Assessment of the long-term water flow capacities of monofilament structures

A. Hérault
Low and Bonar, France (alain.herault@lowandbonar.com)

S. Sama
SKZ – Testing GmbH, Germany (s.sama@skz.de)

ABSTRACT: The in-plane water flow capacity is the significant parameter for the drainage system design, whether the product is made on site or in a factory. The short-term water flow capacity of drainage systems is measured in accordance with the EN standard for given conditions like compressive load, hydraulic gradient and contact surfaces (soft/soft or rigid/soft or rigid/rigid). The impact of the compressive load and contact surfaces on the water flow capacity depends on the type of components, particularly the drainage core structure and the type of filtration geotextile. The study described in this paper evaluates two types of regression (logarithmic and power regression) to simulate the drainage system performance of drainage cores built with a 3D monofilament structure welded or stitch bonded on both sides to a thermally bonded non-woven geotextile. It allows the assessment of the long-term water flow of the product on the basis of spot measurements of water flow capacities including both thickness reduction of the drainage core and the filter intrusion in the drainage core on the long-term. These measurements were carried out during two compressive creep test durations: up to 20 months by SKZ's Geosynthetics laboratory and more than 10 years by Low and Bonar.

Keywords: water flow capacity, contact surfaces, compressive creep, intrusion, regression

1 INTRODUCTION

Discussions are currently taking place to define the best method to assess the long-term water flow capacity of drainage systems (i. e. a drainage geocomposite produced in a factory or a drainage structure covered on one or both sides with a non-woven filter on site).

A first option could be to carry out long-term compressive creep test according to EN ISO 25619-1 between two rigid plates to assess first the residual thickness at the end of the design service life by extrapolation, and then carry out a water flow capacity test at the given residual thickness. One of the issues with this option is the current test standard EN ISO 12958 which considers measurements at a given normal stress only and not at a given thickness.

A second option is to carry out both compressive creep test and water flow capacity tests simultaneously with the appropriate contact surfaces and assess water flow capacity at the end of the design service life with direct extrapolation on water flow capacity performance. The study described in this paper considers this second option.

2 EXPERIMENTAL PROGRAM

2.1 *Testing devices and materials*

The compressive creep tests were carried out in SKZ's Geosynthetics laboratory and in Low and Bonar's laboratory in the similar type of compressive creep test box (blue) as shown in picture 1. This compressive creep test box was designed to carry out creep tests with several types of contact surfaces (Rigid/Rigid, Rigid/Soft or Soft/soft) under normal loads up to 400 kPa.

Picture 1. Blue boxes

The specimen was loaded by means of pressure bags which are placed on top and bottom part of the box. A flexible support is realized by direct contact of the sample with the membrane, a rigid support is realized by metal plates kept between the samples and the membrane. The air pressure on the top and bottom side of the box is monitored using manometers.

The water flow capacity tests were carried out in device as required by the test standard EN ISO 12958 "Geotextiles and geotextile-related products – determination of water flow capacity in their plane".

The tested drainage geocomposites consist of a black colored monofilament structure and grey colored thermally bonded nonwoven geotextiles on both sides of the core. The drainage geocomposite elements are either stitch bonded or thermally bonded.

2.2 *Testing procedure*

In order to measure the water flow capacity variation with time and predict the long-term water flow capacity, specimen was subjected to an air pressure loading of 20 kPa for a period of 20 months in the first laboratory and 125.7 months (10.5 years) in the second one.

The water flow capacity of the specimen was tested under the following conditions:
- same stress (20 kPa) as the one applied in the compressive creep test box,
- hydraulic gradient i = 1.0

- Rigid/Soft contact surfaces in accordance with EN ISO 12958,
- in condition as delivered (after 12 hours storage under water using a wetting agent), and after 2 weeks, 1 month, 4 months, 8 months, 16 months, 20 months storage in the compressive creep test box of the first laboratory. The specimen was reinstalled in the compressive creep test box after each water flow capacity measurement.

The same procedure was adopted by the second laboratory with 13 measurements over a period of approx. 125 months.

3 DISCUSSION ON METHODOLOGY

3.1 *Contact surfaces*

Discussion is in progress in ISO TC221/WG6 regarding the contact surfaces to be used in the compressive creep device. Rigid interface is a first option, soft contact surfaces as defined by EN ISO 12958 could be a second option. Experts is of the opinion that the deformation of foam plate could amplify unrealistically the fleece intrusion phenomenon because an arching effect may sometimes take place in a soil layer. In the case of simulation of soft contact surfaces by membrane with air pressure as used in these creep test boxes, the risk to get conservative values can exist as well because this potential arching effect is not taken into account.

3.2 *Testing process*

For the water flow capacity measurements, it was considered that the best way to reproduce the residual thickness that was reached with the appropriate contact surfaces at a given time and load in the compressive creep test box was by applying the same load to the same specimen within few minutes after its withdrawal from the box.

Indeed, a methodology based on short-term thickness measurements to define stress/thickness relationship would not consider any long-term intrusion phenomenon due to the fact that the soft contact surface would be used during the water flow capacity test only for short period (i.e. around 8 min). In this case, intrusion phenomenon would be measured under a normal load calculated with the previous stress/thickness relationship, and then mainly related to the compressibility of the drainage core. Therefore, the testing stress could be a lot higher than the design load. Moreover, any thickness measurement introduces clearly measurement uncertainties. The water flow capacity being the final performance to assess in order to define the appropriate reduction factor for designs, a direct extrapolation of water flow capacities values seems more justified and realistic.

4 EXPLOITATION OF THE TEST RESULTS

4.1 *Logarithmic and power regression analysis*

Water flow measurements collected in the two sets of tests for the same product were used to evaluate two types of regression: the logarithmic regression $Q_{LN}(t) = A. \ln(t)+ B$ and the power regression $Q_{power}(t) = C. t^n$. The evaluation is done by comparing extrapolated reduction factor to 10 years based on 20 months of testing (first laboratory) with the actual reduction factor based on water flow capacity measured under the same conditions after a loading duration of 10 years (second laboratory).

The reduction factor $RF_{cr-int}(t)$ takes into account both thickness reduction of the drainage core with time (compressive creep) and intrusion of the fleece into the drainage structure with time, it is defined as the ratio:

$RF_{cr-int}(t) = Q(t=0) / Q(t)$

In this study both water flow capacities Q (t=0) and Q (t) were measured under the same load and with the same contact surfaces (i.e. Rigid/Soft).

The power and logarithmic regression curves of water flow capacity values measured from t = 0 to t = 20 months are shown in figure 2a and 2b.

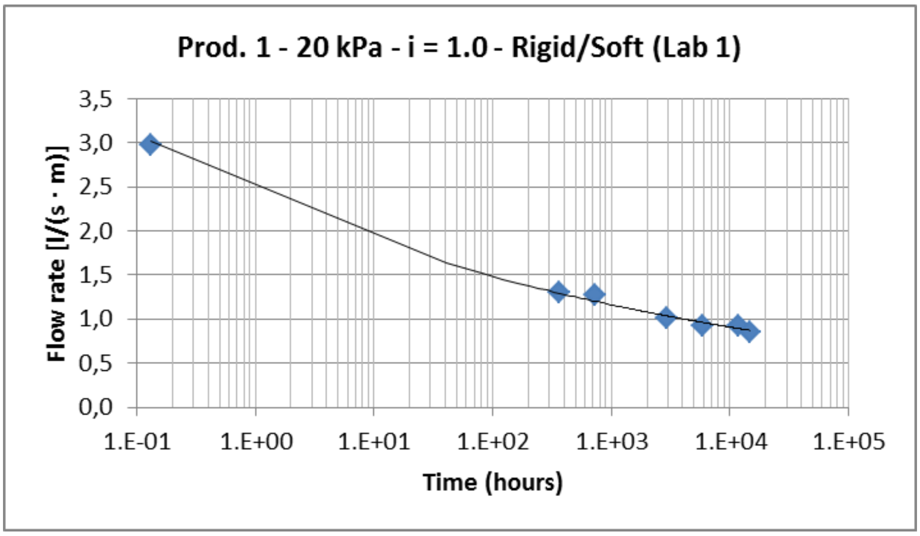


Figure 2a. Power regression (test duration = 20 months)

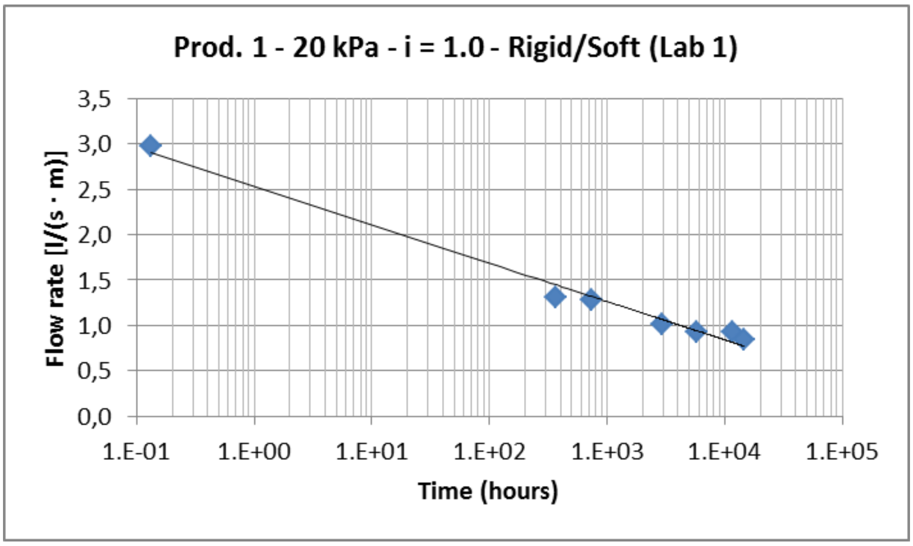


Figure 2b. Logarithmic regression (test duration = 20 months)

Comparison between residual ratios of water flow capacities calculated with the logarithmic and power regressions is given in table 1. The reduction factor $RF_{Actual/cr-int}$ (t = 125 months) based on actual water flow capacity values measured at t = 0 and t = 125 months provides a reference value for the comparison with the other residual ratios of water flow capacities.

Table 1. Impact of the regression type over the water flow capacities assessment at t = 125 months (≈ 10 years).

ΔQ (t=125 months ≈ 10 years) (1)	Estimation of water flow capacity till 125 months based on 20 months loading
Power regression	+1.4% (R^2 = 0.992)
Logarithmic regression	-38% (R^2 = 0.985)

(1) Reference value based on actual measurement

The result shows that logarithmic regression leads to an underestimation of 38% whereas the power regression leads close to actual measured value after 125 months.

4.2 *Direct extrapolation*

In order to assess by extrapolation, the water flow capacity of the product subjected to both thickness reduction of the drainage core and filter intrusion in the drainage core, for a design service life of 50 years, we compared extrapolation results at 50 years for both sets of test results by using logarithmic and power regressions (table 2).

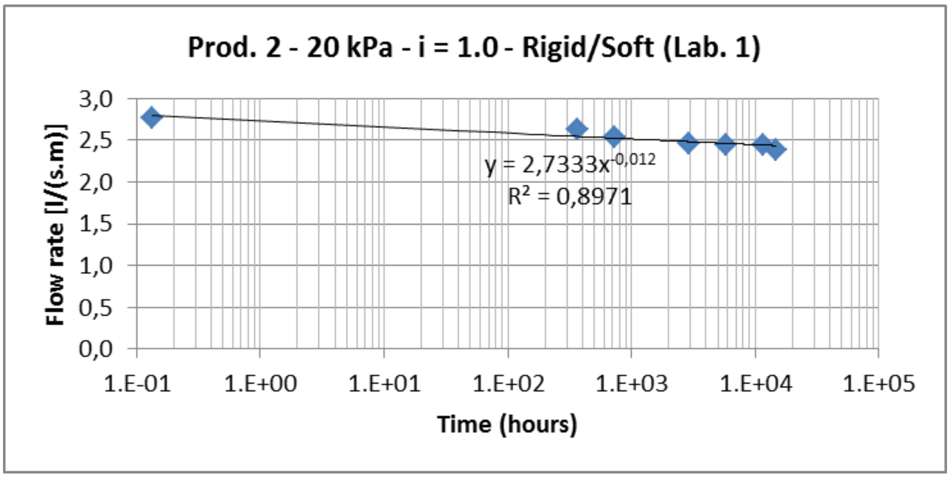
Table 2. Impact of the regression type over the accuracy of the water flow capacities assessment at t = 50 years.

ΔQ (t=50 years) (2)	Estimation of water flow capacity till 50 years based on 20 months loading
Power regression	+53% (R^2 = 0.992)
Logarithmic regression	-63% (R^2 = 0.985)

(2) The extrapolated value till 50 years which is based on measurements carried out for 125 months and offering the best coefficient of determination R^2 is considered as reference value

Logarithmic regression based on relatively short-term compressive creep test (20 months) leads to an underestimation equal to 63%. In contrast, the power regression based on the same relatively short-term compressive creep test (20 months) leads to an overestimation of 53%.

This case is in fact the most critical one of an extensive study carried out as well on less compressible monofilaments structures (see figure 3 and table 3) which leads to a more narrow range of results between power regression and logarithmic regression.



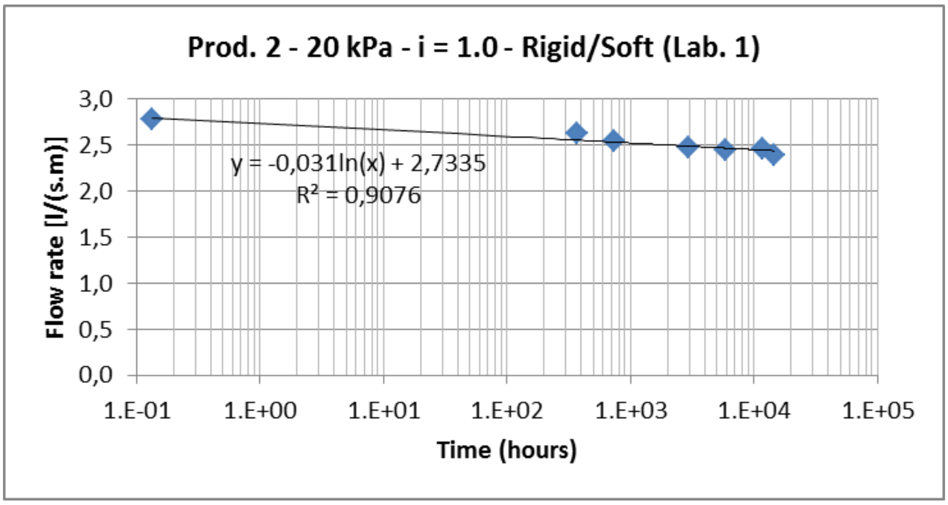


Figure 3. Similar regression curve for logarithmic and power regression in case of semi-compressible monofilament structures

Table 3. Impact of the regression type over the accuracy of the water flow capacities assessment at t = 50 years for a semi-compressible monofilament structure under 20 kPa normal stress

ΔQ (t=50 years) [(3)]	Estimation of water flow capacity till 50 years based on 20 months loading
Power regression	-2.5% (R^2 = 0.897)
Logarithmic regression	-3.4% (R^2 = 0.908)

[(3)] The extrapolated value till 50 years which is based on measurements carried out for 70 months and offering the best coefficient of determination R^2 is considered as reference value

5 CONCLUSION

Logarithmic regression as used sometimes is not always the most appropriate regression to simulate the hydraulic performances of a drainage system. It can be particularly conservative for some compressible monofilament structures. This study shows that, in case compressive creep test has only been carried out on relatively short-term (e.g. 20 months), both power regression and logarithmic regression should be considered simultaneously to approach the actual value of the long-term performances. For less compressible monofilament structures, there’s no difference between both regression types. According to the authors, the contact surface used in the compressive creep device is a main parameter which can greatly influence the long-term performances of the drainage geocomposites in relation with the spacing between fleece-drainage core contact areas.

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7 REFERENCES

Böttcher, R.-D (2006), Long-term flow capacity of geocomposites, *8th International conference on geosynthetics (8ICG),*Yokohama, Japan, pp. 423 – 426.

Jarousseau, C., Gallo, R. (2004), Drainage géocomposites: relation between water flow capacity and thickness in the long term, *EuroGeo 3*, München, pp. 349 – 354.

Koerner, R.M. (1999), *Designing with Geosynthetics,* 4th edition, Prentice Hall pp. 761

Müller, W.W., Jacob, I., Tatzky-Gerth, R. (2008), Long-term water flow capacity of geosynthetic drains and structural stability of their drain cores, *Geosynthetics International, 15, n°6.*

Touze-Foltz, N., Hérault, A., Stoltz, G. (2014), Evaluation of the decrease in long term water flow capacity of géocomposites due to filter intrusion, *7th International Congress on Environmental Geotechnics (7ICEG)* Melbourne, Australia, pp. 321 – 329.

Zanzinger, H., Gartung, E. (1999), Abminderungsfaktoren zum Nachweis der hydraulischen Leistungsfähigkeit von Geokunststoff-Dränelementen, *15. Fachtagung Die sichere Deponie,* Würzburg, pp. F/1-F/28.