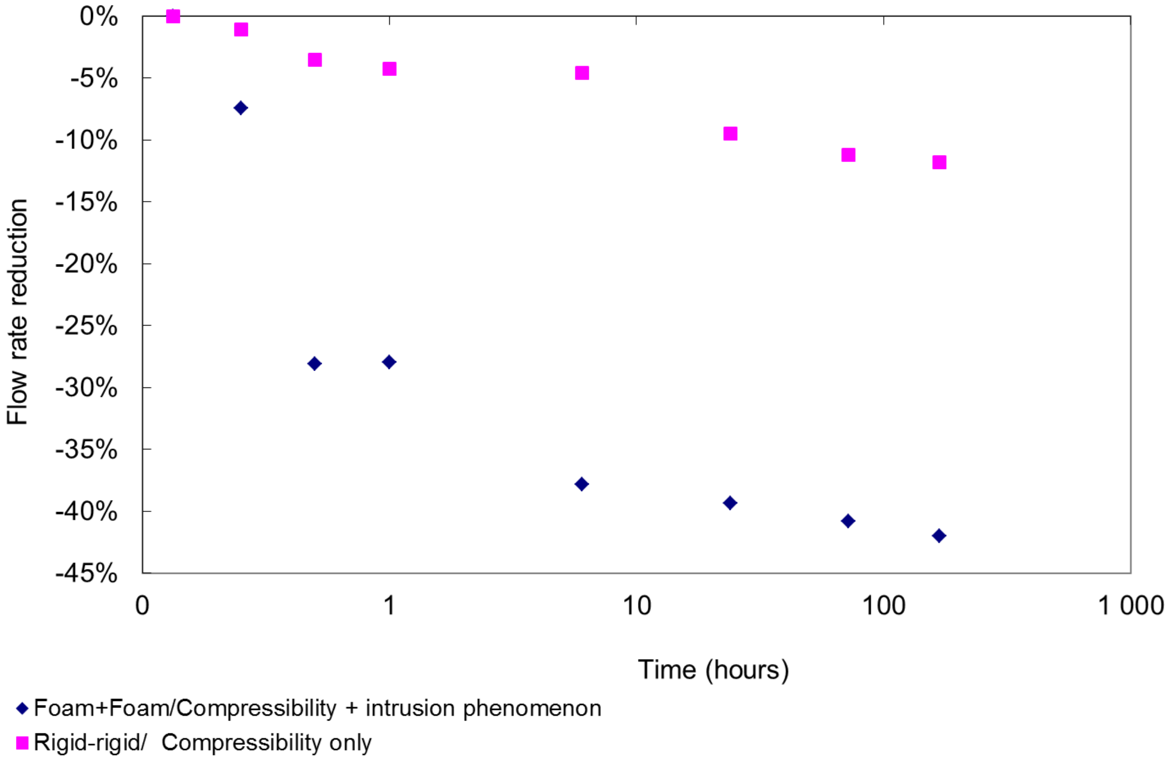

Figure 6. Results obtained with the bi-axial geonet bonded on both sides to a filter

3.2 *Reduction factors*

From the experiments with Rigid/Rigid boundary conditions (no intrusion phenomenon), the reduction factor link to the compression of the drainage core only RF_{CR} (t – t = 8 min) can be easily assessed from the equation 2. Figure 7 shows the evolution over time of this reduction factor for the four tested geocomposites.

To assess the reduction factor linked to the intrusion phenomenon RF_{IN} (t – t = 8 min), the two experiments with Rigid/Rigid and Foam/Foam conditions can be considered, based on the hypothesis that the reduction factor RF_{CR} does not change for the two boundary conditions (R/R and F/F). Based on equation (2), RF_{IN} (t – t = 8 min) can be assessed as follow:

$$RF_{IN}(t-t=8\text{min}) = \frac{q_{12958}^{F/F}(t=8min)}{q_{12958}^{R/R}(t=8min)} \times \frac{q_{12958}^{R/R}(t)}{q_{12958}^{F/F}(t)} \tag{3}$$

Figure 8 shows the evolution over time of the reduction factor RF_{IN} (t – t = 8 min) for the four tested geocomposites.

For all tested geocomposites, it is shown on Figure 7 an increase of the reduction factor linked to the compression of the drainage core only RF_{CR} (t – t = 8 min) over the 7 days .Concerning the reduction factor linked to the intrusion phenomenon RF_{IN} (t – t = 8 min) displayed on Figure 8, it seems to be stabilised for the geocomposite with 3D monofilament structure. For the geocomposites with cuspated structure and bi-axial geonet, the tested time of 7 days was too short to state if RF_{IN} (t – t = 8 min) was stabilised or not at the end of the experiment. Lastly, for the symmetrical thermoformed sheet, it can be said that RF_{IN} (t – t = 8 min) was not stabilised after 7 days.

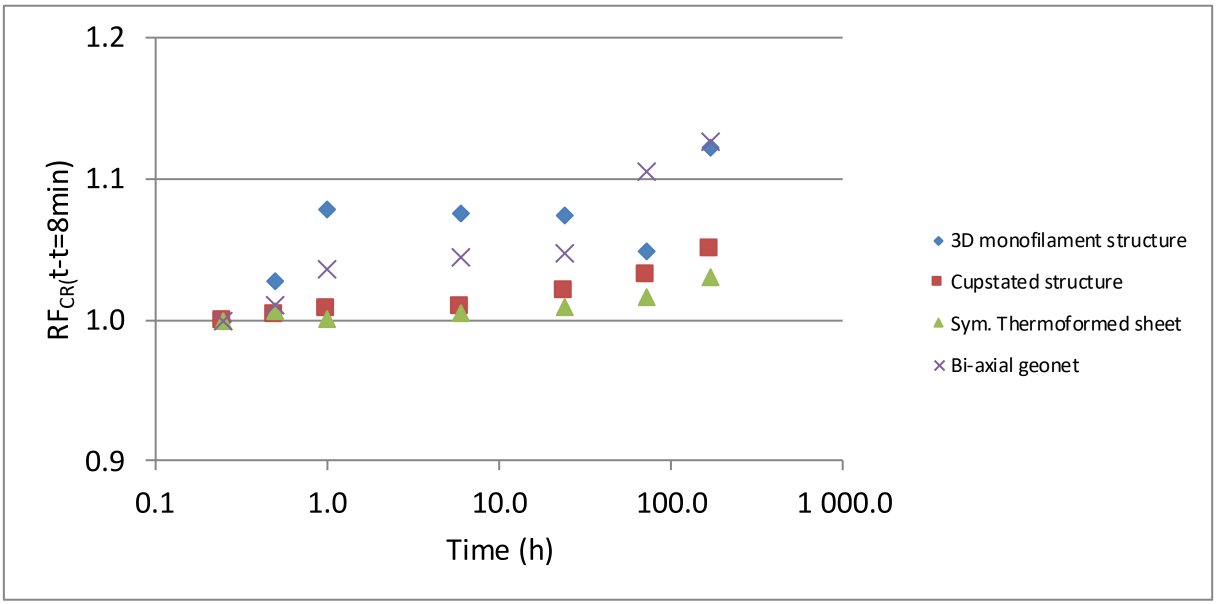

Figure 7. RF_{CR} (t – t = 8 min) for the four tested geocomposites

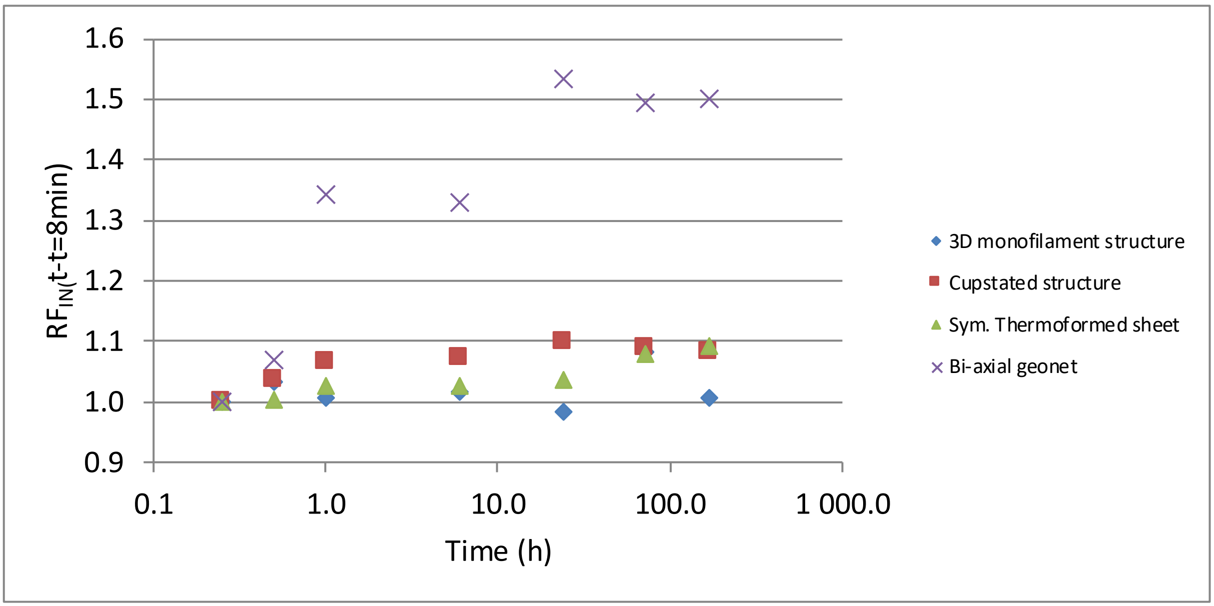

Figure 8. RF_{IN} (t – t = 8 min) for the four tested geocomposites

4 DISCUSSION

From the results, it can be said that, given the various drainage geocomposites, the intrusion phenomenon can act on the long term, which is at least superior to 7 days. The determination of the two reduction factors RF_{CR} and RF_{IN} has to be done once the discharge capacity measurement is made, that is to say after the seating time. In the current index test described by NF EN ISO 12958 (Afnor 2010) standard, the seating time is equal to 8 min so the reduction factors that have to be determined are RF_{CR} (t – t = 8 min) and RF_{IN} (t – t = 8 min). If the seating time changed, other reduction factors have to be determined: RF_{CR} ($t - t_{seating\ time}$) and RF_{IN} ($t - t_{seating\ time}$). In any case, an increase in the seating time does not induce an economy about the determination of one reduction factor. For the authors, based on our experience, in the case of a new performance discharge capacity test, the most crucial parameter is the heterogeneity of the product and it would be more relevant to increase the number of tested specimens than the seating time.

5 CONCLUSION

To assess the in-plane flow capacity, for a given normal stress, hydraulic gradient and for a specific interface conditions (foam/foam to represent soil/soil in-situ conditions or rigid/foam for usual landfill applications or rigid/rigid in more specific applications), the considered standard is the NF EN ISO 12958 that gives a measurement on the very short term (8 minutes for the minimum time in the case of measurement made by discharge gauge, and for only one tested hydraulic gradient and normal stress).

The assessment of the long term in-plane flow capacity following NF G38-061 can be done by dividing the short term in-plane flow capacity by two reduction factors: RF_{CR} related to the creep compression of the drainage core and RF_{IN} related to the intrusion phenomenon of the geotextile filters in the drainage core.

From several tested geocomposites, it is shown that RF_{IN} related to the intrusion phenomenon can increase over a period superior to 7 days. There is still a remaining work to define a relevant testing procedure for assessing RF_{IN} on the very long term, which is needed to design sustainable structures including drainage geocomposites.

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