Third International Conference on Geotextiles, 1986, Vienna, Austria

PETKOV, P., Research Institute for Hydrotechnics and Amelioration, Bulgaria

STUDIES ON THE FILTER PERFORMANCE OF GEOTEXTILES
ETUDES SUR LA PERFORMANCE FILTRANTE DE GEOTEXTILES
UNTERSUCHUNGEN ÜBER DIE FILTERWIRKSAMKEIT VON GEOTEXTILIEN

A laboratory test of three types of nonwoven polyester geotextiles has been carried out with a view to their use as a filter around drain pipes in subdrainage agricultural applications. Besides geotextile specific qualities -water permeability,size and pore distribution also determined is geotextile filter performance in contact with loose clay and sand soils and specific sand fractions. Also the retention capacity of the filter and the processe of blocking and clogging of the contact zone and of the geotextile itself with time under conditions analogous to those in subdrainage construction are investigated.

Es sind drei Typen Geotextilien aus Polyester, im Labor geprüft im Hinblick auf deren Benutzung als Filter bei der landwirtschaftlichen Dränung. Außer der spezifischen Geotextilieneigenschaften wie Durchlässigkeit, Größe und Verteilung der Poren, ist die Wirkung der Filtern aus Geotextilien die im Kontakt mit lockerem Ton- und Sand Boden mit natürlichen Kornverteilungskurven und mit einzelnen kleinen und feinen Sand Fraktionen festgestellt. Diese Feststellung ist nach der Untersuchung des Rückhaltevermögens des Filters, sowie auch des Verstopfens- und Kolmatatoinsverfahrens des Kontaktbereiches und der Geotextilien bei analogischen Bedingungen im Bau der Dränung gegeben.

INTRODUCTION

In subdrainage agricutural construction the soil structure is destroyed in the area around the drain pipes and the seepage flow direction is changed. Soil porosity and pressure gradients considerably increase as a result of which deformation processes in the soil-drainage contact zone activate. Generally they find expression in: internal suphosion and structural changes in the surrounding soil/ fig.1,position 1/ and in the trench bachfill/pos.2/; deposition of fine soil particles in front of the drain pipes or filter/pos.3/ or contact zone clogging /pos.4/; filter and bachfill clogging or blocking/pos.5/; closure of the drain pipe openings /pos.6/; penetration of soil particles in the drains/pos.7/ ets..These deformations affect adversely the hydrologic and hydraulic performances of the drains.

Hydromechanical processes in the zone soil-filter-drain pipe are interrelated and their origine, development and character are determined by soil and hydrodynamic conditions, in which the subdrainage performs, as well as by the laying technology and climatic conditions during and after laying of the drain pipes in the soil. In drainage construction using trenchers, the drains,laid in the trench, are bachfilled with loose soil. The final machine bachfilling is done in several days or weeks. This technology does not raise any objections, if during the period of bachfilling does not fall any rain and the groundwater level is deep enough under the trench bottom. Otherwise water flows out the trench slopes, softens and erodes the

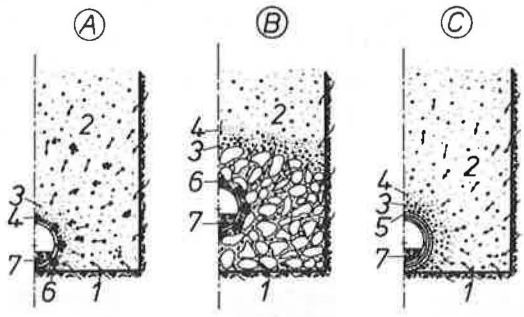

Figure 1 Hydromechanical processes in the zone around the drain: A-a drain pipe without filter; B-with granular filter; C-with synthetic filter.

soil and is retained above the bachfill over the drain pipe and filter envelope.As a result of the high velocity turbulent flow in the pores of the loose bachfill soil, separate soil aggregates and particles are moved to the contact zone and the drain pipe and give rise to the above mentioned deformations. The use of filter envelope in such cases aims at preventing from suphosion processe in the contact zone and at improving the hydraulic conditions the drain pipe. With a view to that the filter must have definite geometric, structural and hydraulic qualities according to the existing conditions immediately around the drain pipe.

Having in mind the macropore structure of the geotextile and its small thickness, it was necessary to check what changes occur in the soil-geotextile contact zone and in the fabric inself in loose and saturated soils with different granulometric composition and how the processes of clogging and blocking develop with time in this zone. This question is not only of scientific, but also of practical importance, because it is connected with the choice of subdrainage construction technology.

METHODIC BASIS AND CONSIDERATIONS

Blocking is the partial closure of the fabric filter pores/ on the surface of the material/ by soil particles, as a result of which its water permeability is reduced. Blocking is an immediate effect, in the initial phase of the drainage performance, to differentiate from clogging which is a time-dependent phenomenon, due to the deposition of very fine particles or chemical compounds in the material which causes the partial or total closure of the fabric pores/ in depth / and considerably reduces its water permeability or completely stops its functioning(4).

As far as subdrainage blocking is concerned the carried out investigation till now show that most dangerous are soils with high content/>50%/ of fine sand/50 to 200 μm/ and small content /<20%/ of clay particles/<2 μm/, as well as those with homogeneous granulometric composition with particle size smaller than drain pipe opening/ usually 0,6-0,8 mm/(1).

To perform well,it is not necessary that a filter should retain all the particles brought by water - that would cause its immediate clogging. Since particles smaller than 0,05-0,08 mm,wich have already entered the drains,are carried out by the flow, without causing mechanical blocking of the pipes, the fabric filter should possess such pores that will retain all the particles bigger than the above mentioned i.e. than 80μm. The bigger particles stick to the filter or form "archs" above its pores, while they form a "natural" filter in the contact zone or clogg it /fig. 2/.

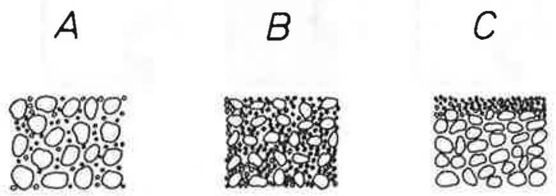

Figure 2 Mechanism of contact suphosion, clogging and blocking with the granular filters: A-almost full migration of soil particles through the filter; B - migration only of the finest particles and closure of the biggest pores of the filter; C -full deposition of soil particles infront of the filter.

Besides this the filter water permebility should be kept high even after the subsiding of seepage deformations/ at least 5 times higher than that of the soil in contact with noncohesive and 20 times higher in contact with cohesive soils/, in order to provide for the minimum resistance for the water flowing in the drains(3).

Filter performance and the occuring changes in it do not depend only on the relation between the soil particle sizes d_s and the filter pores O_g i.e. from d_s/O_g, but on other factors as well (2):

- the penetration of soil particles in the fabric is possible when a motive power to set them in motion is present. This power is resultant from particle weight and seepage flow force and depends on the flow direction - upward or downward in horizontal filter/fig.3/;

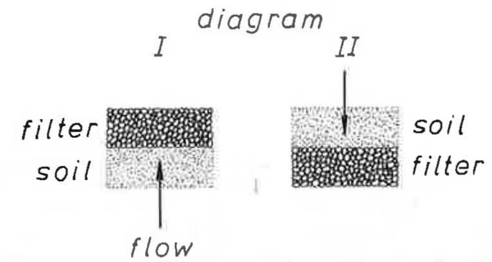

Figure 3 Position of the contact surface in relation to the water flow direction.

- the type of soil with which the filter is in contact - cohesive or noncohesive;
- the form of the soil particles.

Having in mind these considerations and requirements to the filter parameters and conditions in which it functions, a choice has been made of soil types and fabrics for the present laboratory test.

APPARATUS, MATERIALS AND PROCEDURE

The investigations are carried out according to two diagrams in dependance on the soil and geotextile filter position and water flow direction /fig.3/. In diagram I/ upward seepage / hydrodynamic pressure and soil particle weight are opposed, while in diagram II - they are summed. In the first case the natural filter arch-formation above the pores is made difficult. The corresponding seepage apparatus, shown on figure 4,are used for the two diagrams. In the filter cylinder of the first apparatus fabric filter is placed above soil sample/ 100 mm heigh /. Water from the air-trapping reservoir and the upper vessel for maintaining constant water level enters the cylinder from below and after passing through the soil and the filter flows out in the measuring vessel. In the second case water flow direction is reverse/ diagram II /, fabric is placed first and above it is poured loose soil sample/ with size of the aggregates up to 5 mm/.

Three types of geotextiles are investigated, representatives of the three basic groups, according to the way of production - needled/ G300 /, needled with consequent chemical strenghtening / G125 / and chemically bounded/ G80 /geotextile with weight 300, 125 and 80 g/m^2 respectively. Basic characteristics of the tested geotextiles are given in table 1. Pore sizes are defined by the use of sieve analysis with quartz sand, while O_{90} is defined as that average diameter of the fractions fallen through the fabric 10% by weight. Coefficients of normal permeability K_n and these in the material plane K_p are determined with the help of DARCY type equip -

Table 1

Basic characteristics of the geotextile filters tested

Type of geotextile	Symbol	Composition	Mass per unit area μ /g/m²/	Thickness T_g /mm/ at loading/ MPa /		Pore size O_{90} /mm/	Coefficient of normal permeability K_n/m/s $.10^{-3}$/ at loading/ MPa /		Coefficient of permeability in the fabric plane K_p/m/s.10^{-3}/ at loading/ MPa /	
				0,005	0,05		0,005	0,05	0,005	0,05
Nonwoven needled	G300	100 % PE	300	3,0	1,0	0,14	4,6	1,4	10,0	3,2
Nonwoven needled chemically bounded	G125	100 % PE	125	0,7	0,5	0,08	2,5	0,8	4,2	0,6
Chemically bounded	G80	100 % PE	80	0,55	0,35	0,15	2,7	1,2	6,5	2,5

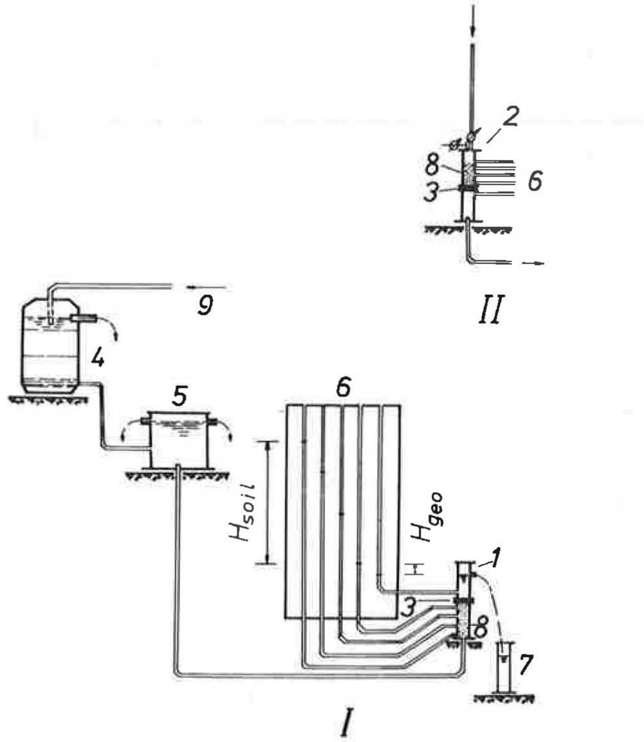

Figure 4 Apparatus for carrying out the investigations: 1-filter apparatus for diagram I; 2- filter apparatus for diag.II; 3-geotextile; 4-water air-trapping reservoir; 5-upper reservoir to control water level; 6-piezometers; 7-measuring vessel; 8-soil sample; 9-water supply.

ments, while the loading was changed from 0,005 to 0,08 MPa.

The granulometric curves of the investigated soils with natural composition/ soils No 1,2,3 and 4/, as well as sand fractions/ 5,6,7 and 8/ are shown on figure 5.

After apparatus preparation for the corresponding soil-fabric variant, water is put in the system. The pressure in front of, in and out of the soil, contact zone and the filter is measured by piezometers. The total pressure difference is 900 mm, which correspondt to a gradient about 6. The last one creates hydrodynamic pressure, which corresponds to its maximum practical values and is sufficient for the soil particle migration to the fabric. In the process of tests piezometer level differances and the discharge, passing through the system are measured periodically.

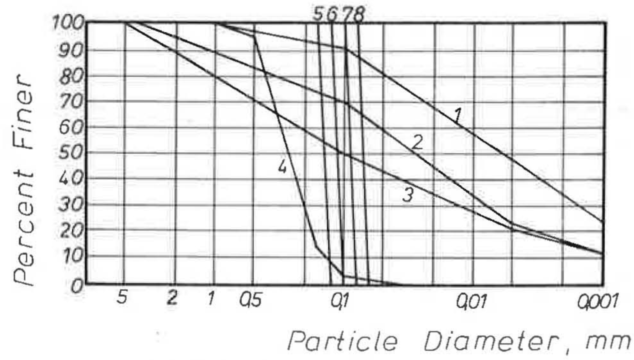

Figure 5 Particle size distribution curve: 1 - silty clay; 2-sandy silt clay; 3-sandy clay; 4-sand; 5,6-fine sand; 7,8-very fine sand fractions.

RESULTS AND DISCUSSION

The problem for the presence or absence of clogging and blocking of the soil -fabric contact zone has been solved in dependance on the hydraulic gradients and permeability coefficient changes with time for the system, for the soil and for the contact zone. As indices of the investigated processes assessment are used the following factors:

-blocking factor BF

$$BF = \frac{Icz}{Isys} \qquad /1/$$

-clogging factor CF

$$CF = \frac{Kcz}{Ks} \qquad /2/$$

where Icz - is hydraulic gradient in the contact zone; Isys - total gradient for the system/soil and filter/; Kcz and Ks - coefficients of permeability of the contact zone and of the soil sample respectively.

When BF>1 and CF<1, conditions are present for contact zone blocking and clogging.

Results, from the tests for the three geotexti-

Table 2

Blocking and clogging of the contact zone geotextiles filter - loose clay and sand soils and sand fractions for diagram I according to figure 3

Test No	Geotextile / symbol /	Soil/Fraction /acc. to figure 5/	Test duration hours	Blocking factor BF	Clogging factor CF	Blocking/ Clogging	
						yes	no
1.1	G 300	1	94	0,76 ÷ 6,62	1,37 ÷ 0,97	x	
1.2		2	366	0,01 ÷ 0,56	1,44 ÷ 2,88	x	x
1.3		3	202	0,40 ÷ 8,13	0,04 ÷ 0,23	x	
1.4		4	296	0,87 ÷ 0,21	2,77 ÷ 5,60		x
1.5		5	310	0,55 ÷ 0,02	2,29 ÷58,33		x
1.6		6	260	0,78 ÷ 0,44	2,02 ÷ 2,00		x
1.7		7	147	2,45 ÷ 1,50	0,83 ÷ 0,23	x	
1.8		8	124	7,17 ÷ 8,18	2,42 ÷ 0,05	x	
3.1	G 125	1	252	0,54 ÷ 3,64	1,96 ÷ 0,23	x	
3.2		2	209	0,04 ÷ 5,64	24,00 ÷ 0,15	x	
3.3		3	222	2,17 ÷ 9,40	0,05 ÷ 0,01	x	
3.4		4	286	2,75 ÷ 1,13	1,03 ÷ 0,88	x	x
3.5		5	380	2,00 ÷ 0,85	0,91 ÷ 1 15	x	x
3.6		6	208	1 63 ÷ 0,59	1.20 ÷ 1,75		x
3.7		7	198	2.08 ÷ 1,75	0,67 ÷ 0,41	x	
5.1	G 80	1	211	0,06 ÷ 2,10	1,21 ÷13,78	x	
5.2		2	264	0,95 ÷10,70	1,05 ÷ 0,001	x	
5.3		3	196	6,87 ÷10,45	0,05 ÷ 0,003	x	
5.4		4	346	2,10 ÷ 0,31	0,81 ÷ 3,17		x
5.5		5	186	1,82 ÷ 0,54	0,63 ÷ 1,95		x
5.6		6	164	1,97 ÷ 0,54	0,54 ÷ 1,68	x	x
5.7		7	234	1,58 ÷ 5,24	1,05 ÷ 0,09	x	

Table 3

Blocking and clogging of the contact zone G 300 - soils and fractions / No 1 to 8, figure 3 / for diagram II

2.1	G 300	1	96	2,08 ÷ 3,50	0,31 ÷ 0,10	x	
2.2		2	287	1,00 ÷ 2,18	0,65 ÷ 0,38	x	
2.3		3	230	0,38 ÷ 1,41	3,02 ÷ 0,61	x	
2.4		4	264	1,52 ÷ 0,84	0,72 ÷ 1,12	x	x
2.5		5	382	1,33 ÷ 0,11	1,08 ÷ 8,68		x
2.6		6	246	1.08 ÷ 0,10	1,24 ÷ 9,23		x
2.7		7	218	1,38 ÷ 0,02	0,81 ÷47,73		x
2.8		8	124	2,61 ÷ 1,13	0,19 ÷ 0,86	x	

les G 300, G 125 and G 80 for diagram I and for the geotextile G 300 for diagram II in tables 2 and 3 respectively. Figure 6 gives the change of factors BF and CF with time for geotextile G 300 in contact with sand and sandy clay soils for the two diagrams. The contact zone includes geotextile and a thin layer of the soil sample.

Blocking and clogging of the three materials to a greater or smaller degree have been notices during the tests. These processes are interrelated and in some cases can not be differentiated. Essential differences in the performance of one and the same variant soil-fabric in diagram I and II have not been specified. In diagram I the calculated differences of the blocking factor BF for the variants with clay soils are greater than these in diagram II, while in the variants sand/No 4/ and sands fractions this is reversed.

The needled fabric G 300 shows better performance in contact with the studies soils than the rest of the fabrics with chemical strenghtening. Indications for the contact zone and the filter itself clogging or blocking have not been registered in the combination of G 300 with sand with sizes over 0,10 mm. In diagram I these processes occur with clays/No 1,2 and 3 according to fig5/ and the fine sand fractions/ No 7 and 8/, while in diagram II - except with the clays, with the sand fraction 0,08 - 0,063 mm. A migration of soil particles through the geotextile has been noticed in the case of the clay soils and the sand fraction/ <0,10 mm/, while for the clays and the fraction 0,10 - 0,08 mm the process was limitted only to separate particles at the beginning of every test. For the fraction 0,08 - 0,063 mm the process is intensive, with long duration. For the last fraction the ratio O_{90}/d_{90} / O_{90} - is the fabric pore size defined above; d_{90} - 90% sand grain size/ for the geotextile G 300 is about 1,70, which value is near to the given by Ogink(4) value of the ratio with a view to preventing particle migration through the fabric:

$$\frac{O_{90}}{d_{90}} < 1,80 \quad \text{..............................} /3/$$

In variants 1.1, 1.3, 1.8 and to a certain degree 2.1 a deposition of fine soil particles in front of the filter has been noticed as a result of which the gradient Icz increases and BF factor gets a high value. The clogging factor CF

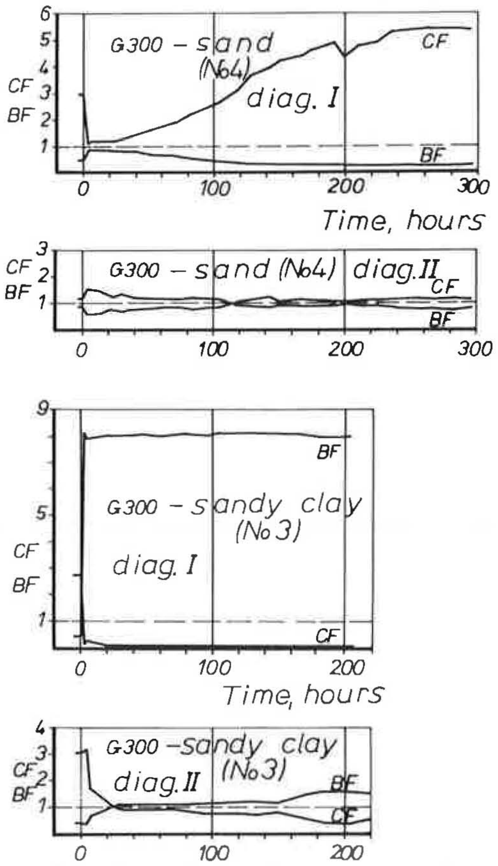

Figure 6 Changing of the factors BF and CF with time for geotextile G 300.

has the lowest values in variants 1.7 and 1.8 i.e. in the cases when a migration of particles through the geotextile G 300 has been noticed.

The combination of the other geotextiles G 125 and G 80 with sand >0,10 mm can also be accepted as proper though some divergencies in test initial phase have been noticed/ till 50-100 hours/ when BF>1 and CF<1. Probably, due to the carried out clogging particles by the water, the water permeability of the contact zone is kept high. In tests 3.4 and 3.5 of geotextile G 125 the values of the BF and CF factors are about the limitted value. It can be said that with the chemically bounded geotextiles greater values of the gradient Icz and bigger variation of the gradients and coefficients of permeability in the different parts of the system when testing the three types of clay, have been observed. In such cases all the signs of contact zone clogging are present. Migration of the soil particles through the fabric G 80 has been noticed for the fraction 0,08 - 0,063 mm/ $O_{90}/d_{90}=1,88$/.

For clogging of the chemically bounded geotextiles in the full sense of this term we can not speak, because of their small thickness.

The fabric material degree of clogging is checked up for geotextile G 300 by defining the coefficient of permeability of the clogged sample and comparing of its value with that of the material before and after conducting the clogging test. The degree of clogging is calculated by the formula:

$$DC = \frac{K^c}{K} . 100 \ /\%/ \ldots\ldots\ldots\ldots /4/$$

where K^c and K are the coefficients of normal permeability of the fabric filter before and after carrying out the tests.

The calculated values of DC for G 300, only for the cases in which clogging has been noticed, are shown in table 4.

Table 4

Degree of clogging of geotextile G 300

Test No	Soil/Fraction /acc. fig.5/	Factor DC, %	
		0,005MPa	0,05MPa
1.1	1	56	71
1.2	2	78	93
1.3	3	28	43
1.4	4	43	64
1.7	7	39	50
1.8	8	22	29
2.1	1	74	86
2.2	2	76	79
2.3	3	80	89
2.4	4	37	54
2.7	7	50	64
2.8	8	32	40

A given relationship as far as clogging degree depends on the soil composition has not been registered. In contact with clay soils the clogging ranges from 7 to 44%. In fabric samples investigated in contact with sand/ No 4 and with fractions <0,10 mm/ a deposition of particles has been noticed, as a result of which the coefficient of permeability is reduces considerably. In the case with fine sand Kn of the clogged filter ranges from 22 to 50% of the initial material coefficient. Nevertheless fabric G 300 remains sufficiently permeable.

SUMMARY AND CONCLUSIONS

The processes of clogging and blocking with time of three types of nonwoven geotextiles have been investigated in a laboratory. Studied is theire capacity in contact zone with loose clay and sand soils having natural granulometric composition and separate sand fractions for two water flow directions. As evaluation indicators for the contact zone and all the system processes are introduced the factors BF and CF, representing the ratios of the gradients in the contact zone and in the system and coefficients of permeability in this zone and in the soil, respectively. The following conclusions can be made:

- in the laboratory tests the contact soil-fabric zone and the fabric itself are clogged to a certain degree which affects the filter and hydraulic performance of the system;

- non woven needled fabrics perform better in comparison with chemically bouded ones, due to their structure and greater thickness;

- combinations of the investigated geotextiles with fine sand/ >100 mm / can be regarded as suitable;

- in the combination of geotextile - loose silty and sandy clays and very fine sand, blocking and clogging of the contact zone and of the geotextile itself have been registered. The danger for further development of these processes increases with the O_{90} value reduction. The migration of soil particles through the geotextile takes place at values greater than 1,6 - 1,8 of the ratio O_{90}/d_{90}.

- the earlier investigations of the author with fabrics in contact with clay soils with undisturbed structure show that in such cases there is a minimum danger for drain blocking and filter clogging and their performance is not affected. That is why in laying drains in silt clay and fine sand soils certain requirements have to be kept thanks to which lower velocity of the water flow to the drains and small hydraulic gradients in the zone around the pioes and the filter must be provided; the soil should remain undisturbed; the trench and the drain pipes should be bachfilled immediately with dry soil; use of trenchless machines ets.

REFERENCES

(1) Cestre, Th., "Revue des critères d'appreciation des risques de colmatage mineral des drains agricoles", Bulletin d'information du CEMAGREF, Bl.n 325, Fevrier, Antony,1985

(2) Davidenkoff, R., Anvendung von Filtern im Wasserbau, Verlag Wilhelm Ernst & Sohn, Berlin, München, Düsseldorf, 1976

(3) Mc Keand, E. "The behaviour of nonwoven fabric filters in subdrainage applications", C.R. Coll. Int. Soil Textiles, Paris, 1977

(4) Oging, H. J. M., "Investigations on the Hydraulic Characteristics of Synthetic Fabrics", Delft Hydraulics Laboratory, publication No 146, May 1975.