Filtration Behaviour of Geotextiles in Slurries

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ABSTRACT: To study the behaviour of geotextiles used as filters under the critical circumstance of soils in suspension this research was carried out in cooperation with the University of Grenoble.

A global study with geotextile-wrapped drainage pipes under different soil conditions was carried out. In a first test the fine soil was slightly compacted around the pipe, in a second test the same fine soil was built in by stacking compacted soil blocks. This second system showed a 15 times higher long-term permeability compared with the first one.

A local study with a permeameter for suspension filtration with different geotextiles and different slurries has also been realised to analyse clogging and piping mechanisms.

The result showed e.g. that geotextiles with an opening size 3 times larger than particle size held back 50 % of the soil after 8 min. (concentration 3 g/l). Also the better soil retention capability of nonwoven geotextiles against monofilament woven geotextiles and a very fast clogging of slit film wovens and heat bonded geotextiles is obvious.

In addition to that an optimum range for the number of filaments is given. That should lead to a good path size distribution of nonwoven geotextiles.

1 INTRODUCTION

If a well designed geotextile filter is in good or immediate contact with a well graded soil, piping or reduction of system permeability should not occur. The soil structure is held together and excessive surface erosion is prevented. However, if there is a loose contact between geotextile and soil (or a crack or a gap) fines can erode easily with the waterflow, which itself will become more turbulent. This will clearly decrease the chance of a good long-term behaviour of the system (Koerner et al., 1993) and increase the number of parameters for an optimal filter design which in fact should also include the kind of installation system and soil compaction.

In order to study the mechanisms under these critical conditions two test series were carried out within a research work at the Joseph Fourier University Grenoble:

- Global study: The whole soil-geotextile-drainage pipe-system was investigated in 1:1 scale in two large boxes.
- Local study: Analysis of the filter behaviour at the interface geotextile - soil in suspension under different conditions in a permeameter.

2 GLOBAL STUDY

To simulate an agricultural drainage two long term tests have been realized in large boxes with 0,6 x 0,6 x 1,0 m. The principle is illustrated in Figure 1:

- Box A: homogenous, soft compacted soil.
- Box B: artificially disturbed soil obtained by piling up of soil blocks.

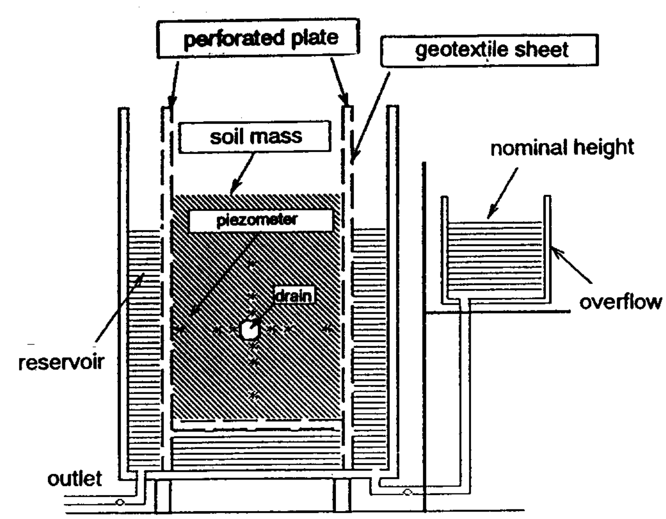

Fig. 1: Principle arrangement for large scale test

Both tests were made with soil B 700 (Fig. 2) and a drainage pipe with a diameter of 50 mm wrapped by needlepunched nonwoven PF 22 (Tab. 1). For a constant water supply the outflow of the pipes and the hydraulic pressure were measured with time.

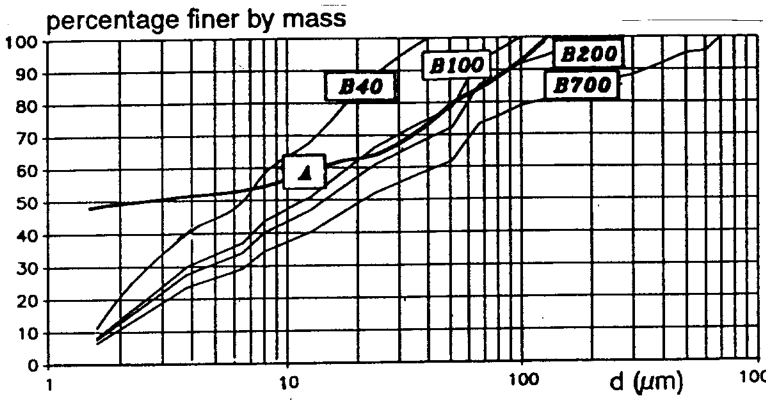

Fig. 2: Grain size distributions of the test soils

2.1 Homogenous soil

Figure 3 shows the variation of the drainage capacity with time for different hydraulic pressures which were increased step by step. It should be noted that:

- after increasing the water head supply the drainage capacity also increased in all cases suddenly, but then it decreased strongly with time. This strong decrease was not only due to accumulation of fines close to the filter interface but also due to a formation of seaweeds (algea) which seemed to increase with temperature.
- after cleaning the pipe with copper sulphate the drainage capacity increased substantially again.

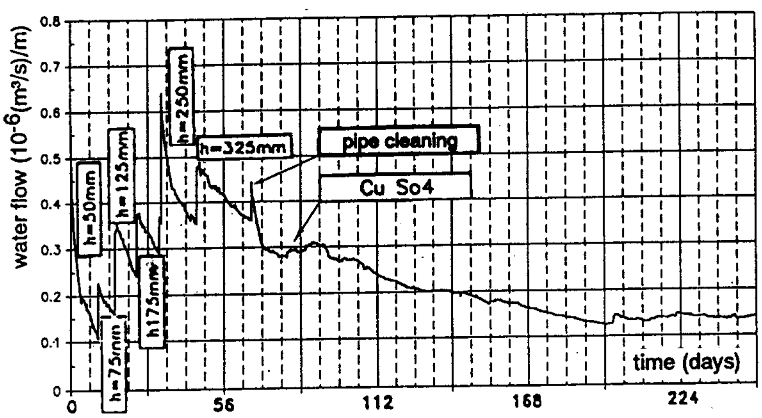

Fig. 3: Variation of drainage capacity, homogenous soil

2.2 DISTURBED SOIL

Due to erosion of some soil blocks and turbid waterflow in the cracks fine particles were transported to the geotextile filter and a small part of less than 1g by step piped through. So a strong decrease in the drainage capacity could be noticed. However, because of the much higher starting level the capacity after 250 days remained at H = 125 mm even 6 times higher than the starting level of the homogeneous soil at H = 325 mm (Q = 3 to 0.5 cm³/s/m).

Probably due to the high water flow velocity no seaweeds have been observed in the drainage pipe.

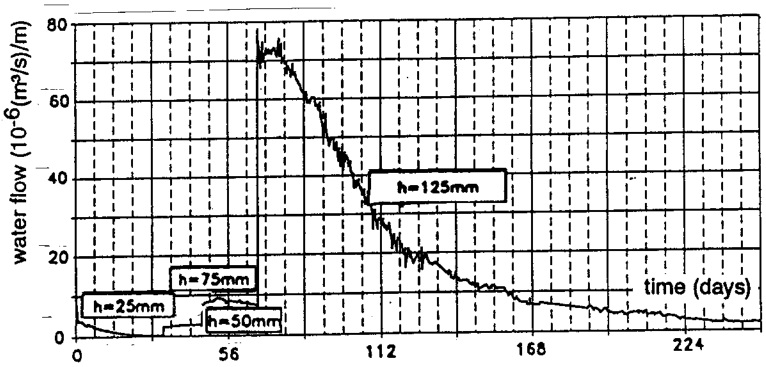

Fig. 4: Variation of drainage capacity, disturbed soil

2.3 Conclusions of the global study

After 252 days the drainage capacity of the disturbed soil system at H = 125 mm is 15 times higher than with soft compacted homogeneous soil at H = 325 mm (Q = 3,0 to 0,15 cm³/s/m, i < 1). For this type of soil it is therefore preferable to have a disturbed zone in the vicinity of the drain. There is a risc of local clogging but:

- the water finds its way through less clogged cracks.
- the resistance against water flow of a filter with a thin filter cake is much smaller than that of a homogeneous undisturbed fine soil with around 30 cm thickness.

3 LOCAL STUDY

To filter special suspensions with a given concentration Co, a permeameter with a pump for constant flow was constructed (Fig. 5). Different test series with single soil fractions on one hand and grain size distributions (Fig. 2) on the other hand were carried out with needlepunched and heatbonded nonwovens, as well as with monofilament and slit film wovens (Tab. 1).

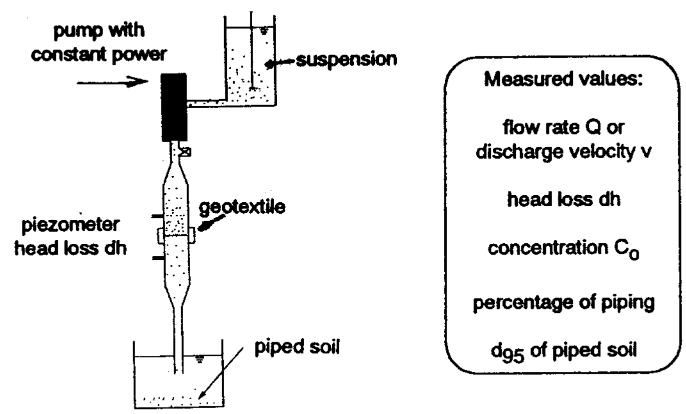

Fig. 5: Arrangement for filtration of suspensions

Geotextile	Type	Weight (g/m^2)	Thickness (mm)	Opening size (μm)
PF 22	needlep. NW.	110	1.2	135
PF 500	needlep. NW.	184	1.7	126
PF 600	needlep. NW.	194	1.9	89
PF 700	needlep. NW.	310	2.6	76
BD U 24	needlep. NW.	210	2.1	147
BD U 34A	needlep. NW.	300	2.9	110
BD U 34N	needlep. NW.	300	2.6	94
TM 2000	heatbonded NW.	270	1.2	62
TP 136	heatbonded NW.	136	0.48	121
tPT 48	monofilament W.	48	0.15	122
AM 230	slit film Woven	230	0.36	105

Tab. 1: Tested geotextiles

3.1 Piping

This study was investigated with single fractions. As result piping is illustrated as a function of time, of filtration opening size and of the slurry concentration. Only little influence of the flow velocity was observed.

- Time: In all cases a decrease of soil passing with time is obvious. Due to the monodirectional waterflow, arch formations can build up easily which reduce piping suddenly. This break in the soil passing curve per time is greater and earlier, the closer the O/d ratio (opening size/grain diameter) is to 1. After that the percentage of passing decreases only slowly, which means, that some openings let the fines pass steadily.
- Filtration opening size (by hydrodynamic sieving after French standard): The O/d-ratio (Fig. 6) is the most significant parameter for the filter behaviour of all geotextiles, the retention efficiency of wovens is much less than that of nonwovens at the same O/d-ratio. E.g., for O/d = 2, nonwovens let pass less than 30 % in comparison to wovens with about 80 %. For wovens there is also a significant break in the passing curve at O/d = 1 noticable, so they have to be designed very safe with exact knowledge of all site circumstances (soil, installation, etc.).

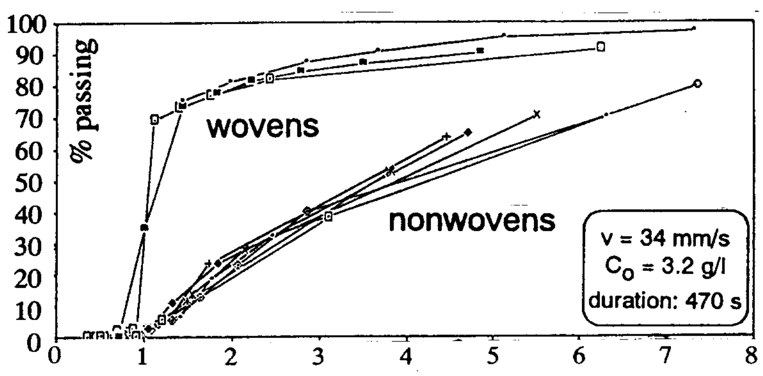

Fig. 6: Influence of the opening size

- Concentration: The higher the concentration Co of suspension, the lower the percentage of soil passing. Again there is a better retention capacity of nonwovens compared to monofilament wovens at the same opening size. E.g. the retention capability of the nonwoven PF 500 at Co = 3,2 g/l is similar to that of the woven tPT 48 at Co = 38,4 g/l.

3.2 Clogging

To asure a considerable decrease of the flow capacity, a very fine clay (soil A, B in Fig. 2) was used for these test series. In contrast to the single fractions the fine soil led to increased water pressures upstream the filter, which was measured by piezometers. That was taken as a parameter for clogging.

Very low concentrations < 1,0 g/l were used to increase the time factor. At teststart the pressure grew always slowly up to about 5-10 kPa (1m water head), so the time t_{10} at 10 kPa was taken as a characteristic parameter. After that mark the water pressure increased quickly which means "clogging" of the system.

- Geotextile structure (Fig. 7): Four different kinds of geotextiles with comparable opening sizes (105 to 126 μm) were tested. The monofilament woven tPT 48 with its low retention capability shows nearly no surpressure. On the other side the system with the slit film woven AM 230 and the heat bonded nonwoven TP 136 clogged very early. Compared to them, the needlepunched nonwoven PF 500 shows a significant delay in "clogging", in particular with low concentrations.

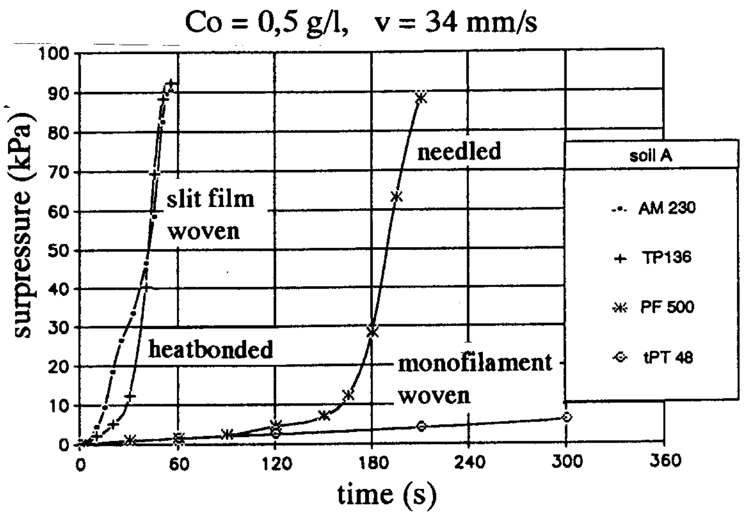

Fig. 7: Influence of the geotextile structure

- Filtration opening size (Fig. 8): Three needlepunched nonwovens PF 22, 500, 600 with equal structures but different opening sizes (89 to 135 μm) were tested with soil A (d_{max} = 135 μm). The test result shows only little influence for $O/d_{max} < 1$.

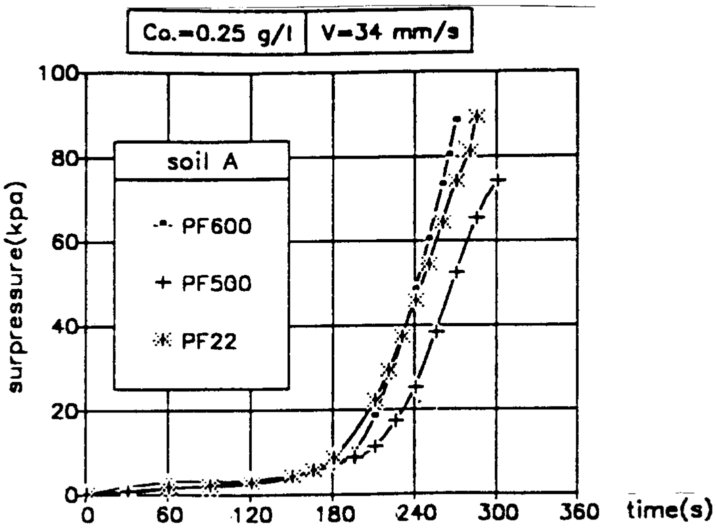

Fig. 8: Little influence of O for needlep. nonwovens

- Concentration: The higher Co, the earlier the clogging.
- Gradiation: t_{10} got smaller with greater soil particles. Once d_{max} is greater than O (200 or 700 μm compared to 135 μm, Fig. 9), t_{10} stays nearly constant. If d_{max} is smaller than O, the soil with more fines clogs faster.

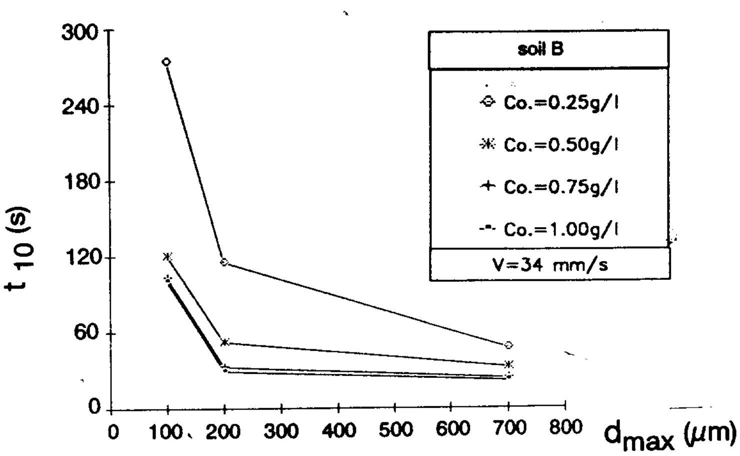

Fig. 9: Influence of dmax (soil B 100 - 700, PF 22)

3.3 Conclusion of the local study

- Concerning piping nonwovens are more efficient than wovens, which also have a significant break in retention capacity at O/d = 1.
- The systems with heatbonded nonwovens and slit film wovens showed a very fast decrease in permeability. The reason seems to be the surface structure, so that fine soil particles can settle very easily at the smooth parts of the geotextiles and subsequently close the filter openings.
- Needlepunched nonwovens have a significant delay of t_{10} (later "system-clogging"). The rough or "3-dimensional" surface structure is helping the fines to avoid blocking of the filter openings and to build up arches close to them.
- The monofilament woven system has a very high t_{10}, but this is due to the continued piping of fines.

4 PATH SIZE DISTRIBUTION (PSD)

For mineral filters a minimum number of 25 layers of average grain sizes is normally recommended (Heerten, Wittmann et. al., 1985). The reason is the more uniform PSD. Also for nonwovens a higher number of layers led to advantages in the PSD, because then more paths are in the same range of the tested max. opening size O, which means a safer filter.

If the number of filament layers increases more and more, the influence for the PSD decreases. However, the danger of intrusion of fines into the geotextile, the lowering down of permeability and also the cost factor has to be taken into account. This led to a optimal range of required layers (Tab. 2).

Flow conditions	Number of filaments
monodirectional	25 - 75
turbulent, bidirectional	50 - 100

Tab. 2: Optimal range for the number of layers

Within that range of numbers of layers (or filter length, FL) the experiences have been very well not only in laboratory tests (e.g. Fig. 8: 1,2 to 2 mm geotextile thickness, with a filament diameter of .0,04 mm ==> FL = 30 to 55), but also for excavated geotextiles (De Groot and Verheij 1993, Heerten 1986, Rollin 1993,...).

5 REFERENCES

Eichenauer (1993) Necessary Thickness of Geotextiles used as Filters, *Kunststoffe in der Geotechnik*, München 3.93, DGEG, pp. 9-15.

Farkouh (1994) Les filtres géosyhthétiques dans les ouvrage de drainage, *Univ. of Grenoble* (to be publ.).

Faure, Elamir, Farkouh and Gendrin (1993) Geotextile filter behaviour with critical filtration conditions, *Filters in Geotechnical and Hydraulic Engeneering*, Karlsruhe, pp. 209-217.

Faure and Reisinger (1992) Filtration of soils in suspension with geotextiles, *5th International Drainage Workshop*, Lahore, pp 229-240.

De Groot and Verheij (1993) Long-term filter performance of Polyfelt geotextiles, *unpublished*, Polyfelt.

Heerten and Wittmann (1985) Filtration Properties of Geotextile and Mineral Filters related to River and Canal Bank Protection, *Geotextextiles and Geomembranes 2/85, pp 47-63.*

Koerner et al (1993) Long term performance of Geosynthetics in Drainage Applications, *GRI*, USA.

Rollin (1993) Geotextile Thickness Influence on Filtration Design Criteria, *unpublished*, Polyfelt.