Influence of joints on transmissivity of drainage geocomposites

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Keywords: Geocomposite, Transmissivity, Joint, Discontinuity, Draining system

ABSTRACT: Hydraulic and mechanical properties of drainage-geocomposite are measured in the laboratory and on current part, as for all geosynthetic materials. However particular sites conditions result in differences in operation between the specimen tested in the laboratory and that in place. Many factors of influence had ever been determined but not always quantified. A test program was therefore carried out to quantify the effects of the joints between two strips on the transmissivity of the system. The tests involve the commonest types of draining geocomposite. The effects of joins in these products were measured for flow parallel and perpendicular to the join. They seem indicate different performances depending on nature of geocomposite.

1 INTRODUCTION

The presence of water in soil is often synonymous with disorders for geotechnical structures. Indeed, water causes a change in the mechanical properties of the soil, leading to the breakdown of embankments, the liquefaction of saturated soils and the destabilization of excavation bottoms.

To protect the stability of structural works, it is essential to evacuate the water.

Soil drainage presupposes transporting water and also maintaining the soil in place. Geosynthetics have been operating as drain and filter for several years, as a replacement for the traditional solution using granular material. Because they have to fulfill two roles, these geosynthetics usually comprise several parts: a draining core associated with one or two filters. In this case, they are referred to as drainage geocomposites.

The association of several components obviously leads to a diversity in terms of behavior.

Drainage geocomposites are fully defined by their hydraulic and mechanical properties. However, transmissivity or a flow capacity in plane, according to the European standard, is the basic property because it is significant of the draining behavior.

Transmissivity is measured in the laboratory on samples complying with a standard, for instance EN ISO 12 958, which specifies the gradients, stresses and contact surfaces.

In this case, we can wonder if:

- the test conditions are truly representative of the site mechanical and hydraulic conditions.
- the short-term laboratory results actually represent the long-term behavior (by extrapolation …)
- the characteristics obtained with samples truly represent the characteristics of the system (including connections)

More often than not, a failure to answer these questions will lead to oversizing by the application of safety factors and, on the other hand, failure to take these aspects into consideration will lead to undersizing.

The determine of the factors liable to influence transmissivity may allow designing to be adjusted. Some countries are already attempting to incorporate in their specifications or recommendations reduction factors of the flow that these geocomposites can evacuate (German, according to GDA 1997 recommendations, uses factors determined by Koerner (1994)).

Therefore, the purpose of this article is to take our knowledge of these factors a little further. Initially, the meaning of the various reduction factors is indicated, then we move on to the main results obtained so far. Finally, results concerning the influence of connections on transmissivity are discussed.

2 REDUCTION FACTORS CONCERNING TRANSMISSIVITY

Several phenomena may lead to the reduction of the void index or the modification of their organization, resulting in transmissivity loss.

- the nature of the filter geotextile(s).

The association of a filter or filters on a draining core reduces transmissivity in different proportions, depending on the type of filter(s).

Geotextiles with considerable deformability tend to obstruct voids under the effect of compression stresses on the geocomposite, and more particularly on contact with soft ground. From this point of view, heat-bounded non-woven geotextiles behave better than needled-punched materials. In addition, this difference between geotextiles tends to increase in proportion to the stresses.
Therefore, for the same draining core, a change of geotextiles or of the core / geotextile assembly mode considerably modifies the properties. That is why products obtained by assembly on site differ entirely from ready-to-use finished products.

- the type of contact surfaces.

The presence of soft ground, simulated by foam for transmissi-vity tests, and under the effect of compression stress, causes the filter geotextile to begin obstructing the conduits or voids in the geocomposite, in particular for the draining cores, the surface of which does not have a sufficiently continuous or closed surface pattern (studs or conduits).
Zhao and Montanelli (1999) compared the transmissivity obtained between 2 rigid steel plates and sand or clay. They observed that the bigger the reduction factor, the smaller the hydraulic gradient.

For a stress of 720 kPa, they obtained reduction factors ranging from 1.5 to 20.6, depending on the type of geocomposite and the nature of the soil in contact with it.

Zhao and Montanelli performed very specific tests, but the contact surface areas mentioned by the French and European standards for laboratory testing (rigid plate, foam and inflatable membrane) are sufficient to determine their influence on transmissivity. Indeed, there is an evident loss of 60% of transmissivity when a test is performed with two rigid plates, then two layers of foam.

Accordingly, it is important to bear in mind that the contact surface, during the transmissivity test, has to be appropriate to the subsequent application of the product and reproduce conditions that are least favorable for this application.

- Compression stresses.

Several studies have already demonstrated just how much compression can reduce geocomposite transmissivity. This decrease is essentially due to the reduction in the thickness of the draining core and the intrusion of the geotextile into the voids.

Gardoni and Palmera (1999) brought this compression stress up to 2000 kPa to perform transmissivity tests after deformation stabilization. The reduction factors obtained on different products vary in a very wide range extending from 100 to 1,000.

The loss of transmissivity under compression depends effectively on the behavior of the geocomposites when they are exposed to a constraint. The transmissivity of "compressible" products decreases by 80% when the stress changes from 50 to 200 kPa, whereas the "incompressible" products only lose 40% of their transmissivity.

- Damage on implementation.

The determination of a reduction factor related to the implementation of geocomposites is made more difficult because there is no normalized test method for draining products. However, an experimental European standard (ENV ISO 10722-1) establishes a procedure for laboratory evaluation of damage on geotextile implementation. However, "comparison of the results with those observed on site indicates that this standard is severe and is barely representative of the various situations on site." Khay (1999).

- Mineral clogging / biological clogging.

Theoretically dimensioned to allow fine soil particles to pass while retaining the supporting structure, the filter geotextile is applied so as to assist and accelerate the forming of a natural granular filter. Clogging may lead to the appearance of a sealed coat making it impossible to evacuate the water.

Clogging resulting from the precipitation of mineral, carbonate or oxide salts results in a reduction of the hydraulic and mechanical characteristics of the filters (Cazzuffi & al (1991)). The same applies to the biological clogging caused by the development of bacterial populations.

Clogging can also reduce the volume of voids in the draining core.

But the draining core of the geocomposite is less sensitive to clogging than the filter itself because the openings for water flow are relatively large.

Therefore, the type of clogging can be determined, but knowledge of its influence upon mechanical and hydraulic characteristics requires long-term testing. Data acquisition is therefore a tedious task, but is indispensable for evaluating the reduction factors.

- Connections.

Discontinuity at the connections is an important factor concerning both the product and its implementation. The implementation of draining geocomposites may have substantial influence upon the hydraulic behavior at the join.

Transmissivity measurements in the laboratory are carried out on a basic section of the product. However, transmissivity at the joins cannot be the same as measured in a basic section. The join is in fact a discontinuity of the material. Indeed, depending on the type of geocomposite, hydraulic properties at the join differ because the join can be made with or without overlapping by geotextile, by bonding or by the juxtaposition of the cores. To allow for this diversity of joins, transmissivity tests have been performed on different types of geocomposites.

3 MATERIALS AND METHOD

3.1 *Drainage composites*

Four different drainage composites were submitted to tests. The choice was made so that their structure was representative of different types of products currently available on the market. Their characteristics are presented in table 1. All the geocomposites were made of one core and two geotextiles.

The drainage core of geocomposite C_2 was made of an association of perforated tubes and needle-punched geotextile.

Table 1: drainage composites description

Reference	Core type	Filtration geotextile type
NC_1	Egg box	Heat-bounded
C_1	Entangled mesh	Heat-bounded
NC_2	Extruded net	Heat-bounded
C_2	Tube + GTX	Needled punched

Test specimens were cut from three different places on the roll. The first was in the middle of the strip, for continuous piece transmissivity measurement. The two others were taken at the extremity and on the border of the roll. In each case, sampling was made in both machine and cross direction. Sampling locations are presented in Figure 1, where longer dimension corresponds to direction of flow during the test.

Sampling on the edges of the roll was made so that the core of the composite was in the middle of the sample, whatever the direction of sampling. The same procedure was followed when a geotextile was longer than the core, for overlapping.

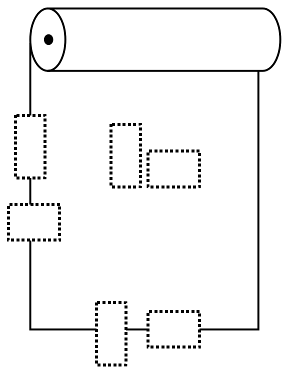

Figure 1: Sampling locations and orientations

3.2 *Method*

The transmissivity tests were performed according to the former French standard NF 38-018. This test consists in submitting a specimen of geotextile to an in-plane flow. The specimen of geotextile is placed between two foams, and confined under different stresses. The effective dimension of the specimen is 20 cm in width and 30 cm in length.

This test differs from others transmissivity tests in that mea-surements are made after stabilization of the thickness of the specimen. The time necessary for stabilization is determined before the test, by submitting a complex made of the specimen to be tested and the two foams to a creep test under desired mechanical compressive stresses. The stabilization is supposed to be reached when the decrease of thickness is less than 0.1 mm in 10 min. For the tested products, the stabilization time was up to 40 minutes.

3.3 *Procedure*

Transmissivity tests were performed under a confining stress of 100 kPa with a hydraulic gradient of 0.2. This conditions were thought to be representative of common fields conditions.

Tests on joins were performed considering the on-site functioning of drainage composites. As strips may not be exactly parallel to slopes transmissivity of extremity and border joins were tested in two directions. Nevertheless, as extremity joins are not submitted to flow parallel to the edge, the corresponding tests has not been performed.

To measure transmissivity of joins, the producer’s requirements for installation were followed. For instance, the recommended overlapping of the geotextile of one strip on the other strip was respected. When this overlapping was wider or longer than the cell, it was cut at the appropriate size.

For reference NC_1 , the cores were fitted together on a width of 10 cm, and for others the core were put in closed contact. For reference C_2 , the tubes of the two strips were put in parallel on a length of 20 cm.

Reference C_2 which structure has a strong anisotropy has not been tested with a flow perpendicular to the tubes, what has been thought to be inappropriate.

4 RESULTS

The results obtained are presented in the table below referring to transmissivity in the production direction, expressed on a basis of 100.

Table 2. Transmissivity on basic part and join for different products.

		Basic section		Connection			
		P_1	T_1	P_2	T_2	P_3	T_3
NC_1	Egg box	100	81	120	97	128	×
C_1	Entangled mesh	100	87	57	48	×	×
NC_2	Extruded grid	100	60	150	95	155	×
C_2	Polycomponent core	100	×	×	×	55	×

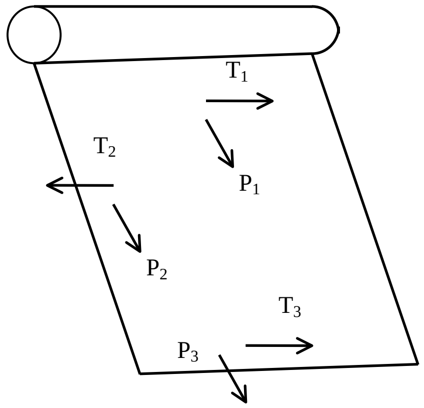

Figure 2. Direction of the flow for transmissivity measures

As a complement to these tests, a test simulating a defective join was made. The physical continuity of the draining cores is no longer ensured, and the cores are 7 mm apart. It is found that transmissivity drops compared to the value obtained for a perfect join.

Table 3. Ratio R between defective join and basic part.

	NC_1	C_1	NC_2
R	0.26	0.18	0.29

The test was not performed for product C_2 . A test of this type on this sort of product would not give the same values, because of the connection mode in the production direction.

The results of the table 3 indicate the influence of a join on a flow perpendicular to it, both for the end of the roll and the edge of the roll.

For columns NC_2 and NC_1 , it is evident that the values of ratios T_2 / T_1 and P_3 / P_1 are very close (respectively 1.58 and 1.55 for line NC_2 and 1.2 and 1.28 for line NC_1).

In this way, we are able to determine the influence of a join for all the products for flow perpendicular to it.

Ratio $\frac{\text{Joint}}{\text{Current section}}$ (rounded-off values) (1)

Table 4. Ratio between a join and a current section for a flow perpendicular to connection

	NC_1	NC_2	C_1	C_2
$P_3 / P_1 = T_2 / T_1$	1.3	0.6	1.6	0.5

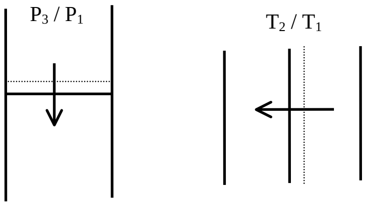

Figure 3. Flow perpendicular to connection

Similarly for flow parallel to connection P_2 / P_1 :

Table 5. Ratio between a join and a current section for a flow perpendicular to connection.

	NC_1	NC_2	C_1	C_2
P_2 / P_1	1.2	0.6	1.5	

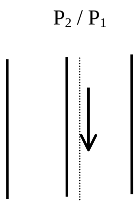

Figure 4. Flow parallel to connection

The previous tables thus indicate that for the same product, similar flows are obtained in both directions, but that behavior differs depending on the type of product.

We observe the following:

- an increase in transmissivity for products NC_1 and NC_2.
- a decrease in transmissivity for products C_1 and C_2.
- a considerable decrease in transmissivity when the cores are at larger intervals for all the products.

5 INTERPRETATION

The results given appear to indicate that for products NC_1 and NC_2 , the transmissivity gain is due to the extra thickness of the geotextile at the connection. Indeed, this limits the decrease in the void volume in the geocomposite, due to compression by the foam. Accordingly, local transmissivity is increased, compensating for the influence of core discontinuity.

A test performed on product NC_2 confirms the origin of the increased transmissivity for products with a semi-rigid core. In reality, transmissivity has been measured for the geocomposite alone, then for the geocomposite covered with a geotextile over the entire surface of the specimen.

The ratio obtained is 1.55, in agreement with ratios T_2 / T_1 and P_3 / P_1 .

On the other hand, for products C_1 and C_2, the phenomenon described previously at the overlap of the geotextile should not occur because of the compressible structure of the cores.

In addition, the phenomenon observed when the cores are no longer in contact is probably due to the creepage of the geotextile between the spaced cores, creating an obstacle to the flow of water.

This result proves just how much implementation can influence the properties of the draining system.

Results obtained in the machine direction and the cross direction enable us to understand the phenomena concerned.

Intuitively, we expect hydraulic discontinuity for joins perpendicular to the flow (fig. 4). The origin of this perturbation would be, theoretically, physical discontinuity between the draining cores of the upstream and downstream strips.

However, the crosswise results, therefore for a join parallel to the flow, demonstrate the same perturbation (fig. 5). The cause is therefore no longer due to the physical discontinuity of the core alone, but to the entire connection zone (including the overlapping of the geotextile).

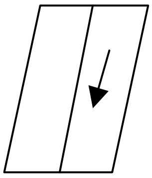

Fig. 5 Flow parallel to connection

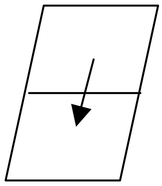

Fig. 6 Flow perpendicular to connection.

6 DISCUSSION

The results of this study show the importance of better knowledge of the properties at the joins. Indeed, it appears that the hydraulic continuity depends on the type of joins themselves (juxtaposed cores, overlapping, etc.), the nature of the cores (more or less rigid) and the overlapping of the geotextile.

All these parameters induce differences in behavior on site, but comparison should not concern the products themselves alone, but the draining systems too.

Indeed, on site, the joins, whether perpendicular or parallel to the direction of flow, create heterogeneous lines respectively at the end of the roll and the edge of the strips. The overlapping areas therefore have a bearing on the drainage behavior.

It is, however, important to refer the surface area on which flow is perturbed to the total surface area of the strips. This ratio obviously depends on the product.

It is seen that the increase in transmissivity concerning products NC_1 and NC_2, is linked with a connection surface area, whereas the loss of transmissivity for products C_1 and C_2, is linked with a line.

Thus, for product type NC_1 and NC_2, we can determine a ratio S / S_R that is representative of the zone on which drainage will be modified.

Where: S = total surface area of a strip.

S_R = effective surface area at the join, also including the overlapping of the geotextile.

(S_R is only calculated for 1 edge of the strip and 1 end of the roll considering the positions of the strips with respect to each other, because there is an upstream section and a downstream section).

For the range of geocomposites investigated here, S / S_R varies from 15.5 to 19.6. The connecting area therefore takes up between 5.1 % and 6.5 % of the total surface area of a strip.

This makes for considerable differences between the products and the variation of the S / S_R coefficient is probably representative of the draining behavior of the system.

For product type C_1 and C_2, the area in which the flow is perturbed does not concern a surface but a length.

To estimate the effect of a set of joins on the operation of a structure, we have to determine the value, referred to as L_R , which gives the length of the connection for a laid strip, associated with it the total surface area of these strips.

Where L_R : 1 length + 1 width

E.g. : for widths of 2m per 100m , L_R = 102, S = 200m²

for widths of 4m per 50m , L_R = 54, S = 200m²

It is evident that the connecting line, the area in which transmissivity drops, is much smaller in the second case, for an equivalent surface area.

Therefore we need to determine for the best the factors representative of the draining behavior of a system. We already know that the coefficients are linked with a line for the products whose transmissivity decreases at the joins.

Concerning the recommendations that will sooner or later be made, acknowledgment of connections in designing should also be modulated by these coefficients.

Zanzinger has also carried out a test campaign concerning the draining geocomposite joins. His results indicate that transmissivity decreases at the joins for a given type of product and increases for others. However, the types of products tested are not mentioned and therefore, we cannot interpret Zanziger's results.

7 CONCLUSION

This study brings us important information concerning the hydraulic operation of geocomposite connections. It contributes to better knowledge of the influencing factors, and therefore to better designing adjustment.

This test campaign has revealed that the transmissivity of so-called "compressible" products decreases in the connecting areas, whether they are at the edge or the end of the lengths. Conversely, for incompressible products, transmissivity is conserved.

The causes of the differences in behavior are described.

Further, it has been demonstrated that a defective connection will lead to a considerable drop in transmissivity, whatever the product. This risk of loss, capable of reaching up to 80%, is not taken into consideration by designing either.

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