Geotextile Thickness: A Relevant Filter Design Criterion

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ABSTRACT: The geotextile filter function is to restrain soil particles migration while allowing evacuation of water from the surrounding soil. In this paper, the results that have been obtained in research investigations on soil/geotextile filtration behaviour, and during monitoring of in-service performances of geotextile filters have been gathered and analysed. The data lead to the conclusion that the geotextile thickness does not influence the long-term filtration behaviour of a geotextile submitted to unidirectional flow conditions.

1. INTRODUCTION

Current criteria are based upon the relationship between an indicative pore size of the geotextile, an indicative particle size of the soil, soil's coefficients of uniformity and curvature (shape of gradation) and the geotextile/soil permeability ratio. Recently, new German guidelines were issued, incorporating the geotextile thickness as essential parameter.

The filter criteria for different applications have to be divided in function of two basic flow conditions: steady-state (unidirectional) and dynamic state (reverse and pulsating flow Christopher et al, 1988; Luettich et al, 1992).

The scope of this paper is to evaluate the performance of thin geotextiles (thickness less than 2 mm) installed in unidirectional flow applications. Field and laboratory investigations were performed on geotextiles installed for many years in different types of so called "problematic" soils in Canada, Germany and Austria (reference Fig.1).

2. CASE STUDIES

The studies were carried out at Ormstown and Drummond, Canada (subsurface agricultural drainage - 8 and 15 years in service); at Landfill Gerolsheim, Germany (cap-drainage layer - 5 years in service); and at Brixen and Innsbruck, Austria (two multi-story parking lots - 5 and 7 years in service). These cases are discussed in detail in this paper while results obtained in other case studies have been used to support the findings: Wuppertal, Germany (drain geocomposite - 13 years in service), Pakistan (subsurface agricultural drainage - 5 years in service), Piaski-Szczyglizki, Poland (earth dike toe drainage-7 and 8 years service).

During these field investigations, samples of thin needle-punched nonwoven, thermally bonded nonwoven and woven geotextiles as well as undisturbed soil/geotextile interfaces were collected. They were analyzed using permeameters and studied by microscopical and computer techniques to investigate changes in hydraulic conductivity, mineral clogging and soil/geotextile interface structure. The gradation of soils in which the geotextiles were installed are presented in Fig. 1.

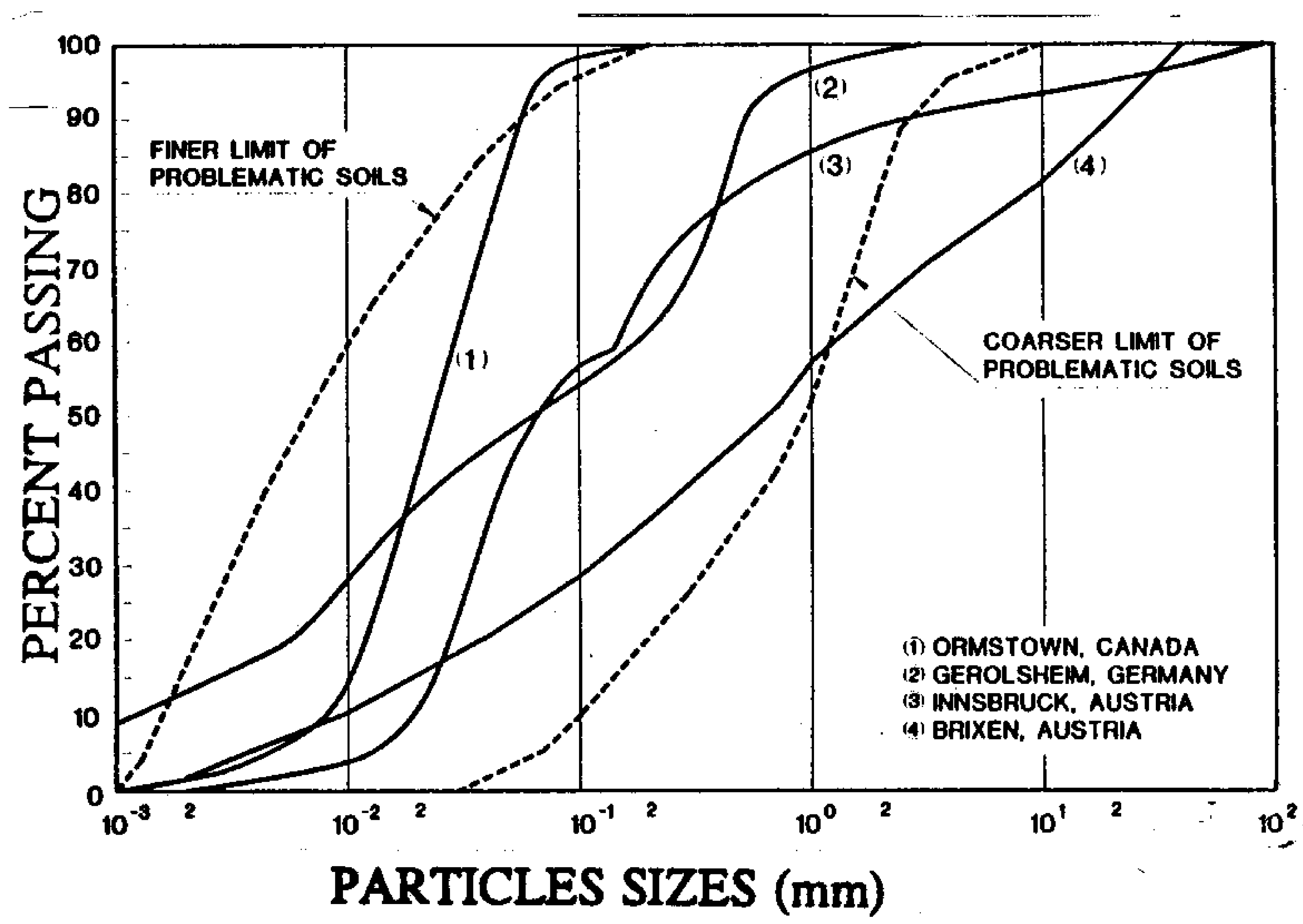

Fig. 1 Gradation of soils from different sites

2.1 Ormstown and Drummond sites

In October 1983, four geotextiles with a thickness ranging from 0.24 to 0.90 mm and a FOS (filtration opening size) ranging from 28 to 200 microns were wrapped around corrugated subsurface drainage pipes and installed in a uniform silty soil (curve 1 in Fig. 1). Field investigations were performed in autumn 1986 (Rollin et al, 1987; Mlynarek et al, 1994).

The drainage system consisted of 30 parallel lateral drains of 220 m length with 6 replicates: 4 drains with different fabric and 1 control drain without a fabric. The geotextiles installed were a nonwoven laid bonded, a calandered needle-punched nonwoven, a knitted pile fabric and a nonwoven slit-film with needle-punched staple fibres. In 1992, after 9 years in service, undisturbed soil/geotextile samples (50 mm x 50 mm) were retrieved from each functioning drain using an embedding technique developed at Ecole Polytechnique of Montreal.

Following this embedding procedure first the soil is excavated close to the filtration system than the sample is isolated by carefully flaking away surrounding soil and leaving a cover of less than 5 mm of soil. Then a colourless epoxy resin is used for embedding the geotextiles and the adjacent soil yielding a structural resolution for electron microscopy analysis. Because of its exceptional penetration of tissues and minerals, the resin permits the infiltration, drying and hardening of geotextile and soil without the need of dehydration by organic solvents. The colourless mixture of resin and catalyst is slightly heated and poured on the field sample. The sample is then placed under slight vacuum for a few hours to remove gas and air bubbles and finally removed from the site.

The cured specimens are easily sectioned with glass or diamond knives and the cross section of both soil/geotextile interfaces are then polished prior to being analysed under a microscope or using an electron scanning microscope (Mlynarek, 1994).

The pipes without a filter clogged within 2 years (Rollin et al, 1987) while pipes wrapped with geotextiles functioned satisfactorily after 9 and 15 years of service. Visual inspection of all drains indicated no sediment deposits in the pipes and no clogging of geotextile filters.

A photographic cross section of a geotextile/soil specimen collected after 8 years of service is presented in Fig. 2. One can observe that the soil particles were retained by the nonwoven geotextile, that only few soil particles are trapped within the textile structure while clear vault formations can be observed at the textile interface with the soil. Also, an interesting visual observation indicated the presence of several preferential water flow path in the soil in front of corrugated pipe slots. The high velocity of the water in front of a slot carried away the fines (the black particles in Fig. 2) leaving in place the coarser ones (white particles) explaining the network of macro-pores in the soil adjacent to the geotextiles.

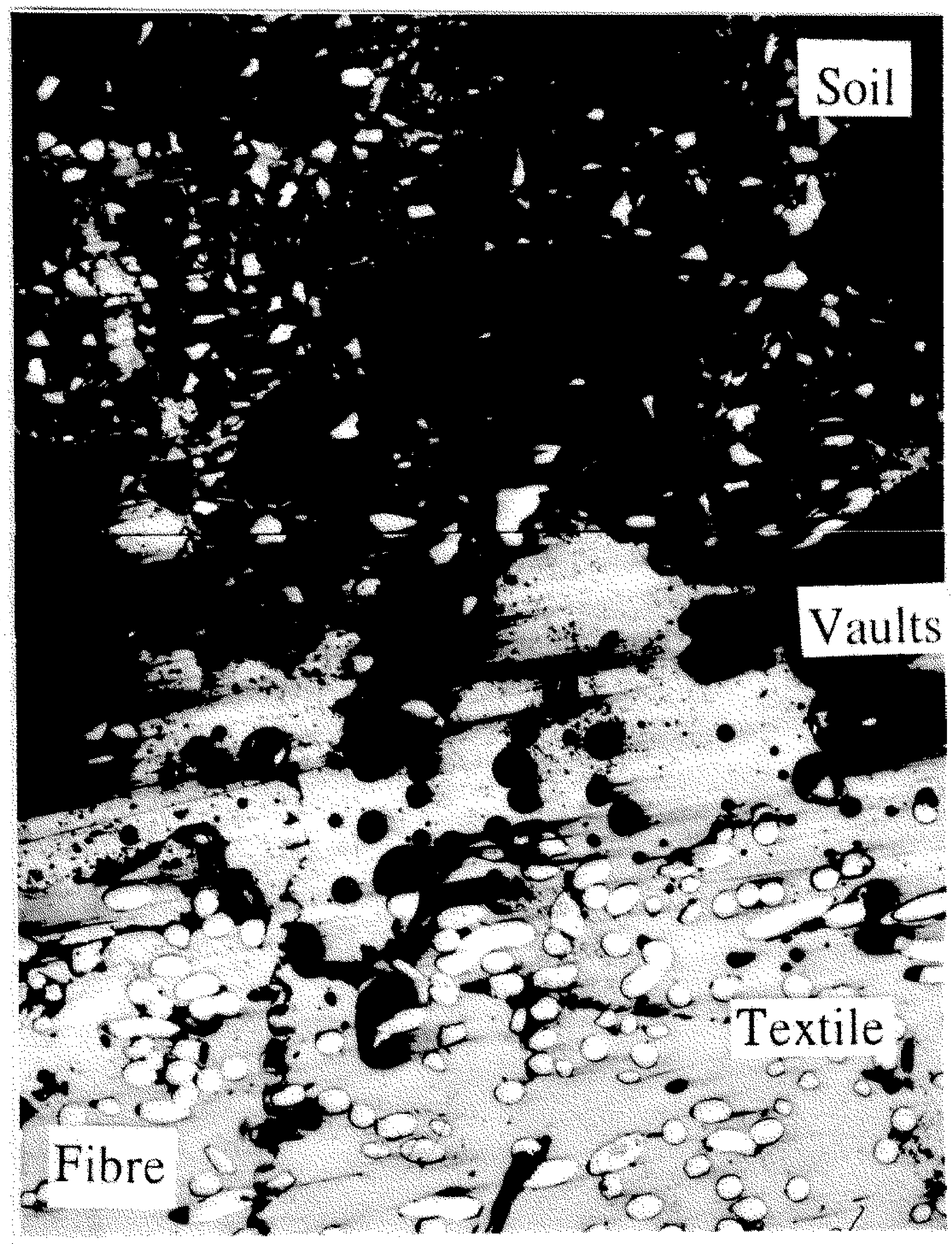

Fig. 2 Microphotograph of a nonwoven geotextile soil specimen collected at Ormstown after 9 years in service

2.2 Gerolsheim landfill site

For the drainage of excess rain water, a geocomposite consisting of two thin heat bonded geotextile (thickness of 0.7 mm, opening size 0.180 mm) and a core of coarse polyamide filaments were used.

Over a five year period, geotextiles and interface soil samples were collected periodically under the supervision of the Research Centre for Hydraulic Engineering at the University of Karlsruhe. The quantity of entrapped soil particles and the water permeability of the collected samples are shown in Fig. 3. In addition, a new scanning technique was developed to assess the clogging level of retrieved geotextile samples.

After removal of the soil cover, samples of 0.2 m in diameter were carefully cut, transported to the laboratory to be dried at 30°C until all loose particles could be removed. The weight of trapped particles was determined and the permeability of specimens of geotextile with soil particles was measured at different hydraulic gradients using an up-flow permeameter.

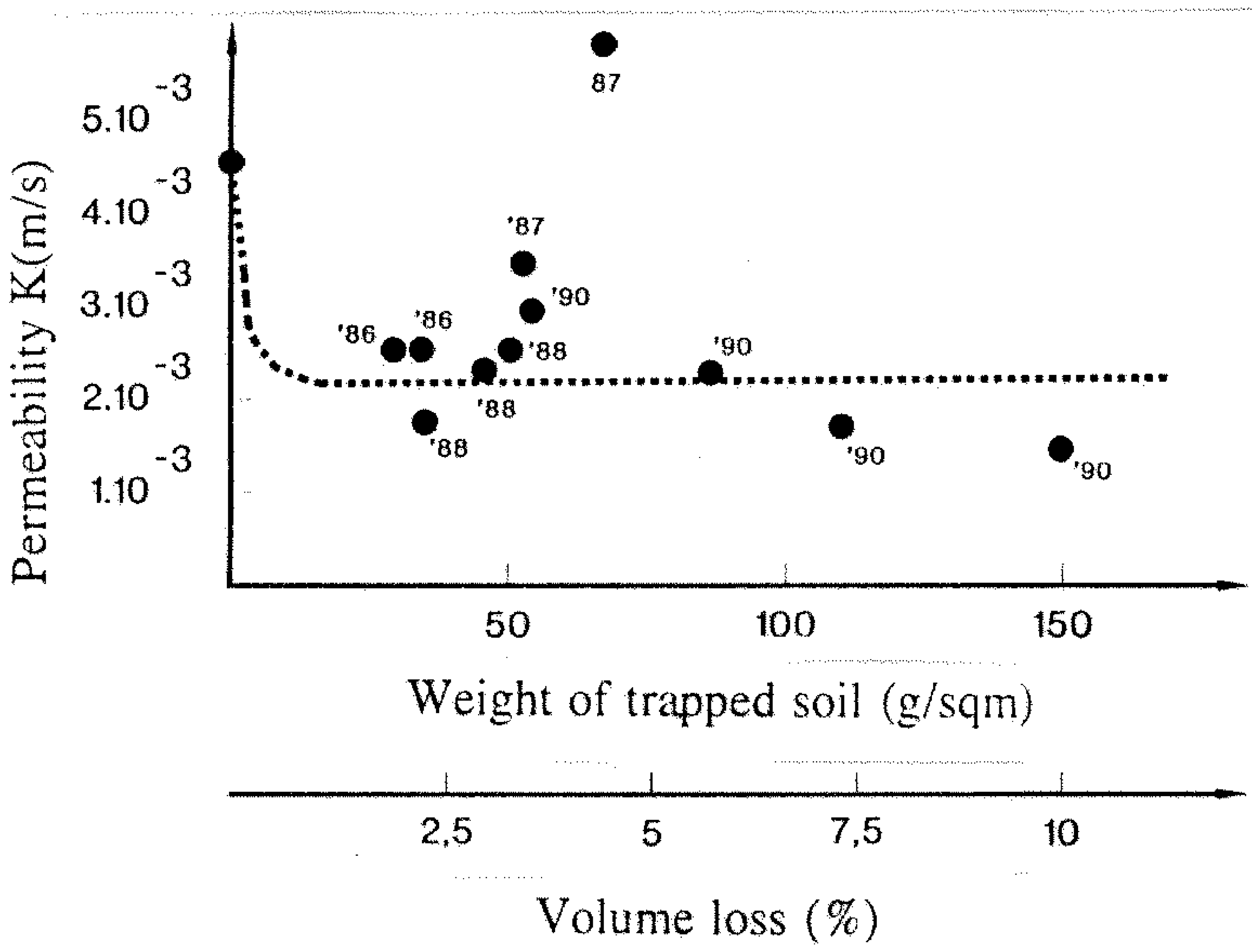

Fig. 3 Permeability of geotextile samples collected at Gerolsheim landfill

Samples were also tested at Winand Staring Centre, Wageningen, The Netherlands, to measure the particle size distribution of the trapped particles, previously washed-out of the textile structure by high-frequency vibrations. The particle size distribution is established by measuring the disturbance of an electric field by washed particles in suspension using a Particle Data Electro Zone Celloscope, model 112.

In 1989, after 43 months of service, two cylindrical soil/geotextile samples were retrieved and analyzed using a Philips Tomoscan scanner, model 350. The tomograph can produce a CT scan measuring density differences in a cross-section of a slice of material 1.5 to 12 mm in thickness. Computer processing of obtained CT data enable the production of a 3-dimensional image of the drain and its natural surroundings.

The analysis of the data gathered from all the tests indicated that no soil particles were found in the drain core. Most particles were trapped in the geotextile filter in the first months of service. The average weight of particles found in the filter varied from 50 to 125 g/m^2 corresponding from 40 to 100% of the mass per unit area of the textile. The analysis of the size of trapped particles indicate the presence of particles greater than 0.005 mm but smaller than 0.100 mm. Dimensions and composition of soil particles adjacent to the filter and of trapped particles measured by the Particle Data Electro Zone Celloscope are presented in Table 1. It can be observed that the adjacent soil composition is similar to the gradation of the original soil as presented in Fig. 1, curve 2.

The final permeability of the geotextile samples (1.5 x 10^{-3} m/s) was reached after the first months of service and remained constant during the five years monitoring period. The residual permeability remained four orders of magnitude greater than the permeability of the adjacent soil (3 x 10^{-7} m/s).

Table 1 Particles size and composition in soil and in geotextile, Gerolsheim landfill

Grain size (mm)	Compositio n of soil trapped in the filter (%)	Composition of soil adjacent in the filter (%)
d < 0.005	0	20
0.005 < d < 0.1	97	40
d > 0.1	3	40

A top view of a 3-D image of a soil/geotextile sample from one of the 20 successive scanned slices obtained from the CT-scanning technique developed by Stuyt (1992) using a Personal Iris 4D/20 computer is presented in Fig. 4. The soil particles are white in color while the color of the macropores are grey/black. The results indicate that the contaguous soil had a well developed structure and that there was no evidence of mineral clogging of the retrieved heat-bonded filter layer.

2.3 Parking lots in Innsbruck and Brixen

A geocomposite drain, consisting of a heat-bonded geotextile and a drain plastic core, was installed as a drainage layer on the roofs of two multi-story parking

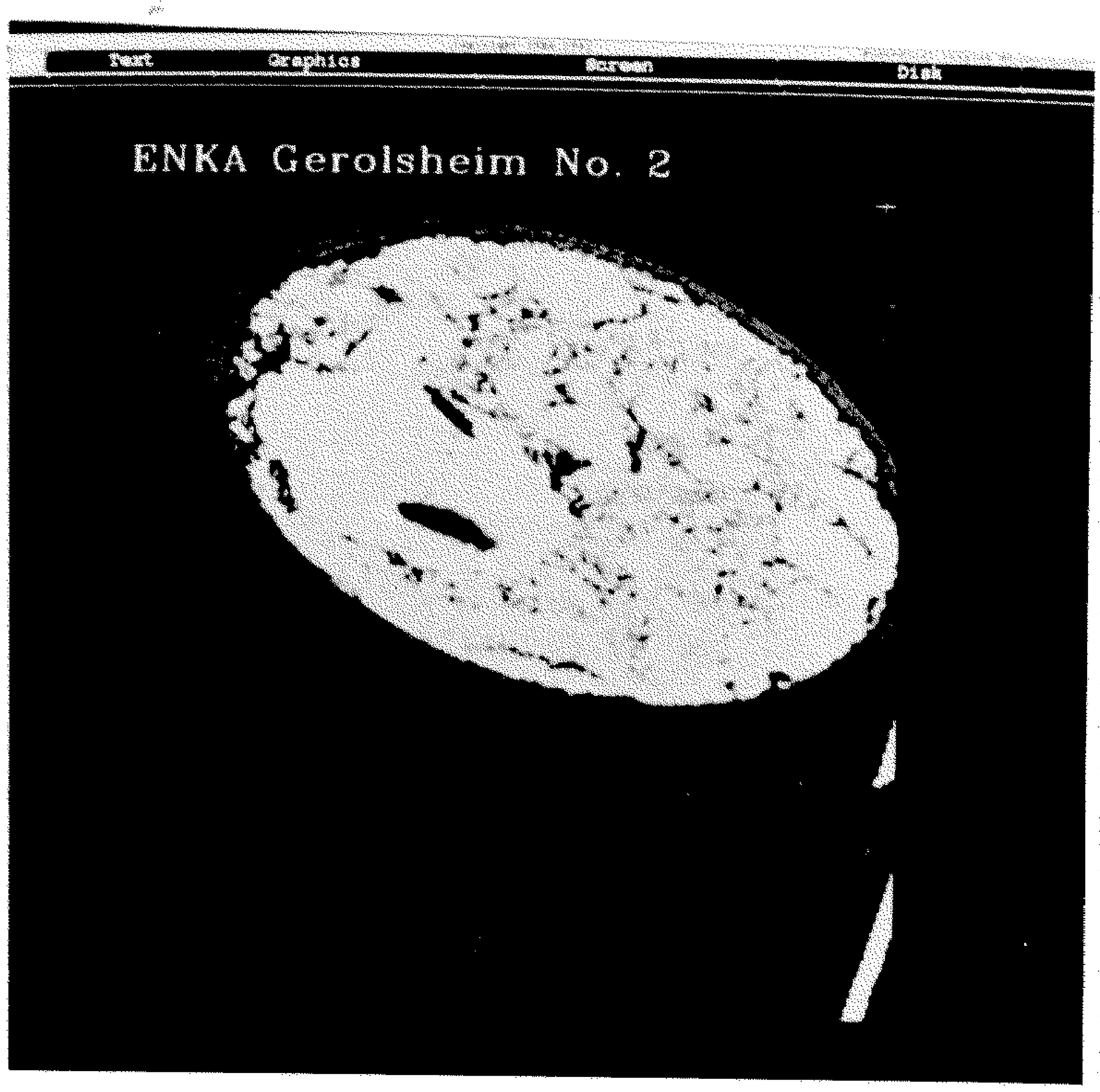

Fig. 4 Top view of a 3-D image of soil/geotextile sample, Gerolsheim landfill

garages at Innsbruck in 1984 and at Brixen in 1986. Both drainage systems were covered with approximately 0.5 m of soil which gradation are presented in Fig. 1, respectively curves 3 and 4. The Innsbruck soil is a sandy silt soil with d_{50} = 0.07 mm and can be classified as problematic soil (potential to cause filtration problems). In both cases, the soil surface was used as playground and footpath were laid out on the soil.

In 1991, geocomposite samples were collected for testing at Innsbruck (7 years in service) and at Brixen (5 years in service). The testing program was performed at Research Centre for Hydraulic Engineering, University of Karlsruhe, using the same techniques as with the Gerolsheim samples. The obtained data on permeability and mass of trapped soils particles are presented in Table 2.

The mass per unit textile area of trapped soil particles is respectively from 48 to 77 g/m² and from 93 to 109 g/m² at Brixen and Innsbruck drainage systems. The larger quantity of particles trapped in the Innsbruck textile samples is probably related to the gradation curve of the soil in contact with the filter and not because of the extra period of two-year service.

The presence of particles within the textile structure decreases the permeability of the collected samples: 12 to 30% at Brixen and 45 to 60% at Innsbruck. The overall capacity to evacuate water was not influenced greatly since the measured permeabilities were 100 to 1000 times greater than the permeability of the soils.

Table 2 Permeability and soil up-take at Innsbruck and Brixen sites

	Exposure (years)	Permeability (k_v) (m/s)	Decrease (%)	Soil up-take (g/m²)
Unused	0	6.01×10^{-3}	-	-
Brixen 1	5	4.16×10^{-3}	31	77
Brixen 2	5	5.29×10^{-3}	12	48
Innsbruck1	7	3.31×10^{-3}	45	109
Innsbruck 2	7	2.41×10^{-3}	60	97
Innsbruck 3	7	3.07×10^{-3}	49	93

3. CONCLUSION

The in-field and laboratory investigations on unidirectional flow of water through thin nonwoven geotextiles, reported in this paper and gathered in others field applications in Germany, Pakistan and Poland, allow to conclude that the thickness of the geotextile does not influence the long-term behaviour of the filter systems. The results have support the fact that the influence of soil is much more fundamental than that of the geotextile thickness.

The role of the geotextile being limited to the retention of the soil particles, this requirement must be satisfied by properly selecting the indicative pore size of the filter. The experiments show, that due to an unidirectional flow through uniformly graded soil (See Fig. 1) a long-term effective restrain of particle migration can be achieved if the ratio of the opening size of the geotextile filter (0_{go}) to the indicative opening size of the soil (d_{85}) is smaller than 4, or in the same way if the ratio $0_{go}/d_{50}$ is smaller than 9.

4. ACKNOWLEDGEMENTS

The authors wish to acknowledge the work of Dr. R. Broughton, Centre of Agricultural Drainage, McGill University, of Dr. L. Stuyt, Winand Starring Centre, Wageningen and Dr. W. Muth , Research Centre for Hydraulic Eng., University of Karlsruhe, in performing research programs as reported in this paper.

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