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# EVALUATION OF FILTER FABRICS FOR USE AS SILT FENCES


by

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Research Scientist



(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)



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SUMMARY

The study reported was initiated to develop tests simulating field conditions that could be used to develop information for the formulation of specifications for use in purchasing filter fabrics to be used to construct silt fences. Fifteen fabrics were subjected to six tests devised to evaluate their performance. Results of the tests were used to develop recommendations for evaluating and purchasing the filter fabrics.

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## INTRODUCTION

Because accelerated erosion can result from denuded areas during highway construction, the Virginia Department of Highways and Transportation's policy is to establish vegetation and other protective measures as early as possible on all construction projects. In addition to turf establishment, nonvegetative temporary erosion and sediment control measures are needed to prevent the construction-generated silt from being carried into nearby waterways or onto adjoining properties. These nonvegetative measures are especially useful for the retention of silt before turf is established.

The Department uses various types of nonvegetative control measures to impede the flow of sediment-laden waters and to filter out sediment. The most commonly used measures are barriers made of straw, gravel or crushed stone, and brush. In very critical areas, however, the protection provided by these barriers has not been sufficient. Faced with this problem and recognizing that a large number of fabrics had been introduced to the highway industry for use as filter materials, in 1975 the Department put into effect a special provision allowing contractors to use fabrics to construct silt fences.

While the number of fabrics on the market is increasing, as is their use on the Department's construction projects, the Department has developed no specifications to facilitate comparisons of competitive materials. The different manufacturers produce materials of different properties and use the results of different approved tests, such as those sanctioned by the ASTM,[1] as evidence of their quality. Also, the properties of the materials do not plainly relate to the properties desired of a fabric to be incorporated in a silt fence. Therefore, this study was initiated to develop tests that could be used to evaluate the properties of the fabrics and provide information that might aid the Department in developing specifications to be stipulated in purchasing them.[2]

## OBJECTIVES

The ultimate objective of this study is to develop information for the formulation of specifications for use in purchasing filter fabrics for building silt fences on the Department's construction projects. To achieve this objective, the performance desired of an installed silt fence made of fabric must be established along with a valid estimation of what is reasonably achievable. Therefore, the first objective was to develop tests closely simulating the conditions to which a silt fence is exposed. Additionally, the tests were to be of a type that could be performed by the Central Office Materials Division without any large investment in additional testing equipment, because that Division will evaluate fabrics proposed for use in silt fences to determine if they meet the Department's specifications.

The second objective of the study was to subject the available fabrics to the tests developed.

The third objective was to write the specifications for use in purchasing filter fabrics.

## CRITERIA FOR FABRICS AND TESTS

In developing the evaluative tests, it was decided that the fabrics should meet several criteria and that the tests should simulate field conditions. The criteria were that the fabrics must —

1. have sufficient strength to resist the force of the sediment-laden water without a large amount of elongation;
2. be resistant to the effects of ultraviolet rays from the sun;
3. be resistant to the effects of water of low or high pH; and
4. be capable of filtering out most of the soil carried in the runoff from a construction project without unduly impeding the flow.

During the course of the testing program, it was decided that the effects of permeability would be investigated along with the susceptibility of the fabrics to creep.

In regard to the tests, it was decided that in addition to simulating field conditions they should be of a type that would not require a large investment in equipment by the Materials Division.

The procedures for the tests developed are given in Appendix A. Only the more pertinent of the procedures included in Appendix A will be recommended for use in acceptance testing.

## FABRICS TESTED

When this project was initiated, the author contacted all manufacturers of silt fence fabrics known to him. Appendix B describes the 15 fabrics obtained for testing. Part of the descriptive data were taken from the literature supplied by the manufacturers but may not be exactly as given by them.

## TESTING PROGRAM

The tests conducted in the study are described under the following subheads.

### Filtering Efficiency

#### Laboratory

In Virginia, each of the three dominant soil types is linked to one of the three major geological provinces. Clayey soils overlie limestone bedrock in the Valley and Ridge province of western Virginia; silty soils overlie mica-rich granite in the Piedmont area; and sandy materials overlie the relatively young sediments in the Coastal Plain province. A large sample of each of these soils was collected, dried, and sieved. The gradation curves are given in Figure 1.

Since straw bale barriers are considered the standard control measure used by the Department, it was decided to evaluate the filter fabrics under conditions to which straw bale barriers are subjected. It was known from previous work, however, that filter fabrics acted more like a dam than did straw bales,[3] and that they therefore could not be subjected to high flow rates.

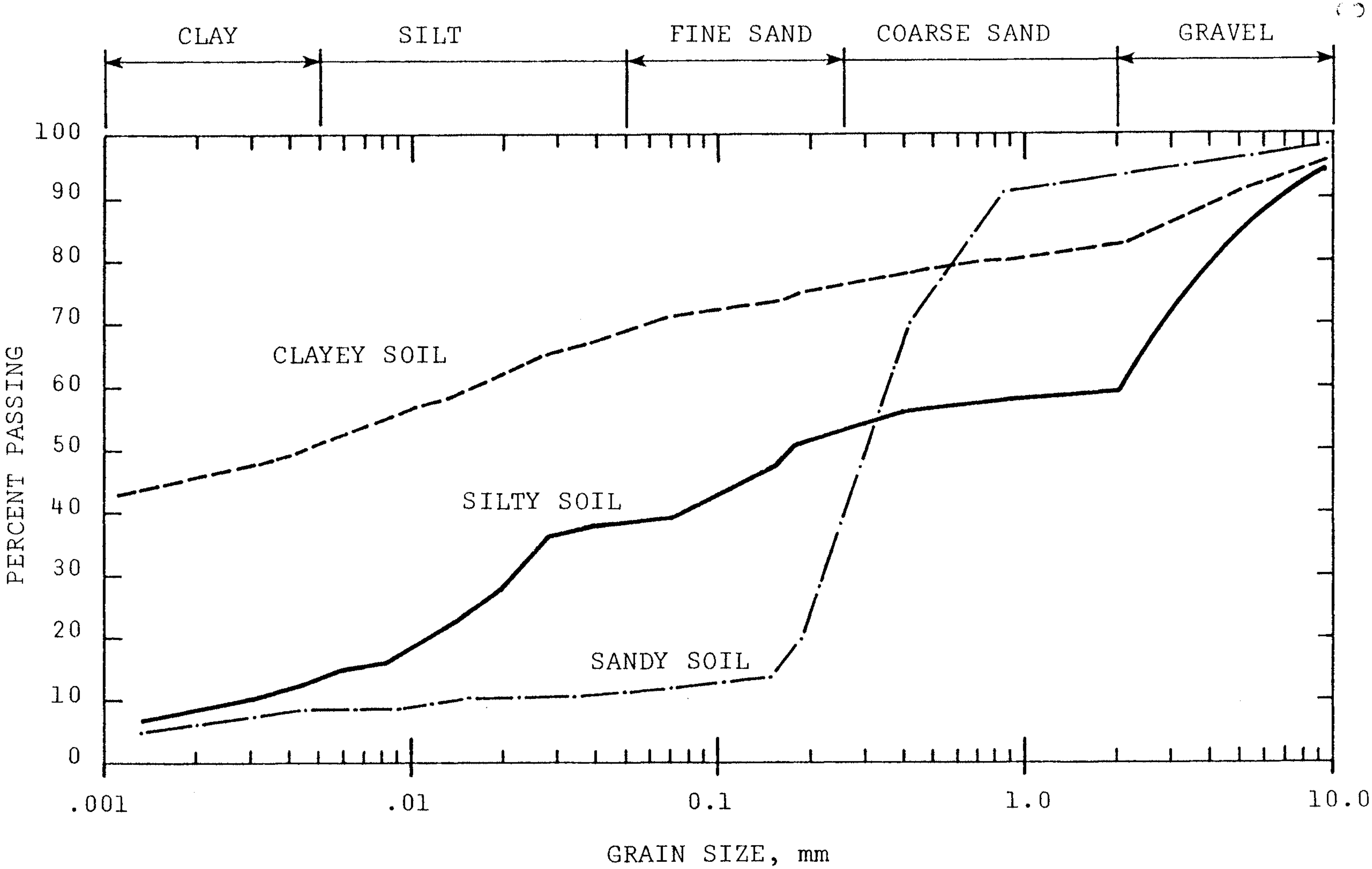


Figure 1. Gradation curves for three soils used.

Consequently, it was decided to test the fabrics in the laboratory in a flume with a slope of 8%, the slope of the average ditch in which straw bales are installed. To simulate runoff water, a sediment-laden mixture of 3,000 parts per million was selected, since this suspended solids value is the maximum encountered in the field during a non-catastrophic storm event. Three such mixtures were run through each fabric to determine the effect three storm events would have on its filtering capability and flow rate. Usually, after three storm events a silt fence is inoperable unless it is cleaned out.

Three samples of each fabric were evaluated using each of the three soils. Sediment-laden water was generated for each test by adding 150 grams of minus 10 material to 50 liters of uncontaminated water. (Relatively clean stream water was transported to the laboratory, since tap water supplied by the local muncipality has alum, a coagulant, in it. The alum will settle out particles quicker than will stream water, and thus indicate a filtering efficiency and flow rate higher than would be found in the field.)

Each soil was sieved on the No. 10 screen to obtain particles of 2.00 mm maximum size because it was believed that particles larger than that would not be in suspension in the field. Table 1 indicates that soil particles 2.00 mm in size would settle 1 m (3.28 ft.) in less than 10 seconds in still water. Thus, the above assumption seems to be reasonable.

The soil and water were thoroughly mixed, the resultant mixture was poured immediately behind the fabric sample in the flume, a clock was started, and the time required to filter 50 liters of the sediment-laden water was recorded. The filtered water was collected in a container and a representative, depth-integrated, well-mixed sample of the filtrate was obtained (Figures 2 and 3). The suspended solids level of the filtrate was determined following the procedure for "non-filterable residue" described in the 14th edition of <u>Standard Methods for the Examination of Water and Wastewater</u>.(4) The filtering efficiency (FE) of the fabric was calculated as

$$FE\ (\%) = \frac{SS_{before} - SS_{after}}{SS_{before}} \times 100,$$

where

$SS_{before}$ and $SS_{after}$ are the suspended solids values before and after filtering, respectively.

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TABLE 1

SETTLING VELOCITIES OF SOIL PARTICLES IN STILL WATER

(Temperature 50°C; all particles assumed to have a specific gravity of 2.65)

| Diameter of Particle | Order of Size | Settling Velocity | Time Required to Settle One Meter (3.28 ft) |
|---|---|---|---|
| mm | | mm/sec | |
| 10.0 | Gravel | 1,000 | 1.0 seconds |
| 1.0 | | 100 | 9.8 seconds |
| 0.8 | | 83 | 12.1 seconds |
| 0.6 | Coarse Sand | 63 | |
| 0.5 | | 53 | |
| 0.4 | | 42 | |
| 0.3 | | 32 | |
| 0.2 | | 21 | 48.0 seconds |
| 0.15 | Fine Sand | 15 | 67.0 seconds |
| 0.10 | | 8 | 125.0 seconds |
| 0.08 | | 6 | |
| 0.06 | | 3.8 | |
| 0.05 | | 2.9 | |
| 0.04 | | 2.1 | |
| 0.03 | | 1.3 | |
| 0.02 | | 0.62 | |
| 0.015 | | 0.35 | 47.6 minutes |
| 0.010 | Silt | 0.154 | 107.0 minutes |
| 0.008 | | 0.098 | |
| 0.006 | | 0.065 | |
| 0.005 | | 0.0385 | 7.2 hours |
| 0.004 | | 0.0247 | |
| 0.003 | | 0.0138 | 20.1 hours |
| 0.002 | | 0.0062 | |
| 0.0015 | Clay | 0.0035 | |
| 0.001 | | 0.00154 | 180.0 hours |
| 0.0001 | | 0.0000154 | 754.0 days |
| 0.00001 | Colloidal Particles | 0.000000154 | 207.0 years |

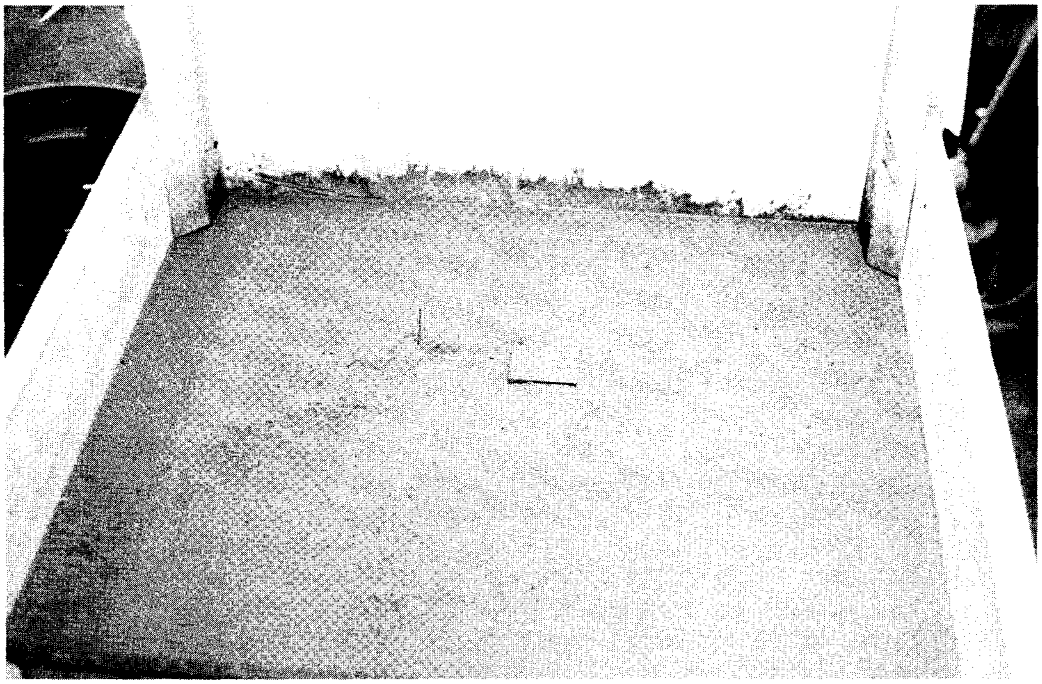

Figure 2. Sediment trapped behind filter fabric.

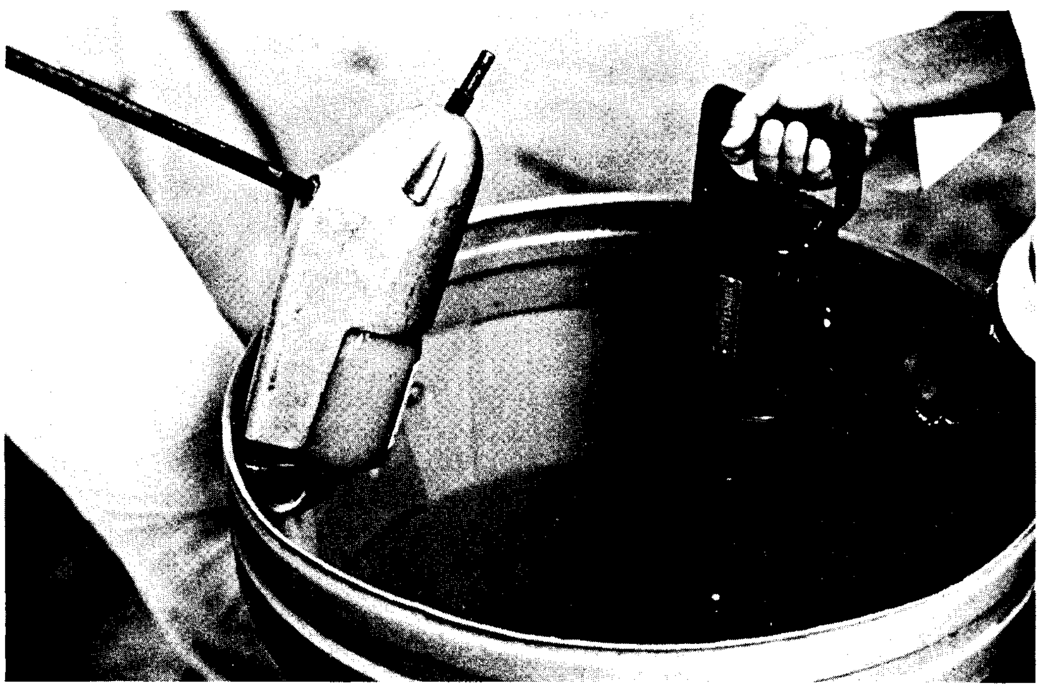

Figure 3. A depth-integrated sample of the filtrate after mixing.

Using the filtering efficiency determined and the corresponding gradation curve of the soil (Figure 1), the largest particle passing through the fabric was determined. The flow rate was determined for this standard size sample from the known volume of 50 liters and the time required for filtration.

Field

Although there are many more variables to consider in the field than in the lab, a correlation of field results with the laboratory results was needed. Therefore, filtering efficiency tests were conducted in the field in the three major geologic areas of the state. To reduce the number of variables among the sites in the three geologic areas and the individual test plots at each site, areas of uniform soil conditions and similar slopes (approximately 8%) were selected. Silt fences of each fabric were constructed (Figure 4) and the denuded area behind each fence was sprayed with water for 15 minutes at an intensity of 1.5 in. per hour (3.8 cm per hour) to simulate an average storm event. Water samples were taken simultaneously upstream and downstream of the fabric at various intervals of time (Figures 5 and 6), and suspended solids determinations were made in the laboratory by the "non-filterable residue."[4] The filtering efficiency (FE) of each fabric in different areas of the state was determined as

$$FE\ (\%) = \frac{SS_{upstream} - SS_{downstream}}{SS_{upstream}} \times 100.$$

## Strength

Silt fences need sufficient tensile strength to withstand the forces exerted by the storm runoff and collected silt. Fabric strength also becomes important with certain modifications in standard installation practices,[5] such as the elimination of the reinforcing wire and the reduction in supports that would simplify the installation and reduce costs. When considering these modifications, equally as important as the tensile strength and selection of the fabric is the elongation, or strain. Silt fences without reinforcing wire and with the maximum allowed support spacing of 10.0 ft. (3.1 m)

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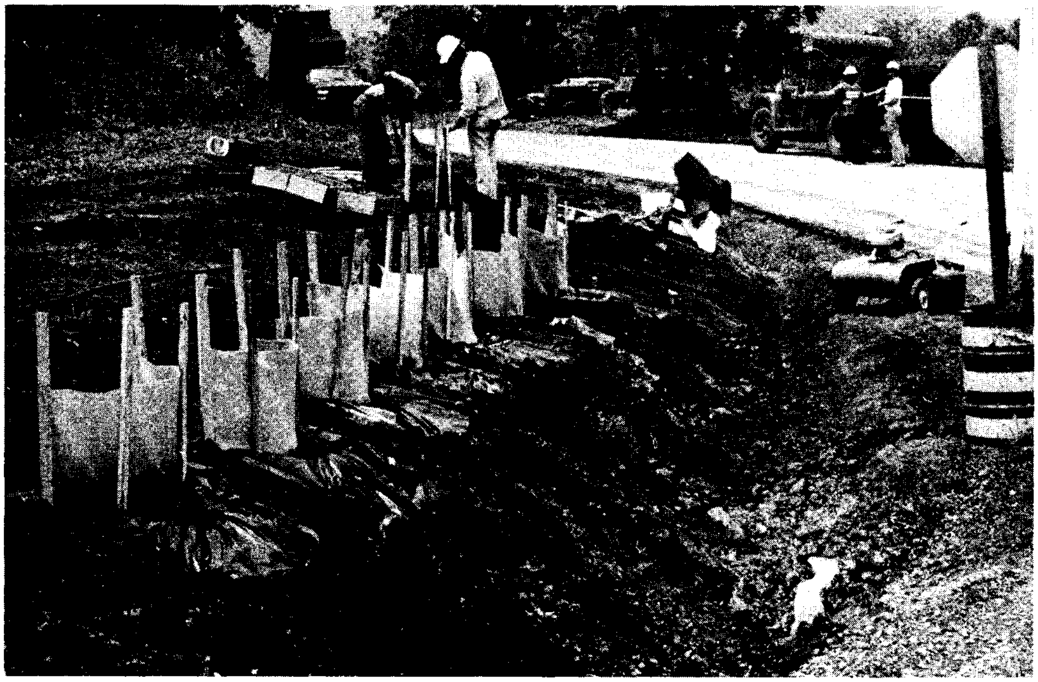

Figure 4. Construction of small silt fences at a field site.

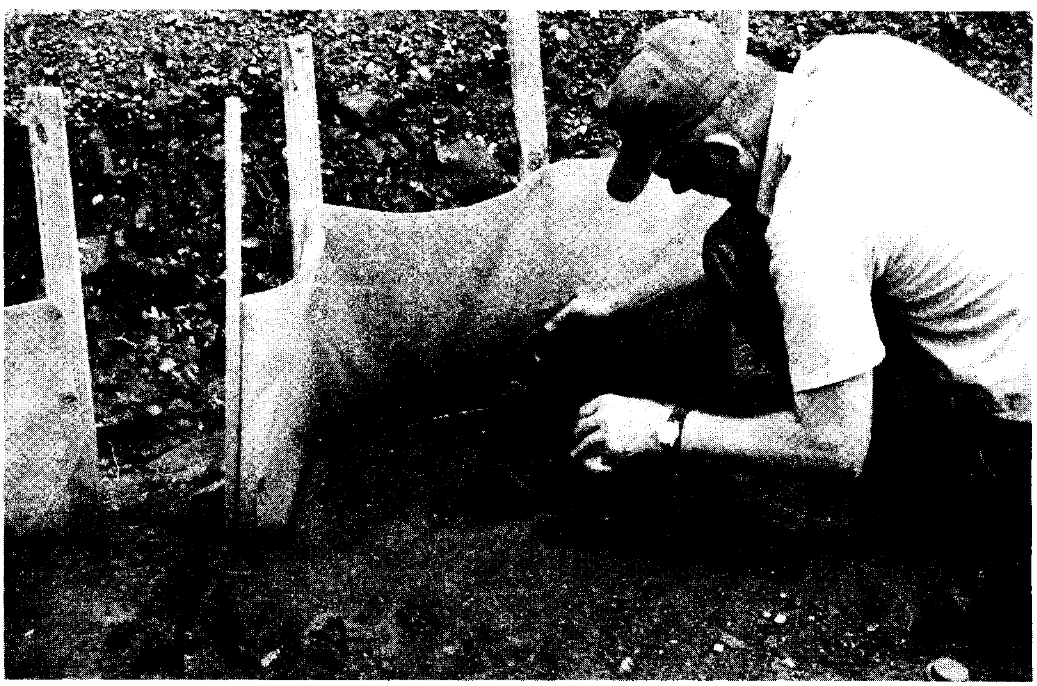

Figure 5. Obtaining upstream suspended solids sample.

Figure 6. Obtaining downstream suspended solids sample. Note the plastic to catch filtrate and prevent interference in the sample.

cannot function properly with over 20% elongation. At this elongation, they would sag over 3.0 in. (7.6 cm) between posts. Therefore, the strength at 20% elongation is very important.

Several factors considered in the tensile testing are discussed below.

1. Rate of strain.

In soils testing a very slow rate of strain of 1% to 2%/min. is used; in testing fabrics the rate is greater than 15%/min. and sometimes exceeds 100%/min. In order to minimize the outlay for testing equipment, a motor driven screw jack was used to extend the fabrics. Also, it was desirable to keep the strain rate as low as possible and hopefully close to that used with soil testing equipment. The rate of strain used was 13% ± 2% per minute.

2. Size of Sample.

To avoid end restraint problems from necking down of the fabric*, a 2:1 ratio of length to width for tensile test samples was chosen. Using the 2:1 ratio and the maximum allowable travel of the test equipment, a sample size of 14.0 in. (35.6 cm) by 7.0 in. (17.8 cm) was chosen. This size is larger than that of most ASTM fabric test samples and should consider the variability in the production of the fabric better than a smaller sample size. In order to have 14.0 in. (35.6 cm) of unsupported sample between the clamps, the samples were cut 27.0 in. (68.6 cm) long by 7.0 in. (17.8 cm) wide. The extra length was needed for overlapping the fabric in the end clamps.

3. Clamps.

Three flat plates were bolted securely together to make an end clamp for each end of the fabric samples. The plates were 16.0 in. (40.6 cm) long by 3.0 in. (7.6 cm) wide by 0.25 in. (0.6 cm) thick. The samples were lapped between the three plates to prevent slippage during testing.

4. Number of Samples.

With the numerous tests to be performed and 15 fabrics to be evaluated, it was decided that no more than three samples could be tested if the project was to be completed within a reasonable time. Also, it was felt that three samples of each fabric would be sufficient for determining an average strength value.

5. Warp Versus Fill.

Samples 27.0 in. (68.6 cm) by 7.0 in. (17.8 cm) were cut from both the warp (perpendicular to the axis of the roll of fabric) and the fill (parallel to the axis of the roll of fabric) directions (Figure 7). Tensile tests were performed on these samples to determine if the strength or elongation varied with the direction of the fabric, since little is known about this subject.

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*Personal communication. I. R. Clough, ICI Fibres, Pontypool, Gwent, Great Britain, NP48YD, September 1979.

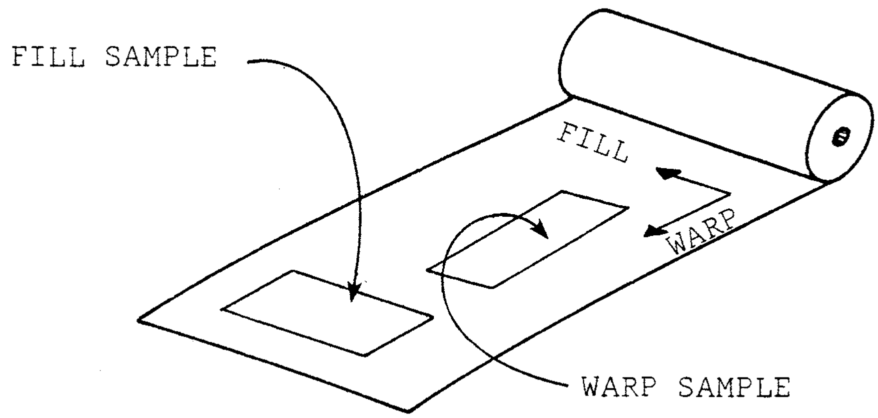


Figure 7. Direction of cut of the samples.

6. Tears.

When silt fences are installed in the field, 0.5 in. (1.3 cm) long tears are made in the fabric to fasten it to the supports with wire or hog rings. It was decided that any reduction in strength resulting from these tears should be determined. Therefore, three samples of each fabric cut in the warp direction and with single 0.5 in. (1.3 cm) slits torn parallel to the length and in the middle were tested to determine the effects of the tears.

## Resistance to Damage by Ultraviolet Rays

Filter fabrics are woven or nonwoven materials constructed by various bonding techniques from artificial textile fibers such as polypropylene, dacron, nylon, olefin, and polyester. Different types of fibers respond differently to ultraviolet rays. Some of the fibers highly susceptible to damage are treated with ultraviolet inhibitors, such as a small percentage of carbon black, to delay deterioration. Therefore, with the entire makeup of each fabric unknown and the experience of early deterioration of silt fences on several construction projects, it was decided that a simple test for evaluating susceptibility to damage from ultraviolet rays was needed.

For this evaluation, a large sample of each fabric was hung from a clothesline, and each month three samples (27.0 in. [68.6 cm] long by 7.0 in. [17.8 cm] wide) were cut from it in the warp direction until the material decomposed or had undergone 6 months (April to October) of exposure. The samples cut each month were brought to the laboratory and tested for tensile strength as described in Appendix A.

## Effects of pH

Prior to the initiation of this study, it had been noticed that several silt fences had deteriorated after only a short time in service. In a discussion of this poor performance, it was suggested that the lime-fertilizer mixture used in the seeding operation was causing the deterioration. Although most fabric manufacturers had claimed that their products could withstand exposure to solutions of low and high pH, it was decided that the claims should be validated. Solutions with pH values of 5 and 12 were chosen for the evaluation, since these values are the limits that could be encountered on most normal construction projects.

Three samples 27.0 in. (68.6 cm) long by 7.0 in. (17.8 cm) wide of each fabric cut in the warp direction were soaked in a lime-fertilizer solution with a pH of 12 for 24 hours and then allowed to air dry for 24 hours. After drying, each sample was tested for tensile strength. Using a solution having a pH of 5, this process was repeated for three new samples of each fabric. (In Virginia, water with a pH lower than 5 may be encountered near the acidic drainage from a mine. In this situation the fabric used in a silt fence should be specially evaluated and designed.)

## Permeability

In an attempt to simplify the testing program, it was felt necessary to try to relate the water permeability of the different fabrics to the filtering efficiency and flow rate from the flume tests for the different soils. Because of the rapid flow of water through the fabrics, the constant head test with some modifications was chosen. With this test, it was hoped that the flow could be kept in the laminar flow range.

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Because the permeameter used in soil testing could not be used without a large amount of modification and a larger sized sample than the permeameter allowed was desired to account for production variability in the fabrics, a plexiglas tube with an inside diameter of 5.0 in. (12.7 cm) was adapted as a constant head permeameter. After the modifications it was modified to allow securing a sample, the diameter of the tested fabric was restricted to 4.2 in. (10.7 cm).

A problem was encountered in measuring the thickness of the fabric, a dimension needed in the constant head equation

$$k = \frac{Ql}{thA},$$

where

l is the thickness of the fabric; and

Q is the volume of water passing through the fabric with an area of A in a time, t, with a head of water, h.

The thickness of each fabric was determined with a pressure sensitive caliper that would exert only a prescribed pressure on the fibers.

Three samples of each fabric were tested in the permeameter at various heads up to the maximum that could be obtained without going into the turbulent flow range (Figure 8).

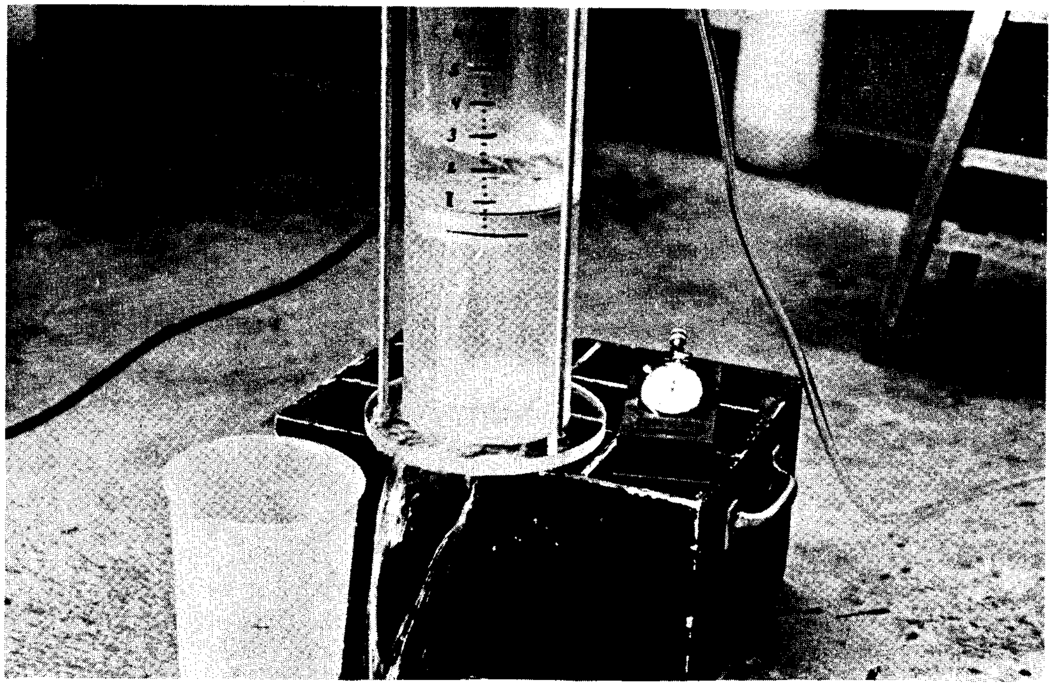

Figure 8. Permeameter.

## Creep

Another property that was felt possibly to be critical was creep. Although a fabric may exhibit good strength and small elongations in the tensile strength test, it is possible that it will elongate over a period of time when loaded with a constant load, such as is the case with a full silt fence. Therefore, three samples of each fabric 27.0 in. (68.6 cm) long by 7.0 in. (17.8 cm) wide were clamped securely across two supports spaced 14.0 in. (35.6 cm) apart.

By calculating the total load that an average silt fence in the field might be exposed to and converting this uniform load into a point load, it was determined by stress analysis that 50 lb. (23 kg) suspended from the middle of the fabric sample would approximate field conditions. Vertical displacements were taken after 1 hour and 24 hours of loading to determine creep.

The test was terminated after 24 hours of loading, since it was believed that by that time most sediment behind a silt fence would be stable and starting to dry. At this point, the sediment would not be exerting the total load against the fabric and the loading would decrease as the sediment continued to dry.

## DISCUSSION OF RESULTS

### Filtering Efficiency

#### Laboratory

Table 2 gives the results of the laboratory filtration tests. The flow rate, the filtering efficiency, and the largest particle size of the soil passing through each fabric are indicated. As shown, the results varied considerably among soil types as well as within each type.

For the sandy soil, a clay size particle was the largest passing through the fabrics. Polyfilter GB and Polyfilter X fabrics allowed the larger clay particles (0.004 mm) to pass through, while the other fabrics filtered down to the smallest clay particle (0.001 mm) measured in the study. The results for filtering efficiency on this soil were high (greater than 92%), which should be expected with most of the particles dropping out of suspension very quickly. Figure 1 indicates that approximately 85% of the particles are larger than 0.15 mm, while Table 1 shows that these same size particles take 67 seconds to settle 1 m (3.28 ft.) in still water. With only approximately 15% of the particles of this sandy soil (Figure 1) in suspension after 1 minute, very little clogging of the fabric openings occurred, even during the three simulated storm events for each fabric sample.

The flow rate varied from a low of 0.01 gal./ft.$^2$/min. ($6.8 \times 10^{-6}$m-s) (Typar 3401) to a high of 86.0 gal./ft.$^2$/min. (0.058m-s). (Laurel Erosion Cloth II). In Table 2, there seem to be no definite trends among the three columns of results for the sandy soil. The filtering efficiency and largest particle to pass through the fabrics did not vary as much as the flow rates.

Table 2

Laboratory Filtration Test Results

| Material | Sandy Soil | | | Silty Soil | | | Clayey Soil | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flow Rate, Gal./ft.$^2$/min. | Filtering Efficiency, % | Particle Size, mm | Flow Rate, Gal./ft.$^2$/min. | Filtering Efficiency, % | Particle Size, mm | Flow Rate, Gal./ft.$^2$/min. | Filtering Efficiency, % | Particle Size, mm |
| Bidim C-22 (NW) | 1.7 | 97 | 0.001 | 0.2 | 95 | 0.001 | 0.6 | 97 | 0.001 |
| Filter X (W) | 0.2 | 98 | 0.001 | 0.2 | 98 | 0.001 | 0.6 | 94 | 0.001 |
| Laurel Erosion Cloth, Type I (W) | 0.4 | 97 | 0.001 | 0.1 | 99 | 0.001 | 0.3 | 98 | 0.001 |
| Laurel Erosion Cloth, Type II (W) | 86.0 | 94 | 0.001 | 59.9 | 49 | 0.180 | 63.5 | 85 | 0.001 |
| Mirafi 140 (NW) | 0.4 | 98 | 0.001 | 0.2 | 98 | 0.001 | 0.2 | 99 | 0.001 |
| Monofelt (NW) | 0.4 | 99 | 0.001 | 0.3 | 90 | 0.001 | 0.3 | 99 | 0.001 |
| Monofilter (W) | 0.2 | 98 | 0.001 | 0.1 | 94 | 0.001 | 0.2 | 95 | 0.001 |
| Polyfelt TS 200 (NW) | 3.8 | 97 | 0.001 | 0.2 | 99 | 0.001 | 1.1 | 94 | 0.001 |
| Polyfelt TS 300 (NW) | 2.2 | 97 | 0.001 | 0.3 | 99 | 0.001 | 0.03 | 93 | 0.001 |
| Polyfelt TS 400 (NW) | 2.7 | 98 | 0.001 | 0.5 | 99 | 0.001 | 0.2 | 95 | 0.001 |
| Polyfilter GB (W) | 53.4 | 92 | 0.004 | 5.3 | 84 | 0.008 | 3.1 | 88 | 0.001 |
| Polyfilter X (W) | 5.1 | 92 | 0.004 | 0.4 | 88 | 0.004 | 0.5 | 89 | 0.001 |
| Supac 5E (PR165A) (NW) | 0.2 | 99 | 0.001 | 0.3 | 98 | 0.001 | 0.2 | 98 | 0.001 |
| Supac 4-P (NW) | 0.1 | 99 | 0.001 | 0.002 | 100 | 0.001 | 0.2 | 98 | 0.001 |
| Typar 3401 (NW) | 0.01 | 99 | 0.001 | 0.1 | 94 | 0.001 | 0.2 | 97 | 0.001 |

Conversion: 1 gal./ft.$^2$/min. = $6.8 \times 10^{-4}$ m-s.

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As indicated in Table 2 and Figure 1, most of the largest particles passing through the fabrics were in the clay size range (less than 0.005 mm). As was seen in Table 1, in still water particles of this size take over 7 hours to settle 1 m (3.28 ft.). Since the water detained behind a silt fence is not completely still and the fence is not higher than 3 ft. (0.9 m), the settlement of these particles would require that the fence perform more as a dam than as a filtering device. However, because of the high volume of water usually accumulating behind a silt fence it would be impossible for the fence to act as a dam without structural failures or the sediment-laden water going around or over it. In addition, clay particles have electrical charges on their surfaces that may keep them in motion (Brownian movement) and prevent them from settling. Consequently, with a silt fence it would seem best to attempt to retain the silt size particles. As indicated earlier, the smallest silt size particle (0.005 mm) would take over 7 hours to settle out in still water.

In light of the settling times shown in Table 1, most of the suspended particles to be filtered will be in the silt and fine sand particle ranges. Table 3 indicates that of the three soils used in the study, the silty soil from the Piedmont region has the highest percentage (40%) of these particles. In addition, Table 3 and Figure 1 show that the gradation curve for the silty soil is more uniform than the curves for the other two soils.

Table 3

Percentage Particles in Each Grain Size Range

(Extracted from Figure 1)

| Grain Size Range | Three Soil Types | | |
|---|---|---|---|
| | Clayey | Silty | Sandy |
| Clay | 51 | 13 | 8 |
| Silt | 19 | 26 | 2 |
| Fine Sand | 7 | 14 | 30 |
| Coarse Sand | 5 | 7 | 54 |
| Gravel | 18 | 40 | 6 |

The filtration test results for the silty soil are more varied than are those for the clayey and the sandy soils. At flow rates from 0.02 to 59.90 gal./ft.$^2$/min. ($1.4 \times 10^{-5}$ to 0.04 m-s), the filtering efficiencies range from 59% to 100%, and the particle sizes from 0.001 mm (clay) to 0.180 mm (fine sand). The rates for the three woven fabrics (Laurel Erosion Cloth - Type II, Polyfilter GB, and Polyfilter X), although quite different (from 0.4 to 59.9 gal./ft.$^2$/min. [$2.7 \times 10^{-4}$ to 0.04 m-s]), allowed the largest particles to pass through. However, with the exception of the first two of these, all the fabrics retained soil particles larger than clay size.

The results for the clayey soil indicate that only clay size particles passed through the fabrics. However, the removal of soil particles was greater than 90% for all the fabrics, except the three just named. The flow rate was high for Laurel Erosion Cloth - Type II (63.5 gal./ft.$^2$/min. [0.04 m-s]), while Polyfilter GB and Polyfilter X had flow rates (3.1 and 0.5 gal./ft.$^2$/min. [$2.1 \times 10^{-3}$ and $3.4 \times 10^{-4}$ m-s], respectively) similar to those of the other fabrics. Most of the flow rates were between 0.2 and 0.6 gal./ft.$^2$/min. ($1.4 \times 10^{-4}$ and $4.1 \times 10^{-4}$ m-s).

Since the most erodible soil in Virginia is the micaceous silty soil in the Piedmont (1.2 to 4.3 tons/acre/year [0.27 to 0.96 kg/m2/yr] of soil loss in undisturbed areas),(6) it should be used by the Materials Division in evaluating fabrics.

## Field

A 1.5 in. (3.8 cm) storm event was simulated in a denuded 10-ft.$^2$ (0.9-m$^2$) area behind each small fabric silt fence. Water samples were obtained upstream and downstream from the fence at 5 and 15 minutes after commencing the storm event. Also, a third set of samples were obtained at the termination of the spraying of water on each plot.

Data were obtained for all fabrics in the three basic soils (sand, silt, and clay). The data are included in Appendix C. Because of the many variables (soil type, soil moisture content, soil compaction, air temperature, etc.) encountered in performing field tests of this type, the data are very variable. No trends are indicated between the different soil types, at different times of sampling, or between different fabrics, whether woven or nonwoven.

## Strength

Table 4 gives the results of three tensile tests performed on each fabric in the warp direction, the fill direction, and in the warp direction with a 0.5-in. (1.3-cm) tear placed in the center of the samples. All samples were tested as described in Appendix A. Load versus elongation curves were plotted for all samples and are available upon request. The strength values shown in Table 4 were developed as follows. If the fabric generated a load-elongation curve as indicated in Figure 9, the maximum load ($P_{max}$) was determined as shown.

Table 4

Average Strength from Tensile Tests

| Material | Strength, lb./lin. in. | | |
|---|---|---|---|
| | Warp Direction | Fill Direction | 0.5-in. Tear |
| Bidim C-22 (NW) | 23 | 108 | 23 |
| Mirafi 140 (NW) | 53 | 43 | 50 |
| Monofelt (NW) | 20 | 30 | 28 |
| Polyfelt TS 200 (NW) | 22 | 2 | 31 |
| Polyfelt TS 300 (NW) | 26 | 3 | 27 |
| Polyfelt TS 400 (NW) | 27 | 5 | 25 |
| Supac 4-P (NW) | 4 | 21 | 4 |
| Supac 5-E (NW) | 3 | 7 | 7 |
| Typar 3401 (NW) | 49 | 62 | 45 |
| Filter X (W) | 36 | 19 | 40 |
| Laurel Erosion Cloth, Type I (W) | 230 | 145 | 180 |
| Laurel Erosion Cloth, Type II (W) | 172 | 172 | 140 |
| Monofilter (W) | 134 | 135 | 158 |
| Polyfilter GB (W) | 91 | 95 | 74 |
| Polyfilter X (W) | 135 | 108 | 139 |

Conversion: 1 lb./lin. in. = 175.1 N/m.

2925

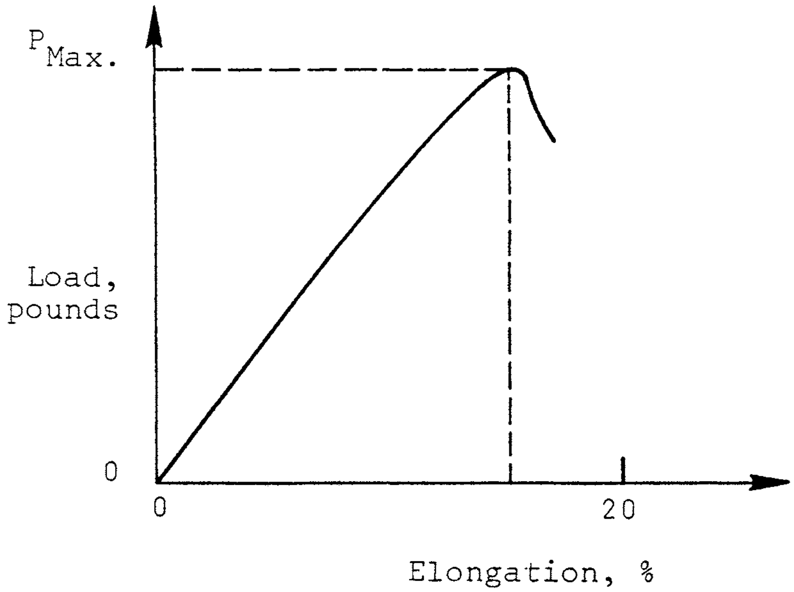


Figure 9. Load versus elongation curve with distinct maximum load.

If the fabric generated a load-elongation curve as shown in Figure 10, the maximum load ($P_{max}$) was determined at 20% elongation for the reasons noted earlier. If the load-elongation curve generated was similar to the curve in Figure 9 but peaked past 20% elongation, then the maximum load ($P_{max}$) was still taken as the load at 20% elongation.

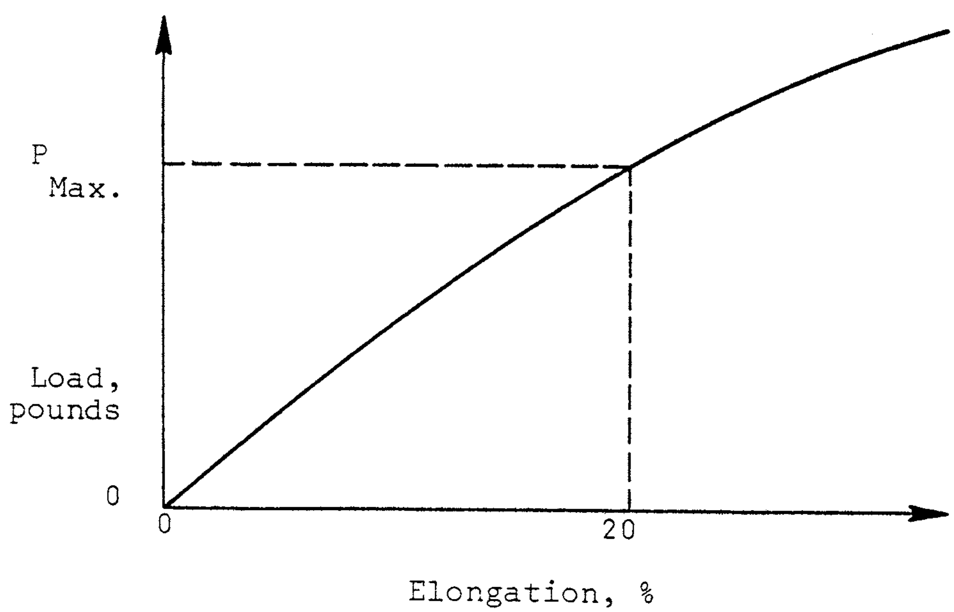


Figure 10. Load versus elongation curve with no distinct maximum load.

The maximum strengths for the three samples of each fabric were averaged and divided by 7.0 in. (17.8 cm), the sample width. Table 4 gives the average maximum strengths.

The nonwoven fabrics, because of their construction and composition, indicate a lower strength value than the woven fabrics, except for Filter X. The fill direction strength is equal to or exceeds the warp direction strength for 7 of the 15 fabrics tested. This trend is shown almost equally by the woven and nonwoven fabrics (three out of six woven fabrics and four out of nine nonwoven).

A comparison of the average strengths of the 0.5-in. (1.3 cm) tear samples with those of the warp direction samples shows for the former that 9 of the 15 fabrics had average strengths equal to or exceeding those of the warp direction samples. This trend indicates that the stress on the fibers is realigned or transferred to unaffected fibers for small tears of 0.5 in. (1.3 cm). The remaining six fabrics (three woven and three nonwoven) indicate an average reduction in maximum strength of 20% (range 19% to 22%) for the woven fabrics and 7% (range 6% to 8%) for the nonwoven fabrics.

From a structural standpoint, it can be calculated that a 3.0-ft. (0.9-m) high silt fence full of sediment needs to withstand an active earth pressure of 170 lb./lin. ft. (2,481 N/m) of fence. This pressure amounts to a total load of 1,720 lb. (780 kg) against a 10 ft. (3.05 m) long fence, or a warp tensile strength of approximately 50 lb./in. (8,755 N/m). As indicated in Table 4, one nonwoven fabric (Mirafi 140) and all of the woven fabrics except Filter X had a warp tensile strength, with or without the 0.5-in. (1.3 cm) tear, in excess of this requirement. The remaining fabrics need support from some source such as woven wire to meet the requirement.

At present the Department requires a reinforcing or woven wire support behind all silt fences. Considering the above information, however, it would be possible to eliminate the reinforcing wire behind most silt fences, and thus reduce the cost of installation.

Because of the high cost of straw bale barriers, the Department is considering alternatives, particularly a small silt fence less than 18.0 in. (0.46 m) in height,[7] for use in drainage ditches and other locations. From a structural standpoint, the active earth pressure against this type of barrier would be 43 lb./lin. ft. (628 N/m) of fence, for a total load of 430 lb. (195 kg.) against a 10.0 ft. (3.05 m) long section of fence. In order to withstand this load, the fence would need a warp tensile strength of 24 lb./in. (4,203 N/m). From Table 4 it can be seen that all of the fabrics except the nonwoven Bidim C-22, Monofelt, Polyfelt TS200, Supac 4-P, and Supac 5-E meet the strength requirement for this type of filter barrier.

Since an 18.0-in. (0.46-m) filter barrier used in place of a straw bale barrier would generally be a maximum of 10.0 ft. (3.05 m) long, the Department's design personnel desire that the barrier posts not be spaced over 3.0 ft. (0.9 m) apart. With this spacing, the needed warp tensile strength would be reduced to 7 lb./in. (1,226 N/m). At this strength value, all but Supac 4-P and 5-E would meet the strength requirement without reinforcement.

## Resistance to Damage by Ultraviolet Rays

Table 5 indicates the average warp tensile strength of the fabrics when exposed to the weather conditions indicated in Table 6. The months chosen for exposure are the ones of heaviest construction activity and the hardest on the fabrics. In addition, because most silt fences are helpful in the control of silt for 3 months and sometimes for as much as 6 months, the fabrics were evaluated over 6-months of exposure.

As indicated in Table 6, the rainfall for each month was from 1 to 4 in. (2.54 to 10.16 cm) less than normal, while the air temperature was from 1° to 3°F above normal, except for June, when the average was 2.9°F less than normal.

After 3 months of exposure three nonwoven fabrics (Mirafi 140, Monofelt, and Supac 4-P) deteriorated to the point that no samples could be obtained for testing.

These three fabrics were the only untreated polypropylene or non-polyester materials tested. Fabrics composed of polyester or black polypropylene material have good stability under exposure to ultraviolet rays. For all of the woven and two of the nonwoven fabrics (Supac 4-P and 5-E) there was a gain in tensile strength after 1 month of exposure. The two nonwoven fabrics did not exhibit a large amount of tensile strength at any period of the testing. For Supac 5-E, however, there was an almost fourfold increase (from 3 to 11 lb./lin. in. [525 to 1,926 N/m]) in strength after 6 months of exposure. Supac 4-P deteriorated after 3 months of exposure.

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Table 5. Average Strength From Ultraviolet Tests

| Material | Strength, lb./lin. in. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 Mo. | 1 Mo. | 2 Mo. | 3 Mo. | 4 Mo. | 5 Mo. | 6 Mo. |
| Bidim C-22 (NW) | 23 | 14 | 17 | 18 | 16 | 18 | 12 |
| Mirafi 140 (NW) | 53 | 11 | 11 | 5 | --* | -- | -- |
| Monofelt (NW) | 20 | 9 | 8 | 4 | -- | -- | -- |
| Polyfelt TS-200 (NW) | 22 | 17 | 17 | 15 | 14 | 14 | 2 |
| Polyfelt TS-300 (NW) | 26 | 17 | 20 | 18 | 13 | 17 | 14 |
| Polyfelt TS-400 (NW) | 27 | 20 | 18 | 28 | 31 | 18 | 24 |
| Supac 4-P (NW) | 4 | 6 | 5 | 4 | -- | -- | -- |
| Supac 5-E (NW) | 3 | 6 | 5 | 8 | 6 | 8 | 11 |
| Typar 3401 (NW) | 49 | 28 | 24 | 22 | 23 | 19 | 18 |
| Filter X (W) | 36 | 69 | 78 | 88 | 88 | 83 | 16 |
| Laurel Erosion Cloth, Type I (W) | 230 | 244 | 259 | 260 | 213 | 171 | 154 |
| Laurel Erosion Cloth, Type II (W) | 172 | 182 | 179 | 195 | 166 | 172 | 183 |
| Monofilter (W) | 134 | 211 | 220 | 227 | 193 | 194 | 200 |
| Polyfilter GB (W) | 91 | 124 | 78 | 136 | 155 | 163 | 122 |
| Polyfilter X (W) | 135 | 230 | 123 | 249 | 233 | 218 | 132 |

*Fabric completely deteriorated, no samples tested.
Conversion: 1 lb./lin. in. = 175.1 N/m.

Table 6

Summary Weather Data for Ultraviolet Tests

| Date | Rainfall, in. | Deviation from Normal RF, in. | Avg. Temp., °F | Deviation from Normal Temp, °F | High Temp, °F | Low Temp, °F | Degree-Days |
|---|---|---|---|---|---|---|---|
| April 1977 | 2.15 | -1.13 | 59.2 | 2.2 | 88 | 9 | 232 |
| May 1977 | 2.70 | -1.20 | 68.1 | 2.1 | 92 | 37 | 49 |
| June 1977 | 1.56 | -1.88 | 70.4 | -2.9 | 91 | 45 | 18 |
| July 1977 | 1.14 | -4.02 | 80.0 | 2.9 | 103 | 53 | 0 |
| August 1977 | 2.37 | -2.46 | 76.6 | 1.0 | 97 | 53 | 0 |
| September 1977 | 1.42 | -2.77 | 71.9 | 2.5 | 96 | 50 | 4 |

Conversion: 1 in. = 2.54 cm. Deg. C = $\frac{5}{9}$ (°F - 32°)

Degree-Days - sums of negative degrees of average daily temperature from 65° as established by U. S. Department of Commerce, National Oceanic and Atmospheric Administration.

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Of the nine nonwoven fabrics, three — Polyfelt TS-400, Supac 4-P, and Supac 5-E — showed essentially equal or greater tensile values after 3 months of weather exposure, while only two nonwoven fabrics — Polyfelt TS-400 and Supac 5-E — displayed this same trend after 6 months of exposure.

After 3 months of exposure, all of the woven fabrics showed an increase in tensile strength over their original strength. Only Filter X and Laurel Erosion Cloth, Type I indicated a substantial reduction in tensile strength after 6 months of exposure, while for the remaining four woven fabrics the strengths stayed essentially the same or increased.

## Effects of pH

Table 7 summarizes the tensile strengths resulting from the pH soak tests. From the table, one would observe that the effects on the nonwoven fabrics were the reverse of those on the woven fabrics. The nonwoven fabrics had essentially equal or less tensile strength after soaking, which indicated some possible deterioration, while the woven fabrics had the same or increased strength after soaking.

Considering these results and the problem with early deterioration of silt fences that was discussed previously, it can be concluded that the silt fence failures were not due to the lime-fertilizer mixture used in the seeding operation. After discussion with field personnel and the fabric manufacturer, it was concluded that the deterioration of the fabric was due to ultraviolet radiation, since the fabric was an untreated polypropylene material. The results obtained in this study verify the above conclusion.

Therefore, it would not be very worthwhile to subject fabrics to a pH soak test.

## Permeability

The coefficient of permeability results for the fabrics at the heads of water tested are listed in Appendix D. From a comparison of these results among the fabrics or at different heads, it was concluded that no trends were evident. The conclusion was the same when the coefficients of permeability were compared to the filtering efficiencies, flow rates, and the thicknesses of the fabrics. At the outset of the study it was hoped that some relationship could be determined between the permeability and the filtering efficiency or flow rate. Since no relationships were evident, it was concluded that this test would not simplify the evaluation of filter fabrics.

Table 7

Summary of Results from pH Soak Tests

| Material | Strength, lb./lin. in. | | |
|---|---|---|---|
| | Unsoaked | pH = 5 | pH = 12 |
| Bidim C-22 (NW) | 23 | 13 | 21 |
| Mirafi 140 (NW) | 53 | 15 | 14 |
| Monofelt (NW) | 20 | 10 | 13 |
| Polyfelt TS-200 (NW) | 22 | 14 | 16 |
| Polyfelt TS-300 (NW) | 26 | 32 | 18 |
| Polyfelt TS-400 (NW) | 27 | 19 | 27 |
| Supac 4-P (NW) | 4 | 5 | 4 |
| Supac 5-E (NW) | 3 | 4 | 6 |
| Typar 3401 (NW) | 49 | 33 | 35 |
| Filter X (W) | 36 | 108 | 105 |
| Laurel Erosion Cloth, Type I (W) | 230 | 265 | 223 |
| Laurel Erosion Cloth, Type II (W) | 172 | 168 | 154 |
| Monofilter (W) | 134 | 237 | 166 |
| Polyfilter GB (W) | 91 | 145 | 148 |
| Polyfilter X (W) | 135 | 194 | 215 |

Conversion: 1 lb./lin. in. = 175.1 N/m.

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## Creep

Table 8 lists the results of the creep tests on the fabrics. The average changes in length for the three samples tested in both the warp and fill directions are shown. As indicated, most of the elongation for the fabrics occurred within the first hour of loading. Between the first and twenty-fourth hours the additional creep ranged from 0 to 0.57 in. (0 to 1.45 cm).

For all but the Typar 3401, the nonwoven fabrics had more elongation in the warp direction than the woven fabrics, while in the fill direction only six of the nonwoven fabrics had more elongation than the woven fabrics. Twelve of the fabrics exhibited larger or equal creep in the fill direction than in the warp direction.

# COST ANALYSIS

The costs per square yard (including material plus freight) of the fabrics are shown in Table 9. The price reflects the cost of freight to Charlottesville for 10,000 ft.$^2$ (929 m$^2$) of each material. It was estimated that 10,000 ft.$^2$ or 1,111 yd.$^2$ (929 m$^2$) of a fabric would be needed to install silt fences on an average construction project in Virginia. However, most manufacturers consider this quantity to be a small lot, and the indicated cost may be several cents higher than that for a larger quantity.

As indicated in Table 9, the nonwoven fabrics cost less than the woven materials. Also, it can be noted that several of the nonwoven fabrics have been discontinued.

# CONCLUSION

Of the eight tests used in this study, only two would be worth using for evaluating fabrics. These are the laboratory filtering efficiency and the tensile strength tests. These two ascertain three of the four most critical characteristics desired of a silt fence; namely, (1) a high filtering efficiency, (2) fast flow rate, and (3) adequate tensile strength. The only other critical parameter a design engineer could use in selecting a fabric and designing a silt fence is the resistance of the fabric to damage from ultraviolet radiation. Although the effect of ultraviolet rays on fabrics was considered in this study, similar exposure conditions would be extremely hard to reproduce. However, the Department should consider developing an ultraviolet radiation test method using a weatherometer for future evaluations.

Table 8

Creep Results

| Material | Average Change in Length, in. | | | |
|---|---|---|---|---|
| | Warp Direction | | Fill Direction | |
| | 1 hr. | 24 hrs. | 1 hr. | 24 hrs. |
| Bidim C-22 (NW) | 2.19 | 2.38 | 2.69 | 2.94 |
| Filter X (W) | 0.59 | 0.66 | 1.28 | 1.47 |
| Laurel Erosion Cloth-Type I (W) | 0.13 | 0.13 | 0.38 | 0.44 |
| Laurel Erosion Cloth-Type II (W) | 0.34 | 0.41 | 0.25 | 0.38 |
| Mirafi 140 (NW) | 1.13 | 1.63 | 1.13 | 1.63 |
| Monofelt (NW) | 2.56 | 3.13 | 1.31 | 1.69 |
| Monofilter (W) | 0.13 | 0.13 | 0.19 | 0.25 |
| Polyfelt TS-200 (NW) | 2.56 | 2.78 | 10.75 | 11.28 |
| Polyfelt TS-300 (NW) | 2.13 | 2.38 | 8.38 | 8.81 |
| Polyfelt TS-400 (NW) | 1.22 | 1.41 | 4.44 | 4.97 |
| Polyfilter GB (W) | 0.25 | 0.38 | 0.25 | 0.38 |
| Polyfilter X (W) | 0.13 | 0.16 | 0.31 | 0.38 |
| Supac 5E (PR 165A) (NW) | 4.25 | 4.38 | 3.38 | 3.50 |
| Supac 4-P (NW) | 4.19 | 4.72 | 2.81 | 3.13 |
| Typar 3401 (NW) | 0.44 | 0.53 | 0.44 | 0.56 |

Note: 1 in. = 2.54 cm.

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Table 9

Fabric Cost
(Includes material plus freight to Charlottesville)

| Fabric | Cost/Square Yard |
|---|---|
| Bidim C-22 (NW) | $0.63 |
| Mirafi 140 (NW) | 0.67 |
| Monofelt (NW) | 0.80* |
| Polyfelt TS-200 (NW) | ** |
| Polyfelt TS-300 (NW) | ** |
| Polyfelt TS-400 (NW) | ** |
| Supac 4-P (NW) | 0.58 |
| Supac 5-E (NW) | 0.68 |
| Typar 3401 (NW) | 0.70 |
| Filter X (W) | 3.20 |
| Laurel Erosion Cloth, Type I (W) | 1.35 |
| Laurel Erosion Cloth, Type II (W) | 1.98 |
| Monofilter (W) | 1.45 |
| Polyfilter GB (W) | 2.39 |
| Polyfilter X (W) | 1.68 |

* Is not being produced except for special orders of 50,000 yd.$^2$ (41,800 m$^2$) or more.

** Discontinued.

Conversion: 1 yd.$^2$ = 0.836 m$^2$.

The results from the study indicate that the field tests used for evaluating the filtering capabilities of the fabrics and their resistance to ultraviolet radiation, as well as their permeability under laboratory conditions, are not reproducible. In addition, because the fabrics showed no adverse effects from exposure to solutions covering the extremes of pH encountered in the field, there is no need for a pH soak test. The large range of creep exhibited by the materials is related to the warp tensile strength. The higher the warp tensile strength, the lower the warp creep.

In future evaluations of fabrics for silt fences, the laboratory filtering efficiency test should be performed with a uniformly graded silty soil similar to the one used in this study. The fabric should remove 75% of all the soil particles carried in the agitated, sediment-laden water and should allow the water to pass through at a rate of 0.3 gal./ft.$^2$/min. ($2.0 \times 10^{-4}$ m-s) or faster. Although 0.3 gal./ft.$^2$/min. ($2.0 \times 10^{-4}$ m-s) was chosen as the lowest flow rate desired, the rate needs to be increased without causing the filtering efficiency to drop below 75%. If this could be achieved, progress toward building an optimal silt fence would be made.

The tensile test results indicate that the reinforcing wire used behind a 3.0 ft. (0.9 m) high silt fence could be eliminated, if the strength of the fabric exceeds 50 lb./lin. in. (8,755 N/m). For the small silt barriers used to replace straw bale barriers (less than 18.0 in. [0.46 m] in height), the tensile strength should exceed 24 lb./lin. in. (4,203 N/m) of width of the fabric, if the support posts are 10.0 ft. (3.05 m) apart. If the posts are placed at 3.0-ft. (0.9-m) spacings, the tensile strength can be as low as 7 lb./lin. in. (1,226 N/m) of width, and the barriers will be structurally sound without any reinforcement.

In addition to their usefulness in designing silt fences, some of the data generated can be used to advantage in other engineering applications such as underlayment for riprap, drainage filter around pipe or stone, and stabilization material across marshy, weak soil.

## RECOMMENDATIONS

The following recommendations are made to the Department for implementation.*

1. All filter fabrics should be evaluated using a silty soil and filtering efficiency apparatus similar to those used in this study. The test procedure described in Appendix A should be followed.

2. All filter fabrics should be evaluated for tensile strength using the test procedure described in Appendix A.

3. Specifications for filter fabrics to be used in silt fences and barriers should meet, at the least, the requirements given in Table 10.

Table 10

Purchasing Specifications

| Structure | Filtering Efficiency, % | Flow Rate, gal./ft.$^2$/min. | Tensile Strength, lb./lin. in. |
|---|---|---|---|
| 3-ft. silt fence with reinforced backing | 75 | 0.3 | Reinforcing governs |
| 3-ft. silt fence without reinforced backing | 75 | 0.3 | 50 |
| 18-in. silt barrier without reinforced backing and posts 10 ft. apart | 75 | 0.3 | 24 |
| 18-in. silt barrier without reinforced backing and posts 3 ft. apart | 75 | 0.3 | 7 |

Conversion: 1 gal./ft.$^2$/min. = 6.8 x $10^{-4}$ m-s.
1 lb./lin. in. = 175.1 N/m.

*Recommendations 1, 2, and 3 have been implemented as Virginia Test Methods 51 and 52.

4. The Department should not allow the use in silt fences of polypropylene fabrics not treated with carbon black or other stabilizers to provide resistance to deterioration from ultraviolet radiation.

   (As shown in this study and documented in the manufacturer's literature and correspondence,* untreated polypropylene breaks down under ultraviolet bombardment within 3 to 4 months. Therefore, this type of material should not be used in the construction of silt fences or in any other application where it will be exposed to ultraviolet rays.)

5. The Department should investigate the use of the weatherometer for determining the effects of ultraviolet rays on filter fabrics.

   The Department, with the assistance of the Research Council, can establish an evaluation program to determine if any correlation is possible between the field results obtained in this study and different exposure times in the Materials Division weatherometer. If a correlation and a simple testing procedure can be developed, then the fourth critical parameter essential for a good silt fence fabric specification can be ascertained.)

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*Personal correspondence. J. H. Blore, Phillips Fibers Corporation, Towson, Maryland, April 1977.

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ACKNOWLEDGEMENT

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# APPENDIX A

# TEST PROCEDURES

FILTERING EFFICIENCY

LABORATORY

1. Scope

This method is used to determine the filtering efficiency and flow rate of a filter fabric in the laboratory.

2. Apparatus

a. A flume 48 in. (1.2 m) long by 32 in. (0.8 m) wide by 12 in. (0.3 m) high with a gutter attached to one side. (See Figures A-1 and A-2.)

b. Two 20-gal. (0.08 $m^3$) containers.

c. A stirrer on a 1/4-in. (0.01 m) portable drill.

d. Stopwatch.

e. A DH-48 integrated water sampler with ten 500 ml bottles.

3. Procedure

a. Stretch a sample of the fabric 39 in. (1.0 m) long by 12 in. (0.3 m) wide across the flume opening 32 in. (0.8 m) wide and fasten securely in place to assure that all the sediment-laden water passes through the sample. Note: The flume opening is the standard length of a straw bale.

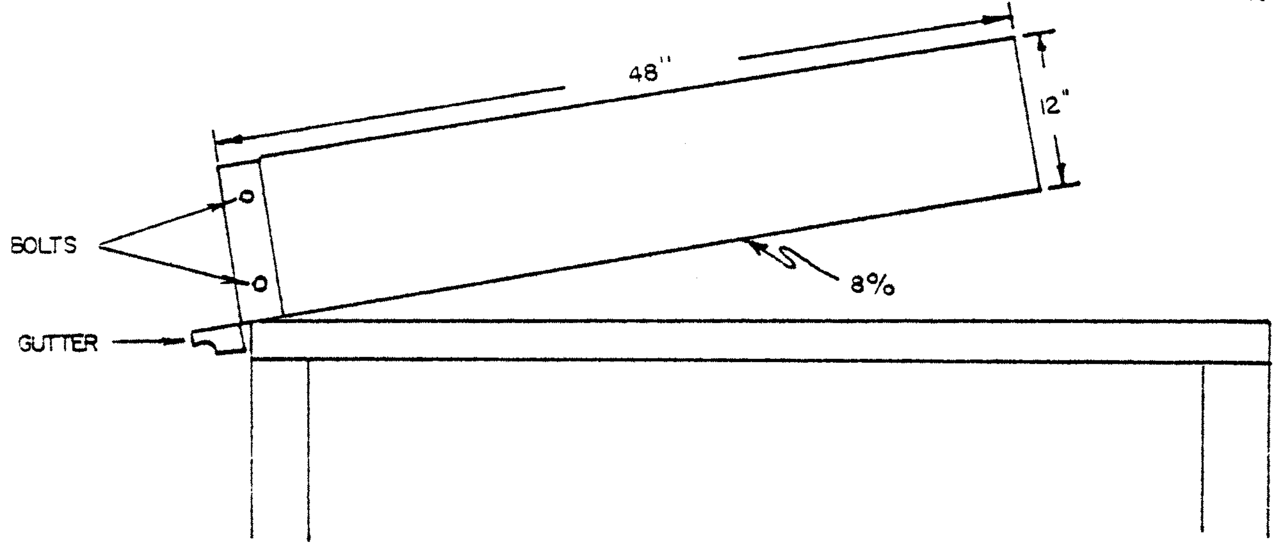
b. Elevate the flume to an 8% slope.

c. Take a depth integrated, suspended solids sample from an untreated, fairly sediment-free water supply. Continuously agitate the supply for uniformity during the sampling process.

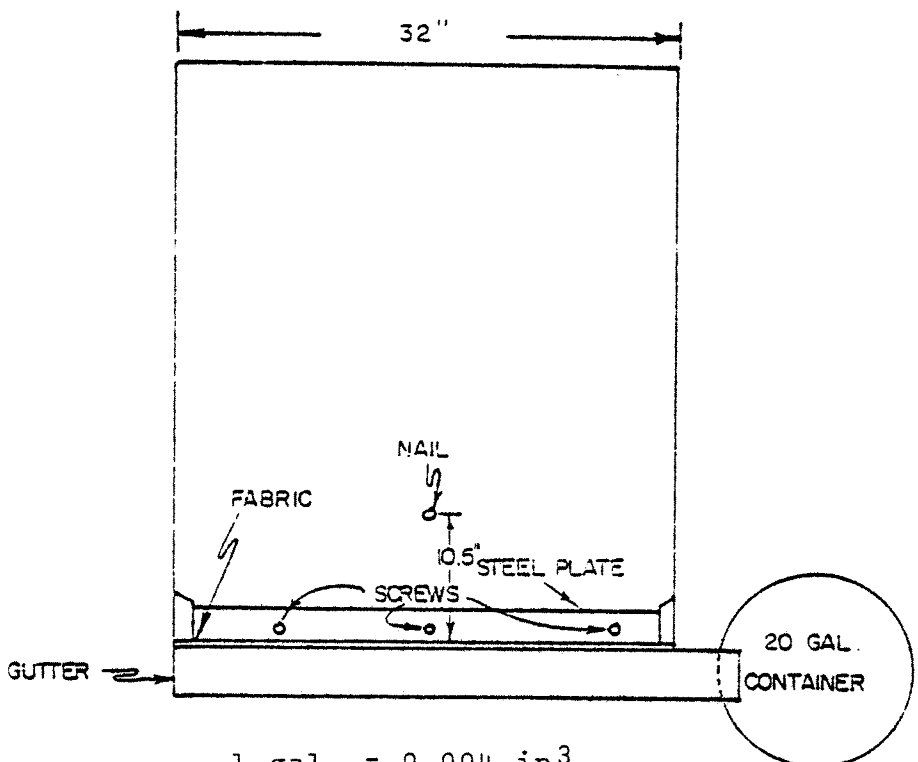
d. Prewet the fabric by passing 50 litres of untreated, fairly sediment-free water through it.

e. Mix 150 grams of minus 10 material of a silty soil (see gradation curve, Figure A-3) in 50 litres of the untreated water placed in one of the 20 gal. (0.08 $m^3$) containers. Thoroughly agitate the solution with the stirrer on the 1/4 in. (0.01 m) portable drill to obtain a uniform mix.

2945



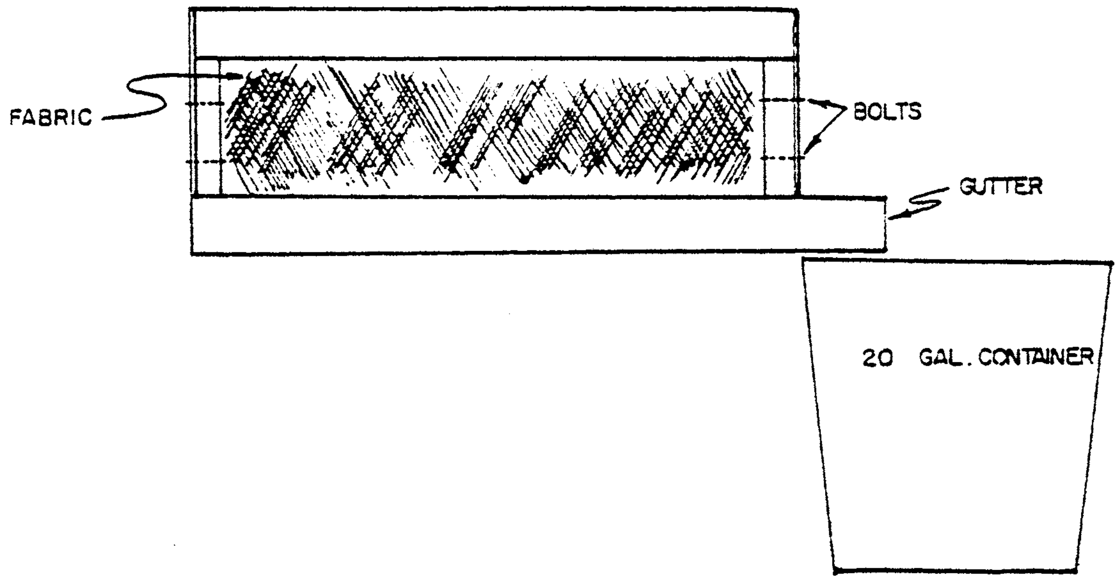

NOTE: All dimensions are inside measurements.




1 gal. = 0.004 $in^3$
1 in. = 0.03 in

Figure A-1. Side view (upper sketch) and top view of flume.

2946




NOTE: 2 Side plates and a bottom plate are used to fasten the sample of fabric in place.

1 gal. = 0.004$m^3$

Figure A-2. End view of flume.

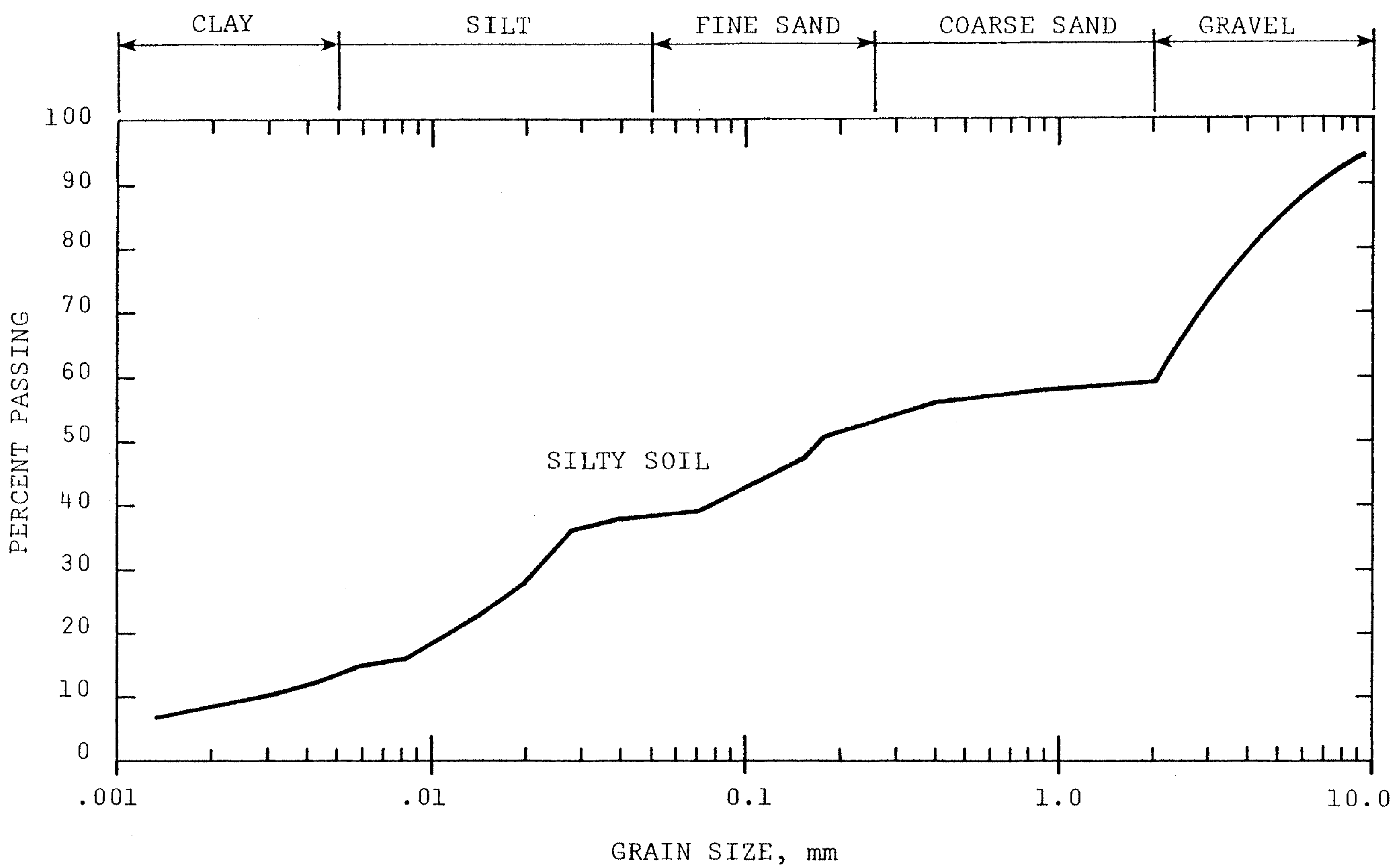



Figure A-3. Gradation curve for soil used.

f. After uniformly mixing the solution, quickly dump the solution behind the fabric sample in the flume. Start the timer at dumping.

g. Rinse the mixing container with 1 to 2 litres of the filtrate and dump into the flume.

h. Time the flow of water through the fabric until the water level drops to a point 10.5 in. (0.27 m) behind the fabric. At this point the flow **has essentially** ceased.

i. Collect all filtrate in a second mixing container.

j. At the completion of the test, agitate the collected filtrate until the mixture is uniformly mixed. Obtain a depth integrated, suspended solids sample from the mixture during agitation.

k. Process the two suspended solids samples by the "nonfilterable residue" procedure described in the Standard Methods for the Examination of Water and Wastewater, 14th ed. (APHA, AWWA, WPCF).

l. Calculate the filtering efficiency (FE) of the fabric as follows:

$$FE\ (\%) = \frac{(SS_{bg} + 3{,}000) - SS_{After}}{(SS_{bg} + 3{,}000)} \times 100,$$

where $SS_{After}$ and $SS_{bg}$ are the suspended solids value after filtration and the background level, respectively.

m. Calculate the flow rate of the fabric as follows:

$$\text{Flow rate (gal./ft.}^2\text{/min.)} = 14.85/\text{time (min.)}$$

n. Repeat steps e through l for the same fabric sample twice more.

FIELD

1. Scope

This method is used in determining the filtering efficiency of a filter fabric in the field.

2. Apparatus

a. Stopwatch.

b. A sprayer to provide a uniform rain event over a prescribed area.

c. A small sampler with ten 500-ml bottles.

d. 30 in. (0.76 m) long wooden stakes.

e. Pick and shovel.

f. Heavy duty stapler.

g. Ruler.

3. Procedure

a. In a silty soil, locate a site with uniform soil conditions and an approximately 8% slope.

b. Construct a small silt fence and mark off a 10-$ft.^2$ (0.9-$m^2$) area behind it.

c. Spray the prescribed area with 20 gal. (0.08 $m^3$) of water at a rate of 1.5 in./hr. (3.8 cm/hr.).

d. Collect a representative 500-ml sample of the sediment-laden water above and below the silt fence at the following times: five and fifteen minutes after commencing the spray, and at the termination of spraying.

e. Process the samples for suspended solids by the "nonfilterable residue" procedure described in Standard Methods for the Examination of Water and Wastewater, 14th ed. (APHA, AWWA, WPCF).

f. Calculate the filtering efficiency (FE) of the fabric as follows:

$$FE\ (\%) = \frac{SS_{above} - SS_{below}}{SS_{above}} \times 100,$$

where $SS_{above}$ and $SS_{below}$ are the suspended solids values above and below the silt fence, respectively.

g. Repeat steps a through f for clayey and sandy soils.

1. Scope

This test determines the stress-strain relationship of a filter fabric.

2. Apparatus

A tensile test device with a capacity of approximately 2,500 lb. (1,134 kg) equipped with a dial that can be read in increments of 10 lb. (4.54 kg. approx.) or less. The device should have a rate of travel of 13% ± 2% of the gage length of the fabric per minute. The device shall have a travel distance of 20 in. (0.51 m) minimum and hold a 7 in. (0.18 m) wide sample.

3. Procedure

a. Cut a sample of the fabric in the direction perpendicular to the axis of the roll. The sample should be 27 in. (0.69 m) long by 7 in. (0.18 m) wide.

b. Securely fasten the sample of the fabric in the clamps of the testing device so the length of the fabric between the clamps is 14 in. (0.36 m). (Figure A-4.)

c. Place the secured sample in the testing device. (Figure A-5.)

d. Start the testing device and stopwatch simultaneously.

e. Take load and elongation readings every 15 sec. up to 2 1/2 min., or until failure has occurred, whichever comes first. (Figures A-6 and A-7.)

f. Plot the load on the vertical axis versus its corresponding elongation on the horizontal axis.

g. Determine the peak load value, if it occurs prior to 20% or 2.8-in. (0.07-m) elongation. If the peak load does not occur before 20% elongation, then record the load at 20% elongation.

h. Repeat steps a through g for a sample cut in the direction perpendicular to the axis of the roll with a 1/2 in. (1.3 cm) long tear crossways in the middle of the sample. (Figure A-8.)

i. Repeat steps a through g for a sample cut in the direction parallel to the axis of the roll.

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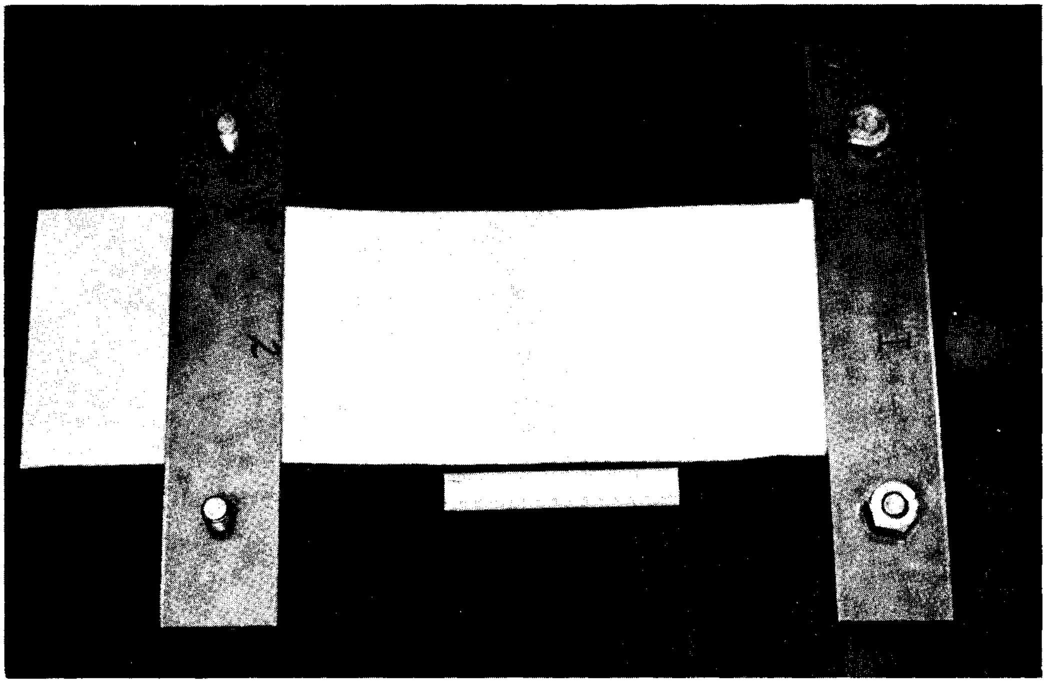

Figure A-4. Fabric secured in end clamps.

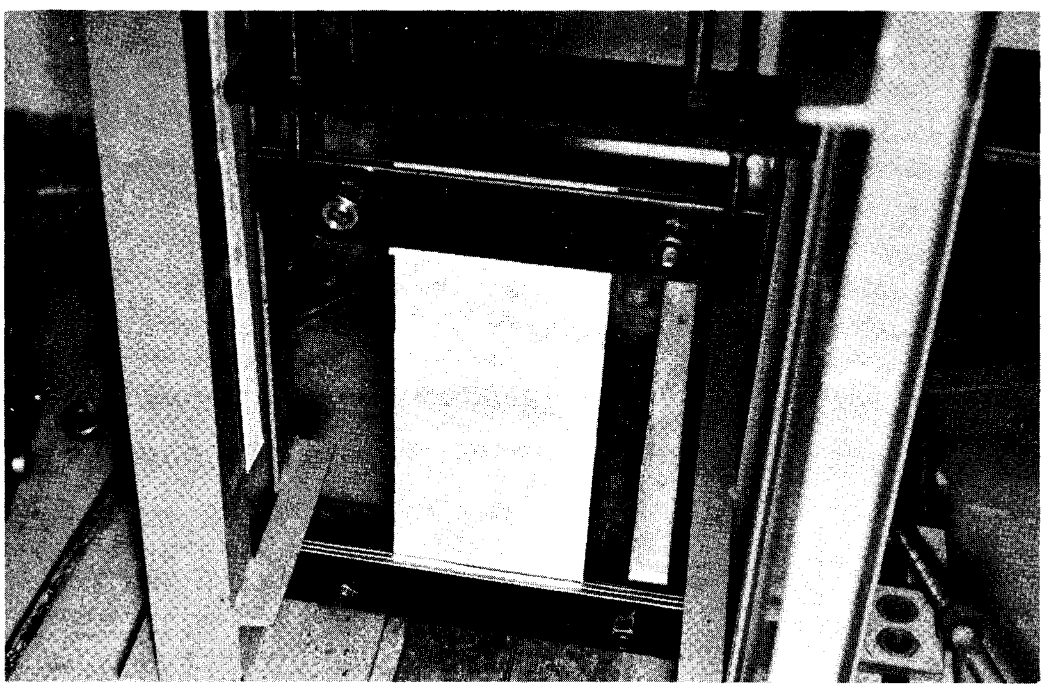

Figure A-5. Sample in place and ready for tensile testing.

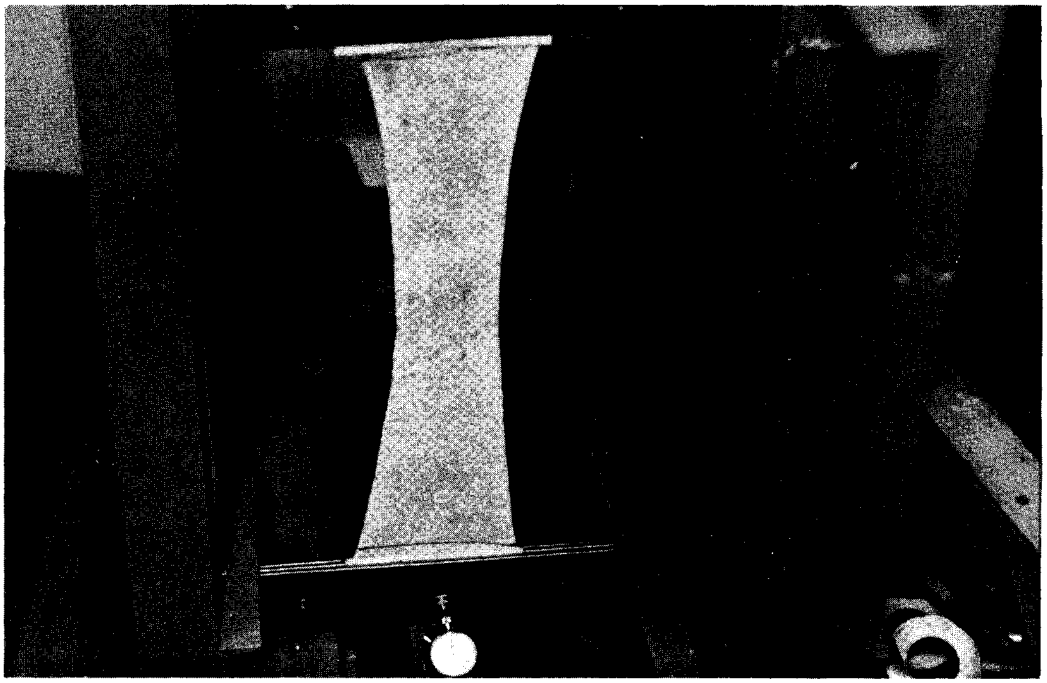

Figure A-6. Sample being elongated.

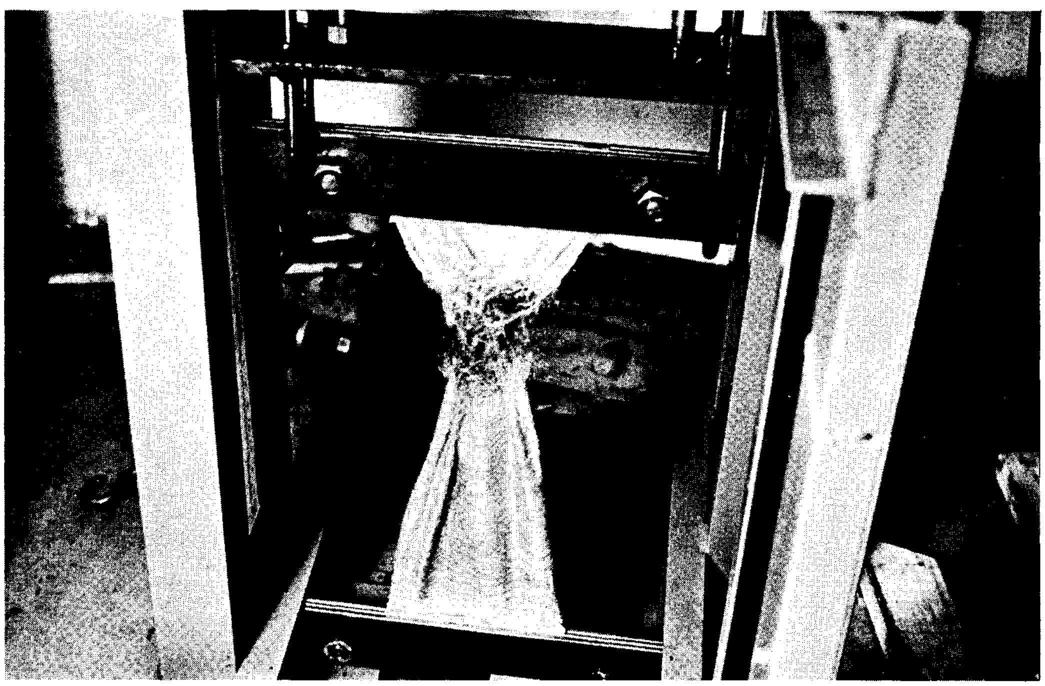

Figure A-7. Sample after failure.

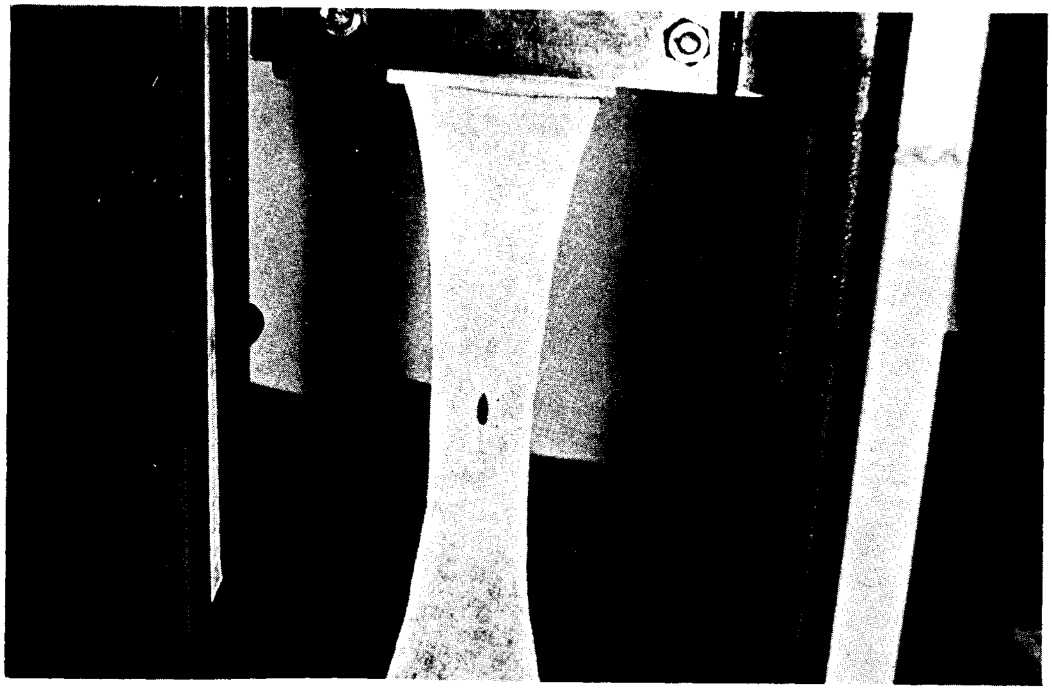

Figure A-8. Sample being elongated with 1/2 in. (1.27 cm) tear.

## ULTRAVIOLET

1. Scope

This method determines the effect of ultraviolet rays on a filter fabric.

2. Apparatus

a. Tensile test device described under Strength Test.

b. Clothesline to hang large samples of fabrics on for 6 months.

3. Procedure

a. Hang at least 25 ft.$^2$ (2.3 m$^2$) of each fabric on a clothesline.

b. After each month of exposure through 6 months, remove three samples perpendicular to the axis of the roll for tensile tests as described under Strength Test, steps b through g.

# pH EFFECTS

1. Scope

This test determines the effects of acid and alkaline solutions on a filter fabric.

2. Apparatus

a. Tensile test device described under Strength Test.

b. 5-gal. (0.02-$m^3$) soaking container.

3. Procedure

a. Cut a 27 in. (0.69 m) long by 7 in. (0.18 m) wide sample of the fabric in the direction perpendicular to the axis of the roll.

b. Place the sample in a solution having a pH of 12 for 24 hr. (Note: A solution having a pH of 12 can be made by mixing lime and fertilizer in water.)

c. After 24 hours of soaking, remove the sample and air dry it for 24 hr.

d. Test the sample under tension as described in steps b through g under Strength Test.

e. Repeat the above steps using a solution with a pH of 5.

# PERMEABILITY

1. Scope

   This test determines the coefficient of permeability of a filter fabric.

2. Apparatus

   A constant head permeameter that holds a sample 4.2 in. (10.7 cm) in diameter.

3. Procedure

   a. Cut a sample of the fabric approximately 5.5 in. (0.14 m) in diameter to fit the constant head permeameter.

   b. Determine the average thickness of the fabric with pressure sensitive calipers.

   c. Place a constant head of water on the sample.

   d. Determine the time required to collect a known volume of water, such as 2 litres, after passing through the sample.

   e. Ascertain the temperature of the water.

   f. Determine the coefficient of permeability, k, for the temperature of the water by the formula

$$k \text{ (cm/sec)} = \frac{Ql}{thA},$$

where

$Q$ = volume of water collected in $cm^3$,

$l$ = average thickness of the fabric in cm,

$t$ = time to collect the water in sec.,

$h$ = head of water used in cm, and

$A$ = area of the permeameter in $cm^2$.

g. Correct the coefficient of permeability as determined for the effects of temperature by the equation

$$k_{20°C} = 0.099\ k_T u_T,$$

where

$k_T$ = coefficient of permeability calculated in step f, and

$u_T$ = viscosity of water at the water temperature of the test.

h. Vary the head and repeat steps d through g.

# CREEP

1. Scope

   This test determines the elongation or creep of a filter fabric.

2. Apparatus

   a. A device with two supports 14 in. (0.36 m) apart for clamping a sample of filter fabric securely in place.

   b. A 50-lb. (23-kg) weight.

   c. A hanger to hold weight in the center of the sample.

   d. Stopwatch.

   e. Ruler.

3. Procedure

   a. Cut a sample of fabric 27 in. (0.69 m) long by 7 in. (0.18 m) wide in the direction perpendicular to the axis of the roll.

   b. Securely fasten the sample to the two supports.

   c. Hang 50-lb. (23-kg) weight in the center of the sample and start the stopwatch.

   d. After 1 hr. and 24 hr. of loading, determine the vertical displacement at the center of the fabric sample.

   e. The amount of elongation is determined as

$$E\ (\text{inches}) = 2\sqrt{x^2 + 49} - 14.00,$$

where x = vertical displacement in inches.

# APPENDIX B

## FABRICS TESTED

| Trade Name | Manufacturer or Distributor | Description |
|---|---|---|
| Bidim C-22 | Monsanto Textiles Co.<br>800 North Lindbergh Blvd.<br>St. Louis, MO 63166 | Gray non-woven mechanically entangeled continuous filament polyester with a weight of 4.5 oz/sq. yd. |
| Filter-X | Carthage Mills<br>Erosion Control Division<br>124 W. 66th Street<br>Cincinnati, OH 45216 | Green woven polyvinylidene chloride monofilament yarn with a weight of 11.6 oz/sq. yd. |
| Laurel Erosion Cloth, Type I | Advance Construction Specialties, Co.<br>P.O. Box 17212<br>Memphis, TN 38117 | Black woven polypropylene monofilament yarn with a weight of 7.2 oz/sq. yd. |
| Laurel Erosion Cloth, Type II | Advance Construction | Same, with a weight of 6.3 oz/sq. yd. |
| Mirafi 140 | Celanese Fibers Marketing Corp.<br>P. O. Box 1414<br>Charlotte, NC 28232 | White non-woven polypropylene nylon monofilaments bonded by fusion and having a weight of 4.5 oz/sq. yd. |
| Monofelt | Menardi Southern Division<br>United States Filter Corp.<br>P.O. Box 12454<br>Houston, TX 77087 | White non-woven polypropylene entangled and fused monofilament with a weight of 5 oz/sq. yd. |
| Monofilter | Menardi Southern Division | Black woven monofilament polypropylene yarn with a weight of 7 oz/sq. yd. |
| Polyfelt TS200 | Advance Construction | Tan non-woven polypropylene made by the needle punching process and having a weight of 6 oz/sq. yd. |
| Polyfelt TS300 | Advance Construction | Same, with a weight of 8 oz/sq. yd. |
| Polyfelt TS400 | Advance Construction | Same, with a weight of 10.5 oz/sq. yd. |
| Polyfilter GB | Carthage Mills | Black woven polypropylene monofilament yarn with a weight of 6.6 oz/sq. yd. |
| Polyfilter X | Carthage Mills | Same, with a weight of 7.2 oz/sq. yd. |
| Supac 5-E (PR165A) | Phillips Fibers Corp.<br>Petromat Marketing Dept.<br>610 Oxford Building<br>8600 LaSalle Road<br>Towson, MD 21204 | White non-woven polyester fabric with a weight of 5 oz/sq. yd. |
| Supac 4-P | Phillips Fibers Corp. | Gray, non-woven, entangled olefin monofilament with a weight of 4 oz/sq. yd. |
| Typar 3401 | E. I. DuPont de Nemours and Company, Inc.<br>Textile Fibers Dept.<br>Centre Road Building<br>Wilmington, DE 19898 | Gray, non-woven, spun-bonded polypropylene monofilament with a weight of 4 oz/sq. yd. |

Conversion: 1 oz/sq. yd. = 0.034 kg/sq. meter.

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# APPENDIX C

# FIELD FILTRATION TEST RESULTS

TABLE C-1

SUSPENDED SOLIDS RESULTS FOR SILTY SOIL

| Fabric | Suspended Solids (ppm) | | |
|---|---|---|---|
| | 5 Min. | Termination of Spraying | 15 Min. |
| Bidim C-22 | +[a] | + | + |
| Filter X | + | + | 461 |
| Laurel Erosion Cloth, Type I | + | + | + |
| Laurel Erosion Cloth, Type II | + | + | -[b] |
| Mirafi 140 | + | 2,539 | 2,575 |
| Monofelt | 16,497 | 5,520 | 1,557 |
| Monofilter | + | + | + |
| Polyfelt TS-200 | 5,830 | + | - |
| Polyfelt TS-300 | + | + | + |
| Polyfelt TS-400 | 6,203 | 5,792 | - |
| Polyfilter GB | + | 13,785 | - |
| Polyfilter X | 1,614 | 715 | + |
| Supac 5E (PR165A) | 32,770 | 37,583 | 1,596 |
| Supac 4-P | + | 25,059 | 96 |
| Typar 3401 | + | + | + |

a. + indicates an increase in suspended solids after the sediment-laden water had passed through the fabric.

b. - indicates that an upstream sample was not taken since no water had ponded up behind the fabric.

TABLE C-2

SUSPENDED SOLIDS RESULTS FOR SANDY SOIL

| Fabric | Suspended Solids (ppm) | | |
|---|---|---|---|
| | 5 Min. | Termination of Spraying | 15 Min. |
| Bidim C-22 | +[a] | + | -[b] |
| Filter X | 4,449 | 55 | + |
| Laurel Erosion Cloth, Type I | 5,164 | + | 325 |
| Laurel Erosion Cloth, Type II | 3,532 | 1,882 | - |
| Mirafi 140 | 7,633 | 3,456 | - |
| Monofelt | 4,415 | 2,790 | 151 |
| Monofilter | 4,258 | 2,206 | + |
| Polyfelt TS-200 | 616 | 2,923 | - |
| Polyfelt TS-300 | 3,179 | 236 | + |
| Polyfelt TS-400 | 5,208 | 4,109 | + |
| Polyfilter GB | 3,762 | 2,930 | - |
| Polyfilter X | 3,496 | 941 | 53 |
| Supac 5E (PR165A) | 10,537 | 2,307 | - |
| Supac 4-P | 15,496 | 974 | 596 |
| Typar 3401 | 3,465 | 1,772 | 2,253 |

a. + indicates an increase in suspended solids after the sediment-laden water had passed through the fabric.

b. - indicates that an upstream sample was not taken since no water had ponded up behind the fabric.

TABLE C-3

SUSPENDED SOLIDS RESULTS FOR CLAYEY SOIL

| Fabric | Suspended Solids (ppm) | | |
|---|---|---|---|
| | 5 Min. | Termination of Spraying | 15 Min. |
| Bidim C-22 | 477 | 1,073 | -[b] |
| Filter X | 5,807 | 76 | 214 |
| Laurel Erosion Cloth, Type I | +[a] | + | + |
| Laurel Erosion Cloth, Type II | 10,136 | 1,762 | 264 |
| Mirafi 140 | + | 355 | + |
| Monofelt | 15,135 | 1,180 | 173 |
| Monofilter | 184 | 625 | 276 |
| Polyfelt TS-200 | 1,317 | 148 | 216 |
| Polyfelt TS-300 | 1,382 | 482 | - |
| Polyfelt TS-200 | 5,851 | 4,455 | 967 |
| Polyfilter GB | 21,540 | 1,436 | - |
| Polyfilter X | 3,848 | 4,639 | 383 |
| Supac 5E (PR165A) | 10,121 | 2,411 | 177 |
| Supac 4-P | 1,502 | 797 | 212 |
| Typar 3401 | 2,641 | 535 | 56 |

a. + indicates an increase in suspended solids after the sediment-laden water had passed through the fabric.

b. - indicates that an upstream sample was not taken since no water had ponded up behind the fabric.

# APPENDIX D

## PERMEABILITY RESULTS

(Note: Numbers of heads vary between fabrics depending upon the number obtainable during testing.)

# PERMEABILITY

| Fabric | Thickness, cm | Head, cm | Coefficient of Permeability, cm/sec |
|---|---|---|---|
| Bidim C-22 | 0.052 | 0.64 | 0.069 |
| | | 1.27 | 0.058 |
| | | 1.91 | 0.057 |
| | | 1.91 | 0.060 |
| | | 1.91 | 0.064 |
| Mirafi 140 | 0.040 | 1.27 | 0.020 |
| | | 2.54 | 0.015 |
| | | 3.81 | 0.014 |
| | | 5.08 | 0.016 |
| | | 5.08 | 0.011 |
| | | 6.35 | 0.014 |
| | | 6.35 | 0.011 |
| | | 7.62 | 0.010 |
| | | 8.89 | 0.009 |
| | | 10.16 | 0.007 |
| Monofelt | 0.065 | 1.27 | 0.064 |
| | | 1.27 | 0.067 |
| | | 1.91 | 0.058 |
| | | 1.91 | 0.073 |
| Polyfelt TS-200 | 0.085 | 1.91 | 0.090 |
| | | 2.54 | 0.062 |
| | | 3.18 | 0.070 |
| | | 3.81 | 0.063 |
| Polyfelt TS-300 | 0.114 | 2.54 | 0.070 |
| | | 2.54 | 0.078 |
| | | 4.45 | 0.052 |
| | | 4.45 | 0.071 |
| | | 6.35 | 0.050 |
| Polyfelt TS-400 | 0.137 | 2.54 | 0.093 |
| | | 2.54 | 0.156 |
| | | 3.81 | 0.097 |
| Supac 4-P | 0.071 | 1.27 | 0.033 |
| | | 1.27 | 0.062 |
| | | 2.54 | 0.032 |
| | | 2.54 | 0.040 |
| | | 4.45 | 0.034 |
| | | 5.08 | 0.030 |

(cont'd) PERMEABILITY

| Fabric | Thickness, cm | Head, cm | Coefficient of Permeability, cm/sec |
|---|---|---|---|
| Supac 5-E | 0.097 | 1.27 | 0.097 |
| | | 1.27 | 0.097 |
| | | 1.91 | 0.088 |
| | | 1.91 | 0.096 |
| Typar 3401 | 0.039 | 2.54 | 0.002 |
| | | 2.79 | 0.002 |
| | | 2.86 | 0.003 |
| | | 5.08 | 0.002 |
| | | 5.08 | 0.005 |
| | | 7.62 | 0.004 |
| | | 7.62 | 0.004 |
| | | 7.62 | 0.005 |
| | | 10.16 | 0.005 |
| | | 10.16 | 0.005 |
| | | 10.16 | 0.006 |
| | | 12.70 | 0.004 |
| | | 12.70 | 0.006 |
| | | 15.24 | 0.004 |
| | | 15.24 | 0.006 |
| | | 15.24 | 0.005 |
| Filter X | 0.034 | 1.27 | 0.014 |
| | | 1.27 | 0.017 |
| | | 2.54 | 0.014 |
| | | 2.54 | 0.015 |
| | | 3.81 | 0.014 |
| | | 3.81 | 0.014 |
| Laurel Erosion Cloth, Type I | 0.042 | 2.54 | 0.003 |
| | | 3.81 | 0.001 |
| | | 5.08 | 0.001 |
| | | 5.08 | 0.003 |
| | | 5.08 | 0.008 |
| | | 7.62 | 0.005 |
| | | 7.62 | 0.010 |
| | | 10.16 | 0.008 |
| | | 10.16 | 0.011 |
| Laurel Erosion Cloth, Type II | 0.051 | 1.27 | 0.080 |
| | | 1.27 | 0.103 |

PERMEABILITY

| Fabric | Thickness, cm | Head, cm | Coefficient of Permeability, cm/sec |
|---|---|---|---|
| Monofilter | 0.051 | 1.27 | 0.005 |
| | | 2.54 | 0.010 |
| | | 3.81 | 0.011 |
| | | 5.08 | 0.012 |
| | | 6.35 | 0.014 |
| Polyfilter GB | 0.064 | 1.27 | 0.087 |
| | | 1.27 | 0.098 |
| Polyfilter X | 0.040 | 1.27 | 0.026 |
| | | 1.27 | 0.054 |
| | | 2.54 | 0.025 |
| | | 2.54 | 0.027 |
| | | 3.18 | 0.025 |
| | | 3.18 | 0.026 |
| | | 3.81 | 0.020 |
| | | 3.81 | 0.028 |