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Geotextile Filter Criteria

R. G. CARROLL, JR.

In the past decade, drainage fabric performance has been the subject of numerous research projects. Two general conclusions can be drawn from the many research findings: (a) both woven and nonwoven fabrics can provide acceptable filtration performance in drainage applications, and (b) soil and hydraulic conditions influence fabric filter properties necessary for optimum performance. More specific observations are made in this paper concerning the relation between fabric and soil properties versus drain fabric performance. These observations include the following: (a) fabric equivalent opening size (EOS) and permeability coefficients do not indicate clogging potential, (b) fabric EOS provides an indirect indication of retention ability, (c) gap-graded soils and high hydraulic gradient conditions are conducive to soil piping and filter clogging, (d) well-graded soils and low hydraulic gradients are not conducive to soil piping, and (e) fabric clogging potential can be determined by testing soil-fabric systems in simulated drainage tests that model expected use conditions. The state of the art in drainage fabric technology is reviewed, and rational filter criteria for geotextiles based on three performance parameters—retention ability, permeability, and clogging resistance—are recommended.

Geotextiles are rapidly replacing graded aggregates as the approved filter medium in drainage systems. Engineers use the performance and cost benefits of geotextiles in their drain designs, but they are often confused in their efforts to select the appropriate fabric filter. Regardless of the filter medium chosen for drainage applications, it must meet two conflicting requirements to assure optimum performance:

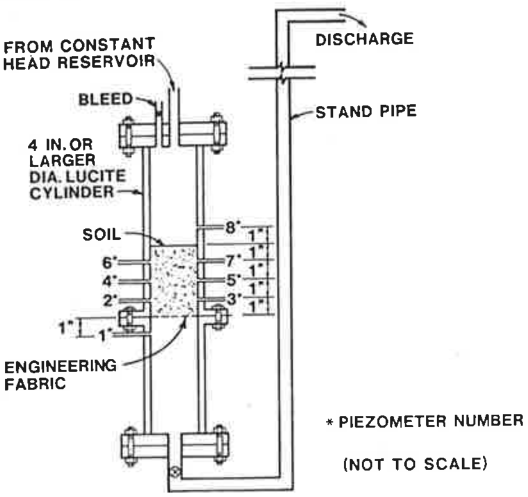
1. Retention--the filter must have a pore structure fine enough to retain erodable soils, and
2. Permeability--the filter must maintain adequate permeability so that seepage can escape freely from the protected soil. (Note that clogging resistance is inherent to this requirement.)

Grain-size distribution of a graded aggregate filter creates its pore structure that, in turn, controls filtration performance. There are universally accepted criteria for specifying the grain-size distribution of aggregate filters that relate the particle size of a graded aggregate to that of the protected soil (1). These criteria, based on theoretical relations among particle size, pore size, and retention ability of granular materials, have proved adequate through decades of use.

There are no well-established filter criteria for geotextiles. Filtration performance of a geotextile is controlled by its fiber structure, which in turn determines pore sizes, pore distribution, and porosity--the major characteristics that control fabric retention ability and permeability. The ideal retention criteria for fabrics should specify the appropriate pore structure in order to eliminate piping through the fabric, provide an adequate fabric seepage rate, and to assure clogging resistance. But an accurate measure of pore structure in porous media is difficult to obtain. Although numerous tests have been developed, no method has been universally accepted. The next-best alternative to an accurate measure of filter pores is an index test(s) that relates pore characteristics to filtration performance. Such index values are the basis for filter media selection in most filtration applications.

Geotextile performance in filtration-drainage applications has been the scope of considerable research over the past 10 years. The state of the art in drain fabric technology contains sufficient information on performance mechanisms and pertinent

Figure 1. COG constant-head permeameter.



CORPS OF ENGINEER-TYPE GRADIENT RATIO TEST DEVICE

fabric properties to support the rational development of geotextile filter criteria. A brief review of that drain fabric technology is provided in this paper, and appropriate geotextile filter criteria based on index and performance testing are recommended.

RETENTION ABILITY AND EQUIVALENT OPENING SIZE

In the late 1960s Calhoun (2) performed research on filter cloths at the U.S. Army Corps of Engineers (COE) Waterways Experiment Station. The objective of the COE project was to develop acceptance specifications and design criteria for plastic filter cloths used in filtration-drainage applications.

Calhoun evaluated several fabrics, most of which were woven monofilament, with one woven multifilament and one nonwoven fabric also included. When the study began woven monofilament fabrics were the only type used in the United States for filtration-drainage applications. These woven monofilament fabrics resembled screen mesh, although their yarn spacing varied somewhat and the pore openings were not square. The woven multifilament and nonwoven fabrics were unlike screen mesh; they had no discrete openings and their pore structures were apparently very fine.

Calhoun developed a test for equivalent opening size (EOS) to characterize the soil particle retention ability of the various fabrics. The test involved sieving rounded sand particles of a specified size through the fabric to determine that fraction of particle sizes for which 5 percent or less, by weight, passed through the cloth. The EOS was defined as the "retained on" size of that fraction expressed as a U.S. standard sieve number (e.g., No. 70 sieve). Assuming that fabrics and screen mesh have comparable retention ability, the EOS was a rational means of correlating fabric pore structure to an equivalent screen mesh size.

The EOS test provided a reasonable comparison between woven monofilament fabrics and screen mesh. EOS results could not be obtained for the woven multifilament or nonwoven fabrics. These fabrics retained even the finest particles (No. 100 to No. 120 sieve); their EOS was apparently finer than a No. 120 sieve.

Calhoun sought to modify the criteria for granular material adjacent to holes in drain pipes or well screens to accommodate filter fabrics. The filter criterion for drain pipes and well screen holes is

$$\text{85 percent size of granular material/hole diameter} > 1 \qquad (1)$$

By substituting EOS for hole diameter in Equation 1, Calhoun evolved a criterion for fabric retention ability:

$$D_{85\ \text{soil}}/\text{EOS} > 1 \qquad (2)$$

where $D_{85\ \text{soil}}$ represents the 85 percent size from a grain-size distribution analysis of the protected soil.

Calhoun performed filtration tests on soil-fabric systems to determine the validity of this filter criterion. Fabric and soil were placed in a specially designed apparatus similar in concept to a laboratory soil permeameter [see Figure 1 (2)]. Water flowed at a constant head down through the soil and fabric. The effluent from the apparatus was carefully monitored to detect any soil loss through the fabric. Surprisingly, test results indicated that a fabric with an EOS equal to a No. 30 sieve would effectively retain and prevent piping of a silty sand with D_{85} equal to 0.008 in. at hydraulic gradients up to 50 (maximum hydraulic gradient tested). These results imply that the retention criterion in Equation 2 is overly conservative. A more appropriate filter criterion for fabrics, based on Calhoun's results, might be stated as

$$\text{EOS}/D_{85}\ \text{soil} < 2 \text{ to } 3 \qquad (3)$$

An acceptable ratio of EOS/D_{85} could possibly be greater than 2 to 3, but appropriate combinations of EOS and D_{85} were not tested to establish a maximum limit on retention ability.

EOS VERSUS PORE STRUCTURE

It is imperative to note that EOS values do not accurately define fabric pore sizes, pore structure, or filtration ability. For decades filter media producers and users have adopted various techniques similar to the EOS test for measuring the retention or filtration efficiency of their products. Shoemaker (3) reported that most filter manufacturers have adopted micron-rating techniques, but the method for arriving at the rating varies with the manufacturer and the product. The concept of rating is helpful when developing a relative ranking of retention characteristics of similar products by one manufacturer. A cartridge that has a rating of 5 microns is presumably more retentive than one that has a 50-micron rating. In comparing similar products, such as cartridges from two different manufacturers, the numbers may not be equivalent. When comparing dissimilar products, such as cartridges versus felt versus paper, it is difficult to justify absolute numbers.

The EOS test only provides a crude method for determining the relative size of the maximum straight-through openings in a fabric. EOS values for fabrics of dissimilar construction are not comparable; i.e., a woven monofilament and a nonwoven fabric, both with EOS = No. 70 sieve, will not have the same pore structure or will they provide the same filtration efficiency for all particle sizes.

Visual examination of different fabrics with the same EOS indicates the variety of pore structure and porosity that can exist despite common EOS values. Figures 2 and 3 show a woven monofilament and a nonwoven fabric, both with EOS = No. 70 to No. 80

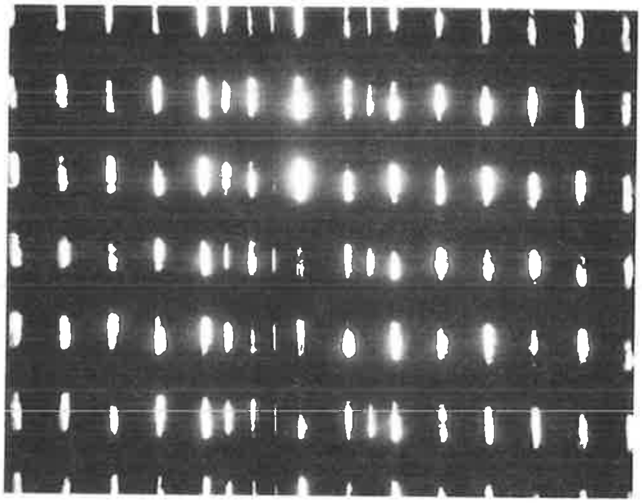


Figure 2. Woven monofilament fabric with EOS = No. 70 to No. 80 sieve.

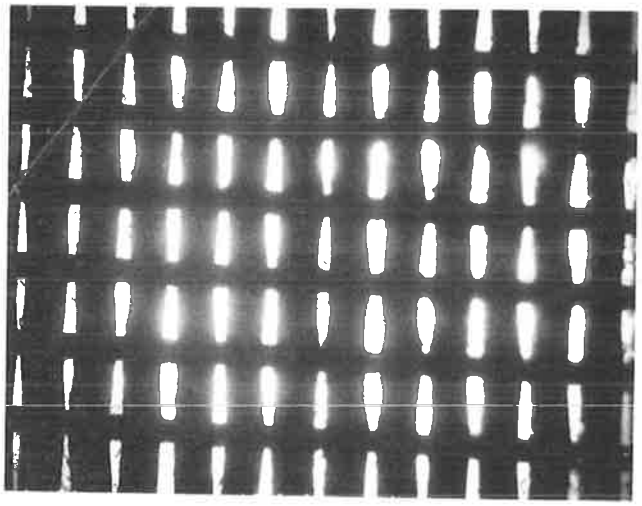


Figure 4. Woven monofilament fabric with EOS = No. 30 to No. 40 sieve.

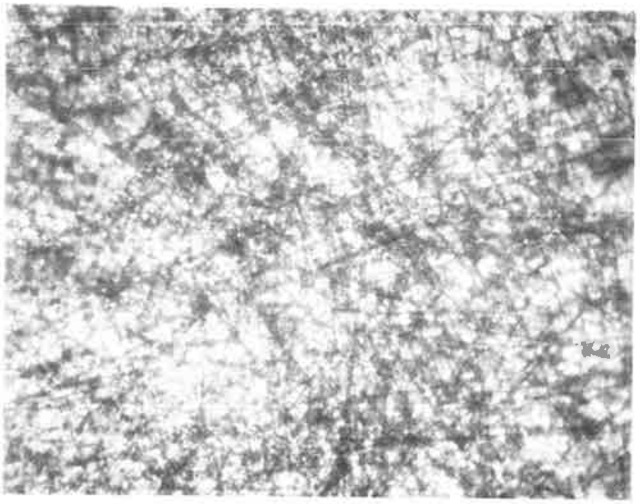


Figure 3. Nonwoven fabric with EOS = No. 70 to No. 80 sieve.

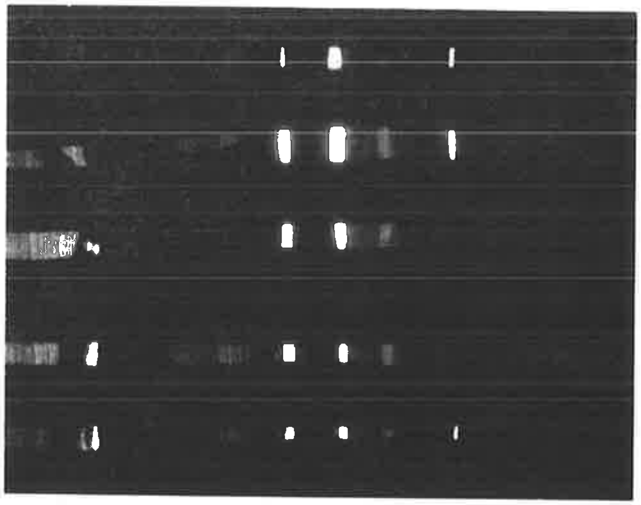


Figure 5. Woven slit film fabric with EOS = No. 30 to No. 40 sieve.

sieve. Figures 4 and 5 show a woven monofilament and a woven slit film fabric, both with EOS = No. 30 to No. 40 sieve. (Note that Figures 2-5 are 7.3 magnifications.)

Filtration tests were run on the woven monofilament and nonwoven fabrics shown in Figures 2 and 3. Fabrics were secured beneath a vertical pipe, and a slurry of soil and water was allowed to flow from the pipe through the fabric as in a falling-head permeameter (see Figure 6). Retention efficiency was measured for each fabric by using several particle size ranges. The results of these slurry filtration tests are shown in Figure 7. Retention efficiency of both the woven and nonwoven fabrics is comparable for the coarsest soil gradation. Note that an EOS of No. 70 to No. 80 sieve is larger than the D_{85} of the coarsest soil. Although the retention efficiency of the nonwoven fabric is greater than the woven fabric, both fabrics provide adequate retention for the No. 100 sieve soil with D_{85} = 0.10. This observation further supports the validity of Equation 3. As soil gradation becomes finer, the woven monofilament exhibits a dramatic decrease in retention efficiency, but the retention efficiency of the nonwoven fabric does not change significantly.

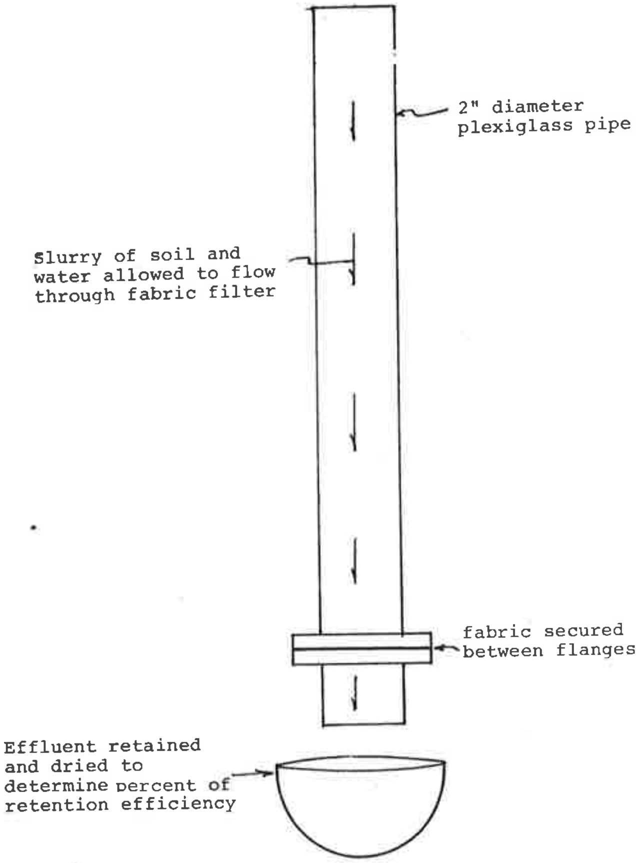
Results from this slurry filtration test confirm that EOS values indicate the retention ability of fabrics. But EOS alone does not distinguish the level of retention that a filter fabric can provide. This difference in filtration performance does not discount the validity of a retention criterion that uses EOS. It does indicate that nonwoven fabrics tend to exhibit greater retention ability than woven monofilament fabrics with the same EOS. Therefore, the retention criterion (Equation 3) is more conservative for nonwovens than for woven monofilament fabrics; it should not be restrictive to acceptable fabrics of any type.

Schober and Teindl (4) performed a state-of-the-art review of geotextile filter criteria based on European research. Their conclusions are summarized below:

1. EOS values can be related to the retention ability of geotextiles,
2. EOS values are not comparable between woven and thick needle-felt nonwovens,

3. Uniformity coefficients for protected soils influence the filtration performance of geotextiles, and
4. Woven and thin nonwoven fabrics should have a different retention criterion than thick needle-felt nonwovens.

Figure 6. Slurry filtration test apparatus.



Based on these conclusions, Schober and Teindl suggest the following retention criterion for woven and thin nonwoven fabrics:

$$M_w/d_{50} = (O_{90}/d_{50}) < 1.7 \text{ to } 3 \qquad (4)$$

where

M_w = woven mesh width (optically measured),
O_{90} = particle size for which 90 percent is retained by using a particle sieving test similar to the EOS method, and
d_{50} = 50 percent size of a protected soil gradation.

For thick needle-felt nonwovens, they suggest the following retention criterion:

$$(O_{90}/d_{50}) > 3 \text{ to } 5 \qquad (5)$$

The maximum limit on the ratios of pore to particle size in Equations 4 and 5 include a substantial safety factor.

The ratio of O_{90}/d_{50} varies directly with the uniformity coefficient of the protected soil. The d_{50} value is used in these criteria rather than the D_{85} value used by Calhoun. According to Schober and Teindl, a ratio of 3 for Equations 4 and 5 is comparable to a ratio of 1 for Equation 2. This suggests that Equation 2 is appropriate for wovens and is conservative for nonwovens, especially thick nonwoven fabrics, thereby reinforcing the previously stated conclusions.

PERMEABILITY AND CLOGGING RESISTANCE

Criteria for permeability and clogging resistance of geotextiles must assure that fabric permeability is greater than that of the protected soil throughout the effective life of a drain. Calhoun (2) performed clogging tests to determine the degree of fabric clogging that might be experienced by fabric in contact with a gap-graded soil. The clogging test used a permeameter device similar to the filtration test apparatus previously described (see Figure 1). Hydraulic gradient data from the soil-

Figure 7. Slurry retention efficiency of woven and nonwoven fabrics.

Fabric	Retention Efficiency (% Particle Weight Retained)		
	Particle Size Ranges*		
	-#80	-#100	-#200
Woven Monofilament (EOS = #70 - #80)	92	82	6
Nonwoven (EOS = #70 - #80)	98	96	94

*Particle Size Ranges:
-#80 : 100% passing #80...D_{85} ∿ .15 mm
-#100 : 100% passing #100...D_{85} ∿ .10 mm
-#100 : 100% passing #200...D_{85} ∿ .06 mm

Figure 8. Soil-fabric permeameter.

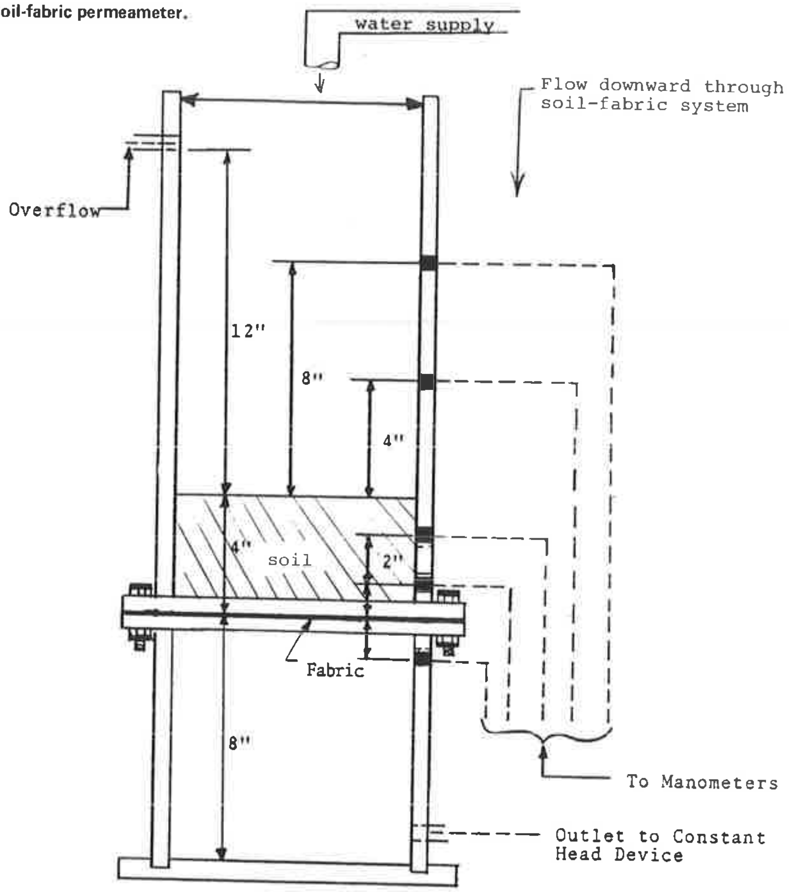


Table 1. Physical properties of protected soils.

						Soil Classification	
Soil Type	LL	PL	PI	D_{10}	C_u	AASHO	Unified
Natural	28	20	8	0.0100	15	A-2-4(0)	SC
S-0	25	20	5	0.0250	7	A-2-4(0)	SM
S-5	24	18	6	0.200	8	A-2-4(0)	SM
S-15	25	20	5	0.0140	11	A-4(0)	ML
S-25	26	17	9	0.0100	11	A-4(3)	ML-CL
S-35	28	20	8	0.0070	12	A-4(5)	CL
S-50	30	21	9	0.0070	9	A-4(6)	CL
K-0	23	21	2	0.0590	4	A-2-4(0)	ML
K-10	24	18	6	0.0070	27	A-2-4(0)	ML-CL
K-20	26	21	5	0.0006	303	A-2-4(0)	ML-CL
K-30	28	17	11	0.0006	214	A-4(1)	CL
M-2	30	22	8	0.0460	4	A-2-4(0)	CL
M-4	39	24	15	0.0175	11	A-2-4(0)	CL
Soil no. 1	24	20	4	0.0740	2	A-2-4(0)	SM
Soil no. 2	25	15	10	0.0060	33	A-2-4(0)	SC
Soil no. 3	27	21	6	0.0007	308	A-2-4(0)	ML-CL

fabric permeameters were analyzed to determine the clogging potential of a fabric. The analysis made use of a ratio of the hydraulic gradient across the fabric plus an adjacent 1 in. of soil to the hydraulic gradient for the entire system, i.e., the clogging ratio. A clogging ratio greater than 1 signified fabric clogging. Clogging ratios varied, depending on fabric and soil gradation, but no clogging ratios exceeded 2. The COE (5) later established a maximum acceptable clogging ratio of 3.0 based on these and subsequent clogging test evaluations.

Drain fabric research by Marks (6) indicated that nonwoven and woven fabrics performed as satisfactorily as graded aggregate filters under simulated drainage conditions. The laboratory permeameter used for this evaluation is shown in Figure 8 (6). The fabrics tested had apparent permeability coefficients ranging from 10^{-3} to 10^{-1} cm/sec. Those fabrics were tested with 16 soil gradations ranging from fine sands [SM (Unified Soil Class)] to clayey, silty sands [CL (Unified Soil Class)]. The percentage of fines (passing the No. 200 sieve) for these soils ranged from 10 to 60 percent. Tested soils included both well-graded and gap-graded materials. The properties of the soils used in Marks' test program are given in Table 1 (6).

Permeability performance of graded aggregate and fabric filter systems was found to be essentially the same for comparable soils. All filter media experienced clogging with all soils except one. Filter clogging was attributed to soil infiltration at the soil-filter interface. The poorly graded silty sand (S-0 in Table 1) did not indicate infiltration or clogging with the graded aggregate filter. Fabric permeability had no apparent effect on permeability performance in soil-fabric systems.

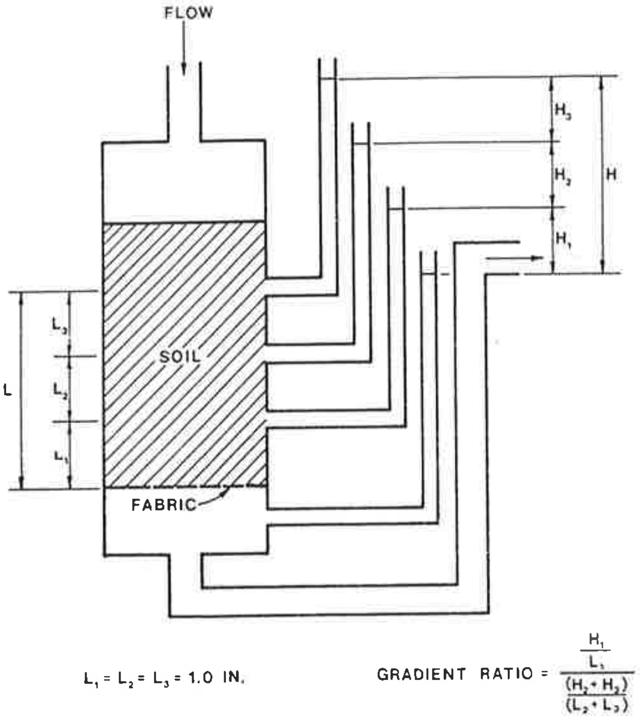
Marks' study is significant because it describes the relative performance between fabric filters and conventionally accepted graded aggregate filters with a broad range of soil gradations.

Haliburton and Wood (7) investigated clogging resistance of woven and nonwoven fabrics by using a hydraulic gradient analysis approach similar to Calhoun's. They based clogging performance on a gradient ratio (GR) value, which is the hydraulic gradient through fabric plus the adjacent 1 in. of soil divided by the hydraulic gradient through the adjacent 2 in. of soil [see Figure 9 (7)]. The soil used was gap-graded to provide the maximum potential for soil piping and filter clogging. In addition, the tests were run under high hydraulic gradients to cause the maximum potential for soil piping. GR results revealed dramatic performance differences between the fabrics tested.

A plot of the GRs for fabrics tested versus silt content in the gap-graded soil is shown in Figure 10 (7). Clogging potential increased for all fabrics as the silt content increased in the protected soil. Results also confirmed that a reasonable limit for a maximum allowable GR is 3. Haliburton and Wood reported that fabric EOS was not related to clogging potential.

The performance results from Marks and Haliburton and Wood appear to be in conflict. Close examination of test conditions, however, reveals that Haliburton and Wood's clogging tests were run at high hydraulic gradients and with gap-graded soils to obtain the maximum effect from soil piping. On the other hand, Marks' soil-fabric systems were evaluated by using a much lower hydraulic gradient with both well-graded and gap-graded soils. As a result, the potential for soil piping and subsequent filter clogging is much greater in Haliburton and Wood's clogging test than in Marks' permeameter tests. Note that the test conditions have a significant influence over performance.

Figure 9. GR permeameter.



Soil-fabric clogging tests performed by Carroll revealed a similar performance contrast between high and low hydraulic gradient testing. A permeameter device similar to those in previous clogging studies was used to generate GRs at various system hydraulic gradients (see Figure 11). Woven and nonwoven fabrics and a graded aggregate filter were evaluated by using a well-graded silty sand (15 percent passing the No. 200 sieve) as the protected soil. The filter properties and the GRs measured at various hydraulic gradients are given in Table 2.

Note that the GRs are approximately 1 or less until system hydraulic gradients become ≥ 3. Fabric clogging or soil infiltration is apparently not significant when system hydraulic gradients are 3 or less. Clogging becomes more noticeable as the system hydraulic gradient increases beyond 3. Neither permeability nor EOS of the fabrics tested indicated a relation to soil-fabric system performance.

Several general conclusions can be drawn from the combined results of the clogging studies by Calhoun, Marks, Haliburton and Wood, and Carroll:

1. Fabric EOS and permeability coefficients do not indicate clogging potential;
2. All filter media are likely to experience some degree of clogging due to soil infiltration;

Figure 10. Results of GR testing for various engineering fabrics at different soil silt contants.

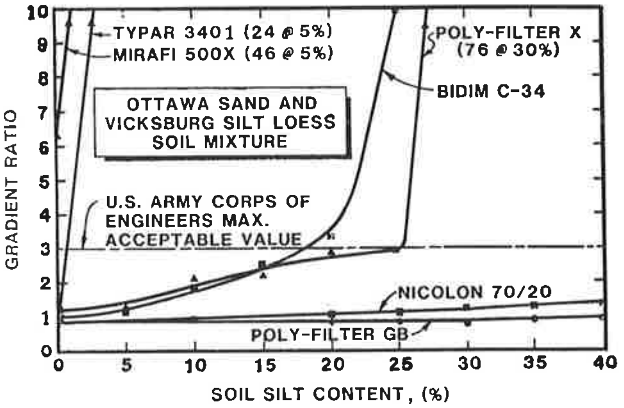
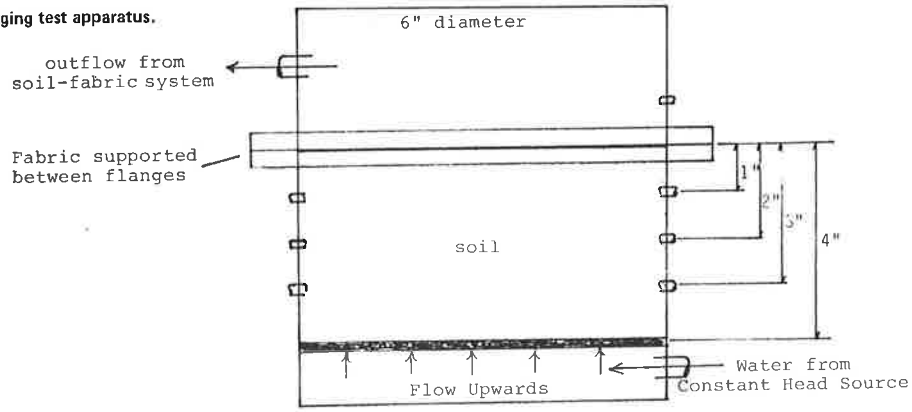


Figure 11. Soil-fabric clogging test apparatus.



Not to Scale

Table 2. Soil-fabric clogging test results.

Filter Identification			Gradient Ratio[a]		
Type	EOS[b]	k (cm/sec)	$i_s = 1$	$i_s = 3$	$i_s = 5$
Graded aggregate	NA	>0.10	0.39	0.66	1.06
Nonwoven					
Heat bonded	100	0.049	0.37	0.84	1.61
Heat bonded	20	0.094	0.12	0.42	0.85
Needle punched	60	0.283	0.52	1.29	2.42
Woven, slit film	50	0.001	0.45	1.05	2.09

Note: NA = not available.
[a] GR values listed for system hydraulic gradients of 1, 3, and 5.
[b] EOS identified by U.S. standard sieve size.

3. Well-graded soils are not prone to piping; however, high hydraulic gradients may cause infiltration of well-graded soils into a filter media;
4. Gap-graded soils are prone to soil piping and subsequent filter clogging, whereas high hydraulic gradients maximize the potential for piping in gap-graded soils; and
5. A reasonable limit for the maximum allowable GR is 3.

These conclusions provide the basis for developing rational criteria regarding permeability and clogging resistance of fabric filters.

FILTER CRITERIA AND TEST METHODS

Three basic elements are suggested for geotextile filter criteria: retention ability, permeability, and clogging resistance.

Retention Ability

Retention ability can be specified by using the EOS criterion defined in Equation 3 [i.e., $(EOS/D_{85\ soil}) < 2$ to 3]. Previous discussion has revealed that EOS is an index value that relates indirectly to fabric retention ability. EOS values alone do not indicate relative filtration performance or do they indicate clogging potential. This criterion should only be used to establish a minimum value of fabric EOS for a given soil gradation to be pro- tected. This criterion may be conservative with regard to nonwoven fabrics, but it should not be restrictive to any acceptable fabrics.

There are two methods for determining EOS: (a) the procedure defined by Calhoun (2) that used graded sand particles, and (b) the modified version defined by the COE (5), which used graded glass beads. Testing laboratories have indicated that the sieving process with glass beads typically yields lower EOS values than sieving with sand particles, i.e., EOS_{glass} = No. 50 sieve and EOS_{sand} = No. 70 sieve for the same fabric. Variability between these tests is attributed to differences between glass beads and sand particles, e.g., particle roundness, static potential.

Equation 3 applies to EOS values determined by sand particle sieving. If glass beads are used to determine EOS, Equation 3 should provide a more conservative assessment of retention ability.

Permeability

Permeability of a geotextile must be substantially greater than that of the protected soil so that partial clogging will not reduce fabric permeability to a critical level, i.e., below that of the protected soil. Accordingly, fabric permeability should be at least 10 times that of the protected soil, i.e.,

$$k_{fabric} > 10k_{soil} \tag{6}$$

Darcy coefficients can be calculated for geotextiles by using flow rate and pressure drop across a fabric as measured in both constant- and falling-head permeameters (8).

Researchers have disputed the validity of computing a Darcy coefficient for fabrics from such permeameter testing. The fabrics are very thin (relative to soil thickness used in conventional soil permeameters), and flow through the fabric is likely to be turbulent even with low head pressures. Therefore, Darcy's theory may not apply to these test conditions. Despite these inconsistencies between test conditions and theory, an apparent Darcy coefficient can be determined for fabrics. If turbulent flow conditions are present during testing, then the k value measured for a fabric will be conservative, i.e., lower than the actual k. An apparent Darcy coefficient can also be determined for fabrics by using results from ASTM D-737 (Air Permeability of Textile Fabrics) (9).

The effect of fabric compressibility on fabric permeability is another concern of researchers. Schober and Teindl (4) have reported that a compressive force of 146 psi can reduce the k value of highly compressible needle-felt fabrics by factors ranging between 2 and 8. This compressive force is roughly equal to fabric buried beneath 150 ft of dense soil. Most drains are near the surface, where compressive force on the fabric filter is relatively low and the potential for reduced permeability is insignificant.

Therefore, it is recommended that the fabric permeability criterion stated in Equation 6 be used for shallow drains, with fabric permeability determined by conventional falling- or constant-head permeameters or through air permeability testing. If ground pressures on the fabric filter are expected to be extremely high, then permeability measurements should be determined on a fabric under the appropriate compressive force.

Clogging Resistance

Clogging behavior of a geotextile should be evaluated in a test that simulates in-place conditions. For a filtration-drainage application, this means testing a soil-fabric system in a permeameter apparatus similar to those described previously. The soil and hydraulic gradient conditions used in testing should duplicate expected field conditions. Test parameters that deviate significantly from the use conditions will not provide a useful performance evaluation.

The GR, as defined by Haliburton and Wood (7), provides a rational analysis of fabric clogging potential. As previously indicated, the maximum allowable GR for acceptable performance should be less than 3. The criterion for clogging resistance of geotextiles can be stated in terms of an allowable gradient ratio:

$$GR \leq 3 \tag{7}$$

IMPLEMENTING FILTER CRITERIA

Drainage projects can be classified in two general categories--noncritical and critical. The following conditions define the noncritical drainage category:

1. Drain failure does not result in either a decrease in structural life or significant structural damage,
2. Evidence of drain clogging appears well in advance of failure,

3. Repair costs are comparable or less than installation costs for the drain,
4. Low hydraulic gradients exist through the soil, and
5. Minimal clogging potential exists (e.g., well-graded or uniform soil to be drained).

Typical applications in the noncritical category are subgrade and pavement drains. Clogging potential for noncritical drains is minimal because of the soil and hydraulic gradient conditions defined. The retention and permeability criteria defined by Equations 3 and 6 provide sufficient filter criteria for filter fabrics in the noncritical category.

In comparison, any or all of the following conditions define the critical drainage category:

1. Drain failure results in either a potential decrease in structural life or significant structural damage,
2. No evidence of drain clogging appears before failure,
3. Repair costs are significantly greater than the installation costs of a drain,
4. High hydraulic gradients exist through the soil, and
5. Protected soils are conducive to piping (e.g., gap-graded soils, fissured clays, dispersive clays, and fractured rock).

Typical critical drain categories include dam chimney drains and coastal erosion-control structures (high risks and high hydraulic gradients, respectively). The consequences of filter clogging in critical drainage applications mandates the evaluation of filter clogging potential. Retention, permeability, and clogging criteria (Equations 3, 6, and 7) should all be used to specify fabric filters for critical drainage conditions.

There is no better proof of performance than actual field use and performance monitoring. Performance testing or trials that simulate conditions of use is certainly the technically preferred approach to filter evaluation and selection. However, the cost of performance testing and trials is often prohibitive to their use for filter media evaluation on individual projects. As a result index values are the basis for filter selection in a majority of filtration applications. The specifier should understand the limits of such index criteria and have experience in filter performance to assure selection of the appropriate filter media.

Geotextiles have been used for filtration-drainage applications for more than a decade. There are numerous users, researchers, and producers who have a wealth of experience regarding geotextile performance. Whenever available, this first-hand experience should be combined with rational performance criteria in selecting the appropriate geotextile for filtration-drainage use or any other application.

The filter criteria recommended in this paper provide only part of the specification requirements necessary to define an acceptable drainage fabric. Appropriate strength criteria must be established to prevent damage caused by installation and in situ stresses. These strength requirements will vary with application and should be defined according to the conditions of use.

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