Filtration Behaviour of Broadly Graded, Cohesionless Tills

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ABSTRACT: Coarse, broadly graded, cohesionless glacial till soils are frequently encountered in construction projects. In filtration applications, these soils can present design problems because of their high silt content, low plasticity and sometimes internal instability. Engineers often are wary of using geotextiles with such soils. To determine the filtration capability of geotextiles with till soils, gradient ratio tests (ASTM D 5101) were performed using tills from northwestern Washington State (U.S.A.) and four different geotextiles. The results of these tests indicate adequate retention of the till soils by the geotextiles. However, some clogging of the geotextiles was observed. Initial indications are that existing geotextile filter design criteria do not adequately predict the behavior of these soils.

1 Introduction

Glacial till soils are frequently encountered in the northern United States and Canada in the construction of engineering structures. In northwestern Washington State, the glacial till soils are typically broadly graded, gravelly, silty sands. Because of their abundance in the region, these soil are used frequently in construction.

Although geotextiles are often appropriate substitutes for graded granular filters, there is a common perception among geotechnical engineers that glacial till soils will clog geotextiles. Consequently, geotextiles are not used to the same degree or with the same level of confidence as granular filters. This perception may have some justification in that the local glacial till soils typically have a high fines content (30 to 50% passing the U.S. No. 200 sieve), broadly graded grain size distributions (uniformity coefficients of 25 or more), low plasticity (plasticity index less than 5), and a small clay-size fraction (less than 10%). These soil properties are often associated with clogging of geotextiles. This paper presents the preliminary results from an on-going, comprehensive study of the filtration behavior of broadly graded, cohesionless tills retained by geotextile filters.

2 Filtration test used in study

A variety of filtration tests have been recommended to study soil-geotextile behavior, including the gradient ratio (Calhoun, 1972), long-term flow (Koerner and Ko, 1982), hydraulic conductivity ratio, HCR, (Williams and Abouzakhm, 1989), and fine fraction filtration (Sansone and Koerner, 1992). For this study, the general procedures of the gradient ratio test (ASTM Designation D 5101) were chosen for the following reasons:

- The gradient ratio test is the only method standardized by ASTM.
- The gradient ratio test setup is simple and inexpensive.
- Measurement of head loss (and therefore permeability) is possible across various levels of the soil and geotextile by the use of piezometers at select locations. This was particularly important because the soils tested were possibly internally unstable. Movement of soil particles in different parts of the test specimen could only be determined by precise head loss measurements.
- The tail water and fines could be collected, thus allowing for observation and measurement of piped fines.
- High flow rates through the soil-geotextile system are possible.

3 Soil properties

Two soils representative of the range of gradations for the typical local tills were used for this study. The first sample, MUK1, was a broadly graded, gravelly, silty sand, classified as SM-SC according to the Unified Soil Classification System. The second sample, OLY1, was a broadly graded, silty, gravelly sand, classified as SM. Grain size distributions of the samples are shown in Fig. 1. Atterberg limits tests conducted on the MUK1 sample indicated a liquid limit of about 20 and a plastic limit of about 16 for a plasticity index of 4. The OLY1 sample was nonplastic. For purposes of testing, the soils were screened through the 10 mm sieve, in accordance with the ASTM standard test procedure. Compaction test results on both samples indicated a maximum dry density of 21 kN/m^3, according to ASTM D 1557.

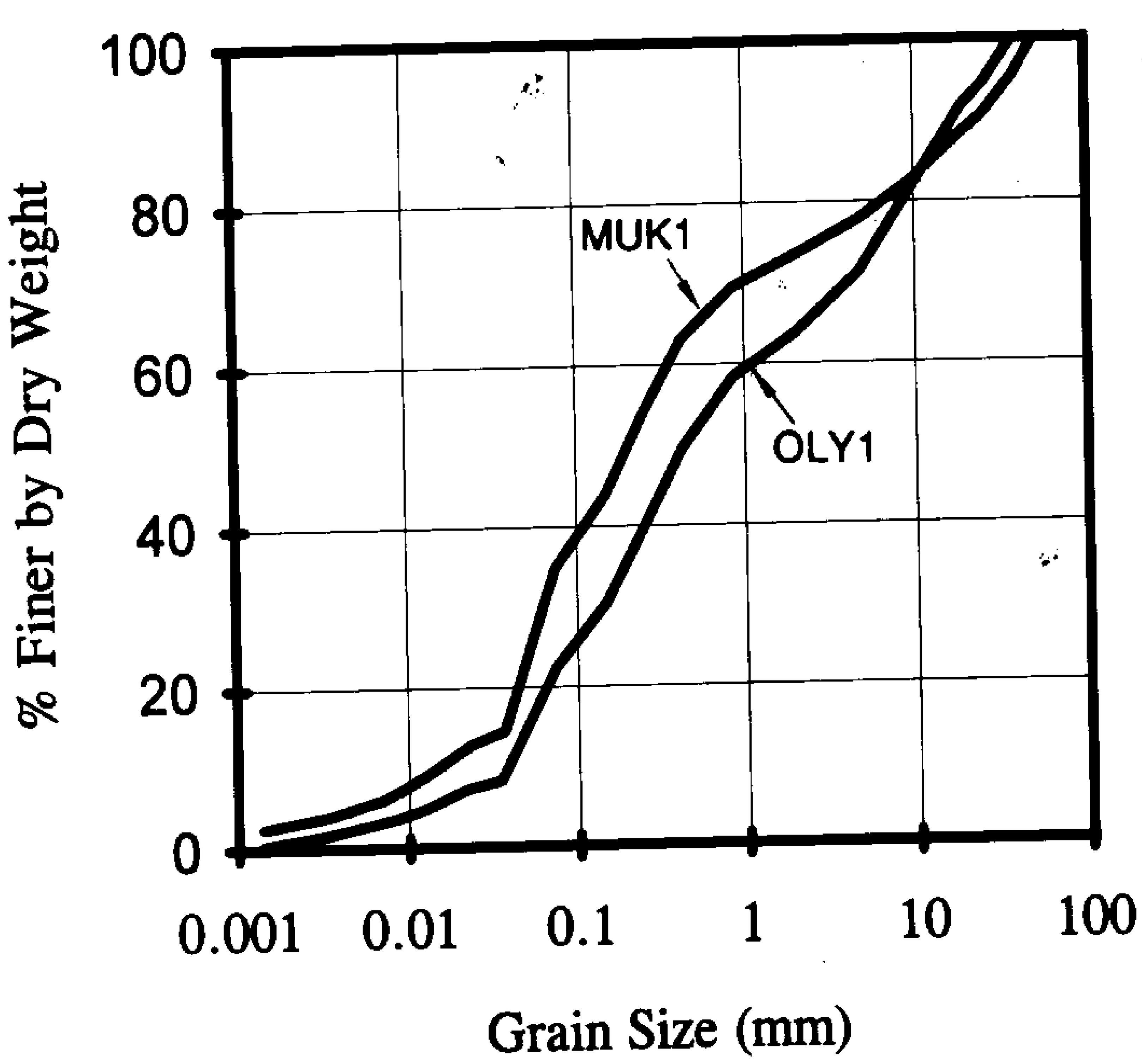

Fig. 1. Grain size distributions of till soils.

4 Geotextiles tested

Fifteen different geotextiles from four different manufacturers are being tested in this study. They are:

- polypropylene, continuous-filament, needle-punched nonwovens (Type 1),
- polyester, continuous-filament, spunbonded, needle-punched nonwovens (Type 2),
- polypropylene, continuous-filament, thermally spunbonded (heatbonded) nonwovens (Type 3), and
- polypropylene, monofilament and multifilament wovens (Type 4).

Results from one geotextile from each manufacturer, of similar mass per unit area and apparent opening size (AOS or O_{95} as defined by ASTM D 4751), are presented later in this paper. The relevant hydraulic and filtration properties of these four geotextiles are listed in Table 1.

Table 1. Typical filter properties of geotextiles tested.

Type	Mass/Area (g/m^2)	AOS (mm)	Perm. (m/sec)	Porosity/POA (%)
1	281	0.12-0.21	4E-3	89
2	254	0.15-0.21	5.6E-3	92
3	213	0.08	1.4E-4	71
4	220	0.21	4.7E-4	10-20

5 Gradient ratio test procedures

The tests were performed using a 100-mm diameter by 100-mm high rigid-wall permeameter with piezometer ports at 25 and 75 mm from the top of the sample in accordance with ASTM D 5101. The water for the experiments was standard tap water, de-aired to a dissolved oxygen content of 2 ppm or less. The air-dried soils were loosely placed, resulting in ASTM D 1557 relative compactions ranging from 69 to 77 percent for the MUK1 samples and 77 to 81 percent for the OLY1 samples. The tests followed the general procedures of ASTM D 5101, with the following exceptions.

- Through numerous tests on clean Ottawa sand, it was determined that a one micron filter was needed to filter impurities in the water prior to its entering the de-airing tanks. The results of these initial tests are presented in Figure 2. As shown in Figure 2, the use of carbon dioxide and an algicide (clorox bleach) did not effect the system flow rate.
- The time measurements generally began at 0.1 hr and were made more frequently than suggested by ASTM. Additionally, the tests under each hydraulic gradient were continued beyond the 24 hr reading, until stabilization of the hydraulic conductivity was observed.

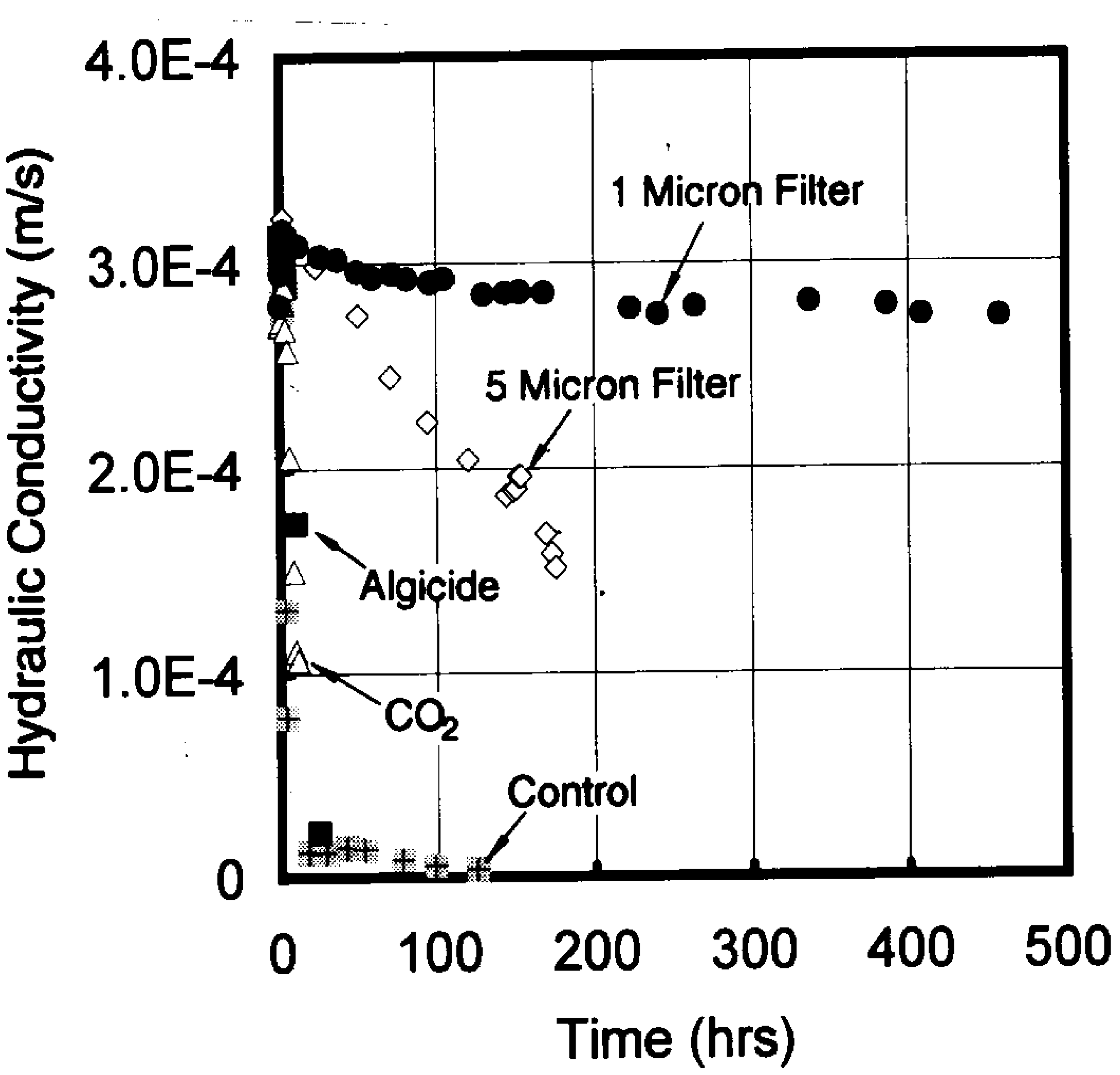

Fig. 2. Effect of test procedures on system hydraulic conductivity for Ottawa sand and Type 2 geotextile.

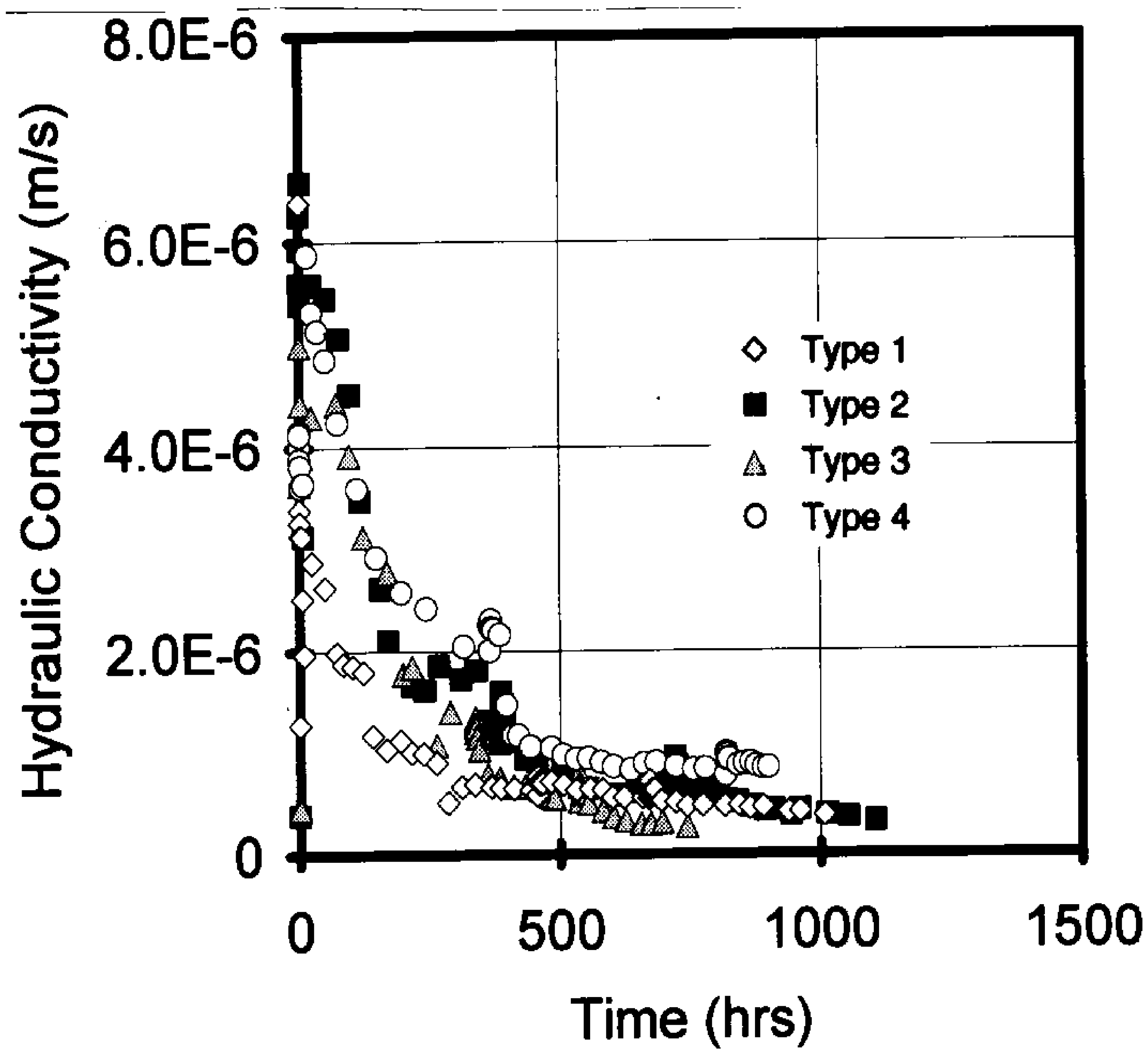

Fig. 3 Hydraulic conductivity of bottom 25 mm of soil/geotextile for MUK1.

6 Internal stability of tills

Coarse, broadly graded soils can be internally unstable; that is, there are enough coarse particles to influence the gradation and fabric of the soil, but not enough that they "float" within the finer matrix with no grain-to-grain contact. As a result, the fines can move through the coarse soil particles. The internal stability of the two soils was analyzed using the recommendations by Sherard (1979) and Kenney and Lau (1985). Based on these procedures, both soils were close enough to the stable/unstable borderline to make them suspect.

7 Results

Test data from the testing program are presented in Fig. 3 for the MUK1 sample and Fig. 4 for the OLY1 sample. The results are presented in terms of the hydraulic conductivity of the bottom 25 mm of soil and geotextile versus time. The overall system hydraulic conductivity was not considered for these tests because of erratic data, likely as a result of some partial internal instability of the soil itself and/or gradual contaminant clogging of the upper portion of the sample.

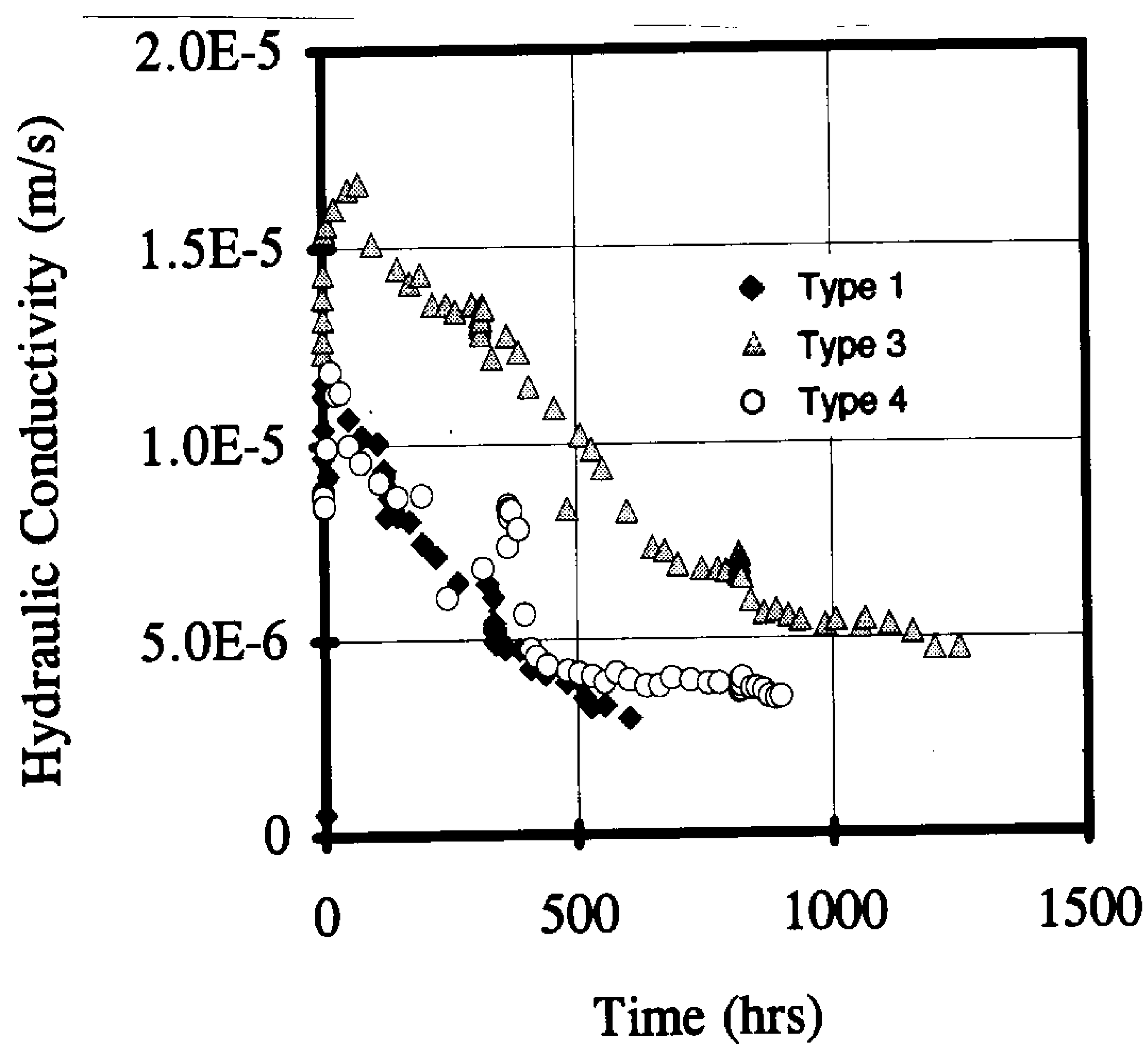

Fig. 4. Hydraulic conductivity of bottom 25 mm of soil/geotextile for OLY1.

A summary of the test results are presented in Table 2 for the MUK1 soil and Table 3 for the OLY1 soil. Gradient ratio values are not presented in these summary tables because they were not conclusive in identifying the stabilization of the tests or in interpreting the results of the tests. Instead, it was felt that local hydraulic conductivity better represented the performance of each soil-geotextile system.

Table 2. Summary of test results for MUK1.

Type	k^a (m/sec)	Fines Piped (g/cm^2)	Fines[b] Clogged (%)
1	5E-7	0.06	0.8
2	4E-7	0.03	0.2
3	3E-7	0.03	2.8
4	9E-7	0.07	---

Table 3. Summary of test results for OLY1.

Type	k^a (m/sec)	Fines Piped (g/cm^2)	Fines[b] Clogged (%)
1	3E-6	0	1.4
3	5E-6	0.01	3.0
4	4E-6	---	---

[a]Stabilized hydraulic conductivity of bottom 25 mm of soil/geotextile at a hydraulic gradient of 10.
[b]Reduction in porosity of geotextile based on weight of soil retained in geotextile after testing.

8 Discussion and conclusions

The data indicate adequate retention by all of the geotextiles for both soils. Some clogging was noted, but the degree of clogging and its effect on the performance of each geotextile could not be easily quantified.

The recommended O_{95} pore size for each soil was evaluated based on the retention filter design criteria of Giroud (1982), Christopher and Holtz (1985) and Lafleur, et al. (1993), as summarized in Table 4.

Table 4. O_{95} requirements based on three design criteria.

Design Criteria	O_{95} (mm) MUK1	OLY1
Giroud	<0.12	<0.17
C & H	<0.9	<3.8
Lafleur, et al.	<0.13	<0.26

Using the Giroud criteria, only the Type 3 geotextile would be acceptable for MUK1 from a retention standpoint. However, there was no retention problem with Type 1, 2 or 4 geotextiles. Similarly, the Type 4 geotextile would be considered unacceptable for OLY1, when clearly this was not the case. Using the Christopher and Holtz criteria, retention is satisfied; however, the large allowable O_{95} size allowed makes the criteria suspect. Finally, the Lafleur, et al. criteria provide similar results to the Giroud criteria. However, it should be noted that the Lafleur, et al. method is based on hydrodynamic sieving, while the other two methods are based on dry sieving to obtain O_{95}. Generally, hydrodynamic sieving results in smaller equivalent O_{95} pore sizes. Thus, the Lafleur, et al. criteria may provide a better prediction of the lack of a retention problem.

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