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Trial Use Results and Experience Using Geotextiles for Low-Volume Forest Roads

Resultats des usages experimentaux des géotextiles dans les voies peu circulation des forets

In 1973, for the first time, geotextiles were considered for use in the Pacific Northwest Region of the U.S. Forest Service. The initial investigations were to use woven monofiliment fabrics as a replacement for graded aggregate filters. These early investigations were followed by construction of two instrumented trial use installations; one was a fabric reinforced retaining wall in 1975, and the other was a subgrade installation on soft ground in 1976. The concepts developed or discovered in these investigations and used in the trial use installations formed the basis for a guideline report published in 1977 for the use of fabrics in low-volume road construction and maintenance. As a result of this work, design methods and specifications have been developed and are being implemented to effectively use geotextiles to build and maintain more reliable roads at lower cost.

En 1973 on a examiné pour la première fois l'usage des géotextiles dans les forêts de la région nord-ouest des forêts nationaux. Dans les premières expériences on a employé les matières tissés à un fil (monofiliment)pour remplacer des substances employées avant comme des filtres matériau granular. Ces premiers essais ont éte suivi de la construction de deux installations d'épreuve, réglées à l'usage des instruments, dont l'un, en 1975, était la construction d'un mur à retention renforcé de textile, et l'autre, en 1976, était l'installation des textile sous l'agrégat sur la terre molle. Les idées developés ou decouerts au cours de ces expériences sont à la base d'une dissertation publiée en 1977 au sujet de l'usage des textiles dans la construction et l'entretien des voies peu circulation. Le resultat de cet ouevre était le développement des methodes et des spécifications dont on se sert pour bien employer ces "géotextiles" pour construire et entretenir des voies aux prixs plus favorables.

INTRODUCTION

Geotextiles were first seriously considered for use in Region 6, of the US Forest Service in 1973. Initial use was to replace graded aggregate filters. Geotechnical engineers hired on several National Forests in the late 1960's designed graded aggregate filters based on soil gradations replacing ungraded rock drains. Graded aggregate filters proved very successful, but properly graded aggregates were difficult and expensive to acquire and install, particularly in remote areas with silty soils. Fabrics were looked at as a method of providing reliable underdrains at a low cost. Initial projects were favorable so investigations into new uses and methods continued. Today, geotextiles are specified and used extensively on low-volume aggregate and bituminous paved roads for drainage, road subgrades and retaining walls.

The Pacific Northwest Region (referred to as Region 6 or R-6), includes 19 National Forests containing approximately 11 million hectares or 27 million acres. The Region has a 137,000 km (85,000 mile) transportation system with plans for another 19,000 km (12,000 miles). Annually, 2,500 km (1,600 miles) of roads are constructed or reconstructed at a cost of $160 million with another $35 million spent on maintenance. Most of these roads are located in remote areas with mountainous terrain. About 96% of the transportation system is either aggregate surfaced or unsurfaced.

Road design and construction supervision is performed by National Forest personnel. Technical assistance and program monitoring is provided by the Regional Office. Most roads are constructed for log haul.

Papers written concerning geotextile use are based on observations, tests, experiences, and viewpoints of the authors. Typically, manufacturers and marketers relate to the benefits of their fabric, university professors present theoretical aspects and new ideas, consultants present applications to specific projects, often very large projects, and users relate to what was done and how well it worked. This paper presents some history, experience and philosophy concerning use of geotextiles in the Pacific Northwest Region of the U.S. Forest Service. The viewpoint in this paper is that of a user knowledgeable in many of the theoretical aspects of geotextiles and the very real challenge of effectively using these materials in widely varying field conditions. Design methods and specifications are aimed at cost effective utilization of geotextiles within current operating conditions. Short and long term benefits are considered, with an emphasis on minimizing challenges for designers, construction inspectors, and road builders.

This paper discusses the work done in Region 6 to establish current design methods and specifications. The information should be useful to both geotextile users and suppliers.

DEVELOPMENT OF GEOTEXTILE USE WITHIN REGION 6

The first geotextiles used in the Region in 1973 were woven monofiliment fabrics, meeting the US Army Corps of Engineers specifications based on Calhoun's research (1). The fabrics were used to replace graded aggregate filters in subsurface drains along roadways and in landslide stabilization. The fabrics worked very well, helping stabilize several areas that had been unsuccessfully stabilized using other methods. The fabrics were found to be easy to use once the contractors got over the shock of using "new methods." The costs were much lower than using graded aggregate filters and the reliability judged much higher (2).

The uses that followed in 1974 and 1975 were subgrade restraint, subgrade separation, and retaining wall reinforcement. Limited amounts of fabric have also been used for erosion control and pavement cracking.

Restraint is the use of a geotextile to increase system strength and reducing aggregate thickness, whereas separation is the process of preventing two materials from mixing. Initially, fabric samples were donated by manufacturers for limited trial subgrade uses and laboratory testing. The subgrade installations were based on a combination of several manufacturer's recommendations. The retaining walls were built using design recommendations from Bell (3).

The early fabric trials included limited testing to gain understanding about the fabrics and their properties. Due to limited budgets and facilities, testing was usually limited to that necessary to answer immediate questions, rather than to develop and validate standard procedures. Test methods and procedures have changed as a result of testing by ourselves and others.

Field visits and discussions with several researchers and manufacturer's representatives resulted in construction of two instrumented trial use projects, including different fabric brands and weights. An instrumented fabric test wall was built on the Shelton District, Olympic National Forest in 1975. Several instrumented fabric road test sections were built on the Quinault District, Olympic National Forest in 1976.

This work with geotextiles resulted in a report "Guidelines for Use of Fabrics in Construction and Maintenance of Low-Volume Roads", and reference notebooks for Region 6 National Forests in 1977. The publication was "written to increase awareness and improve understanding of the function and uses of fabrics" (2). The rapidly moving technology and increasing availability of fabrics for use in construction made the publication necessary. The remainder of this paper deals with materials evaluations, design methods, and specifications, with primary emphasis on road applications.

LABORATORY EVALUATION OF MATERIALS

A difficult task has been to find fabric tests that have wide acceptance by users and producers, are easy to perform, and have been correlated with the intended performance. Tests meeting these criteria are still being pursued.

A number of tests have been performed in our laboratory to gain information, to confirm testing by others, or to check for compliance with specifications. Tests our laboratory has performed are:

- Grab (ASTM D-1682)
- Cut strip 25.4 millimeter (1 inch) (ASTM D-1682)
- E.O.S. (Equivalent Opening Size)
- Percent Open Area
- Weight/Unit Area
- Gradient Ratio (4)
- OSU Ring Test (5)
- Wide Cut Strip Test (up to 381 millimeter or 15-inch width)
- Seam Strength (ASTM D-1683)

Visual tests have included determining the type of fabric construction, type of fiber or filiment, the uniformity of fiber distribution, and effectiveness of the bonding process. Grab and cut strip tests have been performed on several fabrics before installation and after 1-3 years of service.

The standard grab strength and 25.4 millimeter (1-inch cut) strip test results have no direct correlation with the strength required in a retaining wall to resist imposed static and dynamic loads. The OSU ring test (5) and the wide cut strip test were performed to obtain a better measure of fabric strength when used as a wide tensile member, such as reinforcement in a retaining wall. Both tests are relatively simple, and can be performed using standard tension/compression testing machines. The ring test is performed using a converted CBR mold and plunger as shown in Figure 1. The wide cut strip tests are performed on fabric widths less than or equal to the jaw width. Figure 2 shows the results of wide cut strip tests performed with two different fabrics. For nonwoven fabrics, the cut edge greatly effects the average strength per inch of width for strips less than about 152 millimeters (6 inches) wide. The wide cut strip test and ring test yielded similar results for samples greater than 152 millimeters (6 inches) wide. We abandoned the ring test in favor of the wide cut strip test since the strength measurement is more conventional and direct. The cut strip test is used to check fabric strength for retaining wall applications.

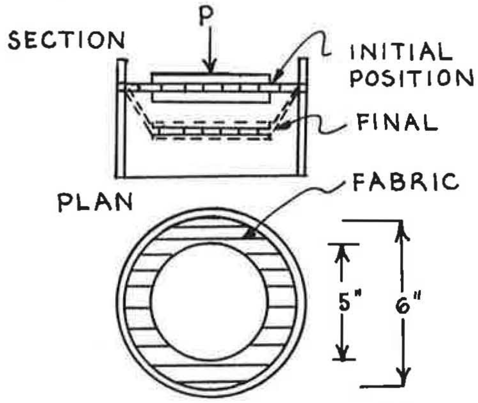

FIG. 1 OSU RING TEST

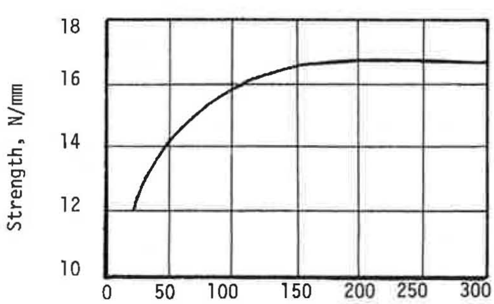

Figure 2-Fabric Width vs. Strength (nonwoven, needle punched)

The gradient ratio test (4) was performed with a number of fabric and soil types. The soils tested had very low permeabilities when placed in the test apparatus, resulting in extremely long testing periods. The test was judged impractical for routine evaluation of soil/fabric systems on a project basis.

Grab, cut strip 25.4 millimeter (1 inch) and weight per unit area tests were performed on many samples from 1974 through 1976. These tests documented the range of fabric strengths and weights available, and checked the values reported in sales literature. The results were reported for users in the guidelines report (2).

Seam strength tests were performed on samples from the Quinalt test road (6). Seams were sewed with a portable sewing machine using polyester thread. No problems were encountered with the seams in the field.

The E.O.S. test using glass beads, percent open area using the slide projection method, grab, cut strip 25.4 millimeter (1 inch), weight per unit area, thickness, and visual identification of filiment or fiber type have been performed to verify or check specification compliance. Other tests such as burst, puncture, and abrasion have not been performed in our laboratory.

FIELD EVALUATION OF MATERIALS

Field evaluations of materials have been made on several projects. Two of these projects; the Shelton retaining wall, and the Quinalt test road were instrumented to monitor performance.

The Shelton wall shown in Figure 3 was 53.7 meters (176 feet) long by 6 meters (19.5 feet) high. The Quinalt test road consisted of 1,434 meters (4,700 feet) of road containing 16 fabric types or weights of fabric. The test wall and test road segments were incorporated into scheduled projects for timber harvest. Both test projects were instrumented and sampled to monitor performance. Results of both test projects have been reported elsewhere (6, 9).

Samples of fabric for the Shelton wall were exposed at the site with and without treatment and with emulsified asphalt for weathering protection. Coupons were tested periodically for the first year to measure strength changes. Strength decrease was very rapid for the untreated, non ultraviolet stabilized polypropolene. Deterioration of the lightly ultraviolet stabilized polyester fabric was less rapid than for the polypropolene. Both fabrics require ultraviolet protection for long life. Emulsified asphalt appears to be an effective ultraviolet protection when sprayed on the surface of the fabric. The wall was recoated with emulsified asphalt in 1979 (4 years after construction) to ensure a continuous protective coating.

A 106.8 meter (35-foot) long by 30.5 meter (10-foot) high fabric wall was built on the Siskiyou National Forest in 1974. This wall, which preceded the Shelton wall, was built to confirm the laboratory model tests by Bell (7). Although the wall was not instrumented, it did confirm that a fabric wall could be constructed in the field. The face of this wall was treated with a gunite (sprayed concrete) for ultra violet light and vandal protection. The wall has performed very well.

Another fabric property of concern in reinforcement applications is fabric creep under long term loads. Polypropolene and polyester nonwoven and needle punched fabrics were both used in the Shelton test wall to determine if creep properties under field loadings were represented by laboratory creep tests. Laboratory creep tests (8) indicate polypropolene fabrics have as much as 5-10 times as much creep as polyester fabrics. Typically, laboratory tests are performed with nonlaterally restrained specimens as opposed to almost total restraint of fabrics in retaining walls. Retaining wall movements measured during the first 2 years after construction showed no difference in movement, stretching, or creep of the two materials. All movement of the wall face or stretching of the fabric occurred during the first 6 months after the wall was constructed (9). Neither fabric stretched or elongated as much as was predicted from laboratory load tests and internal fabric stress calculations. The wall was designed and stresses calculated using methods proposed by Bell (3).

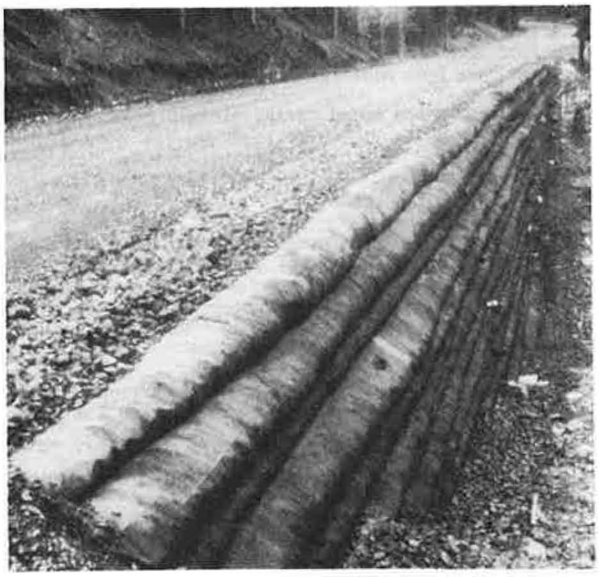

Figure 3. Photograph of
The Shelton Fabric Wall

The fabric road test sections were built to answer a number of questions. Some of the questions were:

- What weight, strength, or type of fabric is best and most cost effective (manufacturers all claimed, "mine is the best fabric for your project")?

- How do we design, specify, and construct a project with fabric on the subgrade (again, manufacturers, university professors, engineers, and sales people all had different methods)?

- What are the economic considerations?

- What are the social considerations (acceptance of new ideas)?

A brief summary of the findings from the test road and other projects are·

- All of the fabrics used in the test road performed equally and satisfactorily. The fabrics were all nonwoven with weights between 136 and 420 g/m2 (4.0 and 12.4 oz./yd.2), grab strengths between 3.8 and 19.7 KN/m (21.6 and 112.5 lbs./in.), cut strip strengths 25.4 millimeter (1 inch) between 4 and 25.4 KN/m (22.6 and 145 lbs./in.), and fabric elongations of 40-200 percent.

- The Barenberg (10) method of thickness design using field cone penetrometer or vane shear strenghts is a reasonable method of establishing design depths of cover aggregate. Barenberg's method and design curves discussed later in this paper have been modified for our use.

Specifications based on the minimum properties of fabrics used in the test road provide good field performance, free competition between fabric suppliers, and permit contractors to install fabric with minimum inspection.

- Fabrics use on subgrades is usually economical for aggregate surface roads over low strength soils (CBR less than 2 or 3). Fabrics use on higher strength subgrades may be economical, but is very dependent on aggregate costs and performance expectations.

- The construction season can be extended into wetter seasons when fabrics are used on the subgrade.

- The weakest condition of the subgrade is during construction. The subgrade gets stronger with use due to soil consolidation. It may, therefore, be economical to remove and reuse a portion of the cover aggregate after the road has been used for a period of time.

- The thickness design method establishes a design thickness of cover aggregate. The most economical road for a project can be achieved by adjusting the cover thickness in the field based on rutting under construction traffic.

DESIGN METHODS

Subsurface Drainage: Drainage applications are designed using conventional groundwater seepage calculations as outlined in conventional text books (11). Fabric selection is based on the expected service condition and the particle size of the protected soil. The E.O.S. and percent open area of the fabric are determined using criteria originally proposed by Calhoun (1). Use of very high permeability aggregates are encouraged for the drainage layer. This design method is used because it works, it is simple enough to be understood and use in the field, it minimizes testing on hundreds of small projects each year, and the resulting design has a high chance of success.

Woven monofiliment fabrics are specified to ensure the fabrics will survive installation without tears, punctures, or deformation and that the actual fabric installed will function as designed. Nonwoven fabrics are not currently specified for drainage applications due to the wide variation in fabrics available (and liable to show up on a project), and the lack of a widely accepted and proven method of design and specification. Nonwoven fabrics are used by other agencies for drainage applications. To use nonwoven fabrics on our projects with our current capabilites would require extensive testing for specific projects to ensure that the selected or specified fabric would function. Few of our projects are large enough to warrant the extra cost of this work. We are looking to other users and researchers to do the testing and development work in this area.

Geotextile Reinforced Retaining Walls: Fabric retaining wall construction is shown in Figure 4. Laboratory model tests (3) and field experience indicate (7) the walls can be designed with reasonable confidence using the active Rankine case.

A very important consideration in fabric walls is defining the appropriate fabric properties. Although no creep or long term deformation of the fabric test wall has been observed (9), creep and fatique properties of fabrics continues to be a concern. Current evaluations of fabrics for wall reinforcement follow recommendations by Bell (12): Test wide strip tensile specimen after soaking, 203 millimeter (8-inch) width, 50.8-101.6 millimeter (2-4 inch) jaw spacing, 10% per minute. The design strength is taken as the lesser of the strength at 10% strain or 40% (polypropolene) or 60% (polyester) of the ultimate strength.

Soil-geotextile friction is taken as 2/3 ϕ for granular material on both sides of the fabric. A minimum factor of safety of 1.5 is used, with higher values for less certain loadings.

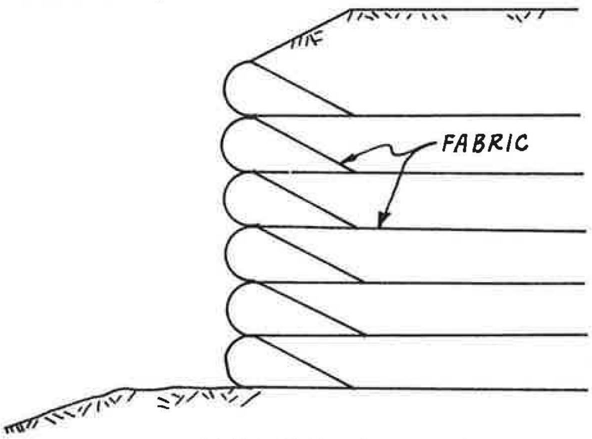

FIGURE 4 - FABRIC RETAINING WALL

Subgrade Restraint: The method outlined in the guideline report (2) has proven adequate for design of geotextile/aggregate structural sections over low strength soils (CBR less than 2 or 3). The basic procedure recommended by Barenberg (10) uses the undrained shear strength of the subgrade soil and the bearing capacity formula used in foundation design:

$$q = CN_c$$

where, q = the stress level in the subgrade
C = undrained shear strength of the subgrade soil
N_c = a bearing capacity factor

The bearing capacity factors normally used are 2.8 without a geotextile and 5.0 with a geotextile when a large number of axles (probably greater than 1,000 80.1 kn or 18 kip axles) and very little rutting (less than 50.8-76.2 millimeters 2 or 3 inches) is expected. These bearing capacity factors may be increased to 3.3 and 6.0 (about a 15% increase) when a small number of axles (probably less than 100) and greater rutting (greater than 76.2 millimeters or 3 inches) is expected. The amount of cover aggregate required is determined from design curves for dual tandem wheel loadings derived from Boussinesq's equation for vertical pressure under a circular load applied at the ground surface. Figure 5 is an example of one of the design curves.

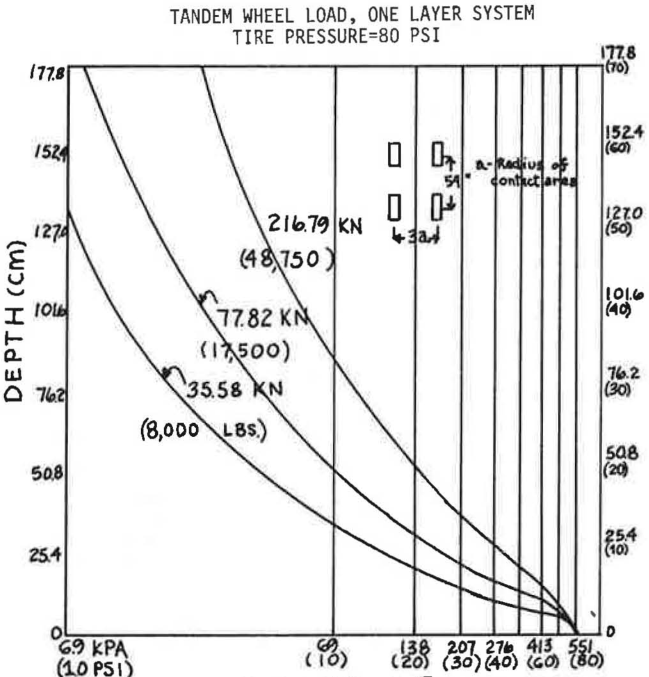

FIGURE 5

The undrained shear strength of the soil is measured in the field using a cone penetrometer or vane shear. Multiple measurements are recommended at several representative locations. Due to wide variability in the field measurements within a small area, the strength value at the 75th percentile (75% of the strength readings are higher than this value) is used for design. Theoretically, 25 percent of the road area will be underdesigned.

Where possible, the actual thickness should be adjusted during construction to obtain adequate performance under construction haul traffic. The design thickness using the bearing capacity method identifies a starting point. Ajust the thickness in the field until a 50.8-76.2 millimeter (2-3 inch) rut occurs under a few axle repetitions (probably 5-10). Increasing the thickness 15-20% over the depth should yield an adequate road structural section. This method works because the worst condition is usually during construction before the subgrade consolidates and increases in strength.

IMPLEMENTATION

A large amount of research has been done on subgrade soil/fabric/aggregate interaction to explain what happens and how to design the most cost effective road. The challenge for the Forest Service and other users is to select and utilize those methods and materials that can be used effectively in the field with a high chance of success under limited guidance. Methods that require extensive soil sampling and testing, highly technical designs, tight specification, and intensive construction inspection and supervision are not compatible with our low-volume road construction program.

New ideas, methods, and materials are constantly being explored, evaluated, and tried. Some evaluations are through formal evaluation programs, but most are in response to solving a particular problem. If the problem solution shows promise of wide application and savings within our skill capabilities, we will evaluate it for general use. If general use is feasible, we will modify our specifications and procedures to include the method or material.

Several specifications (13) have been developed and implemented for the use of geotextiles. The degree of control contained in the specification for geotextile properties and installation procedures depends on several factors. The key factors are design procedure, chances of success, consequence of failure, costs, and construction and inspection capabilities.

The most controversial specification is Standard Specification 720 - Woven Plastic Filter Cloth (13). This specification is used for subsurface drainage applications. The specification requires that the cloth be a pervious sheet of plastic filament woven into a uniform pattern with distinct and measureable openings. The material properties are similar to those specified by the U.S. Army Corps of Engineers in 1976 (4), with a 50 percent strength reduction for nonabrasive conditions. The woven filament fabrics specified are compatible with the design methods used and apply to a wide range of soil conditions.

These fabrics are easily recognized and have strength to survive severe construction conditions. Although the nonwoven fabrics normally cost less per unit area than woven filament fabrics, the compatibility with the design criteria, the ease of recognition, and the strength properties of the woven filament fabrics lead to a higher expectation of survivability of the woven filament system. This is particularly the case for the many small installations in a wide range of soil and construction conditions encountered in the National Forests.

Although the woven filament fabrics are easily recognizable, we have had difficulty preventing the use of slit film or ribbon fabrics. The slit film or ribbon fabrics, which are widely used on subgrades, generally have very low percent open areas and irregular openings which result in poor drainage capabilities. Several drainage installations have been made using the wrong fabric (usually slit film or ribbon) resulting in poor performance or, more usually, extra cost to the contractor or fabric supplier to correct the error. To our knowledge, the proper mill certificate or affidavit had not been supplied by the contractor prior to installation of the nonspecification fabrics.

All of our current specifications require a mill certificate or affidavit from the supplier stating that the geotextile complies with the physical and chemical requirements of the specification. Certificates for drainage fabrics, subgrade restraint, and separation fabrics can be based on previous testing and quality control testing by the supplier. Certificates for fabrics used for retaining wall reinforcement must be based on tests performed on the lot of fabric actually shipped to the site. Certificates are required prior to installation.

The grab and strip 25.4 millimeter (1 inch) test methods are usually specified since they are routine tests performed by most manufacturers. The acceptable test result is adjusted for each specification. The test requirements for subgrade treatments (woven, slit film, or nonwoven fabrics) are:

Weight: 136 g/m2 (4.0 oz./yd.2) minimum
Thickness: 0.38 mm (15 mils), minimum
Width: 3.66 meters (12 feet), minimum
Grab Tensile Test: 21 KN/m (120 lbs./in.), minimum (ASTM D-1682)
Elongated at Failure: 25% minimum
E.O.S.: Smaller than the #70 sieve (E.O.S. requirement waived for subgrade restraint)

The subgrade treatment specification is based on the minimum properties of the fabrics successfully used on the Quinault test road sections and modified to permit slit film and ribbon fabrics. Slit film and ribbon fabrics have been used successfully on many subgrade projects both inside and outside the Forest Service. The minimum elongation at failure will probably be reduced to 20 percent minimum with the next specification revision.

The subgrade treatment specification has worked very well allowing a wide range of manufacturers to compete. Unlike drainage and retaining wall reinforcement applications, difficulties or failures of the fabric in the subgrade applications usually show up during construction and are easily corrected.

The drainage and retaining wall reinforcement specifications are more restrictive since problems with the fabrics or the installation probably will not be recognized until months or years after construction. Any problems that are encountered in drainage or retaining walls may involve the entire road section or structure, making costs for correction very high.

FUTURE APPLICATIONS

A major challenge to everyone in the geotextile field, whether user, manufacturer, or researcher is to interpret the great volume of information being developed to produce a cost effective end use. Standard writing groups such as ASTM and AASHTO have a difficult task in developing performance related standards to aid in cost efficient use of geotextiles. The challenges and tasks are worth working on when we consider the cost saving potential in the use of geotextiles.
The potential savings using fabrics in Region 6 of the Forest Service was estimated to be 4-11 million dollars per year in 1977 (2). Geotextile usage has increased greatly since 1977, but due to inflation and improved applications, and knowledge, the potential savings is probably still in the 4-11 million dollar range.

A key factor in actually realizing the potential savings is developing enough successful experience for management, design, and construction personnel to accept and recommend geotextile applications. Another key factor is having credible technical information and specifications in understandable and usable formats. The future will see more geotextile options as fabrics are manufactured and accepted for specific applications. The third key factor is keeping up with and implementing improvements without excessive failed trial uses. The project designers and constructors must be trained and kept up-to-date on geotextile uses.

The increased knowledge about geotextiles and confidence in their successful use has recently resulted in some very cost effective solutions to difficult problems. Fabric reinforced retaining walls were built across two unstable areas using lightweight wood fiber backfill. The lightweight backfill reduced slope loading by up to 1/2, and the fabric reinforcement permitted large wall deformations without structural damage. On another project, discovery of endangered wildlife required relocation of a road away from a nesting area and limiting activity during the nesting season. The result was a requirement that the road subgrade be completed and base rock placed during wet weather. A geotextile was successfully used on the subgrade as a restraint layer for weaker areas and as a separation layer to prevent the shallow layer of mud on the surface from contaminating the aggregate.

More of these "unique uses" will be developed in the future, limited only by our willingness, and patience to try something new and learn from both successes and failures.

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