Interlaboratory Study on Drainage Capacity of Geosynthetics

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ABSTRACT: The paper presents the results of an interlaboratory research concerning the drainage capacity of geosynthetics, in view of their use in drainage systems. Different types of geosynthetics (i.e. geotextiles, geocomposites and geonets) were submitted to radial and unidirectional flow conditions in order to evaluate short-term and long-term flow capacity behaviour, by using different devices. Preliminary results on compressive creep are also presented.

1 INTRODUCTION

The drainage capacity of geosynthetics can be evaluated by different kinds of transmissivity apparatuses (see, for example, Koerner and Bove, 1983). These devices can be grouped into two categories which are based on the drainage pattern of water flow within the geosynthetic itself, that is, radial (see, for example, Rigo, 1979) or parallel (see, for example, Cancelli et al., 1987). Both types of transmissivity devices can be used to evaluate the short term and the long term flow capacity. Moreover compressive creep tests give an indication of the intrinsic behaviour of geosynthetics to costant applied loads.

2 TESTING DEVICES

2.1 Flow apparatus

The radial flow apparatus used for this experimental program is illustrated in Fig. 1. It consists of a cylindrical permeameter cell provided with a measuring device for the pressure drop which occurs in consequence of the flow resistance in the geosynthetic specimen. Both static pressures and hydraulic gradients can be varied. This apparatus measures radial in-plane flow through a circular, disk-shaped specimen of the geosynthetic; a circular opening in the centre of the specimen allow the water to enter, the flow direction is from the centre of the specimen to the outside.

The unidirectional flow apparatus used for the discharge capacity evaluation of different geosynthetics is shown in Figs. 2a-b.

In both apparatuses during flow rate tests a transducer measures the specimen thickness under the different static pressures.

Details of both experimental devices can be found in Avanzini et al. (1992).

The compressive creep testing apparatus is shown in Fig. 3: it consists of a rigid steel beam which supports the testing boxes; the specimen can be placed in the box in dry condition or underwater; the specified pressure is applied through a dead load applied under the beam and transferred to the specimen through a steel frame and a rigid steel plate; a thickness gage is applied at the center of the specimen for measuring the reduction in thickness versus time. The test apparatus and procedure is in accordance with the draft Euopean standard for compressive creep (Doc. CEN/TC 189/n148, December 1993).

3 EXPERIMENTAL TESTING ACTIVITY

3.1 Types of tests

In order to evaluate the hydraulic characteristics of the tested geosynthetics three different types of tests were planned:

a-short term flow tests: tests of radial and unidirectional flow under different static pressures and different hydraulic gradients;

b-long term flow tests: tests of radial and unidirectional flow under constant pressure with hydraulic gradient equal to 1.0 for a prolonged time;

c-compressive creep tests: tests of the variation of thickness versus time under constant normal load, prolonged for a very long period.

3.2 Tested geosynthetics

The drainage capacity measurements were conducted on three different needle-punched nonwoven geotextiles, three drainage geocomposites and the three geonets making the cores of the geocomposites. Their physical characteristics are summarized in Table 1, where t_{GT} is to be intended as the nominal thickness.

Geosynthetic	Manufacturers	μ (g/m²)	t_{GT} (mm)
Geotextiles			
DRENOTEX	Politex (Italy)	808	5.27
POLYFELT	OMV (Austria)	800	5.46
STRATUM	Viganò Pav.(Italy)	774	6.97
Geocomposites			
TNT 100	Tenax (Italy)	1120	5.50
TNT 300	Tenax (Italy)	1530	7.65
TNT 500	Tenax (Italy)	840	4.30
Geonets			
CE 905	Tenax (Italy)	905	5.06
CE 906	Tenax (Italy)	611	4.03
GNT 100	Tenax (Italy)	1295	6.98

Table 1 The tested geosynthetics

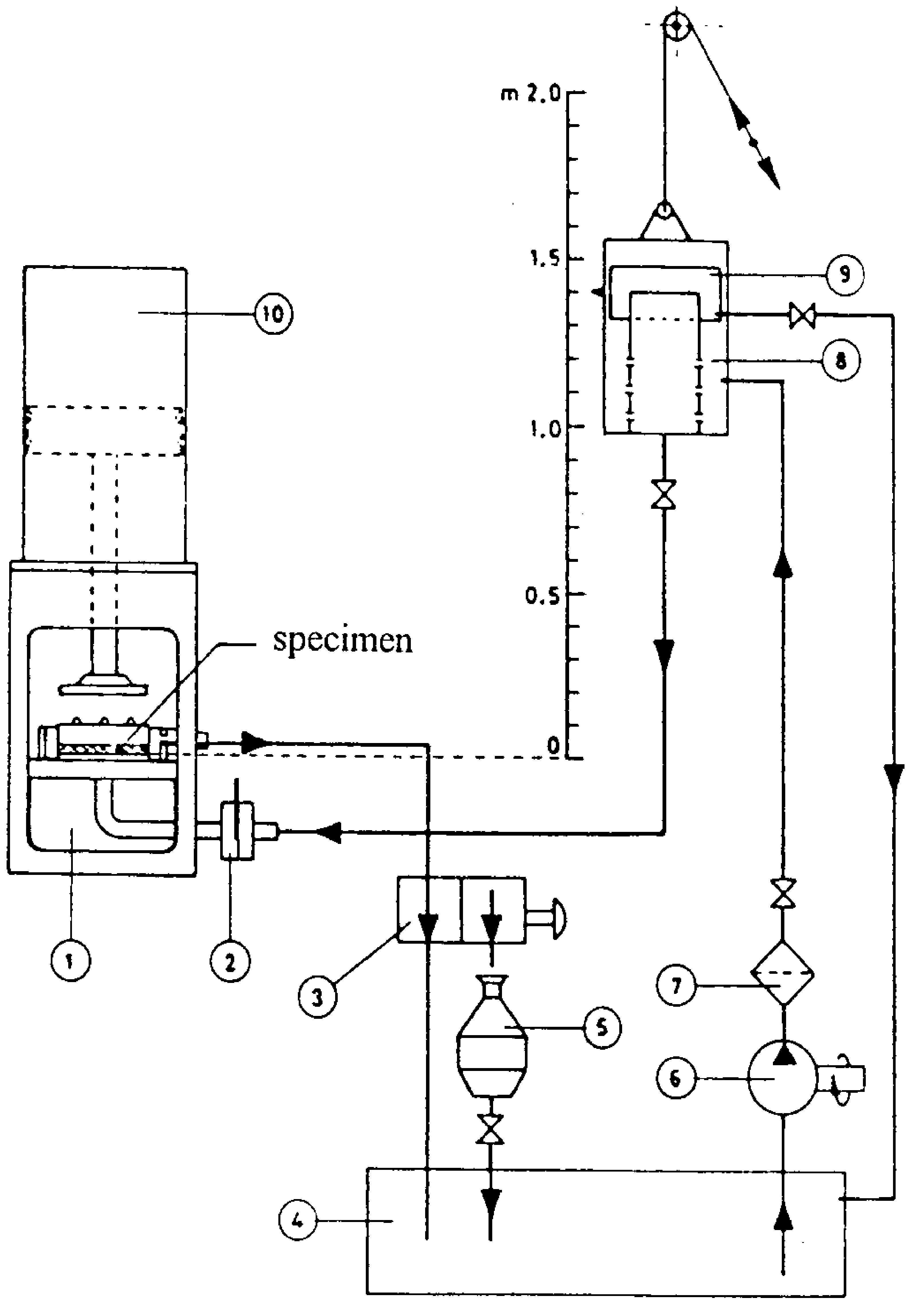


Figure 1. Radial flow apparatus.
1.Permeameter 2.Intercepting valve 3.Two-way valv
4.Backwater tank 5.Calibrated container 6.Feed pump 7.Filte
8.Constant level tank 9.Overflow system 10.Pneumatic device

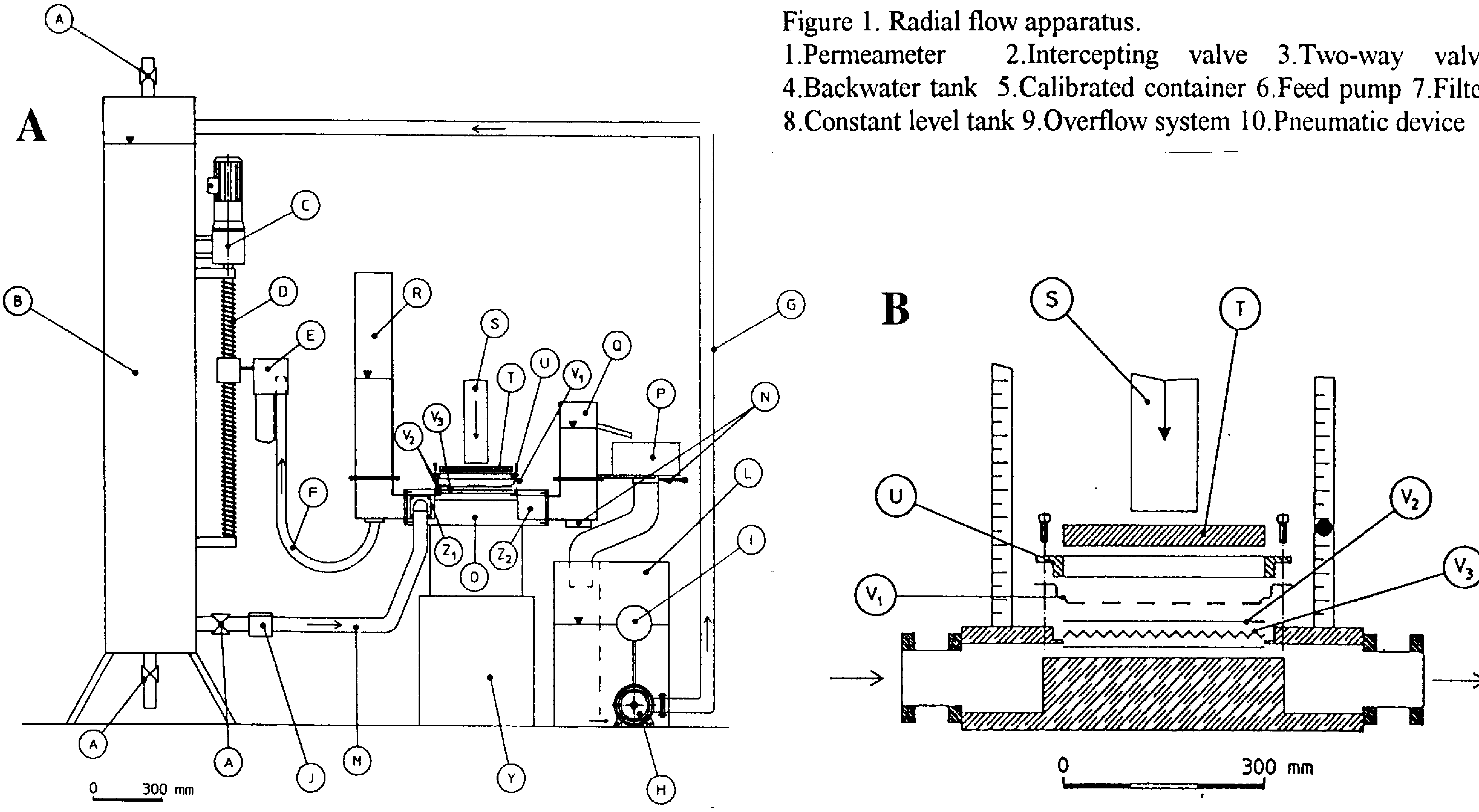


Figure 2. Unidirectional flow apparatus; (a) side view, (b) detail of the specimen housing.
A.Tap B.Large water reservoir C.Electrical engine D.Elevation regulating screw E.Upstream water level regulating reservoir F-G.Connecting tube H.Pump I1.Floating sphere I2.Pump inlet regulating piston L.Water tank M.Inlet tube to upstream chamber N.Discharge on-off tap O.Specimen chamber P.Water collecting tank Q.Downstream chamber with weir R.Upstream chamber with weir S.Loading piston T.Loading plate U. Neoprene membrane holding frame V1.Neoprene membrane V2.HDPE geomembrane (2mm thick) Z1.Upstream chamber Z2.Downstream chamber J.Flow-meter Y.Hydraulic press W.Piezometer of the downstream chamber K.Piezometer of the upstream chamber X.Loading cylinder

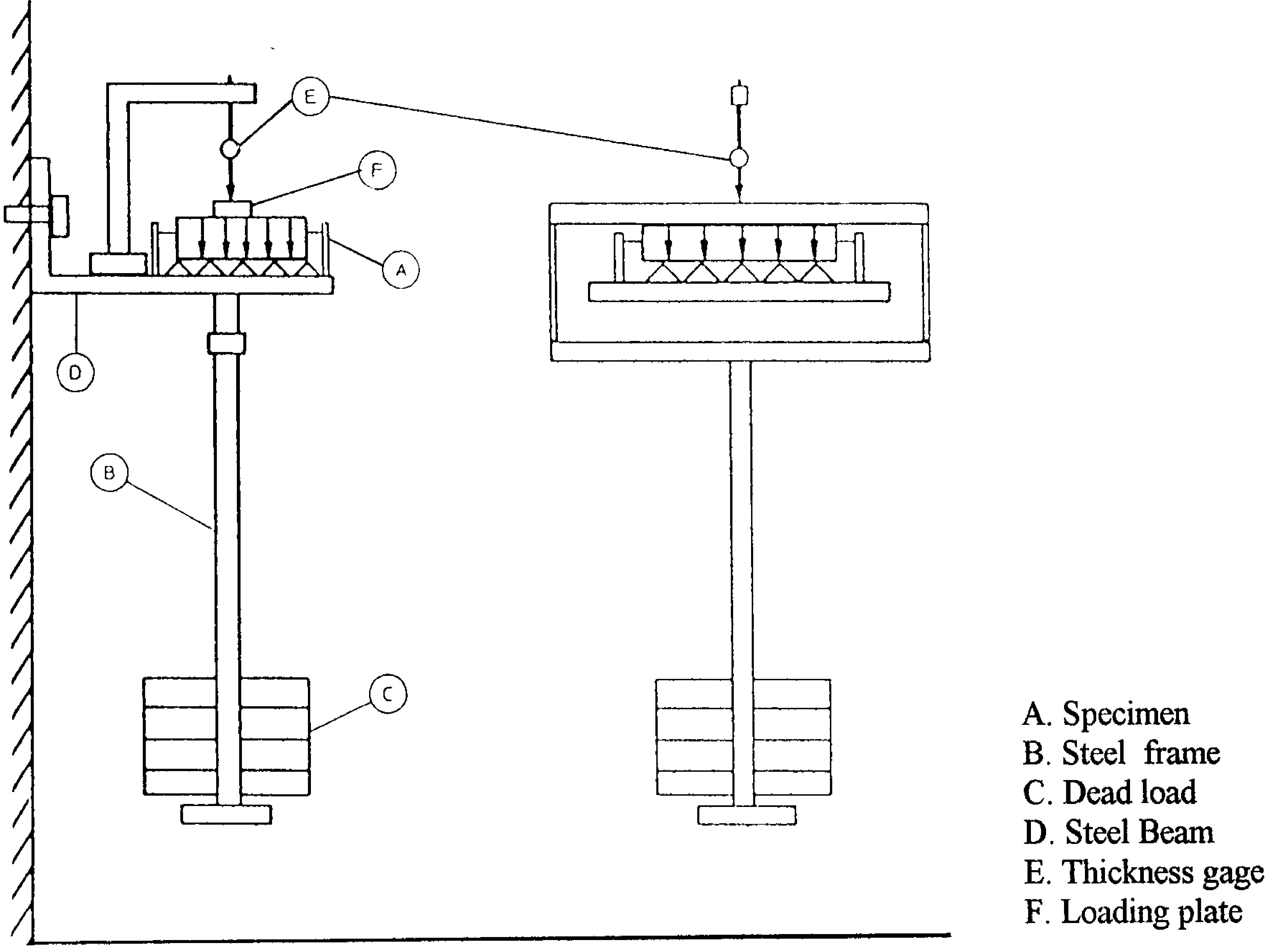


Figure 3. Compressive creep apparatus.

3.3 Testing conditions

-Sampling: specimens, taken from the sample, were soaked in water for 24 hours at room temperature; then they were deaired.

-Water: tests were performed with distilled demineralized and deaired water in a closed circuit.

-Temperature of water: ambient temperature; the values of the measured discharge were related to a standard temperature of 20°C.

4 RESULTS

The results of the short term flow tests, conducted under different static pressures and for unitary hydraulic gradient, are summarized in Figs 4 ÷ 6.

All values of transmissivity of the tested geotextiles, up to 500 kPa of applied pressure, using the different test devices, are in the range from 5x10E-7 to 3x10E-5 m²/s as shown in Fig.4.

For drainage geocomposites the results, shown in Fig. 5, are expressed in terms of specific flow rate, as it was already pointed out that under a variable hydraulic gradient the flow in these types of geosynthetics is not laminar (Avanzini et al., 1992; Cancelli et al., 1987).

The geocomposites are characterized by higher drainage capacity than the geotextiles and their values for specific flow rate range from 1x10E-5 to 2x10E-3 m²/s for an unitary hydraulic gradient, with reference to normal applied pressure up to a value of 500 kPa (Fig.5).

For better studying the drainage behaviour of geocomposites, the short term discharge capacity tests were also carried out on the geonet core (see Table 1), using the unidirectional flow apparatus.

Their specific flow rate curves are also shown in Fig. 5.

It should be pointed out that the geonets cores (Tenax CE906 for Tenax TNT 500 geocomposite, Tenax GNT100 for Tenax TNT 300 geocomposite and Tenax CE905 for Tenax TNT 100) exhibit values of specific flow rate about five time greater than the correspondent geocomposites, because of the effect of geotextile intrusion into the geonet channels which occurs in geocomposites.

The evolution of the specimen thickness under variable pressure is plotted in Fig. 6 for all tested geosynthetics.

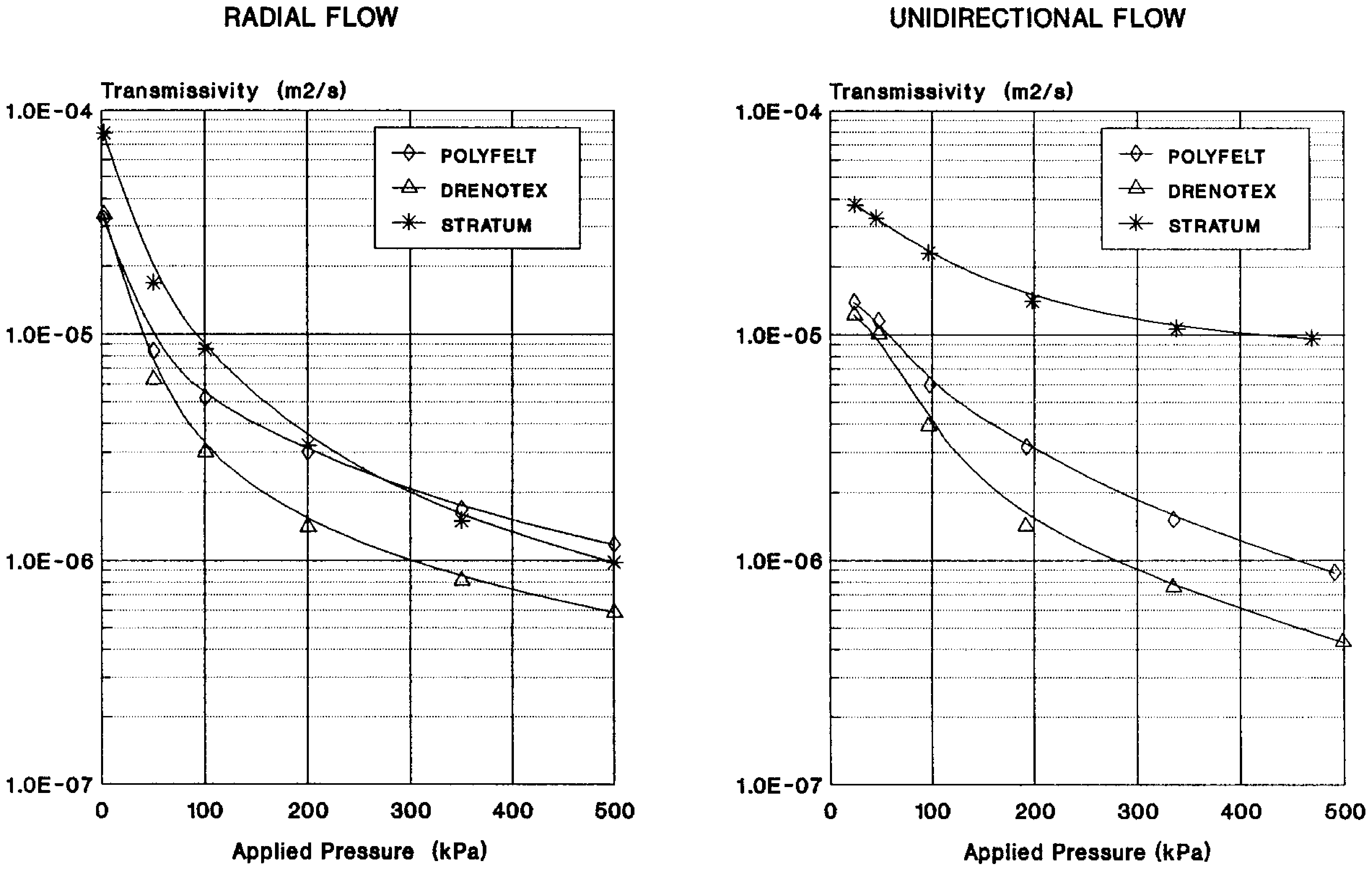
As expected, the specimen thickness decreases with increasing static pressure, but it can be seen that the decrease in flow rate is much faster than the correspondent reduction of thickness.

In fact, a small change in thickness causes a great variation in the density of the fibres of nonwovens and consequently in the porosity, thus producing a fast reduction of the passages and a fast increase in the resistance to water motion.

The results related to the behaviour of geosynthetics in the medium-long term (type b tests) are shown in Figs 7-8.

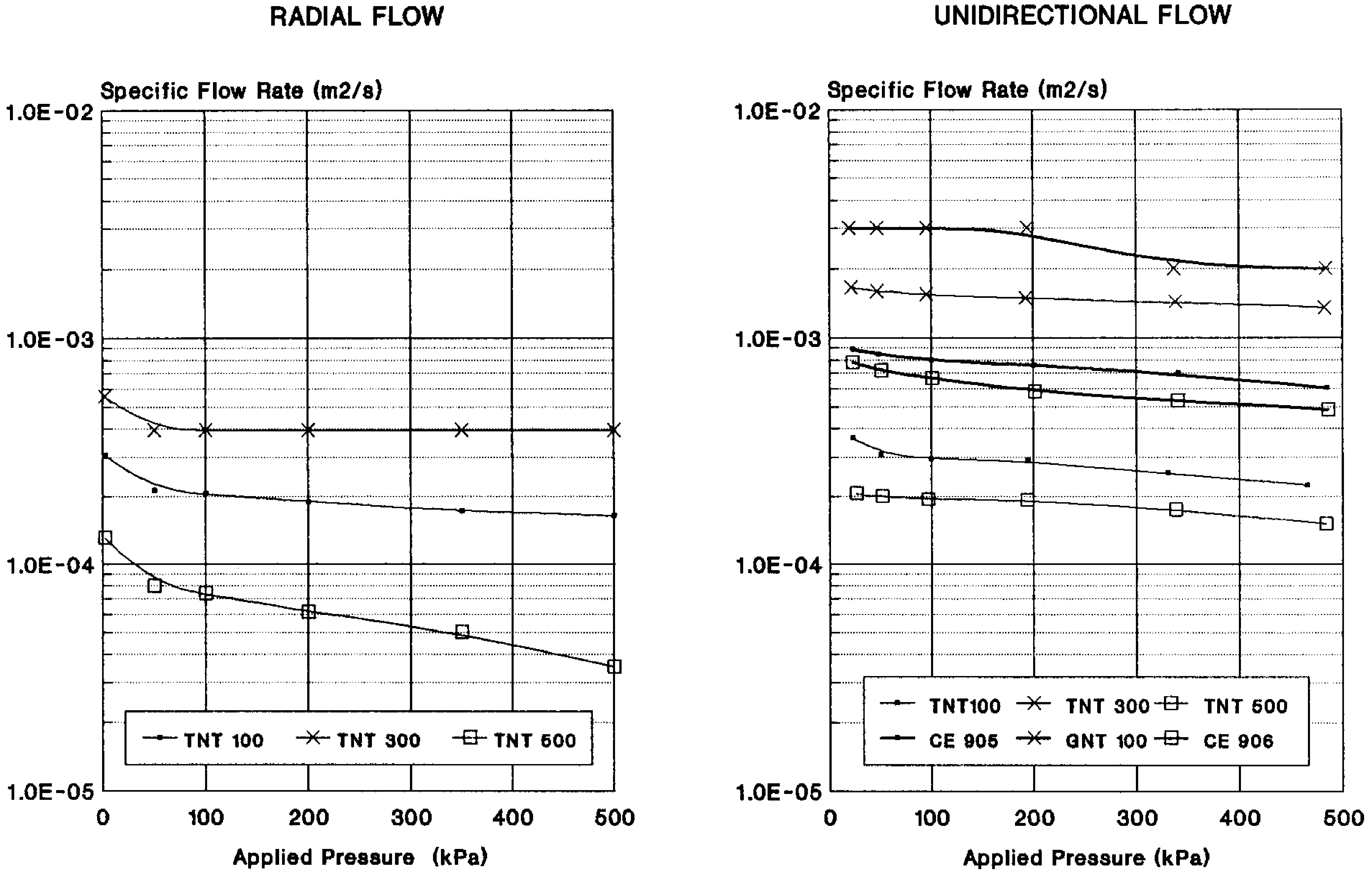
In Fig. 7 transmissivity curves of geotextiles versus time (up to 250 h), under a constant pressure equal to 50 kPa and for unitary hydraulic gradient, are represented.

It is possible to observe that the behaviour of all the tested geotextiles differs greatly using the two flow devices; in particular, with the radial flow one, there was a rapid decrease of the drainage capacity.


RADIAL FLOW

UNIDIRECTIONAL FLOW

Figure 4. Transmissivity versus static pressure under an unitary hydraulic gradient, for tested geotextiles.


RADIAL FLOW

UNIDIRECTIONAL FLOW

Figure 5. Specific flow rate versus static pressures under an unitary hydraulic gradient, for tested geocomposites and geonets.

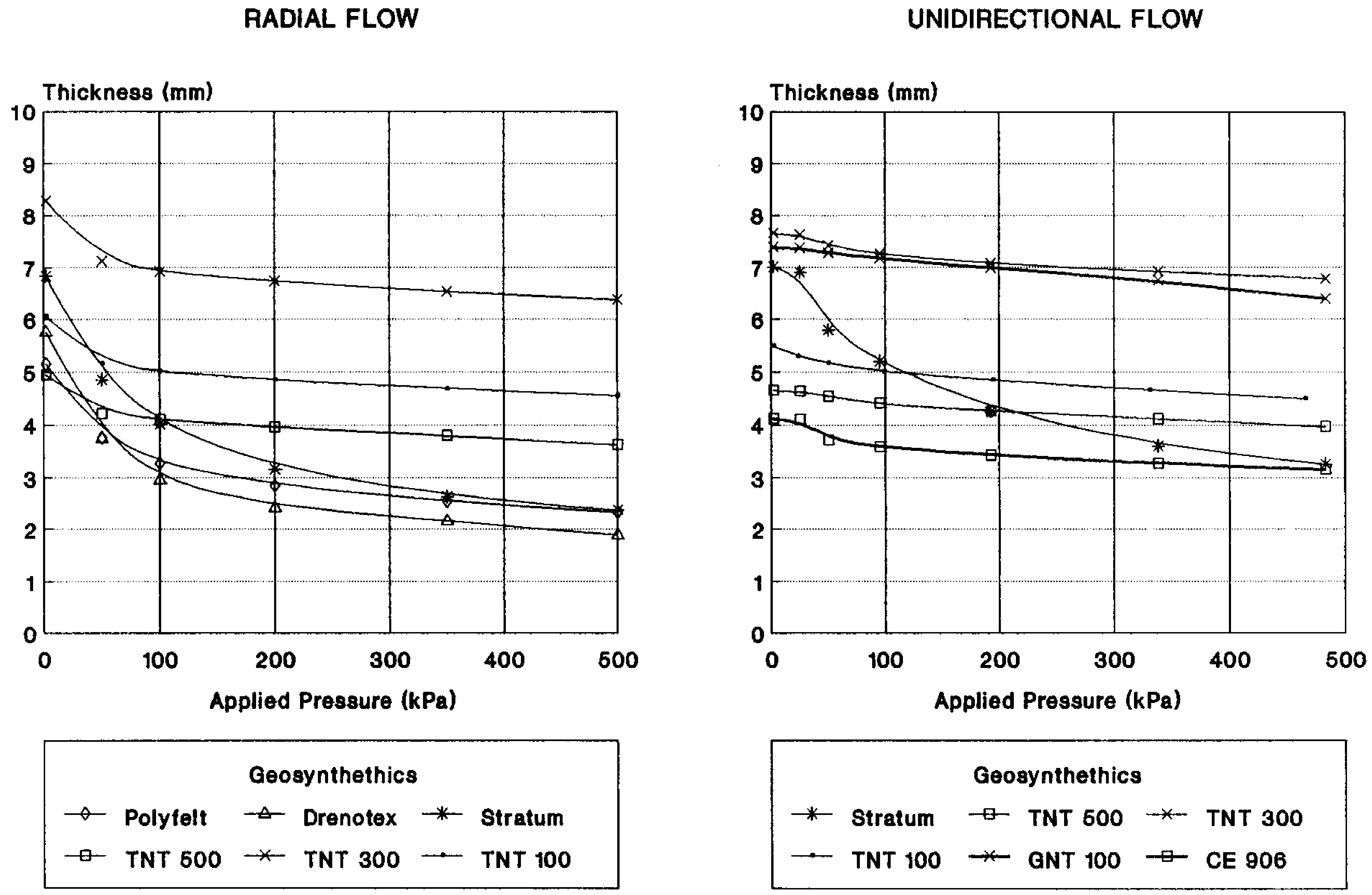
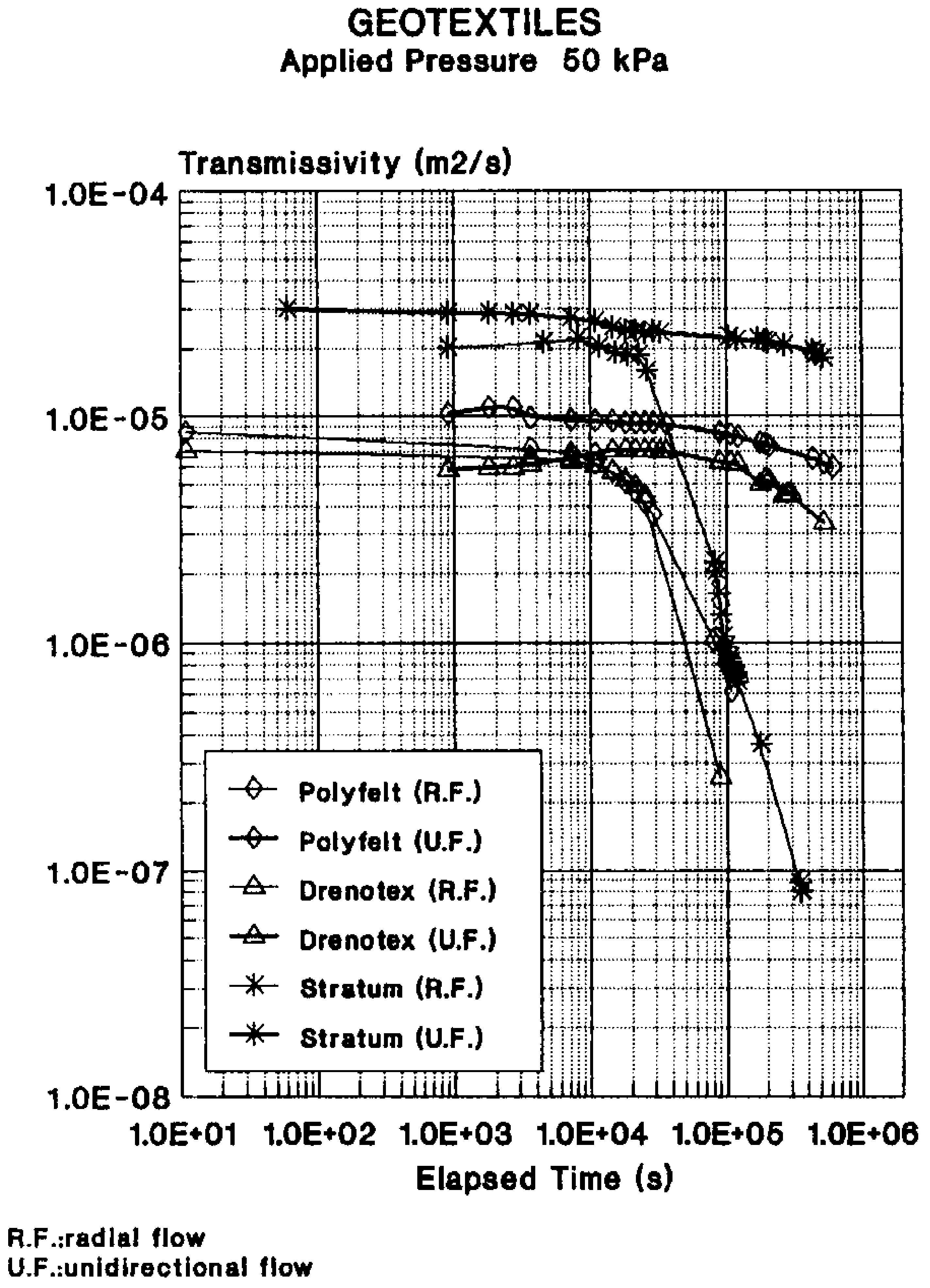
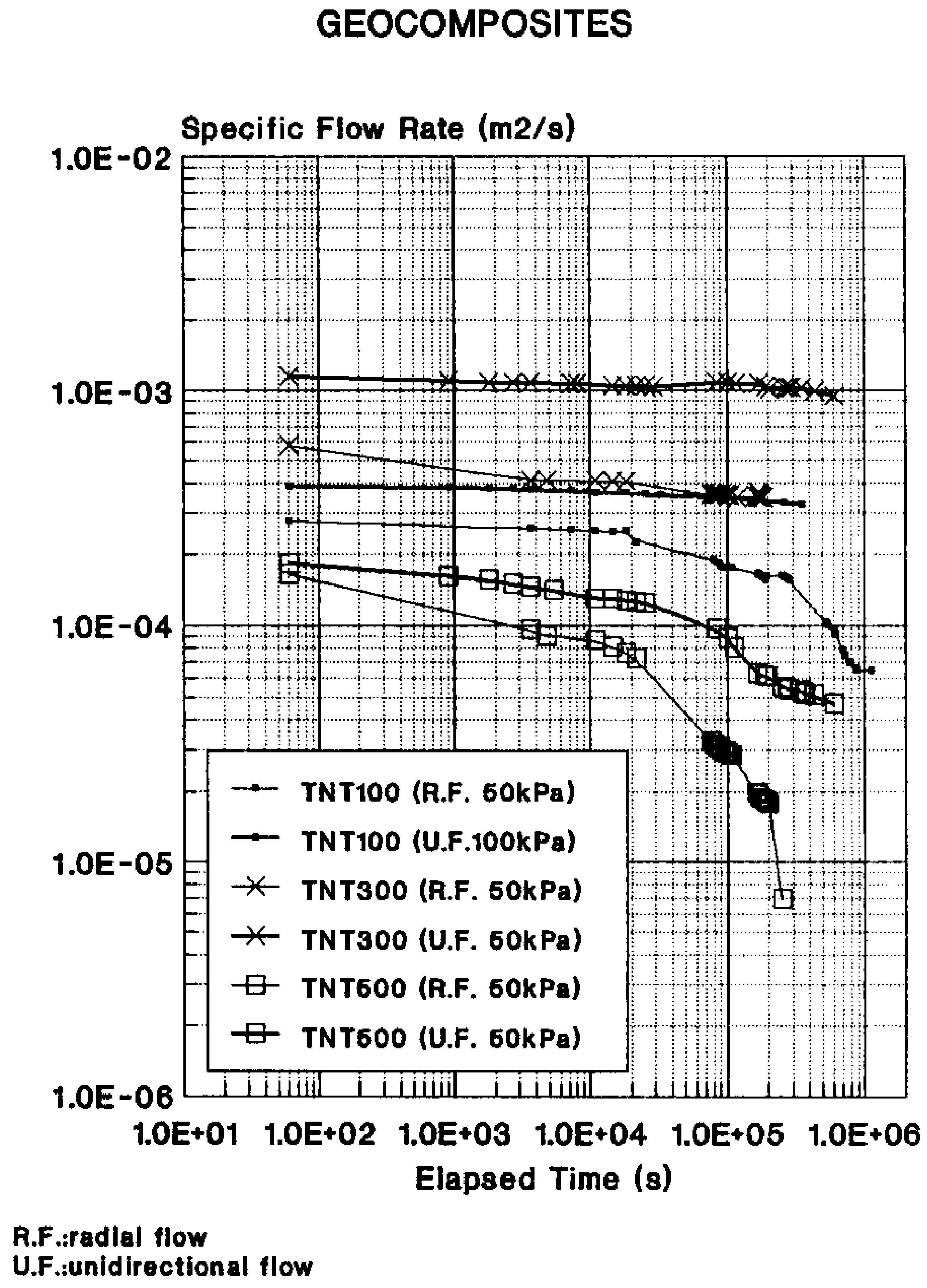


Figure 6. Thickness versus different static pressures, under an unitary hydraulic gradient, for tested geosynthetics.



R.F.:radial flow
U.F.:unidirectional flow

Figure 7. Compared radial and unidirectional transmissivity versus time under a static pressure of 50 kPa and an unitary hydraulic gradient, for tested geotextiles.



R.F.:radial flow
U.F.:unidirectional flow

Figure 8. Compared radial and unidirectional specific flow rate versus time under different static pressure and an unitary hydraulic gradient, for tested geocomposites.

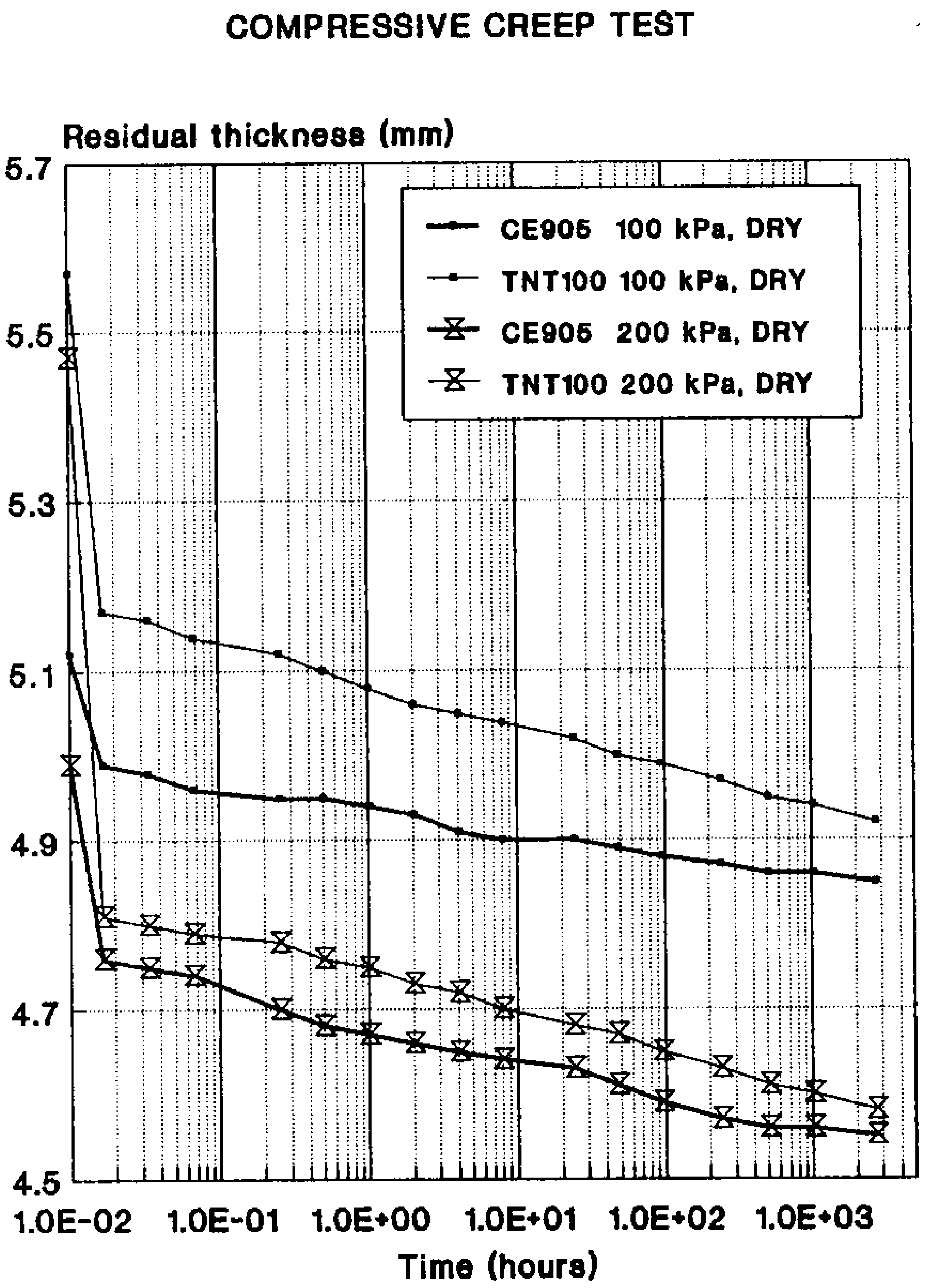


Figure 9. Normal compressive creep tests under dry condition for geocomposite Tenax TNT 100 and related geonet core CE 905.

For geocomposites the specific flow rate curves versus time are shown in Fig. 8.

For long term tests too it was found that the thickness reduction does not fully explain the observed drainage capacity decrease, in particular using radial flow apparatus (Avanzini et al., 1992).

The results of the compressive creep tests, performed in dry conditions on one geocomposite (TNT 100) and on the corresponding geonet core (CE 905), are shown in Fig.9. It can be noticed that the curves for the geocomposite and the geonet, for the same applied pressure, are sensibly parallel: this is due to the fact that the two geotextiles bonded to the core of TNT 100 are thin needle-punched nonwoven geotextiles (140 g/m^2 each), which don't provide any sensible contribution to the total creep, which is therefore concentrated in the geonet. This kind of core, anyway, presents limited compressive creep with an asymptotic behaviour, at least for the used pressures (up to 200 kPa). It will be interesting to compare the long term behaviour of the other types of geotextiles, like thick nonwovens, and other types of core structures.

The creep test curve at 100 kPa for Tenax TNT 100 (Fig.9) can be compared with the long term transmissivity curve of the same product at the same pressure with unidirectional flow (from Fig.8): it can be noticed that, in this case, the curves have similar trends. This fact confirms that there is no influence of the geotextile intrusion and of the packaging of the geotextile fibers on the long term discharge capacity of this type of geocomposites, at least for relatively low pressures.

For thinner geonet cores and/or thicker geotextiles, like TNT 500 (see again Fig.8), the influence of the geotextile on the long term discharge capacity becomes sensible.

The three ribs structures of the GNT 100 geonets of the TNT 300 geocomposite make it almost unaffected by the geotextile intrusion (Fig.8).

5 CONCLUSIONS

The conclusions emphasized from this research program can be summarized as follows:

-For the tested geotextiles the transmissivity values under different static pressures and different hydraulic gradients, obtained with radial flow apparatus, are comparable with values determined with the unidirectional one.

-On the contrary, for the tested geocomposites the results obtained by means of the two apparatuses are not completely in accordance, due to the fact that the radial apparatus is not able to reproduce carefully the conditions of transitional flow.

-The study of percent reduction of transmissivity (or specific flow rate) vs. time, performed by testing geosynthetics under the same constant static pressure (50 kPa) and the same hydraulic gradient (i=1.0) for a period of time of up to 10 days, has proved that it depends above all on the type of testing apparatus and not on the intrinsic properties of geotextiles and geonet cores.

In particular the radial flow apparatus is not recommended for studying the behaviour vs. time.

-The preliminary results of the compressive creep test confirm it as a relatively easy, reliable and reproducible test. It will be interesting to extend this test to other geosynthetics and to compare the results with the short term thickness measurements. Higher pressures may be applied in the future for simulating the conditions occurring, for example, in deep landfills or high dumps.

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