Long term filter intrusion phenomenon in several types of drainage structures

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ABSTRACT: Short term intrusion phenomenon of fleeces in the drainage cores is taken into account in the product performances by using the appropriate contact surfaces Rigid/Foam or Foam/Foam in the in plane water flow capacity test (EN ISO 12958). The consequences of both these options on the hydraulic performances of the drainage products depend on the normal stress, the type of the drainage core, the space between fleece/core contact areas, the properties of the fleece, and whether the fleece is added on site or in a factory. This paper is based on testing program designed to follow the intrusion phenomenon on the long term under a normal stress of 100 kPa. Several drainage composites with various drainage core structures are tested.

Keywords: water flow capacity, contact surfaces, compressive creep, intrusion, arching effect

1 INTRODUCTION

The European standardization (CE making) and the French certification (ASQUAL) require for geosynthetic materials for use in filtration and drainage that a value of in-plane flow capacity be given. These materials shall be tested in the laboratory according to the international standard EN ISO 12958 (AFNOR 2010). One of the measurement parameters is the normal compressive stress applied to the product. This normal compressive stress shall be applied to the geosynthetic located either between two foam layers, to simulate the presence of a soil on both sides of the geosynthetic, or a foam layer and a rigid plate to simulate for example the presence of concrete on one side. The application of the normal compressive stress for the geosynthetic located between two rigid plates is not accounted for in the standard as it is not representative of in-situ conditions.

The design of drainage systems involving geosynthetics following the French standard NF G 38-061 (AFNOR 2016) considers two mechanical phenomena: the reduction in thickness of the geosynthetic versus time (creep) and the second one is related to the potential for intrusion of the filter into the geonet/geospacer (see Figure 1). They can be studied jointly by applying the appropriate option rigid plate / foam layer or foam layer / foam layer during the complete assessment process of the long-term water flow capacity of the product and lead in this case to a unique reduction factor or they can be studied separately through two reduction factors applied to the short term in-plane flow capacity. The factor related to the compressive creep of the drainage core clearly depends on time and data from the literature show that values can range between 1.1 and 4.2 depending on the drainage core (Jarousseau and Gallo, 2004).

Touze-Foltz et al. (2014) show that the second factor related to the intrusion of the geotextile into the drainage core in contact with soil depends on the type of the drainage core. Following their study, this reduction factor can increase with time (evolution assessed during 7 days) but the effect of long term is still in question.

Discussion is in progress in ISO working groups to define the best methodology for assessment of long term water flow capacity of drainage composites, particularly regarding the impact of the intrusion phenomenon over the product performances. There's an agreement to consider that the degree of fleece intrusion depends on the normal load applied on the drainage geocomposite, the stiffness of the fleece, and the drainage core structure, particularly the space between contact areas of the core with the fleeces. The main issue is now to define the needed testing time, the adjacent material in contact with the composite during creep test and how best to simulate the possible field conditions during discharge capacity testing.

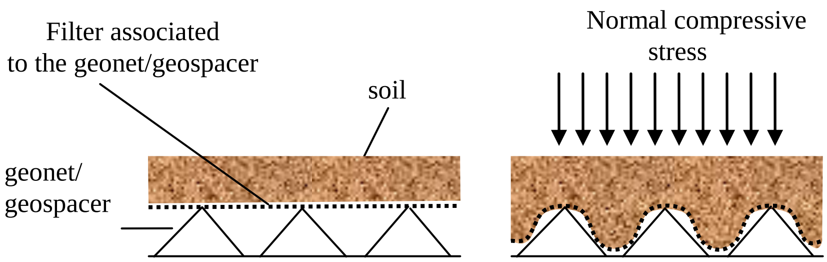


Figure 1: Intrusion phenomenon of the filter layer into the drainage core (from Touze-Foltz et al., 2014)

2 EXPERIMENTAL PROGRAM

2.1 *Testing apparatus*

The testing program used specific three tailor made apparatus designed to carry out compression creep tests under constant normal stress of 100 kPa on geosynthetic specimens of 200 mm x 320 mm. Three contact surfaces are considered in this study:

- rigid/rigid (R/R): the rigid plates used are not deformable under the testing load
- foam/foam (F/F): two foams that fulfill the requirements of EN ISO 12958 are insert between each rigid plate and the geosynthetic specimen
- soil/soil (S/S): between each rigid plate and the geosynthetic specimen, a three-centimeters thick sand layer (see description in 2.2.1) retained on the border by an hollow rectangle made in very compressible polystyrene

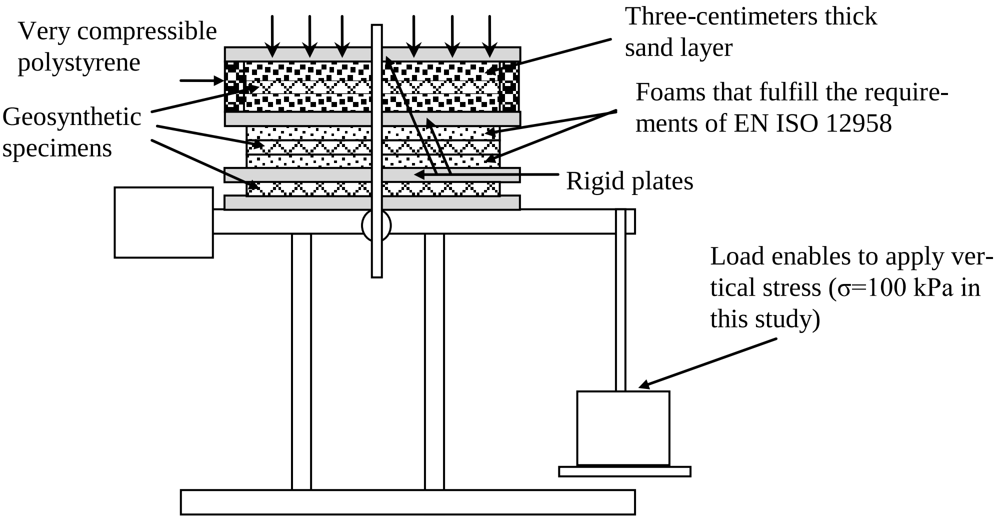


Figure 2: Apparatus for compression creep test under three specimens of a geosynthetic sample with three different contact surfaces (rigid/rigid ; foam/foam ; soil/soil)

Discharge capacity tests were carried out in apparatus which fulfill EN ISO 12 958 requirements (Figure 3).

Figure 3: In-plane flow capacity measurement device (Irstea)

2.2 *Materials*

2.2.1 *Soil used in the compression creep test*

We tried to simulate the actual field conditions in the compressive creep test by using a sand, derived from a mixing of three sand, that fulfills the opening size test requirements EN ISO 12956. The thickness of each sand layer on both sides of the specimen is equal to 3 cm. Soil compaction parameter is not relevant for sand.

2.2.2 *Contact materials for water flow capacity test*

Regarding water flow capacity tests, all specimens were tested between two foam layers in accordance with EN ISO 12958.

2.2.3 *Geocomposites*

Three types of drainage structures were tested: two 3D monofilament structures and one geonet (Figure 4).

- Rigid geonet (Figure 4) with needlepunched geotextile 120 g/sqm (technical data sheet value according to EN ISO 9864), thickness of the geocomposite = 5.8 mm (technical data sheet value according to EN ISO 9863-1);
- Semi-compressible heterogeneous 3D monofilament structure (Figure 5) with needlepunched geotextile 120 g/sqm (technical data sheet value according to EN ISO 9864), thickness of the geocomposite = 5.0 mm (technical data sheet value according to EN ISO 9863-1);
- Semi-compressible uniform 3D monofilament structure (Figure 6) with needlepunched geotextile 110 g/sqm (technical data sheet value according to EN ISO 9864), thickness of the geocomposite = 4.2 mm (technical data sheet value according to EN ISO 9863-1)

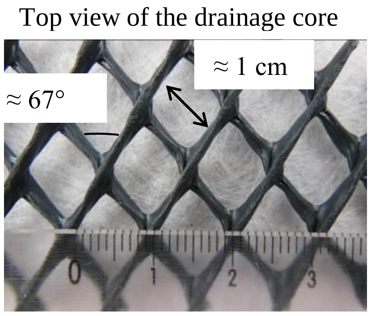


Figure 4: Typical plan view of the drainage core of rigid geonet

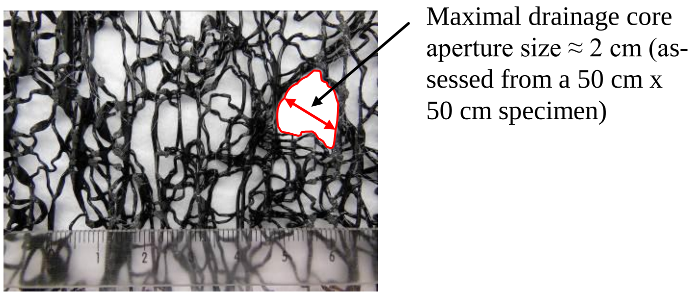


Figure 5: Typical plan view of the drainage core of semi-compressible heterogeneous 3D monofilament structure

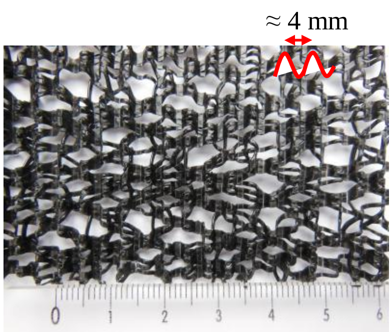


Figure 6: Typical plan view of the drainage core of semi-compressible uniform 3D monofilament structure

2.3 *Testing procedure*

The testing procedure used consisted of applying over three specimens of each product a long term normal stress of 100 kPa, between two rigid plates for the first specimen, between two foam layers as described in EN ISO 12958 for the second specimen and between two sand layers for the third specimen (Figure 2).

The specimens are extracted from the compressive creep test devices several times during the test duration, to measure, under 100 kPa, their in plane water flow capacity in accordance with EN ISO 12 958 for hydraulic gradients i = 1.0, with Foam/Foam option for all specimens. Specimens are reinstalled in the compressive creep test apparatus after each water flow capacity measurement.

The results are used to assess for each product the time effect on the intrusion phenomenon under a normal stress of 100 kPa, which can occur in the case of foam/foam and soil/soil contact layer, unlike the case of rigid/rigid contact surface.

3 RESULTS

3.1 *Methodology of analysis*

In the rest of the document, we will consider:
q0 = short term flow rate obtained with foam/foam boundary conditions measured at t=0.
q = long term flow rate obtained with foam/foam boundary conditions measured at t.
RFin = Reduction factor for the intrusion of filter geotextiles into the draining core, due to tensile creep of the geotextile, occurring after the short term test.
RFcr-Q = Reduction factor for impact over the flow rate of the thickness reduction due to compressive creep of the core.

Since clean water is used, we can consider there will not be any clogging during this test pro-gram, therefore RFcc for chemical clogging and RFbc for biological clogging are equal to 1.0.

In these conditions, we can write q/q0 = 1/(RFin.RFcr-Q) with RFin =1.0 when the compressive creep test is carried out between two rigid plates. Moreover, considering no impact of the boundary conditions over the thickness reduction of the draining core, RFcr-Q is the same for the three test conditions.

Therefore, RFin can be calculated with the ratios:

$$RFin\ (F/F) = \frac{q/q0\ (R/R)}{q/q0\ (F/F)} \qquad (1)$$

$$RFin\ (S/S) = \frac{q/q0\ (R/R)}{q/q0\ (S/S)} \qquad (2)$$

3.2 *Rigid geonet drainage core*

The decrease of the water flow capacity of the geonet structure in foam/foam conditions is equal to 36 % after 6 months when creep contact material is Rigid/Rigid, it increases to 66 % when creep contact material is Foam/foam and 77% when creep contact material is Sand/Sand. Reduction factor RFin due to fleece intrusion on long term can be assessed to a value ranging from 1.9 (case F/F) to 2.8 (case S/S). As values from F/F are close to those from S/S, no arching effect occurs.

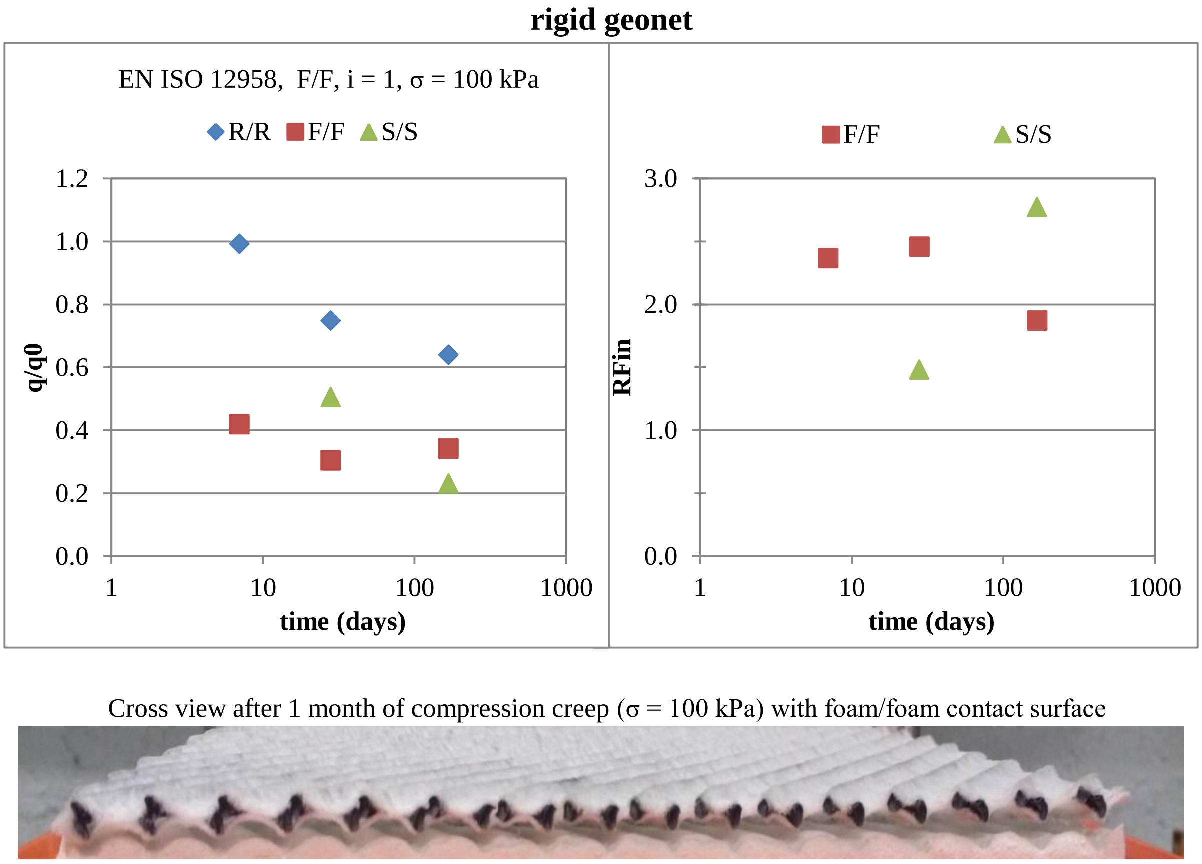
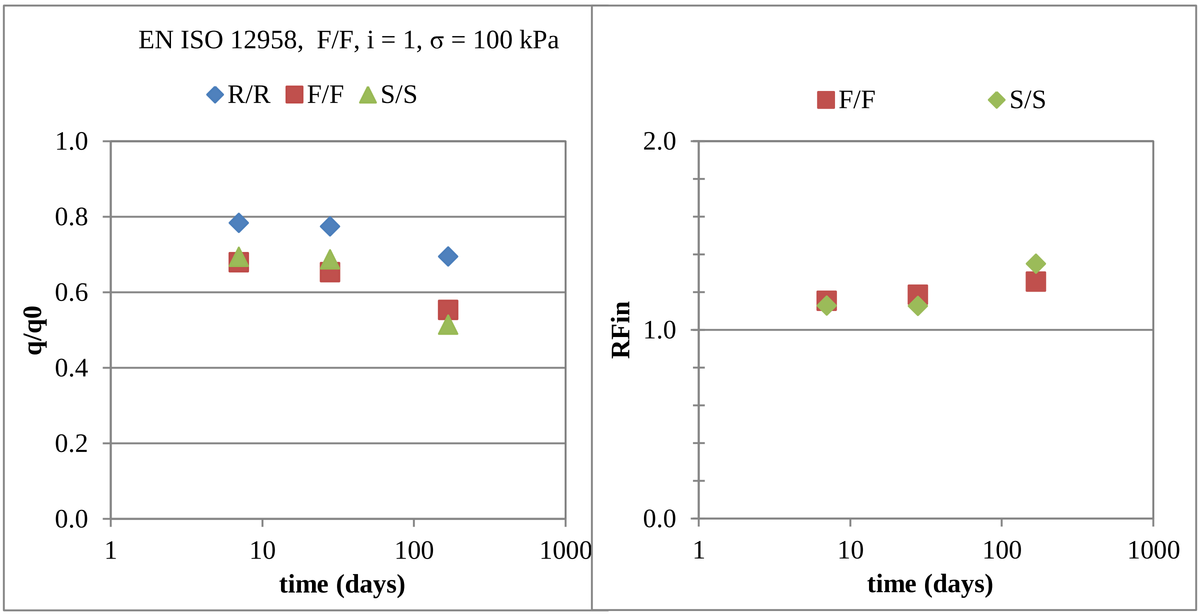


Figure 7: Water flow capacity (Foam/Foam, i = 1.0, 100 kPa) decrease of rigid geonet for three compressive creep conditions (Rigid/Rigid – Foam/Foam – Sand/Sand) and corresponding reduction factor RFin

3.3 *Heterogeneous 3D monofilament structure*

The decrease of the water flow capacity of the heterogeneous 3D monofilament structure in foam/foam conditions is equal to 31 % after 6 months when creep contact material is Rigid/Rigid, it increases to 45 % when creep contact material is Foam/foam and 49 % when creep contact material is Sand/Sand. Reduction factor RFin due to fleece intrusion on long term can be assessed to a value ranging from 1.3 (case F/F) to 1.4 (case S/S). As values from F/F are close to those from S/S, no arching effect occurs.

semi-compressible heterogeneous 3D monofilament structure



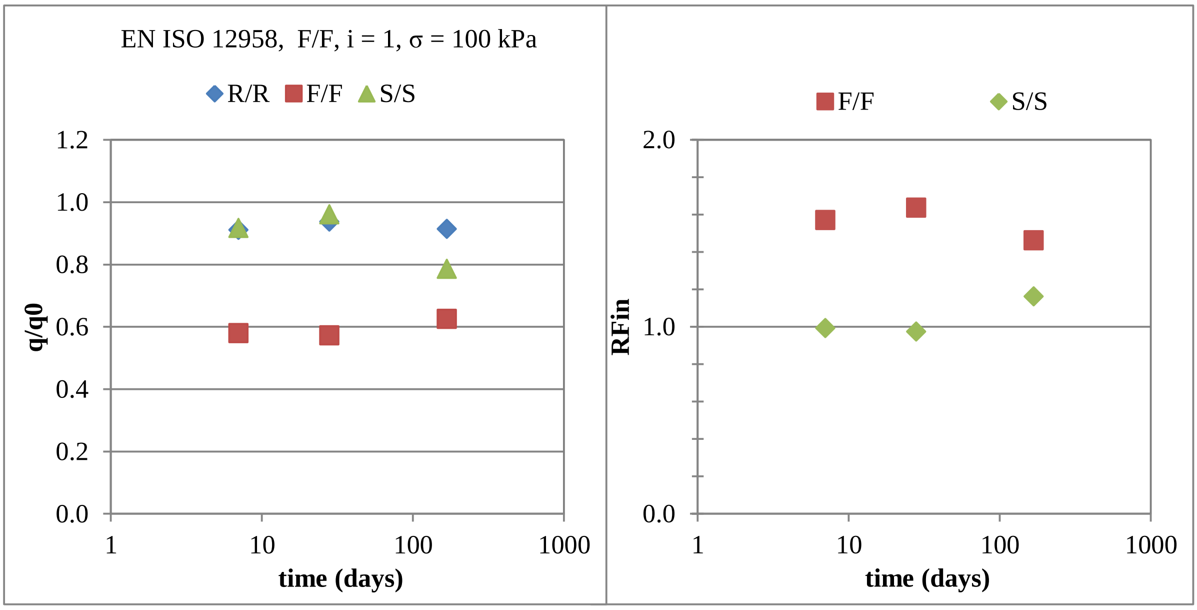
Cross view after 1 month of compression creep (σ = 100 kPa) with foam/foam contact surface

Figure 8: Water flow capacity (Foam/Foam, i = 1.0, 100 kPa) decrease of semi-compressible heterogeneous 3D monofilament structure for three compressive creep conditions (Rigid/Rigid – Foam/Foam – Sand/Sand and corresponding reduction factor RFin

3.4 *Uniform 3D monofilament structure*

The decrease of the water flow capacity of the uniform 3D monofilament structure in foam/foam conditions is equal to 9 % after 6 months when creep contact material is Rigid/Rigid, it increases to 37 % when creep contact material is Foam/foam and 21 % when creep contact material is Sand/Sand. Reduction factor RFin due to fleece intrusion on long term can be assessed to a value ranging from 1.2 (case S/S) to 1.5 (case F/F). At 7 and 28 days of compression creep, arching affect is observed (values from S/S condition close to those of R/R condition, RFin = 1.0) probably due to a smaller aperture size of the drainage core (see Figure 6) but this effect disappears after the reinstallation of the specimen at 28 days. It has to be noticed here that since t=0 to t=6 months, F/F condition leads always to conservative values versus S/S condition .

semi-compressible uniform 3D monofilament structure



Cross view after 1 month of compression creep (σ = 100 kPa) with foam/foam contact surface

Figure 9: Water flow capacity (Foam/Foam, i = 1.0, 100 kPa) decrease of semi-compressible uniform 3D monofilament structure for three compressive creep conditions (Rigid/Rigid – Foam/Foam – Sand/Sand and corresponding reduction factor RFin

4 CONCLUSION

The testing process developed in this paper enables the assessment of the actual long term impact of the intrusion phenomenon. It is clearly shown that appropriate contact surfaces have to be used in the creep test as well as in the discharge capacity test, otherwise, the long term water flow capacity can significantly be overestimated for some drainage structures types. The water flow capacity of a drainage geocomposite measured between two foam layers in accordance with EN ISO 12958 after creep test with rigid boundary conditions doesn't provide the same results when the creep test is carried out with soft boundary conditions, whether with soil layer or foam.

The effect of a foam material over long term intrusion phenomenon has been checked: it leads to conservative values versus actual field conditions if arching effect can be developed in the soil layer, as was the case during 28 days on the product with the smaller aperture size. In the other cases, soil induces stronger water flow capacity reduction than foam.

Results show that the reduction factor RFin can increase with time, depending of the draining core structure which proves that the intrusion phenomenon can have on long term significant impact of the product performance. The compression creep tests have to go on to fully assess the impact of the intrusion phenomenon on the very long term. At six months of compression creep, values of reduction factor RFin ranging from 1.2 to 2.8, depending on the product, for a normal load of 100 kPa and hydraulic gradient equal to 1.0. These differences are particularly due to the various draining core aperture size that is a relevant and main parameter to qualify the sensitivity of a drainage core to fleece intrusion.

5 ACKNOWLEDGEMENTS

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