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Evaluation of Filter Fabrics for Use in Silt Fences

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This study was conducted to develop tests that simulate field conditions and that could be used to generate information for the formulation of specifications for purchasing filter fabrics to be used to construct silt fences. Fifteen fabrics were subjected to seven tests devised to evaluate their performance. Two of the tests—laboratory filtering efficiency and warp tensile strength—have been adopted by the Virginia Department of Highways and Transportation for evaluating filter fabrics to be used on construction projects. Three of the four parameters found to be critical in the design of a silt fence—filtering efficiency, flow rate, and warp tensile strength—are ascertained by these two tests. A third test, to determine the fourth critical parameter (resistance to damage by ultraviolet rays), is reported but was not recommended to the department for use because of its lack of reproducibility. Further work on a method for evaluating this critical parameter is needed.

Because accelerated erosion can result from areas denuded during highway construction, the policy of the Virginia Department of Highways and Transportation is to employ protective measures on all projects and to establish vegetation as early as possible. In addition to vegetation, 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 vegetation 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 that allowed contractors to use fabrics to construct silt fences.

Different fabric manufacturers produce materials of different properties and use the results of different approval tests, such as those sanctioned by the American Society for Testing and Materials (ASTM) (1), as evidence of their quality. Also, the properties of the materials do not clearly relate to the properties desired of a fabric to be incorporated in a silt fence. Therefore, a study was initiated to develop tests that could be used to evaluate the properties of the fabrics and provide information that might aid in the development of specifications to be stipulated in purchasing them (2).

OBJECTIVE

The objective of the study was to develop information for the formulation of specifications for use in purchasing filter fabrics for building silt fences on highway construction projects. To achieve this objective, the performance desired of an installed silt fence made of fabric had to be established along with a valid estimation of what is reasonably achievable. Therefore, the first objective was to develop tests that closely simulated the conditions to which a silt fence is exposed. In addition, the tests were to be of a type that could be performed without any large investment in additional testing equipment.

CRITERIA FOR TESTS AND FABRICS

In developing the evaluative tests, it was decided that they should simulate field conditions. The criteria established for the fabrics were that they must have the following properties:

1. Sufficient strength to resist the force of the sediment-laden water without excessive elongation,
2. Resistance to the effects of ultraviolet rays from the sun,
3. Resistance to the effects of water of low or high pH, and
4. Ability to filter 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.

FABRICS TESTED

Fifteen fabrics were received from their manufacturers for testing. Table 1 lists the fabrics and their manufacturers.

Table 1. Fabrics tested.

Trade Name	Manufacturer or Distributor
Bidim C-22	Monsanto Textiles Co.
Filter-X	Carthage Mills
Polyfilter X	
Polyfilter GB	
Laurel Erosion Cloth, types I and II	Advance Construction Specialties Co.
Polyfelt TS-200, TS-300, and TS-400	
Mirafi 140	Celanese Fibers Marketing Corp.
Monofelt	Menardi Southern Division, United States Filter Corp.
Monofilter	
Supac 5-E (PR165A)	Phillips Fibers Corp.
Supac 4-P	
Typar 3401	E.I. DuPont de Nemours and Co., Inc.

DISCUSSION OF RESULTS

Seven tests were developed for evaluating the fabrics. The data obtained from two of the tests--water permeability and field filtering efficiency--indicated no trends and are not reproducible. Therefore, they were not considered for further use and are not discussed in this paper. The test for determining the effects of pH indicated no adverse effects from exposure to solutions that cover the extremes of pH encountered in the field; thus this test is not useful. A fourth test, that for creep, also proved not to be useful.

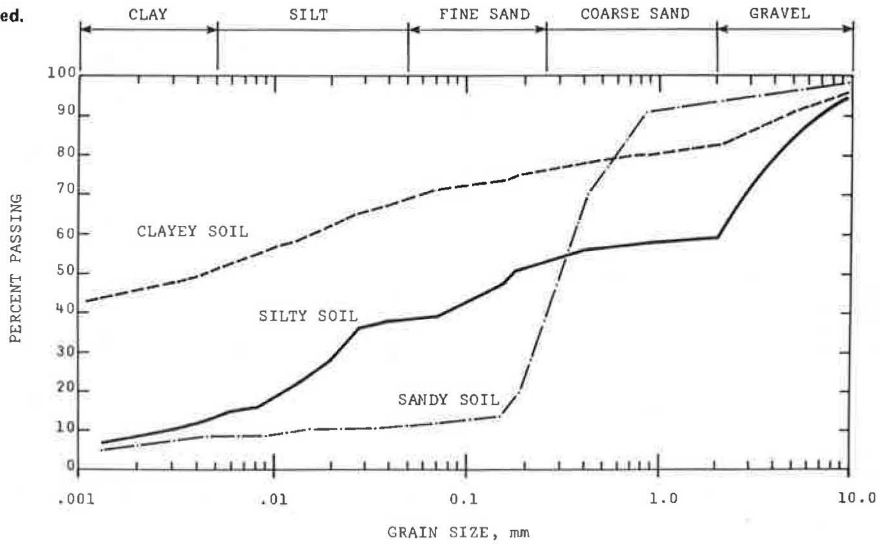
The remaining tests--those for filtering efficiency and flow rate, tensile strength, and resistance to damage by ultraviolet rays--are discussed in the following sections.

Laboratory Filtering Efficiency and Flow Rate

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. Consequently, it was decided to test the fabrics in the laboratory in a flume that had a slope of 8 percent, the slope of the average ditch in which straw bales are installed. To simulate runoff water, a sediment-laden mixture of 3000 ppm was selected, since the previous work had shown that this suspended-solids value was the maximum encountered in the field during a noncatastrophic storm event. Three such mixtures were run through each fabric to determine the effect three storm events would have on the filtering capability and flow rate. It had been found that, usually, after three storm events of greater than

Figure 1. Gradation curves for three soils used.



0.5 in of rainfall, silt fences were inoperable unless they were cleaned out.

Three samples of each fabric were evaluated by using each of the three soils. Sediment-laden water was generated for each test by adding 150 g of minus-10 material to 50 L of uncontaminated water. Relatively clean stream water was transported to the laboratory, since tap water supplied by the local municipality contains alum, a coagulant. 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 that had 2.00-mm maximum size because it was believed that particles larger than that would not be in suspension in the field. The above assumption seems to be reasonable, since soil particles 2.00 mm large would settle 1 m in less than 10 s in still water (4).

The soil and water were thoroughly mixed, the resultant mixture was poured immediately behind the fabric sample into the flume, a clock was started, and the time required to filter 50 L 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. The suspended-solids level of the filtrate was determined following the procedure for nonfiltrable residue described in the 14th edition of Standard Methods for the Examination of Water and Wastewater (5). The filtering efficiency (FE) of the fabric was calculated as follows:

$$\text{FE (percent)} = [(SS_{\text{before}} - SS_{\text{after}})/SS_{\text{before}}] \times 100.$$

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

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

Table 2 gives the results of the laboratory filtration tests. The flow rate, the filtering efficiency, and the largest particle size of the soil that passed 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-sized particle was the largest that passed through the fabrics. Polyfilter GB and Polyfilter X fabrics allowed the larger clay particles (0.004 mm) to pass through, whereas 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 percent), which should be expected when most of the particles dropped out of suspension very quickly. Figure 1 indicates that approximately 85 percent of the particles are larger than 0.15 mm and these particles take 67 s to settle 1 m in still water (4). Since only approximately 15 percent of the particles of this sandy soil (Figure 1) were in suspension after 1 min, very little clogging of the fabric openings occurred, even during the three storm events simulated for each fabric sample.

The flow rate varied from a low of 0.01 gal/ft²/ min (Typar 3401) to a high of 86.0 gal/ft²/ min (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 fabric did not vary as much as the flow rates did.

As indicated in Table 2, most of the largest particles that passed through the fabrics were in the clay size range (less than 0.005 mm) and in still water take more than 7 h to settle 1 m (4). Since the water retained behind a silt fence is not completely still and the fence is not higher than 3 ft, the settlement of these particles would require that the fence perform more like a dam than like a filtering device. However, because of the high volume of water that usually accumulates behind a silt fence, it would be impossible for the fence to act like 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 thus prevent them from settling. Consequently, with a silt fence it would seem best to attempt to retain the silt-sized particles. As indicated earlier, the smallest silt-sized particle (0.005 mm) would take more than 7 h to settle out in still water.

Table 2. Laboratory-filtration-test results.

	Sandy Soil			Silty Soil			Clayey Soil		
Material	Flow Rate (gal/ft²/min)	Filtering Efficiency (%)	Particle Size[a] (mm)	Flow Rate (gal/ft²/min)	Filtering Efficiency (%)	Particle Size[a] (mm)	Flow Rate (gal/ft²/min)	Filtering Efficiency (%)	Particle Size[a] (mm)
Bidim C-22 (NW)	1.7	97	0.001	0.2	95	0.001	0.6	97	0.001
Filter-X (NW)	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 5-E (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

Note: W = woven; NW = nonwoven.

[a] Largest particle that passes through fabric.

In light of the settling times mentioned above, most of the suspended particles to be filtered will be in the silt and fine-sand particle ranges. Of the three soils used in the study, the silty soil from the Piedmont region has the highest percentage (40 percent) of these particles, as shown below:

Grain Size Range	Soil Type 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

In addition, Figure 1 shows that the gradation curve for the silty soil is more uniform than are the curves for the other two soils.

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 0.002 to 59.90 gal/ft^2/min, the filtering efficiencies range from 49 to 100 percent 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 II, Polyfilter GB, and Polyfilter X), although quite different (from 0.4 to 59.9 gal/ft^2/min), allowed the largest particle 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-sized particles passed through the fabrics. However, the removal of soil particles was greater than 90 percent for all the fabrics except the three just named. The flow rate was high for Laurel Erosion Cloth II (63.5 gal/ft^2/min), whereas Polyfilter GB and Polyfilter X had flow rates (3.1 and 0.5 gal/ft^2/min, respectively) similar to those of the other fabrics. Most of the flow rates were between 0.2 and 0.6 gal/ft^2/min. Since the most erodible soil in Virginia is the micaceous silty soil in the Piedmont (1.2-4.3 tons/acre/year of soil loss in undisturbed areas) (6), it should be used in evaluating fabrics.

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 installation practices (7), such as the elimination of the reinforcing wire and the reduction in supports. These modifications would simplify the installation of silt fences and thus reduce the cost. When these modifications are considered, 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 cannot function properly with more than 20 percent elongation. At this elongation, they would sag more than 3.0 in between posts. Therefore, the strength at 20 percent elongation is very important.

Several factors considered in the tensile testing are discussed below.

Rate of Strain

In testing soils, a very slow rate of strain of 1-2 percent/min is used; in testing fabrics the rate is greater than 15 percent/min and sometimes exceeds 100 percent/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, it was hoped, close to that used with soil-testing equipment.

Size of Sample

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

Clamps

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

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 of each fabric could be tested if the project was to be completed within a reasonable time. Also, it was felt that three samples would be sufficient for determining an average strength value.

Warp Versus Fill

Samples 27.0 in by 7.0 in 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. Tensile tests were performed on these samples to determine whether the strength or elongation varied with the direction of the fabric, since little is known about this subject.

Tears

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

Table 3 gives the results of three tensile tests performed on each fabric in the warp direction, in the fill direction, and in the warp direction with a 0.5-in tear placed in the center of the samples. Load versus elongation curves were plotted for all samples. The strength values shown in Table 3 were developed as follows. If the fabric generated a load-elongation curve as indicated in Figure 2, curve A, the maximum load (P_{max}) was determined at the peak as shown. If the fabric generated a load-elongation curve as shown in Figure 2, curve B, P_{max} was determined at 20 percent elongation for the reasons noted earlier. If the load-elongation curve generated was similar to curve A but peaked past 20 percent elongation, then P_{max} was still taken as the load at 20 percent elongation.

The maximum strengths for the three samples of each fabric were averaged and divided by 7.0 in, the

Table 3. Average strength from tensile tests.

	Strength (lb/linear in)		
Material	Warp Direction	Fill Direction	Tear 0.5 in Long
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

Figure 2. Determining maximum load (P_{max}) from tensile-strength data.

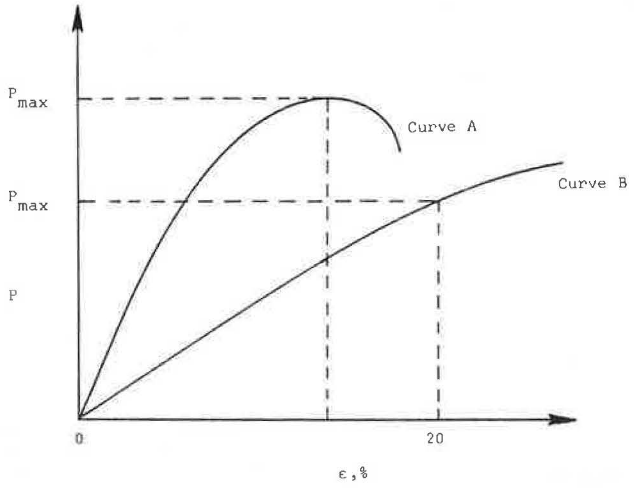


Table 4. Average strength from ultraviolet tests.

	Strength (lb/linear in)						
Material	Initial	1 Month	2 Months	3 Months	4 Months	5 Months	6 Months
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

Note: Where no value is given, the fabric completely deteriorated and no samples were tested.

Table 5. Summary of weather data for ultraviolet tests.

Date	Rainfall (in)	Deviation from Normal Rainfall (in)	Average Temperature (°F)	Deviation from Normal Temperature (°F)	High Temperature (°F)	Low Temperature (°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
Aug. 1977	2.37	-2.46	76.6	1.0	97	53	0
Sept. 1977	1.42	-2.77	71.9	2.5	96	50	4

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

sample width. Table 3 gives the average maximum strengths.

The nonwoven fabrics, because of their construction and composition, indicate a lower strength value than the woven fabrics did, 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 ones).

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

From a structural standpoint, it can be calculated that a silt fence 3.0 ft high and full of sediment needs to withstand an active earth pressure of 165 lb/linear ft of fence. This pressure amounts to a total load of 1650 lb against a fence 10 ft long or a warp tensile strength of approximately 50 lb/in. As indicated in Table 3, one nonwoven fabric (Mirafi 140) and all the woven fabrics except Filter X had a warp tensile strength, with or without the 0.5-in tear, in excess of this requirement. The

Table 6. Summary of recommendations.

Structure	Filtering Efficiency (%)	Flow Rate (gal/ft^2/min)	Tensile Strength (lb/linear in)
3-ft silt fence with reinforced backing, posts 10 ft apart	75	0.3	Reinforcing governs
3-ft silt fence, no reinforced backing, posts 10 ft apart	75	0.3	50
18-in silt barrier, no reinforced backing, posts 10 ft apart	75	0.3	24
18-in silt barrier, no reinforced backing, posts 3 ft apart	75	0.3	7

remaining fabrics need support from something like woven wire to meet the requirement.

Because of the high cost of straw-bale barriers, consideration is being given to alternatives, particularly a small silt fence less than 18.0 in high (8), 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/linear ft of fence, for a total load of 430 lb against a section of fence 10.0 ft long. In order to withstand this load, the fence would need a warp tensile strength of 24 lb/in. From Table 3 it can be seen that all the fabrics except the nonwoven Bidim C-22, Monofelt, Polyfelt TS-200, Supac 4-P, and Supac 5-E meet the strength requirement for this type of filter barrier.

Since an 18.0-in filter barrier used in place of a straw-bale barrier would generally be a maximum of 10.0 ft long, it is desirable that the barrier posts not be spaced more than 3.0 ft apart. With this spacing, the needed warp tensile strength would be reduced to 7 lb/in. 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

To evaluate the susceptibility of the fabrics to damage from ultraviolet rays, a large sample of each fabric was hung from a clothesline, and each month three samples (27.0 in long by 7.0 in wide) were cut from it in the warp direction until the material decomposed or had undergone six months (April to October) of exposure. The samples were brought to the laboratory and tested for tensile strength.

Table 4 indicates the average warp tensile strength of the fabrics when exposed to the weather conditions indicated in Table 5. 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 three months and sometimes for as long as six months, the fabrics were evaluated over six months of exposure.

As indicated in Table 5, the rainfall for each month was from 1 to 4 in less than normal, whereas the air temperature was from 1 to 3°F above normal, except during June, when the average was 2.9°F less than normal.

After three 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 nonpolyester materials tested. Fabrics composed of polyester or black polypropylene material have good stability under exposure to ultraviolet rays. For all the woven and two of the nonwoven fabrics (Supac 4-P and 5-E) there was a gain in tensile strength after one 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/linear in) in strength after six months of exposure. Supac 4-P deteriorated after three months of exposure.

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

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

CONCLUSIONS

In evaluations of fabrics for use in silt fences, the laboratory filtering-efficiency test should be performed by using a uniformly graded silty soil. The fabric should remove 75 percent 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 or faster. Although 0.3 gal/ft^2/min was chosen as the lowest flow rate desired, the rate needs to be increased without causing the filtering efficiency to drop below 75 percent.

The silt-fence analysis indicates that the reinforcing wire used behind a silt fence 3.0 ft high could be eliminated if the strength of the fabric exceeds 50 lb/linear in. For small silt barriers used to replace straw-bale barriers (less than 18.0 in high), the tensile strength should exceed 24 lb/linear in of width of the fabric if the support posts are 10.0 ft apart. If the posts are placed at 3.0-ft spacings, the tensile strength can be as low as 7 lb/linear in of width, and the barriers will be structurally sound without any reinforcement.

Table 6 summarizes these conclusions, which have been recommended to the Virginia Department of Highways and Transportation for purchasing specifications of silt fence filter fabrics.

IMPLEMENTATION OF FINDINGS

On the basis of the results of this study, the Virginia Department of Highways and Transportation has required all filter fabrics used for silt fences to meet or exceed the values shown in Table 6 on all construction projects advertised after April 1980. In conjunction with these specifications, the department is evaluating filter fabrics by the laboratory tests for filtering efficiency and warp tensile strength. These two tests were made effective October 1979. In the laboratory filtering-efficiency test a uniformly graded, silty soil is used to generate the sediment-laden mixture.

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Flood Frequency Analysis for Regulated Rivers

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A case study of the Colorado River at Glenwood Springs, Colorado, is presented to demonstrate several statistical tests for identifying watersheds in which conditions are changing with time. Results of the tests indicate that annual peak flows of the Colorado River are influenced significantly by reservoir regulation. Consequently, conventional methods of frequency analysis are not suitable for obtaining flood estimates from the data series. Time-series analysis is a versatile approach to flood-frequency determinations when conventional statistical methods are not appropriate. The basic strategy of time-series analysis is to treat each value of the regulated annual peak-flow series as a combination of two elements—a deterministic component and a stochastic component. The deterministic component is quantified and removed from the flood series. The residual stochastic components, found to be stationary and independent, are then fitted to a probability distribution from which annual floods are estimated. Results of the time-series analysis show that the 2 percent and 1 percent chance floods, both required for Interstate highway design, are substantially less than corresponding log-Pearson type III estimates. Because the time-series analysis is able to detect and to treat the impact of reservoir regulation on the peak-flow series, the resulting flood frequency estimates are more representative of the watershed.

Analysis of the magnitude and frequency of floods is an important prerequisite of many engineering projects and consequently a routine practice in many engineering offices. During the past 60 years, a variety of techniques have been developed for peak-flow analysis (1). In an effort to promote a consistent approach to these peak-flow studies, the U.S. Water Resources Council (2-4) recommended the log-Pearson type III (LP III) distribution for determinations of flood frequency.

Because the LP III procedure is simple and well documented, it has become a popular method of flood flow determination. Application of this methodology, however, must not preclude engineering judgment. There are a growing number of situations--such as watersheds in which peak flows are altered by reservoir regulation--for which conventional statistical methods are inappropriate. The Colorado River in west central Colorado is a classic example. Experience has shown that myopic application of the LP III method results in flood estimates that are not representative of the Colorado River watershed.

The Colorado Department of Highways is now involved in final design of the uncompleted portions of I-70, much of which will parallel and at times cross the Colorado River. For public safety and project economy, it is imperative that the final design be based on peak-flow estimates that accurately reflect the flood characteristics of the Colorado River. The purpose of this paper, therefore, is to (a) present several objective methods for identifying watersheds in which reservoir regulation significantly influences annual peak flows and (b) demonstrate an alternate approach that combines time-series analysis and engineering judgment in order to obtain flood frequency estimates of regulated rivers.

BACKGROUND INFORMATION

I-70 is the major route for east-bound and west-bound traffic in Colorado. One of the few segments of I-70 that remains uncompleted is that through Glenwood Canyon, a narrow meandering gorge of sheer cliffs shaped over millions of years by the erosive action of the Colorado River. Although it is renowned for its scenic splendor, the canyon also serves as a vital transportation corridor for west central Colorado. Glenwood Canyon now accommodates US-6, the Denver and Rio Grande Western Railroad, and the Shoshone Dam and Power Plant of the Public Service Company of Colorado.

In 1969 the Colorado Department of Highways received and accepted a hydrologic report (5) of the Colorado River at Glenwood Canyon. The report included several LP III analyses for various periods of the annual flood record observed at Glenwood