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Performance of Geotextile Separators — Phase I

WA-RD 280.1

Final Technical Report
April 1991

Washington State Department of Transportation
Washington State Transportation Commission

in cooperation with
U.S. Department of Transportation
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16. ABSTRACT

This research involved field investigations and laboratory testing to evaluate the properties and overall performance of geotextiles from eight different locations in eastern and central Washington. Both nonwoven and woven geotextiles were exhumed from the roadways at the eight locations, and samples of the geotextile were brought to the laboratory for index strength and permitivity testing. Samples of the basecourse and subgrade soils were analyzed for grain-size distribution. The results of the investigations and testing indicated that all of the geotextiles performed the separation function adequately, although three of them were not installed directly against the subgrade soil as intended. Damage to the geotextiles varied considerably with the type of material and the installation conditions; however, this damage was not shown to have affected the performance of the separator.

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Geotextile Separator Performance

PERFORMANCE OF GEOTEXTILE SEPARATORS — PHASE I

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1.0 INTRODUCTION

Geotextiles are widely used in roadway construction as a separator at the sub-base/subgrade interface. The separator can be used as a construction expedient or as an indirect structural component of the design. The explicit purpose of the separator is to prevent the movement of fines (material passing the No. 200 sieve) from the (usually) soft, fine-grained subgrade soil into the subbase aggregate and to prevent the aggregate from pushing down into the subbase. The separator thereby helps to maintain the effective base thickness and the strength of the roadway section. In certain roadway alignments where the presence of soft, compressible subgrades would normally require over-excavation and replacement with imported subbase material, separators can be used to decrease the amount of over-excavation and a significant cost savings can be realized. It is generally recognized, however, that an effective separator must also provide the functions of filtration, drainage, and to some extent reinforcement, to the soil-geotextile system.

In recent years, various state and federal agencies have attempted to specify design criteria which would satisfy all the functional requirements of a geotextile separator. These criterion include specifications for fabric strength, durability and drainage characteristics. Many current state specifications for geotextile strength properties, including Washington State Department of Transportation (WSDOT), have been based on AASHTO-AGC-ARTBA Task Force 25 (Task Force 25) recommendations for construction survivability, Christopher and Holtz (1985). This has led to the extensive use of light-weight, slit-film woven geotextiles which meet the survivability requirements; yet, in many cases, they do not meet drainage and filtration requirements for long-term performance. It is the purpose of this research to evaluate the adequacy of current WSDOT specifications with respect to long-term geotextile separator performance. Specifically, this research investigates whether the lightweight woven slit-film geotextiles perform as well as similar weight nonwovens. The conclusions reached in this study are based on field evaluations of geotextiles used as separators in roads constructed over soft silt and clay subgrade conditions in eastern and central Washington State.

This report contains the results of a literature review and eight site investigations which involved exhuming geotextiles from existing roadways. The results of visual examinations and laboratory testing of geotextiles and soils are presented. The report concludes with an analysis of the performance of the geotextile separators, recommended modifications to current WSDOT specifications and recommendations for future studies.

2.0 STATE OF THE ART AND PRACTICE

2.1 Introduction

This section presents a discussion of current design methodologies and the results of a review of published research on the various properties of geotextile separators. This section is intended to serve as an overview of current design trends and a summary of established methodologies for the use of geotextile separators. The existing information on such topics as geotextile permeability, filtration, and durability is extensive and detailed. The reader is left to pursue these topics in greater detail with the aid of the reference list provided at the end of this report.

2.2 Current WSDOT Design Methods

Current Washington State Department of Transportation design methods for geotextile separators are based in part on the recommendations provided by Task Force 25 for construction survivability of geotextiles (Christopher and Holtz, 1985). Additionally, specifications for apparent opening size (AOS) and permeability are utilized to satisfy the filtration/drainage requirements of separators, although these requirements are not addressed in the Task Force 25 report.

2.2.1 Survivability Classifications

Geotextile survivability can be defined as the ability to resist damage during installation, roadway construction, and initial operation of the road. If the geotextile does not survive the installation process then, to some degree, many of the other engineering properties are irrelevant, at least in the area affected by the damage. Thus, construction survivability may be the single most important design characteristic.

A geotextile's survivability is a function of subgrade conditions, geotextile strength properties, properties of the cover materials, and the construction techniques. As a means of quantifying survivability requirements, Christopher and Holtz (1985) have developed a design table relating fabric survivability to subgrade conditions, construction equipment, and cover material. This information is presented on Tables 2.1 and 2.2. The survivability ratings are low, moderate, high, very high and not recommended. When the degree of

geotextile survivability is determined it can be related to minimum required strength parameters as shown on Table 2.3.

Table 2.1 - Required Degree of Geotextile Survivability As a Function of Subgrade Conditions and Construction Equipment

	Construction Equipment and 6 -12 in. of cover material (initial lift thickness)		
Subgrade Conditions	Low Ground Pressure Equipment (≤ 4 psi)	Medium Ground Pressure Equipment (>4psi, <8psi)	High Ground Pressure Equipment (>8psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth and height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 18 in. in depth and height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than + 6 in. above subgrade Geotextile may be draped directly over tree trunks, stumps, large depressions and humps, holes, stream channels and large boulders. Items should be removed only if placing the geotextile and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

Note: 1. Recommendations are for 6 in. - 12 in. initial lift thickness. For other initial lift thicknesses:

12 in. - 18 in.: Reduce survivability requirement 1 level.
18 in. - 24 in.: Reduce survivability requirement 2 levels.
> 24 in.: Reduce survivability requirement 3 levels.

Survivability levels are, in increasing order: low, moderate, high and very high.

2. For special construction techniques such as pre-rutting, increase survivability requirement by 1 level.

3. Placement of excessive initial cover material thickness may cause bearing failure of soft subgrades.

Table 2.2 - Required Degree of Geotextile Survivability as a Function of Cover Material and Construction Equipment

	Initial Lift Thickness					
	6-12 in.		12-18 in.		18-24 in	>24 in.
Magnitude of Ground Pressure Equipment	Low (≤4psi)	Medium (>4psi, ≤8psi)	Medium (>4psi ≤8psi)	High (>8psi)	High (>8psi)	High (>8psi)
Cover Material						
Fine sand to +2 in. dia. gravel, rounded to subangular	Low	Moderate	Low	Moderate	Low	Low
Coarse aggregate with diameter up to one-half proposed lift thickness, may be angular	Moderate	High	Moderate	High	Moderate	Low
Some to most aggregate with diameter greater than one-half proposed lift thickness, angular and sharp-edged, few fines	High	Very High	High	Very High	High	Moderate

Notes:

1. For special construction techniques such as pre-rutting, increase geotextile survivability requirement one level.

2. Placement of excessive initial cover material thickness may cause bearing failure of soft subgrades.

Table 2.3 - AASHTO-AGC-ARBTA Joint Committee Minimum[a] Geotextile Properties Required for Survivability

Required degree of geotextile survivability	Grab tensile strength[b] (lb)	Puncture strength[c] (lb)	Burst strength[d] (psi)	Trapezoidal tear[e] (lb)
Low	90	30	145	30
Moderate	130	40	210	40
High	180	75	290	50
Very High	270	110	430	75

[a] All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the minimum values in this table). Note: these values are normally 20 percent lower than manufacturer's reported typical values.

[b] ASTM D-4632

[c] ASTM D-4833 tension testing method with steel ball replaced with 5/16-in. diameter solid steel cylinder with flat tip centered within the ring clamp.

[d] ASTM D-3786 test method for Diaphram Bursting Strength of Geotextiles.

[e] ASTM D 4533, either principle direction

There is some question as to the validity of the survivability property values given on Table 2.3 because, rather than being based on any systematic research, they were based on properties of geotextiles which the members of Task Force 25 believed to have performed satisfactorily as separators in temporary roads and similar applications.

An updated version of the Task Force 25 recommendations for geotextile separation applications has been proposed (Task Force 25, 1989) in which the survivability rating system has changed and drainage/filtration requirements have been addressed. The new recommendations are summarized in Tables 2.4 and 2.5. As shown in these tables, the survivability ratings of low and very high have been eliminated. The strength values recommended for the new ratings of medium and high are similar to the values previously recommended for the ratings of high and very high, respectively, with only a slight decrease in the puncture resistance required and a slight increase in the required trapezoidal tear strength.

Table 2.4 - Construction Survivability Ratings

Site Soil CBR At Installation	<1		1-2		>2	
Equipment Ground Contact Pressure (psi)	>50	<50	>50	<50	>50	<50
Cover Thickness (in.)[1] (compacted)						
4[2,3]	NR	NR	H	M	M	M
6	NR	NR	H	H	M	M
12	NR	H	M	M	M	M
18	H	M	M	M	M	M

H = High

M- Medium

NR = Not Recommended

1 Maximum aggregate size not to exceed one half the compacted cover thickness.

2 For low volume unpaved road (ADT < 200 vehicles).

3 The 4-in. minimum cover is limited to existing road bases and not intended for use in new construction.

Table 2.5 - Physical Property Requirements[1]

Elongation[2,3]	< 50 Percent Geotextile Elongation / > 50 Percent Geotextile Elongation *		
Survivability Level	Grab ** Strength ASTM D 4632 (lbs)	Puncture ** Resistance ASTM D 4833 (lbs)	Trapezoidal Tear** Strength ASTM D 4533 (lbs)
High	270/180	100/75	100/75
Medium	180/115	70/40	70/40

Additional Requirements	Test Methods
Apparent Opening Size	ASTM D 4751
1. <50 percent passing a No. 200 US sieve, AOS < 0.6 mm.	
2. > 50 percent soil passing a No. 200 US sieve, AOS < 0.3 mm.	
Permeability	ASTM D 4491
1. k of the geotextile >k of the soil (permittivity times the nominal geotextile thickness)	
Ultraviolet Degradation	ASTM D 4355
1. At 150 hours exposure, 70 percent strength retained for all cases	
Geotextile Acceptance	ASTM D 4759

[1] Values shown are minimum roll average value. Strength values are in the weaker principle direction.

[2] Elongation as determined by ASTM D 4632.

[3] The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

* Required value for wovens/required value for nonwovens (not stated by Task Force 25)

** Higher value for wovens/lower value for nonwovens (not stated by Task Force 25)

2.2.2 Index Strength Tests

A geotextile separator must be capable of surviving the forces exerted on it during construction. These forces include pressure exerted on the geotextile by fine-grained subgrade soils which are squeezed upward as the coarse grained aggregate is placed on the geotextile. Puncture of the geotextile by the sharp edges of the aggregate must also be resisted. Other forces which need to be resisted include pulling and tearing of the geotextile by sharp stones. In the separation application, the required strength needed to maintain separation over the design life of the project is relatively small as compared to the strength required to resist damage during construction. To meet the construction phase demands on the geotextile a series of standard index tests has been adapted by WSDOT based on standard test methods developed by ASTM. These tests consist of the following:

1) Grab Tensile Strength; machine direction and cross machine direction
   WSDOT Test Method 916 based on ASTM D 4632.

2) Burst Strength
   WSDOT Test Method 920 based on ASTM D 3786 test method for Diaphram Bursting Strength of Geotextiles.

3) Puncture Resistance
   WSDOT Test Method 921, based on ASTM D 4833 tension testing method with steel ball replaced with 5/16-in. diameter solid steel cylinder with flat tip centered within the ring clamp.

4) Tear Strength
   WSDOT Test Method 919 based on ASTM D 4533

In general, the current WSDOT procedure for specifying geotextiles for use as separators (construction fabric for soil stabilization) consists only of requiring compliance with the minimum or maximum (depending on the property) strength, AOS, or permeability values included under the appropriate section of the General Special Provisions Division 8, a copy of which is included in Appendix C. The values provided in this specification assume that high survivability conditions exist at all sites and therefore, by default, the specification requires the following minimum (average) roll values for the geotextile:

Tensile Strength - 180 lbs
Seam Breaking Strength - 160 lbs
Burst Strength - 290 psi
Puncture Resistance - 75 lbs
Tear Strength - 50 lbs

2.2.3 Minimum Lift Thickness

Minimum lift thickness is generally dependent on the subgrade and equipment conditions. WSDOT currently specifies a minimum initial lift thickness of 12 in. to 18 in. for high survivability conditions. Rutting of the first lift above the geotextile by equipment traffic is limited to 3 in. to avoid overstressing the material. In some cases, the specification may be changed by the project engineer to suit the specific needs of the project; for example, a minimum lift thickness of 4 in. is specified where the total base course or ballast (2.5 in.-minus crushed, partially crushed or naturally occurring granular material with 9 percent maximum passing the No. 200 sieve) thickness is low, say 9 in. or so. When this is the case the construction specifications state that "the Contractor shall place and compact the crushed surfacing top course in a manner so as not to damage the construction geotextile for soil stabilization".

Occasionally, unanticipated subgrade conditions require a change order to the contract specifications which involves use of a geotextile separator. When this occurs no construction specification for minimum lift thickness is provided. The installation procedure is generally left to the discretion of the project engineer.

2.2.4 AOS and Permeability

The proper design of a geotextile separator must include an allowance for drainage through the geotextile, either from the subgrade upward or the pavement downward. The former case is likely the most prevalent, especially in areas of high water table. Upward drainage can also occur through expulsion of water from a very wet fine-grained subgrade during consolidation after road construction. Downward drainage may occur when rain and snow melt waters leak through cracks in the pavement and infiltrate down through the basecourse and into the subgrade.

The drainage and filtration characteristics of geotextiles have been related to the apparent opening size (AOS). The AOS indicates approximately the largest particle that would effectively pass through the geotextile. The AOS is determined by sieving calibrated glass beads through the geotextile. The opening size which retains 95 percent by weight of the glass beads is considered the AOS index number. A full description of this test method is provided by WSDOT Test Method No. 922 and ASTM D 3776.

The permittivity of a geotextile is defined as the quantity of water which would pass through a geotextile, perpendicular to the plane, under a given head over a particular cross sectional area. The permittivity multiplied by the nominal thickness of the geotextile yields the nominal or Darcy permeability. The cross-plane permeability of the geotextiles must be compatible with the permeability of the subgrade soil. It is generally accepted that the permeability of the geotextile must be equal to or greater than that of the subgrade and must remain so for the design life of the structure.

Permeability is determined by WSDOT Test Method 924: Water Permeability of Geotextiles By Permittivity (ASTM D 4491). There are two procedures which may be used for this test: the constant head method or the falling head method. In general, the falling head method is used at the WSDOT laboratory.

The AOS and permeability of geotextile separators are used as a basis for acceptance of the geotextile in current WSDOT specifications. Specification standards for geotextile separators are currently 0.42 mm (No. 40 US Standard sieve size) maximum for AOS and 0.005 cm/sec minimum for permeability. These standards are not based on site-specific soil conditions but rather on the generalization that all separator applications will be over subgrade soils consisting mostly of fines.

2.4 Results of Literature Search

The following paragraphs present the results of a literature review on the major issues affecting the performance of geotextile separators.

2.4.1 Design Methods of Other States

A report by Koerner and Wayne (1989) presented a comparison of geotextile specifications used by transportation/highway agencies of 46 of the 50 states, the District of Columbia and Puerto Rico. The report dealt with the topic of survivability/separation as a separate application from drainage/filtration. Of the 42 agencies that responded to the survey, 14 were found to address the topic of survivability/separation and 27 addressed the topic of drainage/filtration in their respective state specifications.

Of the 14 which addressed survivability/separation, nine states follow AASHTO guidelines for design and four follow Task Force 25. The main difference between these guidelines being that Task Force 25 provides a range of values for the four main strength properties while AASHTO (Koerner and Wayne,1989) guidelines provide only minimum values for Grab Strength and Puncture Strength.

2.4.2 Survivability

Several writers have discussed the importance of geotextile survivability. In particular, Koerner and Koerner (1990), Bonaparte et al. (1988), Sprague and Cicoff (1989) and Richardson and Behr (1990) have reported on studies completed to evaluate the survivability of various geotextile types under various construction conditions.

Koerner and Koerner (1990) conducted research which involved exhuming geotextiles immediately after installation below roadways. Their report suggested that the survivability ratings of "very high" and "not recommended" be grouped together since, in their experience, it was not possible to adequately distinguish between the two in the field. They also suggested that for construction survivability a minimum geotextile weight of 8 oz/yd^2 is required to prevent the occurrence of holes during cover material placement. A factor of safety against construction damage of 1.3 could be realized in this way. It was suggested that the occurrence of any holes was an unacceptable condition. Their studies suggested that the woven monofilament and the nonwoven needlepunched geotextiles fared better than the woven slit films. It should be recognized that the test sites investigated in this study involved end dumping of base course aggregate directly onto the geotextile separator.

Bonaparte et al. (1988) suggested that "the traditional view that geotextiles survive only if they sustain very minor damage may require modification." This study tends to support the "moderate to high", "high", and "very high" survivability rating system. Overall strength losses were mainly due to disruption of the geotextile structure (mechanical breakage of groups of filaments at concentrated locations and breakage of bonds between filaments and groups of filaments), rather than widespread mechanical damage to individual geotextile filaments or overall abrasion. It was observed that the roadways investigated were in good condition and their fills were dense. Subgrades were observed to be firm while some of the geotextiles were "relatively" damaged. The good condition of the roadways and the damaged condition of some of the geotextiles was interpreted to mean that either the geotextiles were not needed (not thought to be the case) or the geotextiles were able to sustain significant damage and still perform the required separation function.

Studies by Sprague and Cicoff (1989) suggested that road grade, drainage and saturated subgrade strength are important when assessing survivability conditions. They concluded that 4 oz/yd^2 geotextiles of all types are too lightweight to resist localized puncturing when thin base course lifts are used and suggested a minimum 6-in. thick basecourse or subbase lift be used.

The study by Richardson and Behr (1990) involved survivability studies on woven slit film, nonwoven spunbonded and nonwoven needlepunched geotextiles. The subgrade consisted of silty fine sand and the roadway section consisted of 2 in. of asphalt pavement and 8 in. of crusher-run gravel. All gravel was placed by end dumping onto previously placed gravel and spread by rubber-tired equipment. They reported no construction damage, clogging or imperfections in the geotextiles after exhuming them eight years later. This report concludes that installation damage can be limited by proper aggregate placement and equipment selection/operation.

2.4.3 Filtration and Permeability

As previously mentioned, geotextile separators must also serve as filters to prevent fines from pumping up into the subbase. It takes only about 20 percent by weight of subgrade soil mixed into a dense granular base to reduce its bearing capacity to essentially

that of the subgrade soil (Christopher and Holtz, 1985). Geotextiles can fail as filters beneath a roadway through the following processes:

1. Blinding, which is the condition in which soil particles accumulate at or near the soil/geotextile interface and block the voids at the surface of the geotextile, thereby reducing the permeability of the geotextile.

2. Clogging, which is the movement by mechanical action or hydraulic flow of soil particles into the voids of a geotextile and the accumulation therein, thereby reducing the permeability of the geotextile.

3. Piping, which is the transport of soil particles through the geotextile filter, usually from the subgrade up into the more open-graded subbase aggregate, thereby causing degradation of the mechanical properties of the roadway section.

Blinding and clogging of geotextiles can also be caused by chemical precipitation (iron, manganese and calcareous deposits) and microbiological activity such as slime formation (Dierickx and van der Sluys, 1990).

One of the earliest studies into the filtration properties of geotextiles by Snaith and Bell (1978) investigated the migration of fines through geotextiles under dynamic loading. The study found that, under specific loading conditions with subgrade consisting of clayey, silty sand, a lightweight woven geotextile did not perform as well as a lightweight nonwoven geotextile with a sand layer on top or a thick nonwoven geotextile. A double layer of lightweight woven geotextile performed well. This study was later criticized by Ayres and McMorrow (1980) for having based its conclusions on tests involving soil containing 58 percent sand. It was thought that the results could not be compared to geotextile performance on cohesive soils such as clay or clayey silt.

Rosen and Marks (1975) conducted studies on piping of silts through nonwoven geotextiles and concluded that, in general, less piping occurs when the subgrade consists of well graded soils which possess greater plasticity and cohesion. A study by Lafleur et al., (1990) indicated that, for silt subgrades, a finer grained silt will pipe more than a coarser silt. This study also showed that clay subgrades will clog a geotextile more than

silt subgrades. Deirickx and van der Sluys (1990) reached an opposite conclusion in this regard. They state that clogging is more obvious with noncohesive soils having a high content of fine particles.

Saxena and Hsu (1986) reported on a study of permeability changes in a geotextile-soil system under repeated loadings. The tests involved nonwoven geotextiles over a clay subgrade. The authors concluded that after about 20,000 cycles the coefficient of permeability of the system becomes constant. Additionally, an analysis was provided for the clogging mechanism of geotextiles which suggests that, during the loading cycle, soil fines from the subgrade are pumped up through the geotextile where they float in the water above the geotextile until loading is complete. After the loading is removed the fine particles fall back and accumulate on the geotextile's upper surface. Also, there will be some clogged soil particles in between the filaments of the geotextile.

Hoare (1982[a]) reported on a study of pumping clay (40 percent clay and 5 percent sand) through geotextiles under dynamic loading. He found that subgrade fines continued to migrate through the geotextile even after 216,000 cycles and concluded that geotextiles do not provide the same stabilizing effect that might be expected from an internal filter forming within a granular soil. Interestingly, he also found that soil migration through the geotextile did so at the points of contact of the subbase aggregate particles with the subgrade.

A review of geotextiles as soil filters by Hoare (1982[b]), described design criteria for geotextile filters. He concluded that for geotextiles under reversing flow conditions the design criteria are not well defined or accepted. As a rule of thumb, however, thicker geotextiles offer a more "tortuous path" for the migrating fines and are more suitable than thinner fabrics. It was suggested that the best solution is to use geotextiles in conjunction with a granular filter to replace one layer of a multi-layer system.

Schneider and Puhringer (1986) conducted dynamic testing of a soil-geotextile system and compared the performance of four types of geotextiles with each other and with a system without geotextile. The tests involved two nonwoven and two woven geotextiles over a sandy silt subgrade. Of the four geotextiles tested, the 6 oz/yd^2 needle-punched nonwoven material provided the best subsoil drainage properties. A fairly heavy 10 oz/yd^2

woven slit-film material performed better than a heat-bonded lightweight 7 oz/yd^2 nonwoven geotextile and a lightweight 3 oz/yd^2 woven slit film.

McMorrow (1990) also found that the needle-punched nonwoven geotextiles are more efficient as separators than heat-bonded nonwovens. He suggested that the needlepunched material may be better at building up a filter beneath and/or within in the geotextile.

Carroll (1983) described an approach to filter criteria based on three performance parameters: retention ability, permeability, and clogging resistance. He concluded that filter criteria based on EOS (now known as AOS) does not indicate the clogging potential. It is stated that the appropriate pore structure of the geotextile should be specified to eliminate piping through the geotextile, to provide an adequate seepage rate and to assure clogging resistance. Fischer et al. (1990), starting from traditional graded granular filter criteria, developed geotextile filter criteria using relationships between soil grain size distribution and geotextile pore size distribution. It was found that the AOS (O_{95}) of geotextiles is not the best indicator of pore size distribution. Smaller pore opening sizes, O_{15} and O_{50}, were determined to be more appropriate. Therefore, they recommended that the complete geotextile pore size distribution be determined for the analysis of filter criteria.

2.4.4 Dimensional Stability

Dimensional stability is addressed by AASHTO (Koerner and Wayne, 1989) guidelines with the statement, "the geotextile fabric shall be a woven or nonwoven fabric consisting only of long-chain polymeric filaments...formed in a stable network such that the filaments or yarns retain their relative position to each other." Similarly, Task Force No. 25 guidelines provide the following statement, "...they shall be formed into a network such that the filaments or yarn retain dimensional stability relative to each other, including selvages." Current WSDOT specifications typically state, "The material shall be a woven or non-woven geotextile consisting of long chain polymeric filaments or yarns formed into a stable network such that the filaments or yarns retain their position relative to each other during handling, placement, and design service life...."

One would assume from the above guidelines that dimensional stability includes distress or distortion of the geotextile in such a way as to cause a change in its engineering properties; such as strength, AOS, or permeability. It can be argued, however, that dimensional stability, as defined above, is impossible to maintain since even the smallest amount of compressive stress on a nonwoven needlepunched geotextile will cause a slight decrease in the thickness, AOS, transmissivity and permeability. Even a small amount of flexing or bending of a woven slit-film geotextile will change slightly the size and distribution of the openings between at least a few of the woven filaments (Giroud, 1981; Raumann, 1982; Sato et al., 1986; Prapaharan et al., 1989).

As a means of quantifying the changes in dimensional stability of nonwoven geotextiles several studies have focused on the decrease in geotextile thickness, in-plane hydraulic conductivity (transmissivity) and pore size distribution (PSD). Giroud (1981) presented data showing the reduction of thickness, permeability, and transmissivity of a typical needlepunched nonwoven geotextile with increasing compressive stress, Fig. 2.1. This figure indicates that reductions in these properties are rapid with the initial onset of compressive stress and begin to diminish after stress increases beyond about 4 ksf (0.2 MPa). Similar results were reported by McGown, et al.(1982). It is expected that the compressive stress due to burial of geotextile separators would be on the order of 0.3 ksf (0.0144 MPa); however, locally the stresses may be greater where loads are concentrated on large pieces of aggregate at the bottom of the base course layer. Therefore, the amount of compression and permeability decrease would not be everywhere uniform.

Prapaharan et al. (1989) stated that typical field stresses are not likely to be large enough to compress the fabric beyond 20 percent strain. Their tests involved thick nonwoven geotextiles and they concluded that the PSD obtained for an uncompressed geotextile can be used in most cases. Sato et al. (1986) found that earth pressures on the order of 0.3 ksf would produce a reduction in geotextile thickness of about 20 percent. The geotextile used in this test was an 11.8 oz/yd^2, 0.157 in. (4 mm) thick nonwoven needlepunched material.

Other than studies on the compression of nonwoven geotextiles, very little has been published on dimensional stability. It is widely recognized however, that in-situ drainage and filtration properties of geotextiles are best modeled in an apparatus which simulates in-situ conditions rather than predicting the in-situ behavior based on index tests.

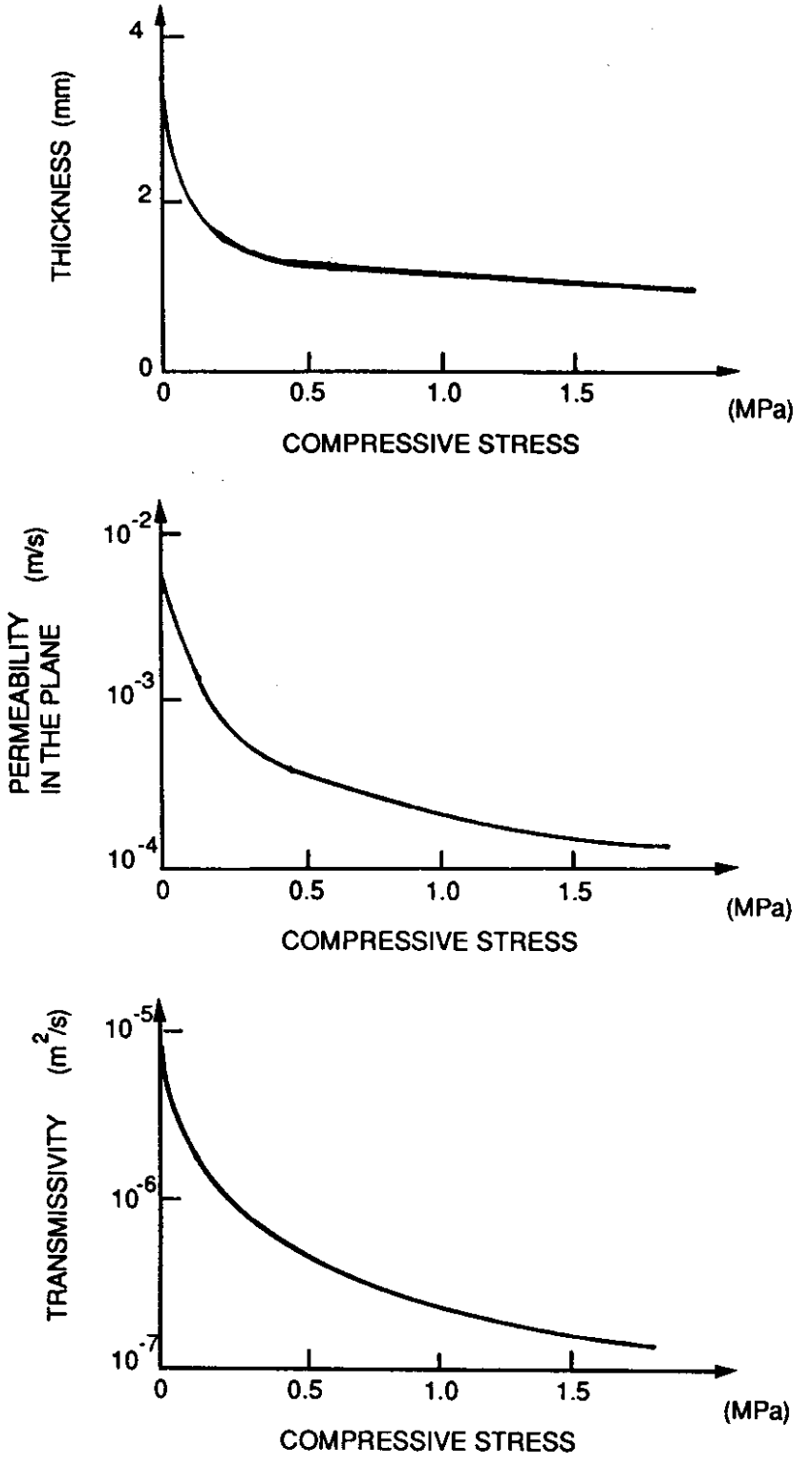


Figure 2.1 - Thickness, permeability in the plane and transmissivity of a typical needlepunched nonwoven geotextile, reprinted from Giroud (1981).

2.4.5 Durability

Durability of a geotextile is defined as the geotextile's ability to resist and maintain resistance to corrosion and degradation when exposed to UV light, extreme temperatures, chemicals, wetting and drying cycles, biological effects, and mechanical abrasion over time. Degradation can occur in-situ by physico-chemical activity in the soil, such as hydrolysis, oxidation, and environmental stress cracking.

All polymers used in geotextiles are subject to degradation from exposure to UV radiation. The rate of attack of polymers by UV radiation depends on the geographic location of the installation and may be increased by air pollution, salt spray, wetting/drying cycles, and freezing/thawing cycles. While UV degradation could be a problem in some unusual cases where the geotextile is left out in the open for extended periods prior to use, it is not generally considered a significant problem in the performance of geotextile separators because of roadway construction practices which generally result in the geotextile being buried relatively soon after placement on the subgrade.

The rate of UV attack also depends on the composition and construction of the material. Geotextiles with greatest exposed surface area per unit volume of material will degrade most rapidly.

The most important consideration in assessing the chemical effect of soil on buried geotextiles is the acidity or alkalinity of the soil. In general, all polymers used in geotextile production have good resistance to acid and alkaline attack. It is only at the higher and lower ends of the PH range where polymer oxidation and/or polymer hydrolysis could be accelerated to the point of threatening the performance of the geotextile (Billing et al., 1990). Such conditions are unlikely to be found in separator applications.

Geotextile separators are most likely to be subjected to detrimental chemical degradation when exposed to fuel spillage. Polyester shows good resistance to organic and dilute inorganic acids; however, degradation becomes rapid when the concentrations increase. Polyester shows very limited resistance to alkalis but is very resistant to fuels and bituminous materials. Billing et al. (1990) reported that polyvalent transition metal ions, such as Fe, Cu and Mn can act as catalysts in the oxidation process for polyolefin materials

and Ca and Na ions can accelerate hydrolysis of polyester materials; however, polymer manufacturers incorporate suitable ion deactivators into their polymers to counteract this problem.

Bonaparte et al. (1988) reported that polypropelene geotextiles undergo some oxidation underground; however, this apparently does not significantly affect the mechanical/hydraulic properties of the geotextile. This was confirmed by Richardson and Behr (1990) as they found no evidence of sizeable chemical degradation of polymers of seven different geotextiles after eight years of burial. Brorsson and Ericksson (1986) have reported a loss of up to 50 percent of the tensile strength (woven geotextile) and 50 percent of the elongation at break (nonwoven geotextile) in geotextiles buried for 10 yrs.

Geotextiles are not considered vulnerable to attack by soil microorganisms; however, geotextiles may be subject to damage by insects, burrowing animals, and the growth of plant roots through fabric pores. These potential problems have not been reported in the reviewed literature on geotextile separators.

Although temperature extremes may affect modulus and failure strain of geotextiles, no adverse effects from this or freeze/thaw cycles have been reported for geotextile separators after installation.

2.4.6 Pavement Performance

As mentioned earlier, Richardson and Behr (1990) reported on a study of geotextile separators used to prevent pumping of a silty fine sand under parking lots. After eight years they report that the the parking lot with the geotextiles has performed successfully while adjacent parking lots over similar subgrades but without geotextile separators have developed pumping failures.

Brorsson and Ericksson (1986) have reported successful performance of roadways in Sweden which included geotextiles. After periods of 5 and 10 yrs., nine different geotextiles were exhumed from the experimental roadway. They conclude that the geotextiles performed well as separators and filters regardless of up to 50 percent reduction in strength and elongation at break.

Scullion and Chou (1986) reported on research involving a woven geotextile installed between the base and subgrade of two "thin" (1.5-in. asphalt or bituminous surface treatment) pavements. Their research utilized falling weight deflectometer and dynamic cone penetration tests to evaluate effective base thickness of the experimental roadways. The results of their research indicate that the geotextile prevented the migration of fines into the base course in the two roadways. Their results are somewhat questionable since the control sections were not constructed with the same base course thickness as the sections which included geotextiles. It was suggested however, that the geotextiles were effective in stabilizing lightly trafficked, "thin" pavements over soft subgrades.

Model tests with a lightweight nonwoven geotextile (Mirafi 140N), used between a cohesive subgrade and granular sub-base, resulted in a reduction in required sub-base thickness of approximately 6 in. as compared to a similar pavement structure with no geotextile (Barenberg et al. 1975). Ingold and Crowcroft (1984) discussed several cases where roadways which included geotextile separators had performed quite well. They also reported on several instances where the geotextile failed; however, most of these failures involved very weak subgrade conditions where the main failure mode was shear failure.

2.5 Summary

Based on a review of the literature, it is apparent that several studies have focused on the construction survivability of geotextile separators in the field while others have looked at the long-term drainage and filtration performance of different geotextiles under various loading and soils conditions in the laboratory. A comparison of the results of these studies indicates that the conclusions are highly disparate and sometimes contradictory. One fact that can be concluded is that the survivability and performance of separators is greatly dependent on specific site conditions and installation procedures.

The state of the art and practice of designing geotextile separators has developed over the years from a qualitative approach to a more quantitative approach. To this end a useful design system based on survivability classifications has been proposed by Christopher and Holtz (1985). What this design system is lacking however, is a practical means of incorporating the drainage and filtration requirements with the survivability requirements in a compatible way. Furthermore, the question of drainage and filtration

requirements in separator applications has not been adequately resolved in such a way that designers can be confident that separators will not do more harm than good.

The results of the literature review indicate that under laboratory conditions geotextiles will blind and clog under repeated loads. Some types of geotextiles clog more readily than others. To date, the blinding and clogging of geotextiles in the field has not been reported as a problem in separator applications. This is not to say that separators have not clogged, but rather it has not been quantitatively shown that clogging has reduced the effectiveness of geotextiles in the field.

It is generally agreed that end-dumping of aggregate directly onto the geotextile will result in increased damage. It is also apparent that the lift thickness above the geotextile is important; however, there is no general agreement as to the required minimum lift thickness.

Although several studies have shown that improper construction practices and/or inadequate geotextile material properties will result in geotextile damage, it has not been shown that geotextile damage is responsible for decreased pavement life or premature failure of the roadway.

The issue of dimensional stability has not been adequately addressed, nor has its implications for separator applications been fully investigated. Durability is generally not considered a significant problem for the separator application. Finally, the qualitative data regarding pavement performance indicates that geotextile separators are being used successfully. Very little quantitative data regarding the influence of geotextile separators on pavement performance has been published, however, what has been published indicates that separators have improved pavement performance.

3.0 PURPOSE AND SCOPE OF WORK

3.1 Purpose of the Study

Many issues involving geotextile separators are still not resolved despite the significant research which has taken place. They include:

1. survivability requirements, especially of woven slit film vs. nonwoven needlepunched geotextiles,
2. AOS and permeability requirements, including clogging potential,
3. dimensional stability of woven slit films,
4. durability, especially chemical, of the geotextile and;
5. current pavement performance as indicated by premature maintenance, falling weight deflectometer (FWD) measurements, drainage problems, or possible subgrade intrusion.

The objectives of this research were to:

1. Assess the impact of normal construction operations on geotextile separator survivability. Variables include construction equipment, subgrade soils, size and angularity of basecourse aggregates, thickness of initial lifts, traffic, climate, groundwater conditions, and type of geotextiles.

2. Evaluate and resolve as many of the above issues as possible and correlate long-term roadway performance with the variables listed above.

3.2 Scope of Work

This research consisted of five phases:

1. Preliminary research and site selection
2. Field evaluations
3. Laboratory tests
4. Analysis of data
5. Preparation of report

The preliminary research and site selection phase involved evaluating the records of various sites where geotextiles were used as separators. Those sites which appeared to be well documented and would offer the most meaningful data were selected for detailed study. Phases 2 and 3 involved field work and laboratory testing which often occurred simultaneously due to the timing and logistical requirements involved with making site visits. Numerous photographs were obtained during the site visits and are presented in the following chapter. The analysis of data and preparation of this report generally occurred after the data had been gathered from the field or the laboratory.

4.0 SITE SELECTION AND INVESTIGATIONS

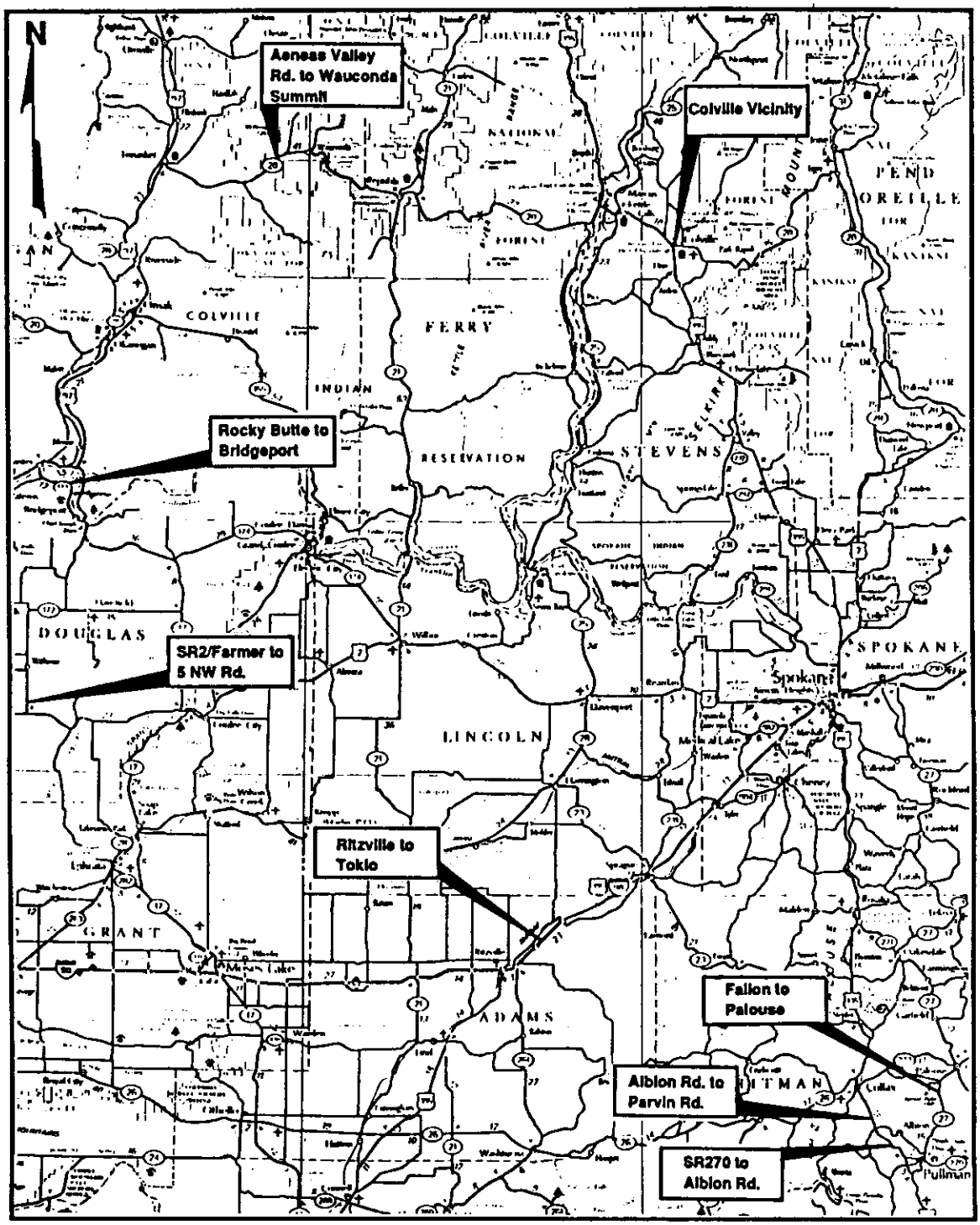
4.1 Site Selection

The objectives of the field investigations were to evaluate at least six sites where geotextiles were known to have been utilized as separators over soft or troublesome subgrade conditions. A list of eighteen sites was initially provided by Mr. Tony Allen of WSDOT. These sites were all located in eastern and central Washington and were believed to be sites where geotextile was placed on soft silt, sandy silt or clayey silt subgrades. By searching through the WSDOT records such as Contract Documents, Field Note Records, Inspectors Daily Reports, Pay Quantities, and through communications with WSDOT personnel, a short list of potential sites was prepared. The criteria for choosing the sites consisted of the age of the installation, type of geotextile used, subgrade and aggregate type, quality of construction records, existence of index strength and permeability test data, access to the site, pavement condition and performance, safety and traffic control costs and interdepartmental-interagency coordination. One of the goals of the initial site selection process was to choose a nearly equal number of sites that used woven geotextiles as those that used nonwovens. Additionally it was desired to choose a few of the older (greater than 6 yrs.) sites that used geotextiles so that long-term performance could be evaluated.

As the project progressed, additional communications with WSDOT personnel indicated that more than the original eighteen sites were available. Ultimately, eight sites were selected for field investigations. The WSDOT project names, contract numbers and roadways where they were located are as follows:

(1) Colville Vicinity, C3331, SR 395
(2) Fallon to Palouse, C2364, SR 27
(3) SR 270 to Albion Road, C2550, SR 195
(4) Albion Road to Parvin Road, C2990, SR195
(5) Ritzville to Tokio and Weigh Stations, C3503, I 90
(6) Aeneas Valley to Wauconda Summit, C3582, SR 20
(7) Rocky Butte to Bridgeport Bar, C3057, SR 173
(8) SR 2/Farmer to 5NW Road, C3369, SR 172.

The approximate locations of the sites are indicated on the Site Location Map, Fig. 4.0.



0 14 28 56

Scale in Miles

NOTE

Map adapted from Washington State Highway Map, WSDOT, 1989 Edition.

Figure 4.0 - Site Location Map

Prior to starting the physical site investigations, a reconnaissance of the Colville, Pullman, and Colfax areas was made to evaluate the roadways, select locations for test pits and meet with the district personnel to coordinate the work. For subsequent site investigations, no preliminary reconnaissance was made since sufficient information on geotextile location was obtained through review of contract documents and communications with WSDOT personnel, including project construction inspectors. Test pit locations were also based on the results of FWD analysis when this information was available.

Site investigations began in April, 1990 with the Colville Vicinity site being the first to be visited. Site investigations were not begun earlier in the year because of a concern that base course and subgrade soils might still be frozen from the previous winter. No frozen soils were found at that time of year which indicates that site investigations could have begun earlier.

4.2 Field Procedures

Field investigations consisted of visual and physical evaluations of the geotextile/base course system and included numerous photographs of the sites before and during test pit excavations.

Preliminary field testing procedures were developed prior to the site visits based on the expected soils and geotextile conditions. During the first few site investigations actual soils/geotextile conditions were found to be incompatible with several of the preliminary investigation procedures and, therefore, several changes were made to the field procedure. Preliminary procedures were based on the assumption that soft clay and silt subgrades would be encountered below the geotextile. Actual subgrade conditions consisted of hard, consolidated silts with numerous gravel or, in three cases, imported granular material which was placed over the native silt subgrade. Thus, the use of a block sampler, consisting of 3/4-in. plywood bolted together to form an 8-in. square box, was found to be impractical. In addition, where clayey silt was found below the geotextile it was in such a hard, consolidated condition that attempts to measure the field permeability with a permeameter were not successful. The permeameter consisted of a 3-in. diameter, steel cylinder (Shelby Tube) with a 1/4-in. wide slot cut in the side parallel to the axis of the cylinder. A 1/4-in. diameter plastic tube was glued to the side to allow viewing of the water level drop.

After the first four sites were investigated with the aid of a backhoe it was found that test pit excavations could be accomplished more precisely, more carefully, faster and at lower cost with a pneumatic or electric jack-hammer and several shovels. The last five sites were investigated in this way. It was found; however, that where several feet of ballast had been placed and compacted over a geotextile in an over-excavation (such as at the Rocky Butte to Bridgeport Bar site) the use of a backhoe would have greatly expedited the excavation and backfilling operations.

The modified field procedures consisted of the following:

1. UW and WSDOT personnel make a visit to eastern Washington to meet with district personnel and evaluate the selected test sites. Identify a poorly performing section of each site, if one exists, based on criteria such as rutting, longitudinal cracking, signs of early resurfacing and the results of FWD tests. Take photographs of the selected locations.

2. Arrange for backhoe or jack-hammer and traffic control personnel to meet at the site on the day of the investigation. If a backhoe is used, arrange for the asphalt pavement to be sawn through at the selected test pit location.

3. Measure, sketch, and mark (with paint or chalk) the test pit location on the pavement . Take detailed photographs of site, surrounding topography and test pit locations. If possible, make measurements to quantify the pavement failure; i.e., rut depth, crack width, etc.

4. Saw or jack-hammer through the asphalt around the section to be studied (3-ft by 4-ft area or larger, if practicable).

5. Use backhoe, if available, to remove asphalt; otherwise cut pavement into manageable size chunks and remove by hand. Very carefully direct the backhoe to remove basecourse aggregate to within 6 in. or so of geotextile. If no backhoe is being used then carefully loosen base course aggregate with jack-hammer and hand excavate test pit. Collect bulk samples of base course aggregate from 6 in. or more above the geotextile. Observe and photograph the excavation.

6. Use pick, shovel, trowel, and hands to excavate last 6 in. of aggregate from above the geotextile. Collect sample of aggregate from 0 to 2, 0 to 3, or 0 to 4 in. above geotextile, as conditions allow, for laboratory analysis of fines migration. Observe and photograph the geotextile's upper surface and make a written record of the appearance noting any holes, folds, evidence of clogging, etc. Evaluate the geotextile's overall condition.

7. Cut out a section of the geotextile (3-ft by 4-ft or as large as possible) with a sharp "Exacto" knife or similar. [A knife with break-away blade sections is best since the blade becomes dull quickly during cutting.] Carefully lift geotextile off of subgrade, place it in a dark, labeled plastic bag. Observe and photograph the subgrade surface.

8. Obtain subgrade samples for grain size distribution and water content analysis by digging into the subgrade with a trowel. Observe, classify and photograph subgrade soils.

9. If the subgrade is soft to stiff, obtain pocket penetrometer and torvane readings from directly below the geotextile.

10. Replace subgrade, geotextile, basecourse, and asphalt material under the direction of WSDOT personnel. New geotextile should be overcut and overlapped by 1-in. or more onto the existing geotextile.

11. Pack up equipment and return to laboratories to perform soil and geotextile analyses, and make laboratory photographs of geotextile.

4.3 Results of Site Investigations

During the period of April through September, 1990 nine site visits were completed. One of the site visits was a return to the Fallon to Palouse project (SR27) on July 18. This return visit included excavating three test pits; two at milepost 13.5 and one at milepost 14.0. No geotextile was encountered in these excavations, contrary to what was indicated on the contract documents; however a sample of the basecourse material was collected from the test pit at milepost 14.0 and the results of a grain-size distribution analysis are presented on Fig. 5.3. As mentioned earlier, imported granular material was encountered over the

native subgrade (beneath the geotextile) at three of the remaining eight sites investigated. This condition amounts to a misapplication of the geotextile as a separator and, therefore, these sites were not considered useful to this study insofar as the prevention of fines migration and providing filtration drainage capability. These sites were useful however, for assessing the construction damage (survivability) of the geotextile as a function of subgrade and base course type and construction practices. Of the five sites that encountered native subgrade beneath the geotextile one was a needlepunched nonwoven and the other four were woven slit films.

Samples of the aggregate, subgrade and geotextile were taken from the test pits and brought back to the laboratory (U.W. or WSDOT) for testing. The geotextile was tested for permittivity and retained strength and the aggregate was tested for water content and grain-size distribution. Laboratory tests are discussed in section 5.0 of this report.

Each site investigation is briefly discussed in the following subsections. The implications of each of the site investigations are summarized and pertinent photographs of each site are presented in these subsections. A more detailed discussion of the results of the site investigations is presented in the Summary of Site Investigations, Section 4.4. The exact locations, dimensions and other details of each site investigation are presented in the Data Summary Sheets, Chapter 7.

4.3.1 SR 395 - Colville Vicinity

This site is located in central Stevens County, Fig. 4.0. The surface geology consists of alluvial silt, sand, gravel and clay deposited by the Colville River. The test pit site was in the southbound lane of SR 395 near the center of the town of Colville. This highway consists of three traffic lanes and 8-ft shoulders, and was reconstructed in the fall of 1987. The highway carries numerous heavy truck loads, mainly logging trucks. An 8 oz/yd^2 nonwoven needlepunched geotextile separator, Supac 8NPUV, was specified for this reconstruction due to the presence of a soft, clayey silt subgrade. The pavement had apparently experienced significant rutting, breakup and alligator cracking prior to reconstruction (personal communication, B. Hausemann, 1990). The existing pavement appeared to be in good condition, as shown on Fig. 4.1.

The exhumed geotextile (Fig. 4.2) appeared to be in very good condition with no observable construction damage. No evidence of clogging or filtration problems were observed. After the geotextile was cut around the sides of the excavation and peeled back to expose the subgrade soils, it was observed that the subgrade consisted of imported fill as shown on Figs. 4.2 and 4.3. The fill consisted of a heterogeneous mixture of cobbles, gravel, sand, silt, clay and chunks of old asphalt concrete. This material appears to have been placed as a working base to expedite equipment traffic during construction. The placement of this fill was considered to have significantly diminished the effect of and the need for the geotextile separator and, therefore, this site is not considered to be useful in the evaluation of separator performance. However, the fact that the geotextile survived the apparent very high survivability conditions with no visible damage is noteworthy and is discussed subsequently in Chapter 7 of this report.

Figure 4.3 shows the location of the geotextile relative to the subgrade and imported aggregate. Figure 4.4 illustrates that, although the geotextile was in good condition, the larger aggregate of the underlying fill left impressions in the material where it had been stretched over the aggregate. These impressions subsequently diminished with time as the geotextile was handled and are not believed to have had detrimental affects on the performance or strength of the geotextile.

Figure 4.1 - Cutting of asphalt pavement at test pit site, Colville Vicinity.

Figure 4.2 - Uncovered geotextile separator with exposed subgrade (fill), Colville Vicinity.

Figure 4.3 - Section showing base course, geotextile, fill and subgrade, Colville Vicinity.

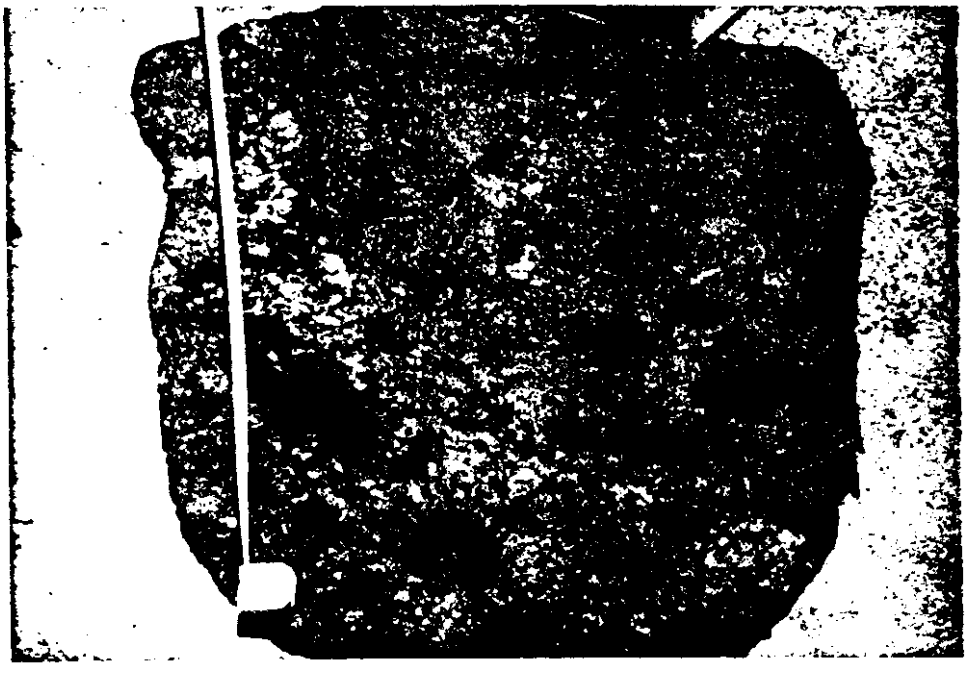


Figure 4.4 - Geotextile specimen showing impressions of fill material, Colville Vicinity.

4.3.2 SR 27 - Fallon to Palouse

This site is located in the southeastern portion of Whitman County (Fig. 4.0). The geology of the region generally consists of extrusive basalt flows mantled by eolian clay and silt (loess). The Fallon to Palouse site is located in an extensive clayey silt deposit.

The roadway was constructed using a geotextile separator in the fall of 1983. It is a two-lane highway with a high volume of passenger vehicle traffic and grain trucks. A 4 oz/yd^2 woven slit film geotextile, Mirafi 500X, was specified for this project due to the presence of soft, clayey silt subgrade. This subgrade had presented numerous problems with pumping and loss of strength during construction which were exacerbated by the presence of springs in the hillside cut along the west side of the road. The existing roadway surface appeared to be in good condition as shown on Fig. 4.5.

The test pit site, at MP 11.35 of the northbound lane, was selected based on discussions with the project inspector who had been present during the road's construction. The geotextile was encountered beneath approximately 18 in. of crushed rock and had been placed directly on the subgrade surface, as shown on Figs. 4.6 and 4.7. It appeared to be in very good condition with no damage attributed to construction; however, blinding of the geotextile was observed on the side of the material in contact with the subgrade (Fig. 4.12). A mottled coloration pattern was observed on the underside of the geotextile and on the subgrade surface (Figs. 4.6, 4.7 and 4.8). Figs. 4.9 and 4.10 present top and bottom views of the geotextile. As can be seen in Fig. 4.10 the mottling pattern is only visible on the underside of the geotextile and consists of randomly oriented, less-clogged zones surrounded by a ring of orange-brown iron-oxide staining. These zones appear to be areas where water is able to migrate up from the subgrade more easily than through the surrounding clogged geotextile. The iron-oxide appeared to be deposited against the geotextile filaments and within the weave as shown on Fig. 4.11.

Upon closer inspection, the iron-oxide was observed to have adhered to the filaments of the geotextile and acted as a cement binding the clay and silt particles together and to the geotextile. Figs. 4.13 and 4.14 show magnified views of the geotextile after vigorous washing with a high-pressure spray of water. It can be seen that fine-grained soil particles remain within the weave of the material. This may be interpreted as clogging.

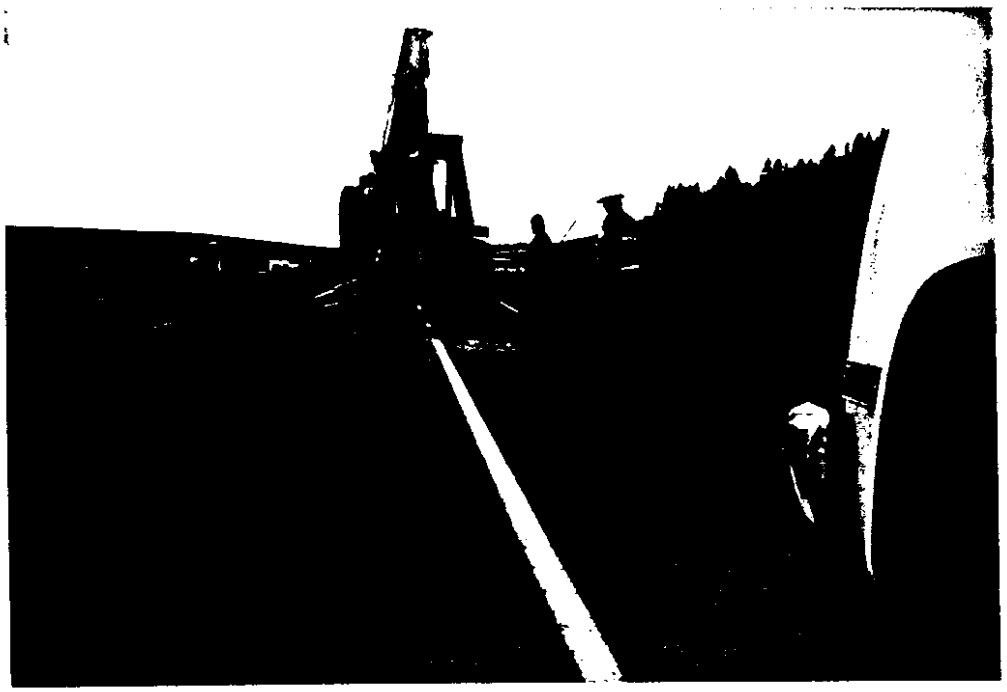


Figure 4.5 - Excavation of roadway with backhoe, Fallon to Palouse.

Figure 4.6 - Uncovered geotextile separator with exposed subgrade, Fallon to Palouse.

Figure 4.7 - Mottled coloration of geotextile and subgrade, Fallon to Palouse.

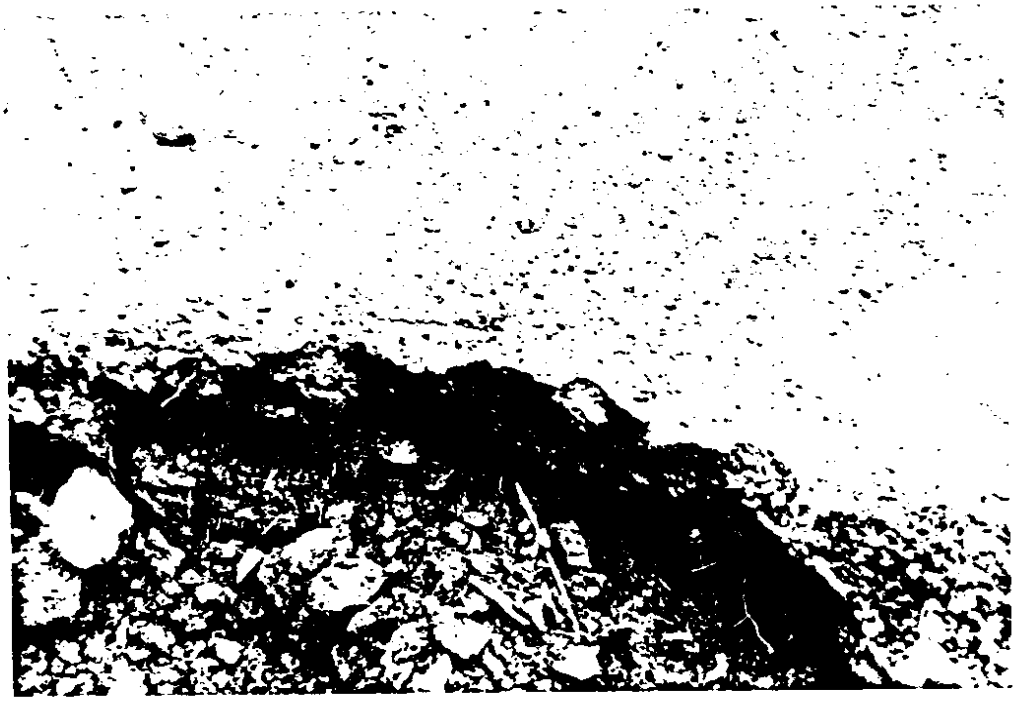


Figure 4.8 - Clayey silt subgrade soil with mottled coloration visible, Fallon to Palouse.

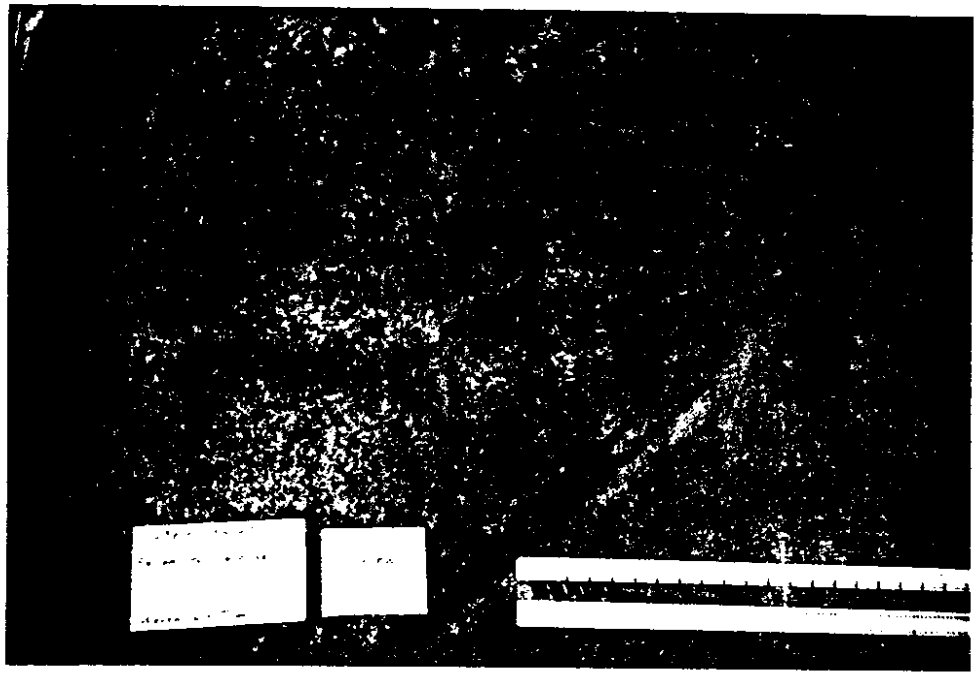


Figure 4.9 - Top view of geotextile in laboratory, Fallon to Palouse.

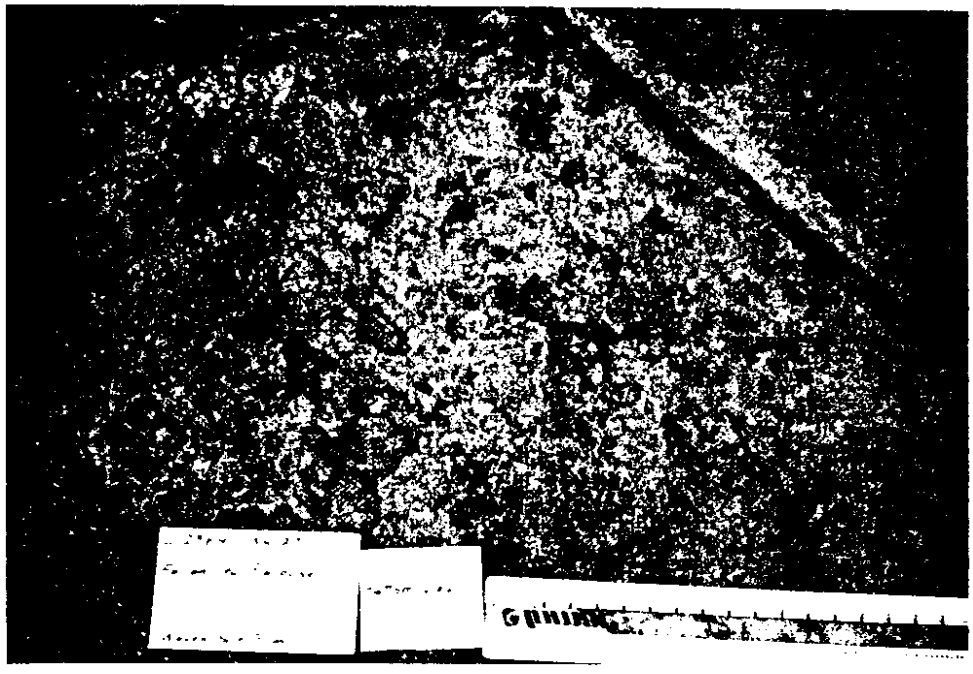


Figure 4.10 - Bottom view of geotextile in laboratory showing mottling, Fallon to Palouse.

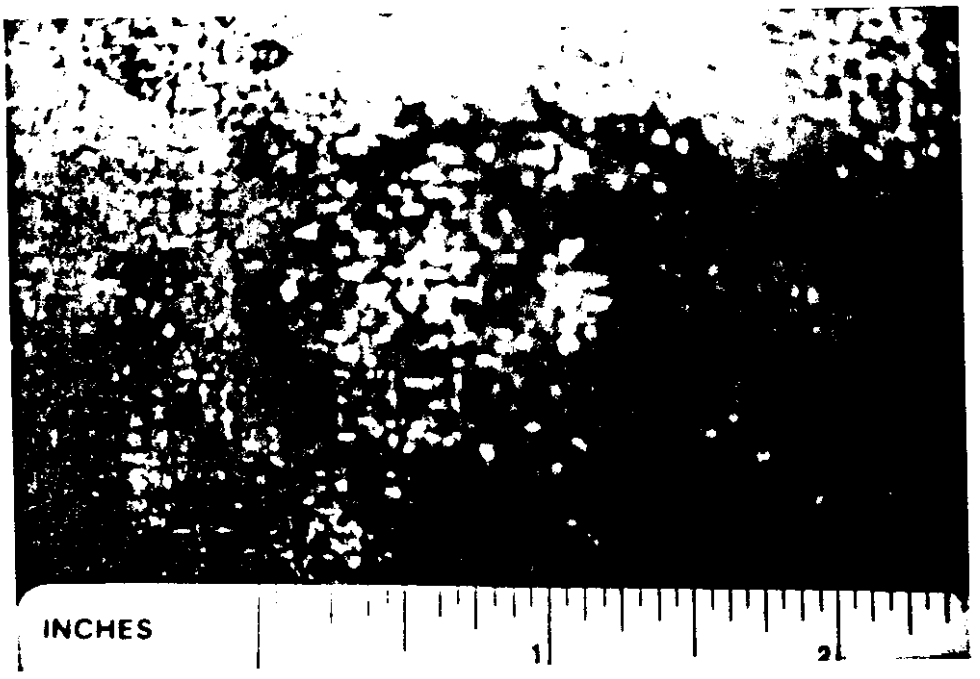


Figure 4.11 - Oxidation rings on geotextile (~1.5 X Magnification), Fallon to Palouse.

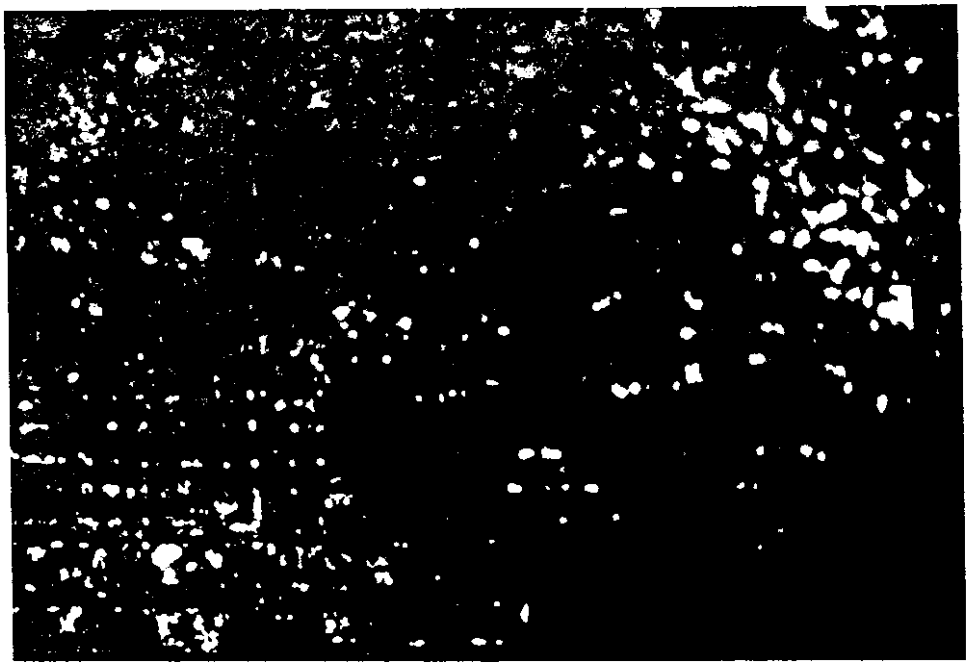


Figure 4.12 - Blinding of bottom side of geotextile with clayey silt (~2X magnification), Fallon to Palouse.

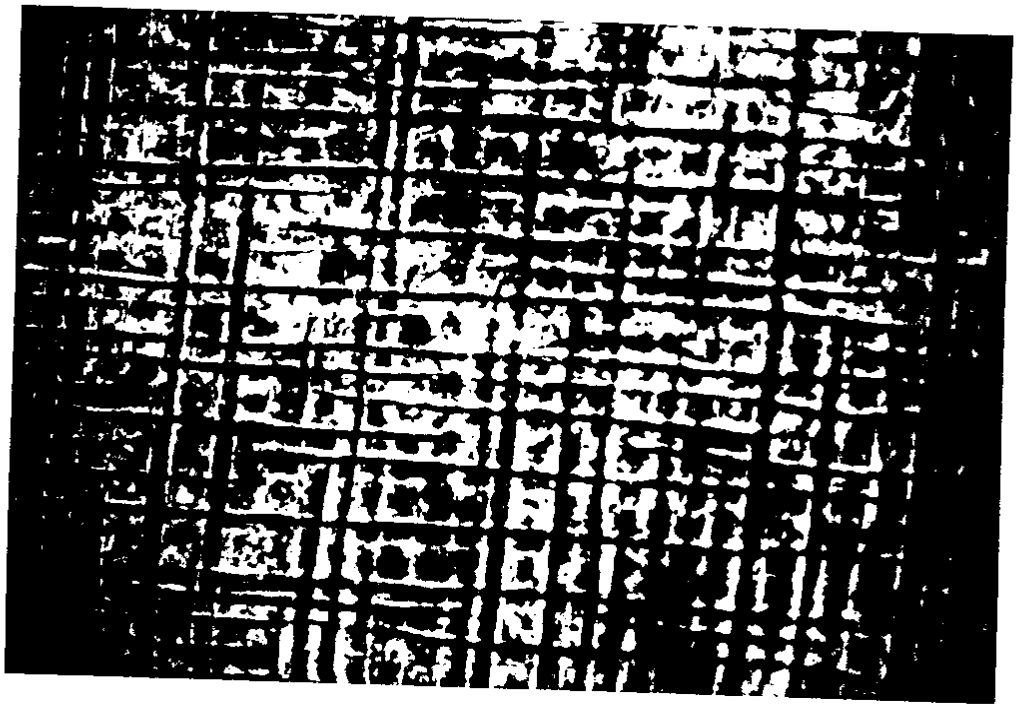


Figure 4.13 - Close up of washed geotextile specimen showing retained soil within weave (~2X magnification), Fallon to Palouse.

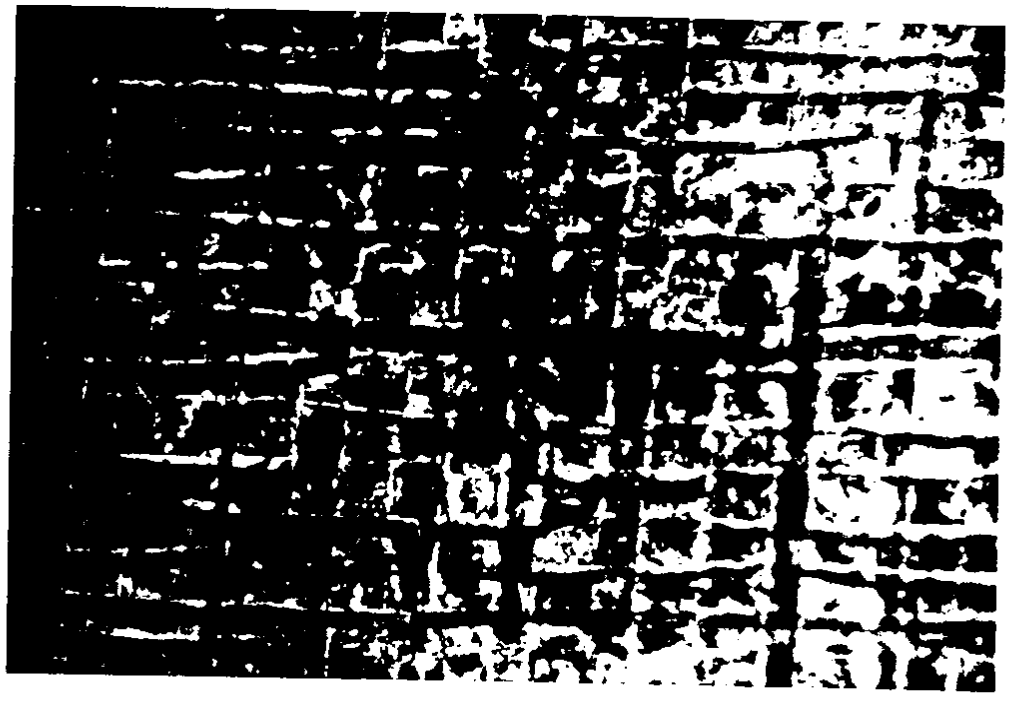


Figure 4.14 - Close up of washed geotextile specimen showing retained subgrade soil within weave (~3X magnification), Fallon to Palouse.

4.3.3 SR195 - SR270 to Albion Rd.

This site is located in the southeastern portion of Whitman County (Fig. 4.0) approximately 3 mi north of Pullman, Washington. The geology of the region is similar to that of the Fallon to Palouse site.

The roadway was constructed with a geotextile separator in the fall of 1983. It is a two-lane highway with a high volume of passenger vehicle and heavy truck traffic. The reconstruction of this road provided an improved roadway section and widened the road to include 8-ft shoulders on both sides. The geotextile consisted of a lightweight nonwoven heat-bonded material which had a laboratory measured weight of approximately 3.7 oz/yd^2. Since it was not possible to wash all of the fine-grained soil particles from the geotextile before weighing, it is assumed that the actual weight of the geotextile was 3.5 oz/yd^2. Based on the weight, color and texture of the material it appears to be a Mirafi 140NL, although no record of the material type was available from WSDOT. The subgrade consisted of clayey silt and had presented numerous problems with pumping and loss of strength during construction and in some locations required overexcavation by several feet and replacement with crushed rock and quarry spalls. The existing pavement appeared to be in very good condition (Fig. 4.15).

Upon excavation, the geotextile appeared to be severely damaged with numerous punctures and tears attributed to construction operations. It was observed that the first lift of ballast rock above the geotextile was approximately 5 to 6 in. thick. This was clearly a high survivability condition. Some minor clogging of the geotextile was observed in the form of fine grained soil particles embedded within the geotextile; however, this did not appear to have impeded the drainage capacity of the geotextile and was not significant relative to the amount of puncture damage. Photographs showing the excavation and condition of the geotextile are presented on Figs. 4.16 through 4.20.

The subgrade consisted of approximately 8 in.of 1-1/2-in. minus crushed rock. This material appears to have been placed as a working base to expedite equipment traffic during construction. The placement of this fill is considered to have negated the effect of the geotextile as a separator and, therefore, this site is not considered to be useful for the purpose of this investigation. No strength or permeability tests were performed on this specimen due to its severely damaged condition.

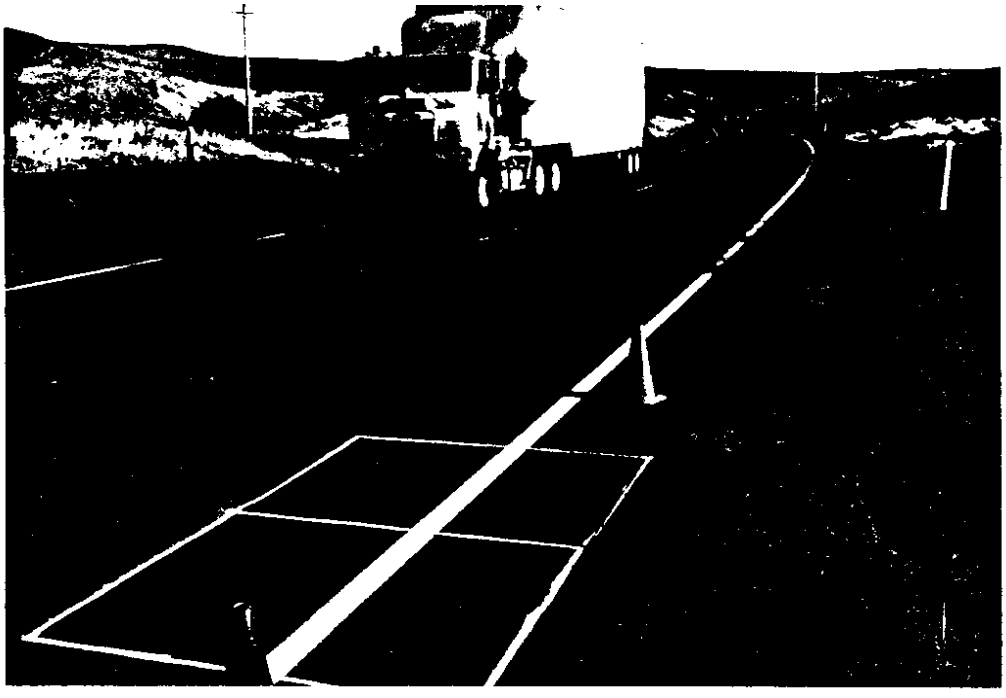


Figure 4.15 - Test pit location and condition of roadway, SR270 to Albion Road.

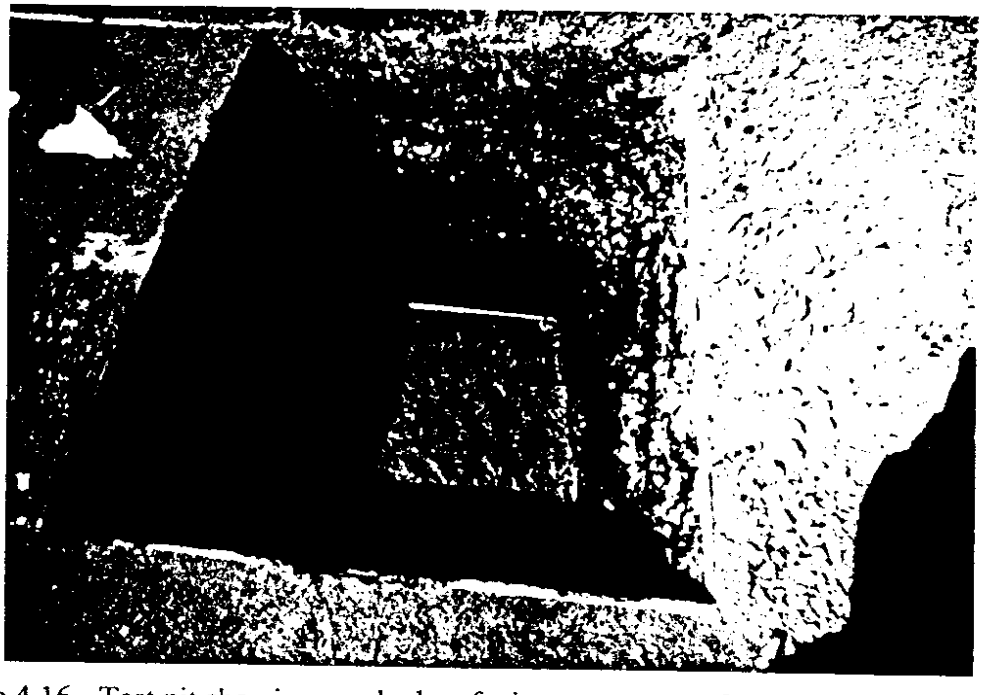


Figure 4.16 - Test pit showing crushed surfacing top course (CSTC), ballast and geotextile, SR270 to Albion Road.

Figure 4.17 - Geotextile pulled back to expose crushed rock fill below, SR270 to Albion Road.

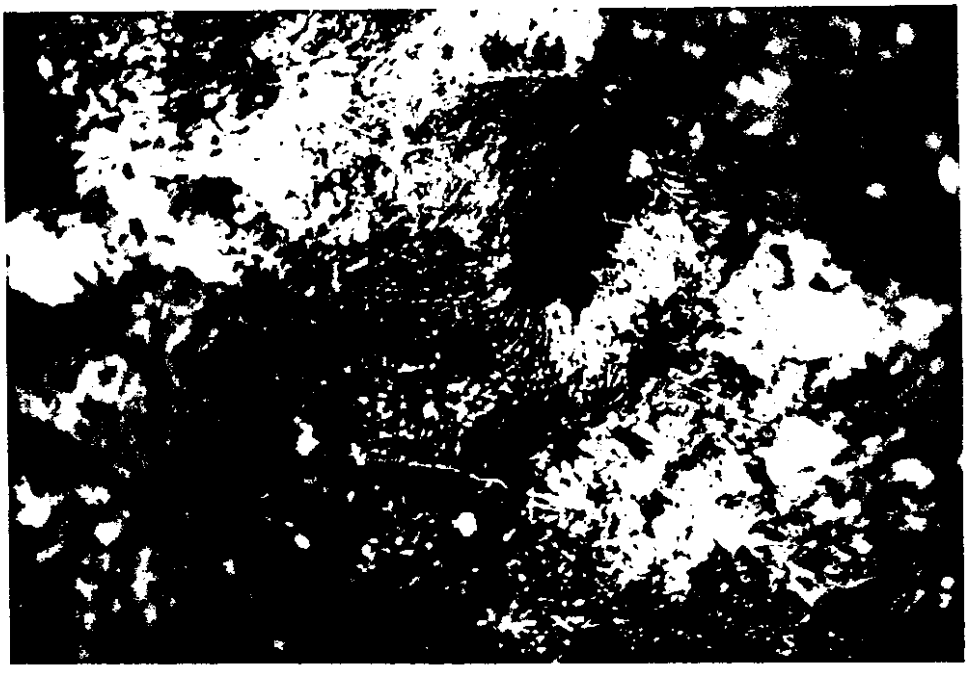


Figure 4.18 - Typical puncture damage in geotextile (~3X magnification), SR270 to Albion Road.

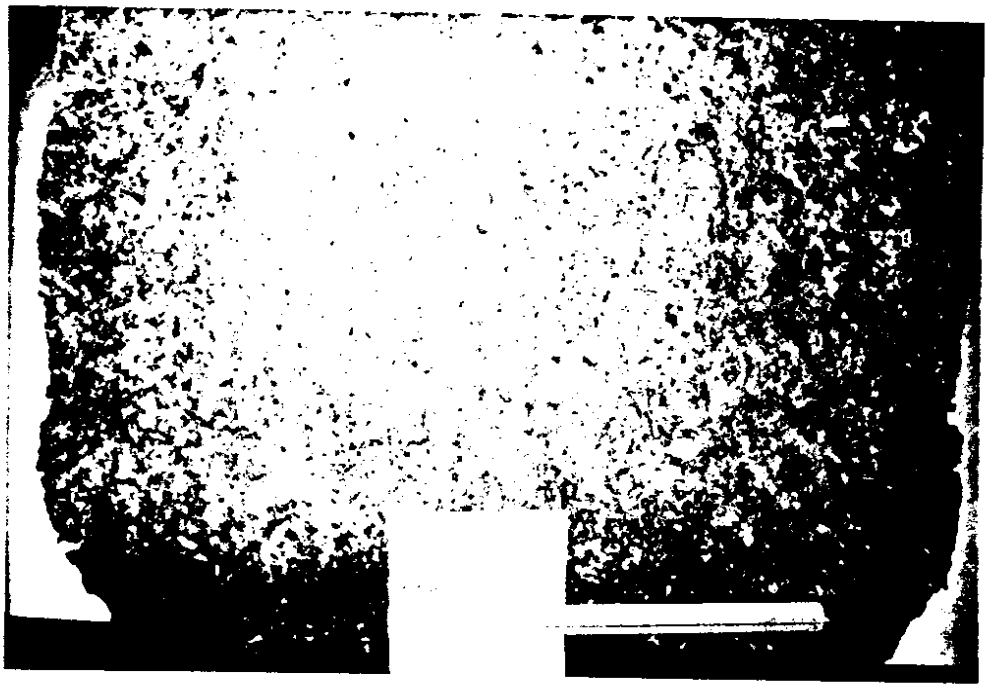


Figure 4.19 - Laboratory photo of geotextile specimen, SR270 to Albion Road.

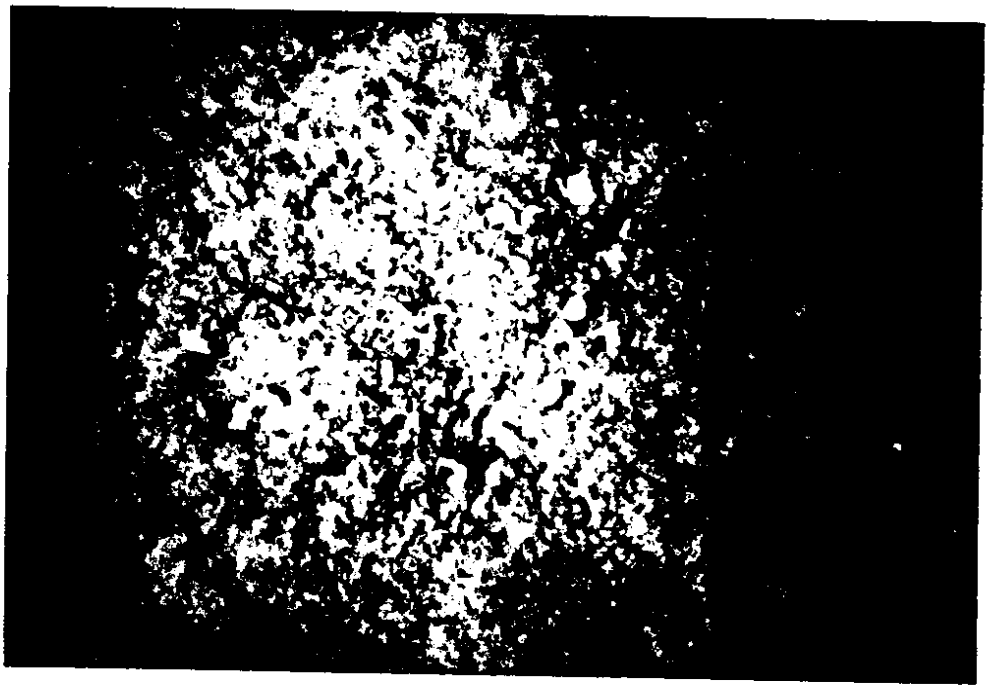


Figure 4.20 - Close-up photo of damaged geotextile (1/2 actual size), SR270 to Albion Road.

4.3.4 SR 195 - Albion Rd. to Parvin Rd.

This site is located in the southeastern portion of Whitman County approximately 7 mi north of the SR270 to Albion Road site (Fig. 4.0). The geology of this site is similar to the previous site.

The roadway was constructed using a geotextile separator in the fall of 1985. It is a two-lane highway with a high volume of passenger vehicle and heavy truck traffic. The geotextile consisted of an 5.3-oz/yd^2 nonwoven needlepunched material, Supac 5NP. The subgrade consisted of clayey silt and had presented problems with pumping and loss of strength during construction. The existing pavement appeared to be in very good condition as shown on Fig. 4.21.

The geotextile was encountered below approximately 8 in. of crushed surfacing top course (CSTC) and 9 in. of ballast as shown on Fig. 4.22. The geotextile had been placed directly on top of the subgrade as shown on Fig. 4.23; however, occasional pieces of crushed rock and asphalt concrete chunks were observed scattered throughout the clayey silt material which indicates that perhaps a thin layer of fill was placed on the subgrade before the geotextile was installed. These conditions would probably be classified as high survivability.

Upon excavation, the geotextile appeared to be in relatively good condition; only a few small holes (up to 1/4-in. diameter) were observed where the sharp edges of the ballast had punctured down through the material. The geotextile was quite wet, as was the subgrade and the first several in. of the ballast above. The geotextile appeared to be allowing the flow of water although some minor clogging of the geotextile was observed in the form of fine grained soil particles embedded within the geotextile, as can be seen in Figs. 4.24 and 4.25.

A mottled coloration pattern was observed on both sides of this geotextile as shown on Figs. 4.22 and 4.24. This mottling appeared to consist of patches of unclogged, clean geotextile dispersed within a field of darker, clogged material. The pattern of the mottling indicates that most of the clogging, or embedment of fine-grained subgrade soils within the geotextile, occurs where the large aggregate of the overlying ballast is in direct contact with the subgrade soil with the geotextile sandwiched in between.

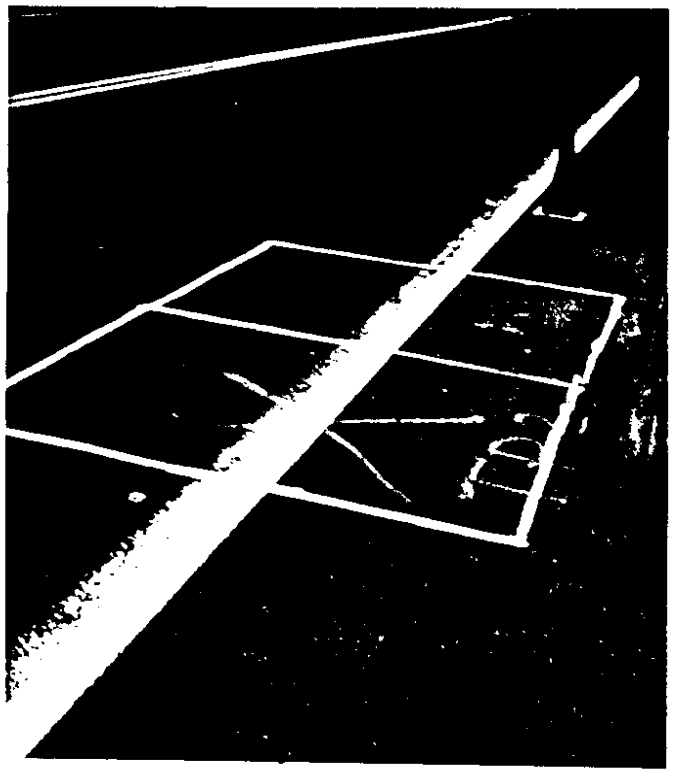


Figure 4.21 -Test pit location and roadway condition, Albion Rd. to Parvin Rd.

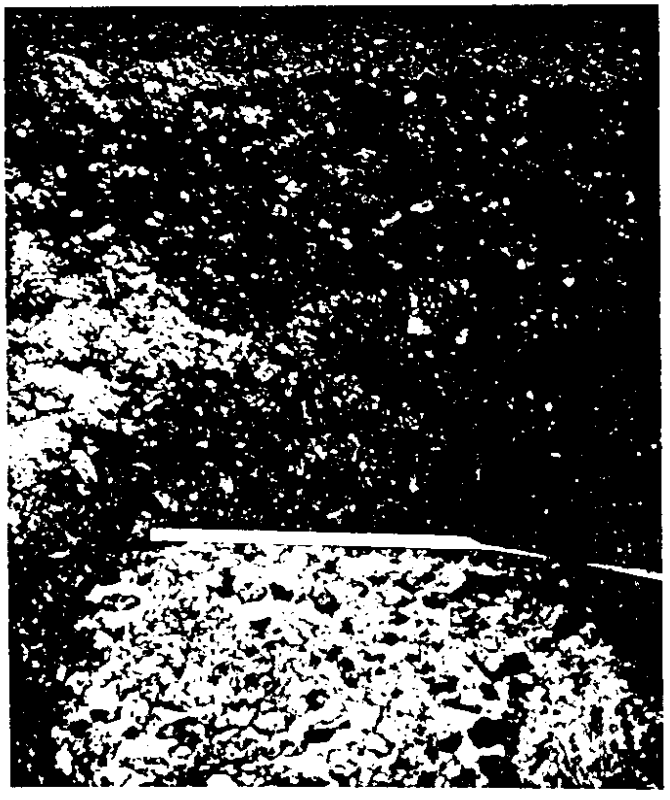


Figure 4.22 - Test pit showing CSTC, ballast and geotextile, Albion Rd. to Parvin Rd.

Figure 4.23 - Geotextile lifted to show clayey silt subgrade, Albion Rd. to Parvin Rd.

Figure 4.24 - Laboratory photograph of geotextile showing mottled pattern, Albion Rd. to Parvin Rd.

Figure 4.25 - Laboratory photograph of unwashed specimen, Albion Rd. to Parvin Rd.

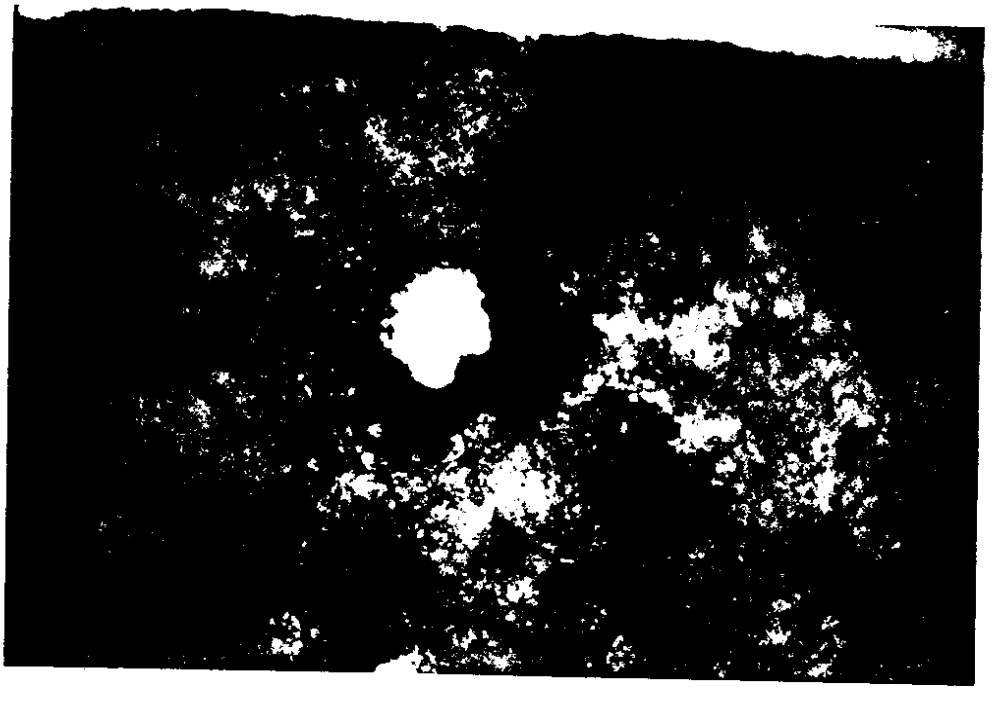


Figure 4.26 - Laboratory photograph of washed specimen, Albion Rd. to Parvin Rd.

4.3.5 SR90 - Ritzville to Tokio and Weigh Stations

This site is located in northern Adams County within an acceleration lane on-ramp to eastbound I-90 (Fig. 4.0). The geology in this area consists of eolian silt (loess) overlying extensive basalt flows. The project consisted of a widening the shoulder of the acceleration lane and was completed in the summer of 1989. A 4 oz/yd^2 woven slit film geotextile , Mirafi 500X, was used as a separator on this project. The geotextile was called for in a change order issued due to wet, muddy subgrades encountered during construction. Since it was a change order, no compliance testing was performed as a basis of material acceptance. During our site visit the existing roadway appeared to be in good condition, as shown on Fig. 4.27.

The test pit was excavated with a jack-hammer and shovels, Fig. 4.28. The exposed geotextile appeared to be in very good condition with no observable construction damage. No clogging or filtration problems were observed. Figure 4.29 shows the removal of the last 5 to 6 in. of crushed rock from above the geotextile. The geotextile was cut and peeled back to expose the subgrade soils. It was observed that the subgrade consisted of imported fill as shown on Figs. 4.30 and 4.31. The fill consisted of a 6-in. to 7-in. thick layer of 1-in. minus crushed rock. This material appears to have been placed as a working base to expedite equipment traffic during construction.

Subsequent discussions with the project inspector indicated that during construction the layer of crushed rock had been placed because the contractor was unable to over-excavate to encounter stable subgrade which would permit construction equipment traffic. The crushed rock was dumped into the wet, muddy subgrade and then bladed off just before installation of the geotextile. The inspector indicated that aggregate trucks had operated directly on the geotextile during placement of the first lift of basecourse. The first lift was approximately 6 in. thick and was compacted with a double drum vibratory roller. This site is not considered to be particularly useful in the evaluation of separator performance because the geotextile was not placed directly on the subgrade.

It is interesting to note that the geotextile appeared to be in very good condition considering the fact that it had been installed on a layer of crushed rock and a 6-in. lift of crushed rock was placed and compacted on top (very high survivability condition). The condition of the geotextile is shown on Fig. 4.32.

Figure 4.27 - Test pit location and condition of roadway, Ritzville to Tokio.

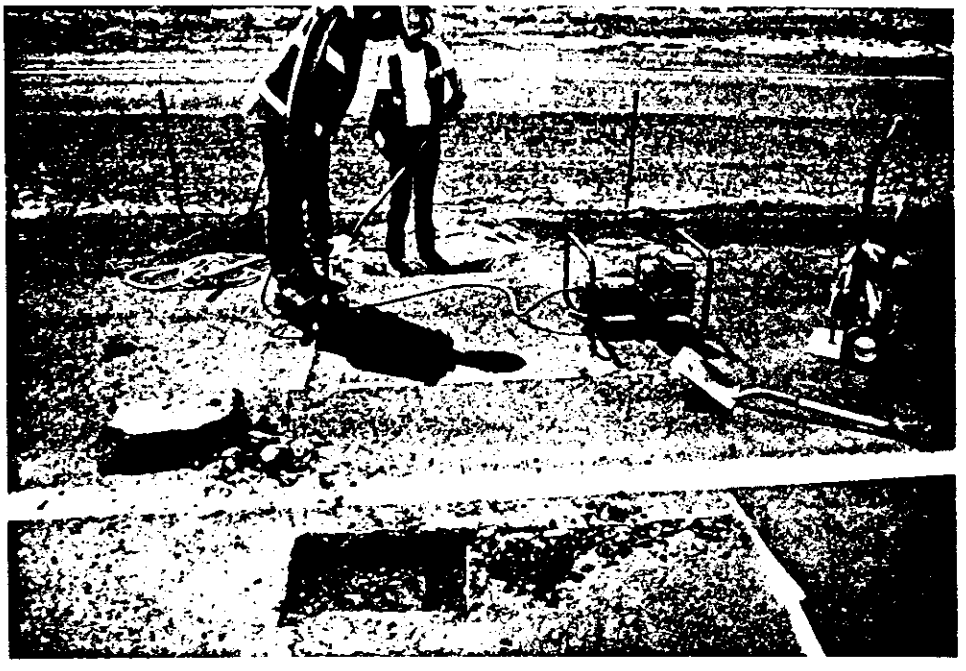


Figure 4.28 - Excavation of test pit with jack-hammer, Ritzville to Tokio.

Figure 4.29 - Removal of base course above geotextile, Ritzville to Tokio.

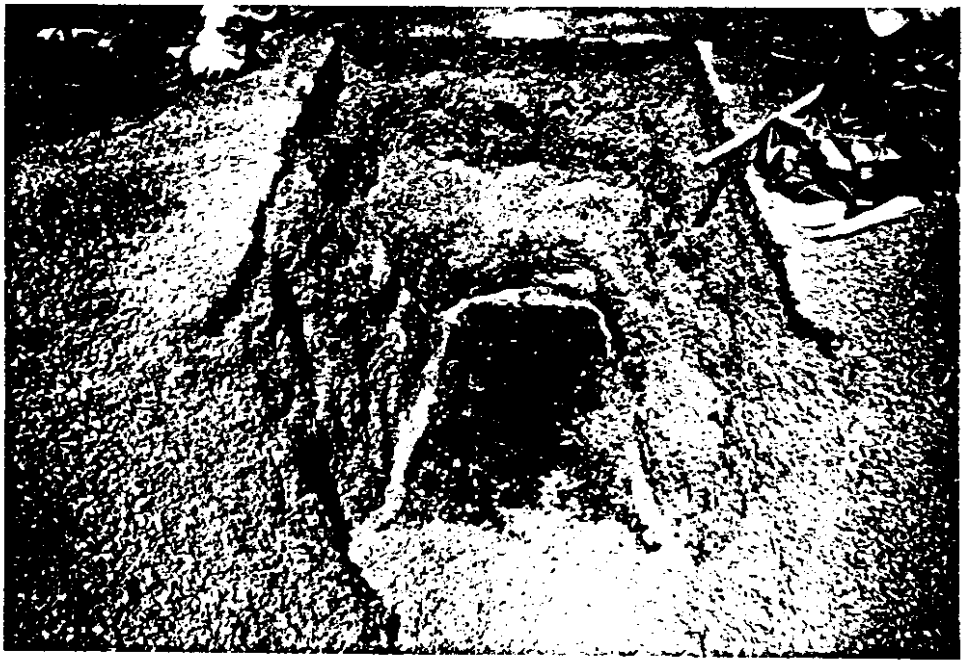


Figure 4.30 - Excavated test pit showing crushed rock below geotextile, Ritzville to Tokio.

Figure 4.31 - Geotextile pulled back to expose crushed rock fill, Ritzville to Tokio.

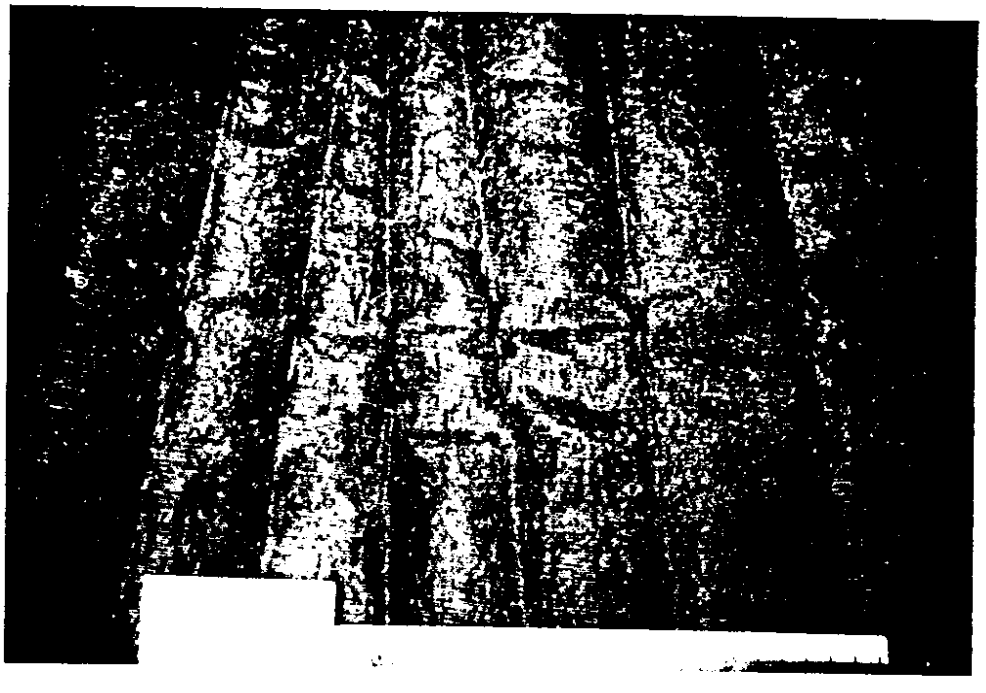


Figure 4.32 - Laboratory photograph of geotextile, Ritzville to Tokio.

4.3.6 SR 20 - Aeneas Valley Rd. to Wauconda Summit

This site is located in the northern portion of Okanogan County (Fig. 4.0). The geology of the site consists of glacial and glaciofluvial sand, gravel and till. The surface geology at the project site where the geotextile was used consisted of slightly gravelly, silty sand.

The roadway was constructed with a geotextile separator in the summer of 1989. It is a two-lane highway with 3-ft .shoulders which was completely reconstructed due to poor performance of the previous roadway. The geotextile consisted of a 4.5-oz/yd^2 woven slit film material, Amoco Propex 2002. The subgrade consisted of wet silty sand and had presented problems with pumping and loss of strength during construction. The unstable sands required approximately 2 ft of over-excavation before they became firm enough to allow construction equipment traffic. Figures 4.33 and 4.34, provided by Mr. Steve Moore of WSDOT, show the placement of geotextile over the subgrade during construction. As shown in these figures, the geotextile was rolled out by hand over a compacted subgrade. Figure 4.33 shows how some areas the subgrade were covered with a thin layer of loose, disturbed material spread around by shovelling. The workers were apparently trying to remove a low berm of soils that had not been compacted by the roller. The survivability rating at this site would be classified as moderate to high.

At the time of our site visit the pavement of the roadway appeared to be in very good condition as shown on Fig. 4.35. Figure 4.36 shows the test pit being excavated with a jack-hammer and shovel.

The geotextile was encountered below approximately 4 in. of CSTC and 13 in. of ballast as shown on Fig. 4.37. The geotextile had been placed directly on top of the subgrade at the test pit location. Figure 4.38 illustrates how occasional gravel at the surface of the subgrade has protruded up through the geotextile. Other than these occasional punctures however, the geotextile was in good condition and did not appear to be clogged. Figure 4.39 shows the amount of damage done to the geotextile specimen during construction. Figure 4.40 shows the same specimen after washing.

Figure 4.33 - Placing geotextile at Station 1131 to 1133 during construction, 6/15/89, Aeneas Valley Road to Wauconda Summit (courtesy S. Moore, WSDOT)

Figure 4.34 - Placing geotextile at Station 1131 to 1133 during construction, 6/15/90, Aeneas Valley Road to Wauconda Summit (courtesy S. Moore, WSDOT)

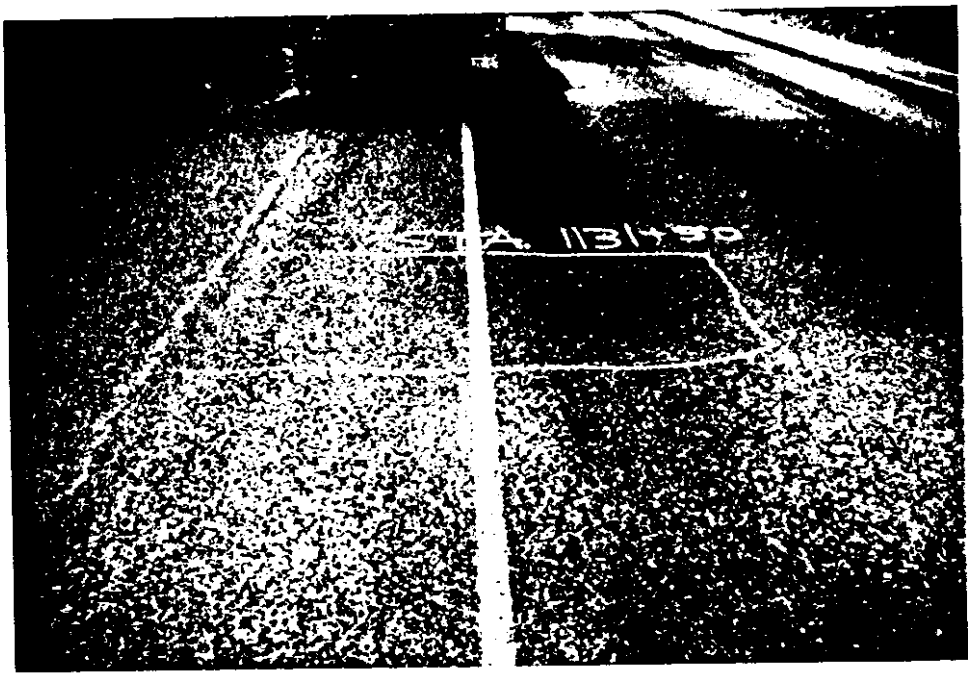


Figure 4.35 - Test pit location and condition of roadway, Aeneas Valley Road to Wauconda Summit

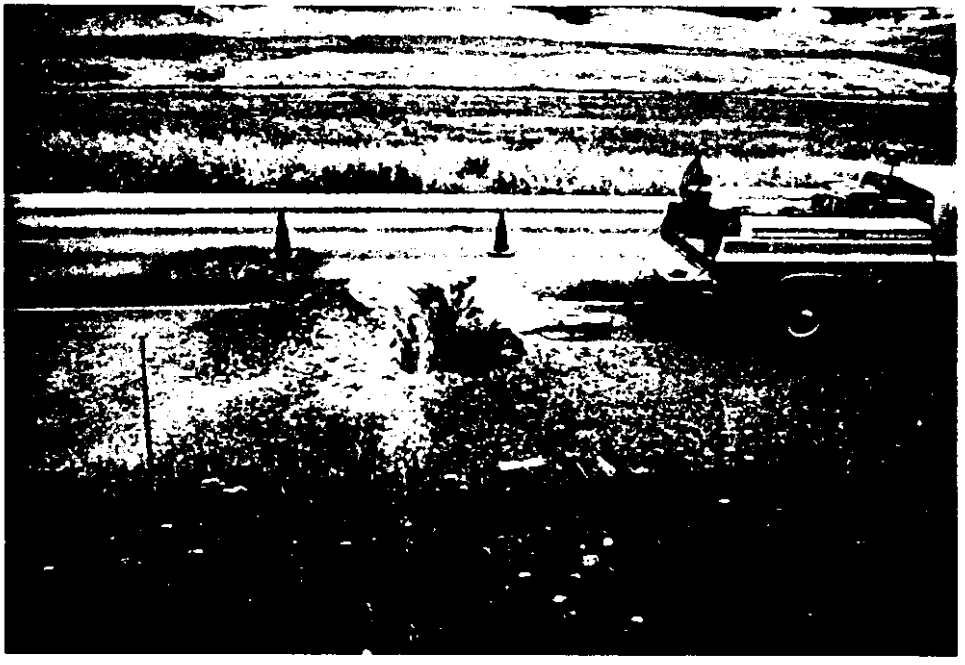


Figure 4.36 - Excavation of test pit, Aeneas Valley Road to Wauconda Summit

Figure 4.37 - Test pit showing depth to geotextile, Aeneas Valley Road to Wauconda Summit.

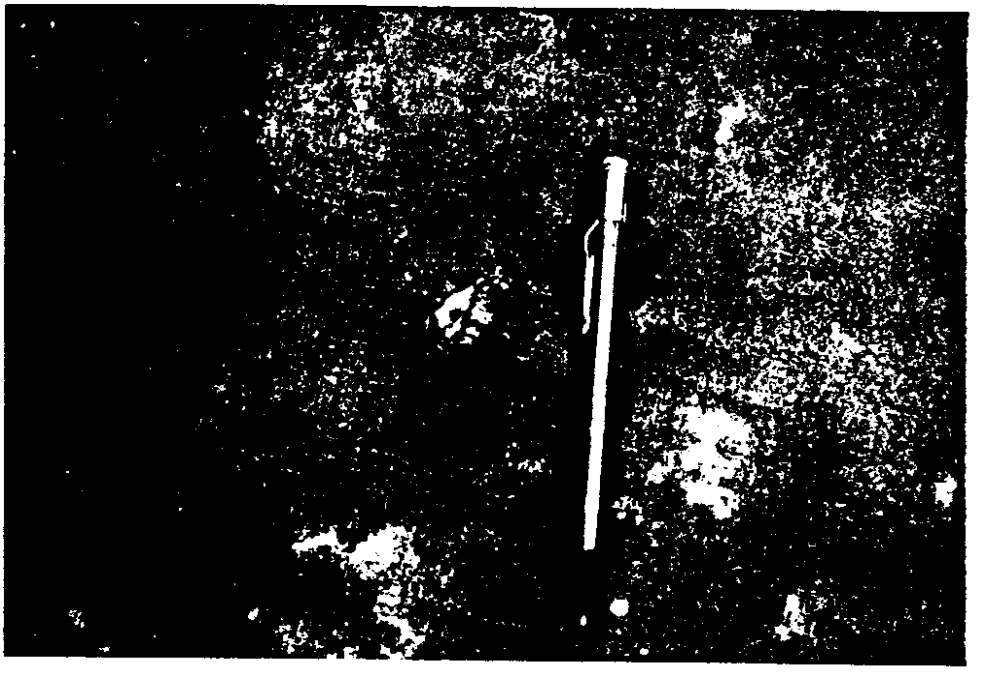


Figure 4.38 - Geotextile with puncture damage, Aeneas Valley Road to Wauconda Summit

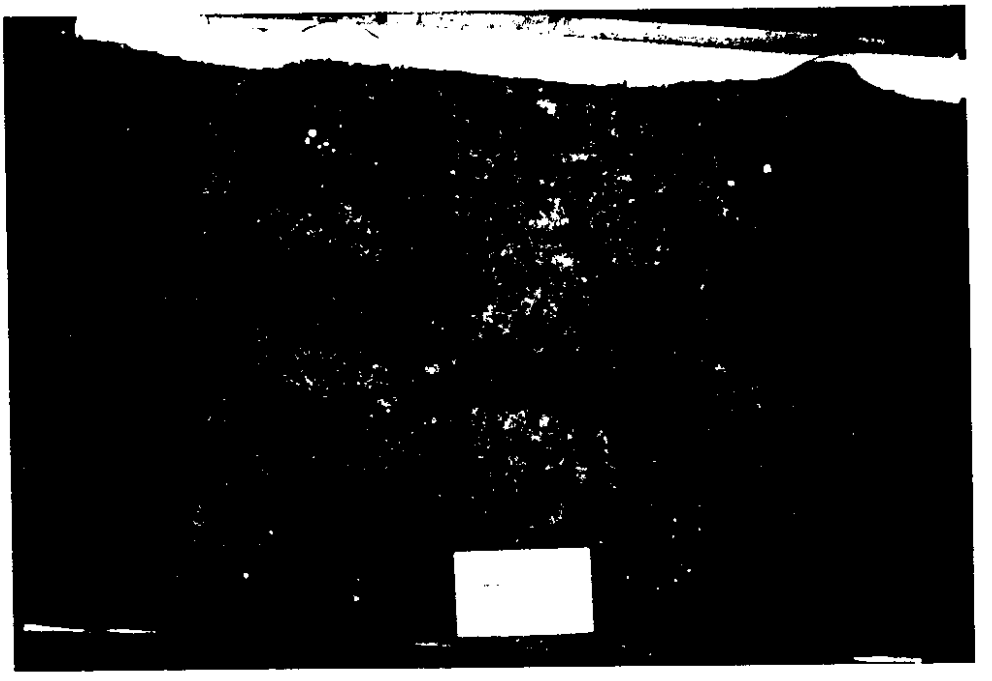


Figure 4.39 - Laboratory photograph of geotextile showing general condition, Aeneas Valley Road to Wauconda Summit.

Figure 4.40 - Laboratory photograph of washed geotextile, Aeneas Valley Road to Wauconda Summit

4.3.7 SR 173 - Rocky Butte to Bridgeport Bar

This site is located in the northern portion of Douglas County approximately 5.5 mi. west of Bridgeport (Fig. 4.0) The geology of this site consists of glacial and glaciofluvial sand, gravel and till. The surface geology at the project site where the geotextile was used consisted of slightly gravelly, silty sand.

The geotextile-included roadway was constructed in the spring of 1986. It is a two-lane highway with 2-ft shoulders. The geotextile consisted of a 4-oz/yd^2 woven slit film material, Mirafi 500X. The subgrade consisted of wet silty sand and had presented problems with pumping and loss of strength during construction. The unstable sands required approximately 3 ft of over-excavation before they became firm enough to allow construction equipment traffic. Figure 4.41 shows the overexcavated subgrade soil which was removed to a depth of about 3 ft during construction. Figure 4.42 shows the geotextile being placed on the subgrade and backfilling with approximately 3 ft of pit-run gravel. The pit-run gravel also contained cobbles up to about 10 in. diameter. Photos were provided by Mr. Steve Moore of WSDOT.

The existing pavement appeared to be in good condition as shown on Fig. 4.43. The test pit was excavated with a jack-hammer and shovel. The geotextile was encountered below approximately 12 in. of ballast and 3 ft of pit-run gravel as shown on Fig. 4.44. The geotextile had been placed directly on top of the silty sand subgrade as shown on Figs. 4.46 and 4.47 The geotextile was in excellent condition with no apparent construction damage or clogging (Figs. 4.45 and 4.48).

The surface of the subgrade was smooth and without sharp stones. Considering the initial lift thickness, this condition would probably receive a moderate survivability rating.

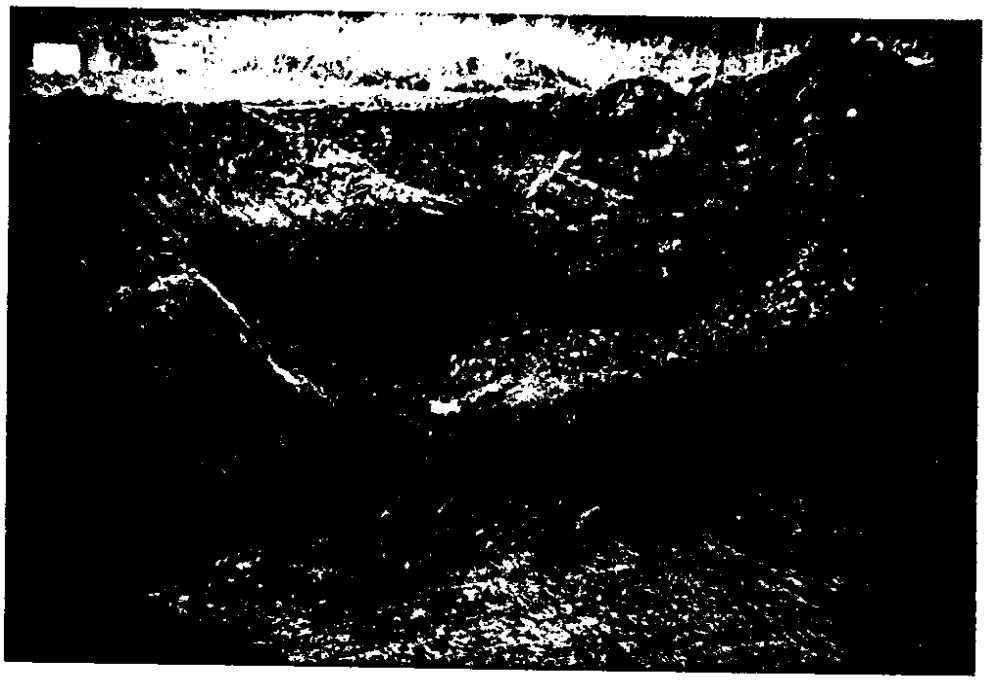


Figure 4.41 - Overexcavated subgrade at Station 444+50, Rocky Butte to Bridgeport Bar (courtesy S. Moore, WSDOT).

Figure 4.42 - Placement of pit-run gravel over geotextile during construction, Rocky Butte to Bridgeport Bar (courtesy S. Moore, WSDOT).

Figure 4.43 - Location of test pit and condition of roadway, Rocky Butte to Bridgeport Bar.

Figure 4.44 - Test pit showing depth to geotextile, Rocky Butte to Bridgeport Bar.

Figure 4.45 - Geotextile in bottom of test pit, Rocky Butte to Bridgeport Bar.

Figure 4.46 - Subgrade below geotextile, Rocky Butte to Bridgeport Bar.

Figure 4.47 - Excavation of subgrade below geotextile, Rocky Butte to Bridgeport Bar.

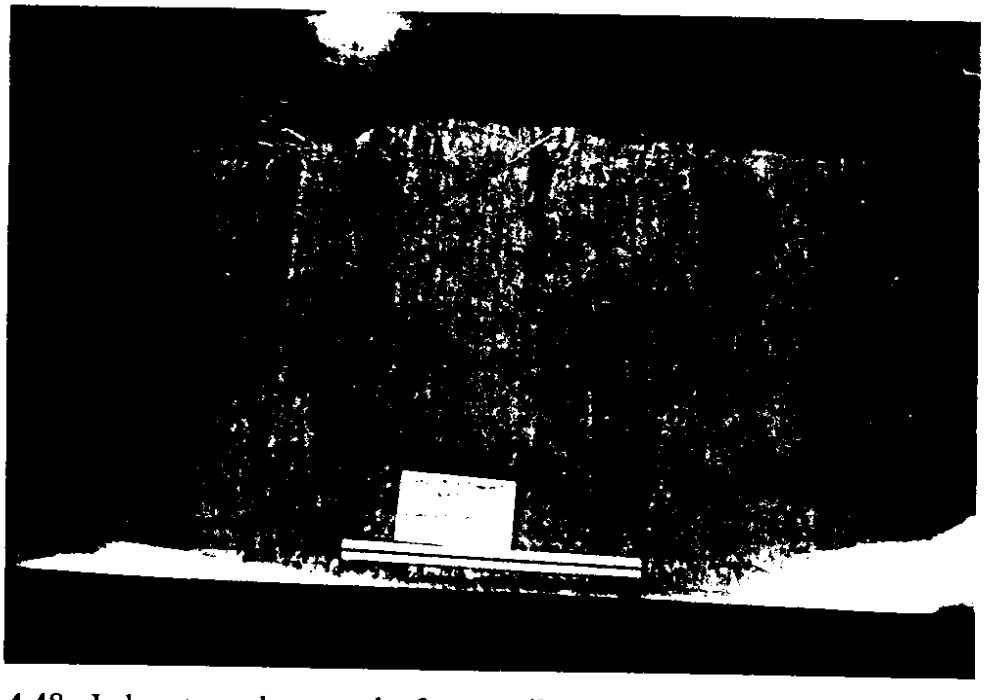


Figure 4.48 - Laboratory photograph of geotextile, Rocky Butte to Bridgeport Bar.

4.3.8 SR 172 - SR2/Farmer to 5 NW Road

This site is located in the center of Douglas County (Fig. 4.0) where the geology consists of eolian silt (loess) overlying extensive basalt flows. At the project location the surface soils consist of sandy silt with occasional gravel. This project involved widening the shoulders in 1989 and the geotextile was used to stabilize soft silts encountered along the shoulder of the existing roadway. A 4 oz/yd^2 woven slit film geotextile separator, Mirafi 500X, was used on this project. The existing pavement appeared to be in good condition at the time of the site visit, as can be seen on Fig. 4.49.

The test pit was excavated with a jack-hammer and shovels, and the geotextile was encountered below 9.5 in. of CSTC. The exposed geotextile appeared to be in good condition with approximately 4 to 5 small holes due to puncture of the material by small stones in the subgrade. No clogging or filtration problems were observed; however, the geotextile did appear to be slightly blinded by silt on the underside. Figs. 4.50, 4.51 and 4.52 show the test pit and the overall condition of the geotextile. Also visible in the upper left-hand corner of Fig. 4.52 is the point where the geotextile began to overlap onto the existing pavement. The geotextile was severely damaged in this area as can be seen in the figure.

Figs. 4.53 and 4.54 show the upper surface of the geotextile as it lies on the subgrade. Figure 4.55 shows the subgrade soil after the geotextile has been removed. Figure 4.56 is a laboratory photo of the geotextile showing the overall good condition.

The survivability rating at this site would be classified as high due to the occasional gravel-size stones in the subgrade and the thin initial lift of base course. The geotextile appears to have survived quite well.

Figure 4.49 - Test pit location and condition of roadway, SR2/Farmer to 5NW Road.

Figure 4.50 - Test pit showing shallow depth to geotextile, SR2/Farmer to 5NW Road.

Figure 4.51 - Test pit and geotextile, SR2/Farmer to 5NW Road.

Figure 4.52 - Uncovered geotextile and overlap section on left, SR2/Farmer to 5NW Road.

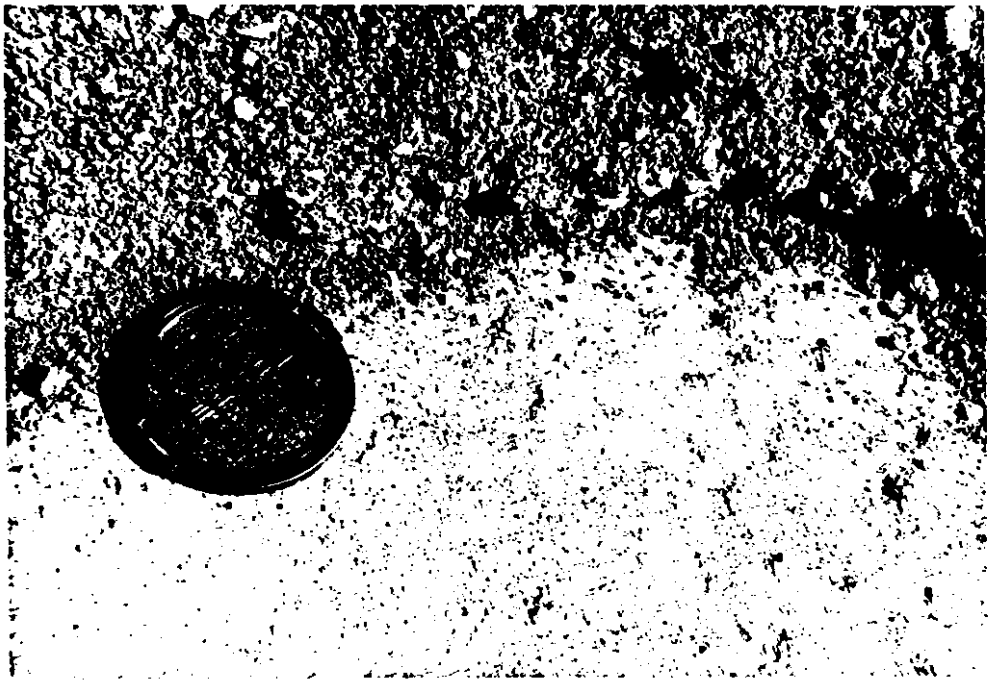


Figure 4.53 - Surface of geotextile, SR2/Farmer to 5NW Road.

Figure 4.54 - Surface of geotextile and basecourse, SR2/Farmer to 5NW Road.

4.55 - Subgrade below geotextile, SR2/Farmer to 5NW Road.

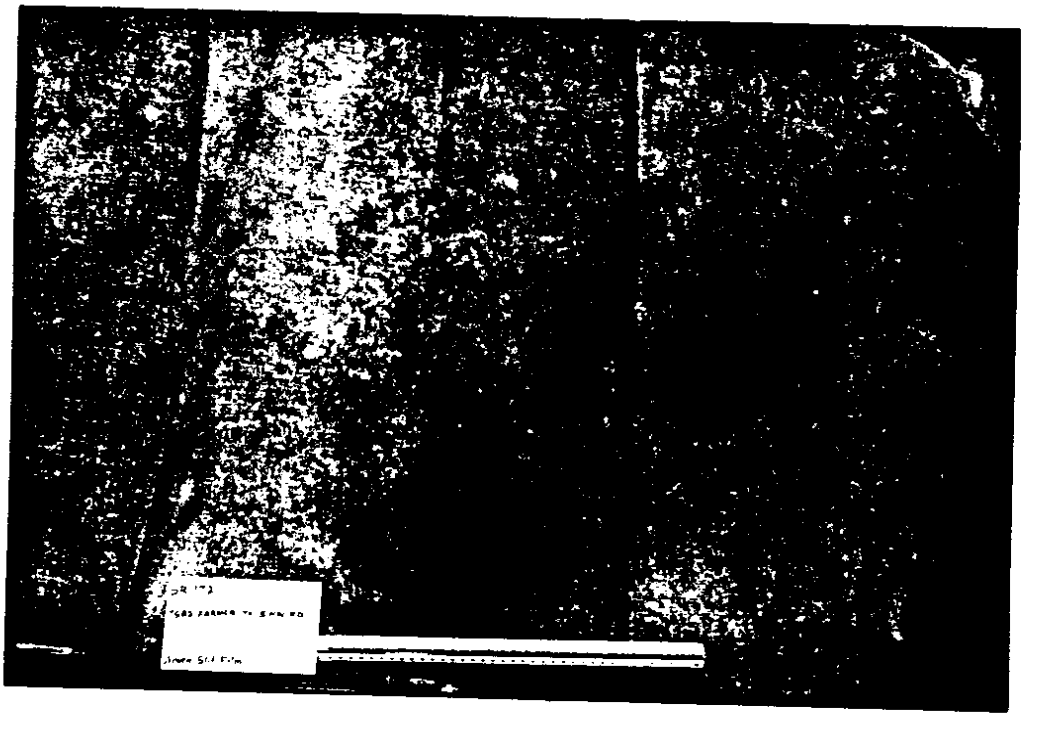


Figure 4.56 - Laboratory photograph of geotextile, SR2/Farmer to 5NW Road.

4.4 Summary of Site Investigations

Visits to nine sites were completed. Out of these nine sites, geotextile separators were encountered at eight of the sites. Of these eight sites, five were considered useful for this study in that the geotextile was placed directly over the soft subgrade soils and had been utilized for its intended purpose. For three sites where the geotextile was not placed directly on the subgrade soils some information regarding construction damage, survivability and retained strength was obtained. A summary of the site conditions observed during site investigations and derived from a review of construction records is presented in Table 4.1.

Of the five sites where the geotextile was placed directly on the subgrade, four utilized woven slit film material with weights of approximately 4 oz/yd^2 and one utilized a non-woven needlepunched material with a unit weight of 5.3 oz/yd^2. At the three sites where fill was found below the geotextile, the geotextile consisted of an 8 oz/yd^2 nonwoven needlepunched, a 3.5 oz/yd^2 nonwoven needlepunched, and a 4 oz/yd^2 woven slit film.

With the exception of the 3.5 oz/yd^2 product at the SR270 to Albion Road site, all the geotextiles have performed well in regards to construction survivability. The 8 oz/yd^2 nonwoven needlepunched geotextile from the Colville Vicinity site survived remarkably well considering the very high survivability conditions under which it was installed. Minor puncture damage was observed in the 5.3 oz/yd^2 nonwoven geotextile from the Albion Rd. to Parvin Rd. site, the 4.5 oz/yd^2 woven geotextile from the Aeneas Valley site, and the 4 oz/yd^2 geotextiles from the Ritzville to Tokio and SR2/Farmer to 5NW Road sites. This minor damage appears to be due to puncture by small stones, which were mixed in with the subgrade. The amount of damage did not appear to have significantly affected the geotextile's performance as a separator. As mentioned previously , the geotextile at the Ritzville to Tokio site was not being properly utilized as a separator since a layer of crushed rock was placed beneath it.

In regards to drainage and filtration, the woven geotextiles exhibited some blinding of the openings between filaments by silt and clay subgrade soils. This was most notable in the geotextile from the Fallon to Palouse site. The nonwoven geotextile from the Albion Rd. to Parvin Rd. site also showed signs of clogging ; however, it appeared that this material was still capable of draining adequately.

Table 4.1 - Summary of Site Conditions

Cont. No.	SR	Site Name	Installation Date	Geo-textile	Subgrade Material	Basecourse Material	Initial Lift Thickness	Geotextile Damage	Geotextile Clogging
3331	395	Colville Vicinity	10/87	8 oz/yd Supac 8NPUV	Sandy Gravel Fill	Crushed Rock Ballast	12-18 in.	None	None
2364	27	Fallon to Palouse	9/83	4 oz/yd Mirafi 500X	Clayey Silt W/ Trace Gravel	Crushed Surfacing Base Course	6 in.	None	Severe
2550	195	SR270 to Albion Rd.	10/83	3.5 oz/yd nonwoven	Crushed Rock Fill	Crushed Rock Ballast	5-6 in.	Severe	Minimal
2990	195	Albion Rd. to Parvin Rd.	9/85	5.3 oz/yd Supac 5NP	Clayey Silt w/ occasional gravel	Crushed Rock Ballast	9 in.	Moderate	Minimal
3503	90	Ritzville to Tokio	7/89	4 oz/yd Mirafi 500X	Crushed Rock Fill	Crushed Surfacing Top Course	6 in.	Minimal	None
3582	20	Aeneas Valley to Wauconda Summit	6/89	4.5 oz/yd Amoco 2002	Silty Sand	Crushed Rock Ballast	13 in.	Moderate	Mimimal
3057	173	Rocky Butte to Bridgeport Bar	4/86	4 oz/yd Mirafi 500X	Silty Sand	Pit-run Gravel	36 in.	None	Mimimal
3369	172	SR2/Farmer to 5NW Road	7/88	4 oz/yd Mirafi 500X	Sandy Silt	Crushed Surfacing Top Course	4 in.	Minimal	Moderate

5.0 LABORATORY TESTS AND FWD ANALYSIS

5.1 Introduction

The purpose of the laboratory testing program was to provide information on the residual or retained engineering properties of the geotextiles in order to evaluate the affects, if any, that the installation process and subsequent roadway use had on the material. The falling weight deflectometer analysis was conducted to provide information on roadway performance which could be correlated to the presence or absence of the geotextile separator. The objective of the testing and analysis was to provide supplemental data to support field observations and to help evaluate the overall performance of geotextile separators.

A study of the migration of fines (soil particles passing the No. 200 sieve) into the base course aggregate immediately above the geotextile separator was conducted by performing grain-size distribution analyses on samples collected from the test pits.

In order to investigate the effect, if any, of subgrade clogging of the geotextile, a permittivity measuring apparatus was constructed. The device, also called a permeameter, is capable of measuring permittivity by the falling head or constant head methods. The permittivities of all the geotextile specimens, except for the severely damaged specimen from the SR270 to Albion Road site, were determined to evaluate the amount of clogging experienced by the material during installation and subsequent use. As a means of calibrating the permittivity apparatus, a control specimen of nonwoven needlepunched geotextile was tested with our laboratory apparatus and the results compared to results obtained with a falling head permeameter located at the WSDOT materials laboratory.

An index strength analysis was also completed on the geotextile specimens to compare the original material strength to the strength after installation and usage. These tests were conducted at the WSDOT Materials Laboratory in Tumwater, Washington. The geotextile specimen from the SR270 to Albion Road site was not included in this analysis.

The results of laboratory tests are presented in the Summary of Test Results, Section 5.3.

5.2 Discussion of Test Methods

The test methods for the determination of grain size distribution and index strength of the geotextiles was, for the most part, conducted in accordance with ASTM and/or WSDOT standard methods. The determination of permittivity was conducted with an apparatus which meets ASTM D 4491 standards; however, the design of the apparatus is considerably simpler than that presented in ASTM D 4491. The apparatus used is considered to be reasonably accurate and, more importantly, practicable for this investigation given the time and budgetary constraints.

5.2.1 Grain Size Distributions

In general, grain-size distribution testing was based on the standard test method ASTM D422. The purpose of this analysis was to evaluate the migration of fines, if any, from the subgrade soils through the geotextile separator, and into the basecourse aggregate. To provide more meaningful data upon which to judge the migration of fines, the analyses were conducted on the fraction of bulk sample which was finer than the 3/4-in. sieve. This was thought to improve the accuracy of the test results since many of the base course aggregates contained large gravel sized crushed rock particles. This was the only deviation from ASTM D422 standard methods. In the process of determining the grain-size distribution, the water content of the samples was also determined in accordance with ASTM D2216.

5.2.2 Permittivity Testing

The permittivity tests consisted of a constant head, unconfined flow test through a single geotextile layer. The principle of the test method is based on ASTM D 4491 and WSDOT Test Method No. 924; however, the apparatus, shown on Fig. 5.1, differed significantly from that used by WSDOT and suggested in ASTM D 4491. The apparatus was designed and constructed based on the "STS geotextile permeameter" design, Christopher (1983).

All reported permeabilities were evaluated with the constant head method. Due to the relatively high permeability of most geotextiles, the rate of flow through the specimen

and, consequently, the rate of head drop in the apparatus was too fast for accurate measurement with the eye and stopwatch system used. In addition, many of the geotextiles were slightly clogged or blinded by soil particles which made the use of a low head and constant flow desirable so as not to cause excessive washing of the geotextile during the test.

We understand that a falling head permeameter with an electronic measuring system is in use at the WSDOT Materials Laboratory; however, this was not available for this project. This system is more suitable for measuring permeabilities of clean geotextiles where flow rates are high and accuracy is important since this test is used as a basis for geotextile acceptance for roadway applications.

The test is performed by placing a sample of geotextile in the permeameter device (Fig. 5.1) and flowing deaired water through it under a constant hydraulic gradient. The testing procedure is presented in Appendix A of this report.

The permittivity is calculated by dividing the flow rate by the area of the specimen and the constant hydraulic head as follows:

$$\Psi = QR_t / hAT \qquad \text{(Eq. 1)}$$

where:

Ψ = permittivity, sec^{-1}

h = constant head of water on the specimen, in.

T = time for flow(Q), sec

A = cross-sectional area of test specimen, $in.^2$

Q = quantity of flow determined using Eq. 2, $in.^3$

R_t = temperature correction factor determined using Eq. 3

$$Q = D(a_1 - a_2) \qquad \text{(Eq. 2)}$$

where:

D = drop in water level in permeameter, in.

a_1 = inside area of standpipe, $in.^2$

a_2 = outside area of air supply tube within standpipe, $in.^2$

$$R_t = u_t / u_{20} \qquad \text{(Eq. 3)}$$

where:

u_t = water viscosity at test temperature, millipoise

u_{20} = water viscosity at 20°C, millipoise

Typical correction factors for R_t are: $R_t = 0.9761$ at 21°C and $R_t = 0.9513$ at 22°C.

The permeability of the geotextile is calculated by multiplying the permittivity by the thickness of the geotextile. The thickness is determined according to ASTM D-1777.

The time for the water level to drop, T, (Eq. 1) and the drop in the water level, D, (Eq. 2) are the two variables which are measured during the test.. All other variables in equations 1 through 3 are constant (temperature is generally constant during the test). The time for the water level to drop is independent of the actual distance the water level drops. That is to say, the time on the stopwatch is stopped at an arbitrary point after the water level is allowed to fall a distance of about 1 in. to 3 in., depending on the type of geotextile used and the rate of drop. Due to the turbulence created in the standpipe above the geotextile specimen by rising air bubbles, it is not possible to control the distance of the drop by more than about 1/2-in.

Error is introduced into the measurement of water level before and after the drop. This measurement is done by sighting across the meniscus at the top of the water column and aligning it with the increments on the ruler. After a thumb is placed over the air supply tube small air bubbles may continue to rise through the water column from the submerged end of the tube. This factor, plus inaccuracies associated with reading the water level by eye contribute to an error of approximately ± 1/16-in.. This fluctuation amounts to approximately ± 3 percent of the calculated permittivity value for a typical calculation.

It is possible that the geometry of the test apparatus may affect the results obtained. To reduce this as much as possible the tests were performed with a constant 2-in. head to achieve laminar flow and with deaired water according to ASTM 4491. Deaired water was obtained by applying a vacuum pump to a vessel of water and maintaining a pressure of approximately -13 psi (-29 in. Hg) for a period of 24 hours. The diameter and wall

thickness of the small air supply tube may also have some affect on the results, through its effect on the size of the air bubbles which emerge from its lower end during the test. The air bubbles displace some water in the standpipe as they rise and also contribute to aeration of the water in the apparatus which may have an effect on the passage of water through the geotextile specimen. Boundary conditions, such as compression of the geotextile specimen around the circumference by the screw-down clamp (Fig. 5.1), may also affect the results.

A test of the apparatus was conducted which involved performing the permittivity test procedures without any geotextile sample in the apparatus. The purpose of this test was to evaluate the effect, if any, that the apparatus may have on the resulting permittivity values. The values obtained for permittivity in these tests ranged from 2.72 sec^{-1} to 2.96 sec^{-1}. Typical values of permittivity for the geotextiles tested ranged from about 0.01 sec^{-1} to 1.4 sec^{-1}, although a control sample of nonwoven needlepunched geotextile, TS600, had a measured permeability of 1.3 to 1.4 sec^{-1}. The results of the apparatus test indicate that, because the permittivity of the geotextiles is significantly lower than that of the apparatus, the geotextile properties will control the test results rather than the apparatus controlling the results.

As a means of checking the accuracy of the test apparatus, the permittivity obtained with the University of Washington (UW) apparatus for a control specimen of nonwoven needlepunched geotextile were compared to permittivity values obtained for the same control specimen at the WSDOT Materials Laboratory using equipment which is similar to that presented in ASTM D4491. The results of this comparison are presented in section 5.3.2 of this report.

It is important to note that the purpose of the permittivity analysis is not to determine the exact value of permittivity or permeability of the geotextile specimens for compliance testing but rather to determine the permittivity of clogged geotextile specimens and to compare the results obtained before and after washing. The objective of this is to be able to evaluate the degree of clogging of the geotextile.

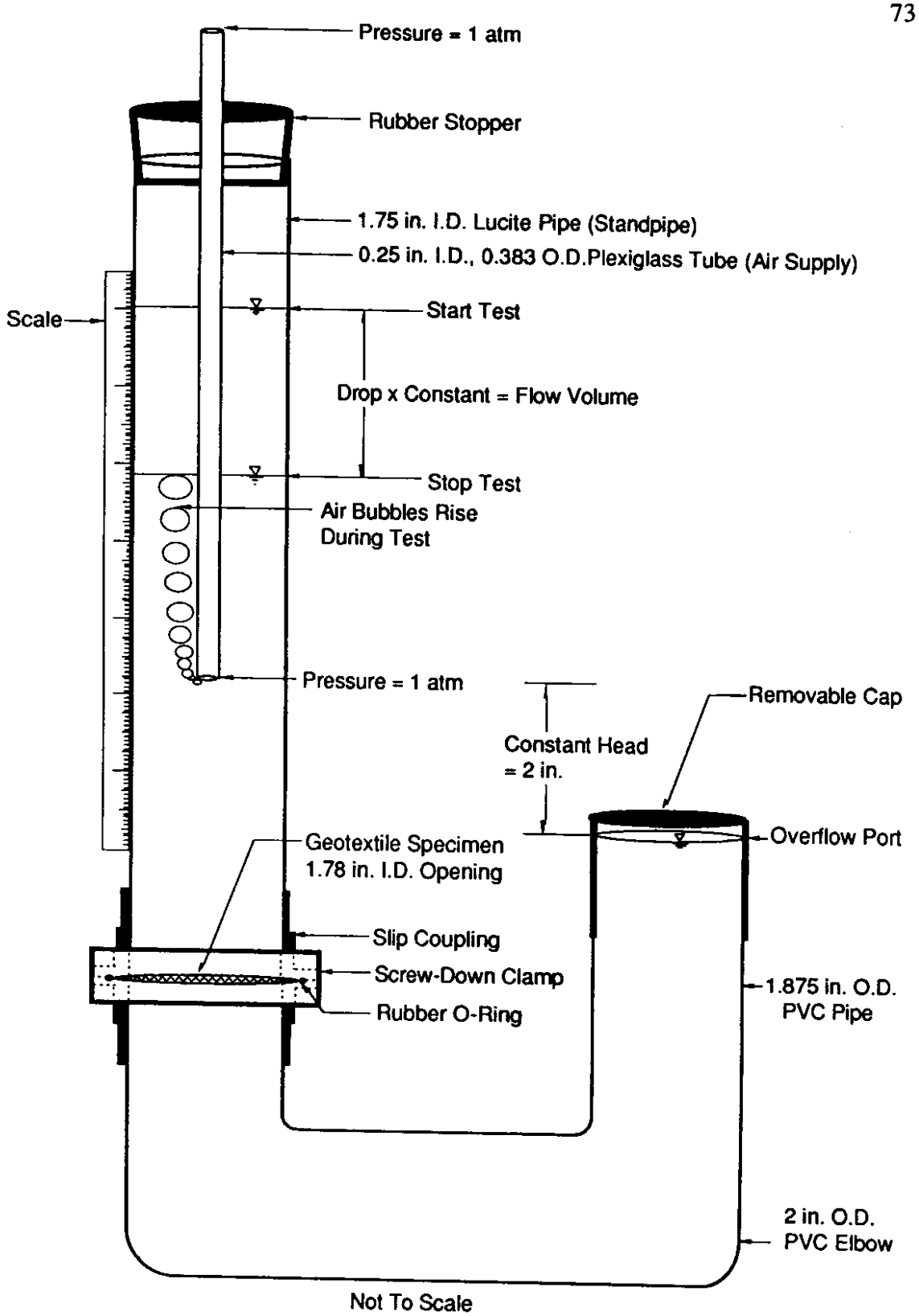


Figure 5.1 - Geotextile Permeameter; Adapted from Christopher (1983)

5.2.3 Index Strength Tests

Index strength tests consisting of grab tensile, trapezoidal tear, Mullen burst and puncture were conducted on all specimens except the severely damaged material from the SR270 to Albion Road site. All testing was carried out at the WSDOT Materials Laboratory by WSDOT personnel. In this way, consistency of the test methods and procedures was ensured. This is considered important for this study because several of the geotextiles had been tested by WSDOT for compliance with strength and permeability property requirements prior to being used at the various project sites, and a comparison of before and after strength and permeability properties was thus possible.

As discussed in Section 2.2.2, the WSDOT methods for index strength testing are based on the appropriate ASTM standard methods. WSDOT methods differ from ASTM only slightly in that the lot sampling requirements have been reduced, laboratory sampling size has been increased to provide greater sample area for cutting out specimens and the specimens for grab tensile testing are preconditioned at a slightly different relative humidity.

5.2.4 Falling Weight Deflectometer Test

The falling weight deflectometer (FWD) is a trailer-mounted piece of equipment which can deliver an impulse load of 1,500 lb to 24,000 lb to a pavement. The impulse is essentially a half sine curve with a duration of 25 to 30 ms. The load is transmitted to the pavement through a 12 in. diameter loading plate which rests on a thick rubber pad in contact with the pavement surface. In principle, the force applied to the pavement is dependent on the mass of the drop-weights used, the height of the drop, and the spring constants of the rubber pad as well as that of the pavement structure. In practice, however, only the mass of the load relayed to the pavement is measured by the load cell located just above the loading plate.

The deflection basin is obtained by monitoring the deflection at seven locations on the pavement surface using velocity transducers. One of these is located in an opening in the center of the loading plate. In the tests conducted for this study the height of drop and weight were adjusted to produce a load level of 9,000 lb with the exact magnitude being registered with one load cell.

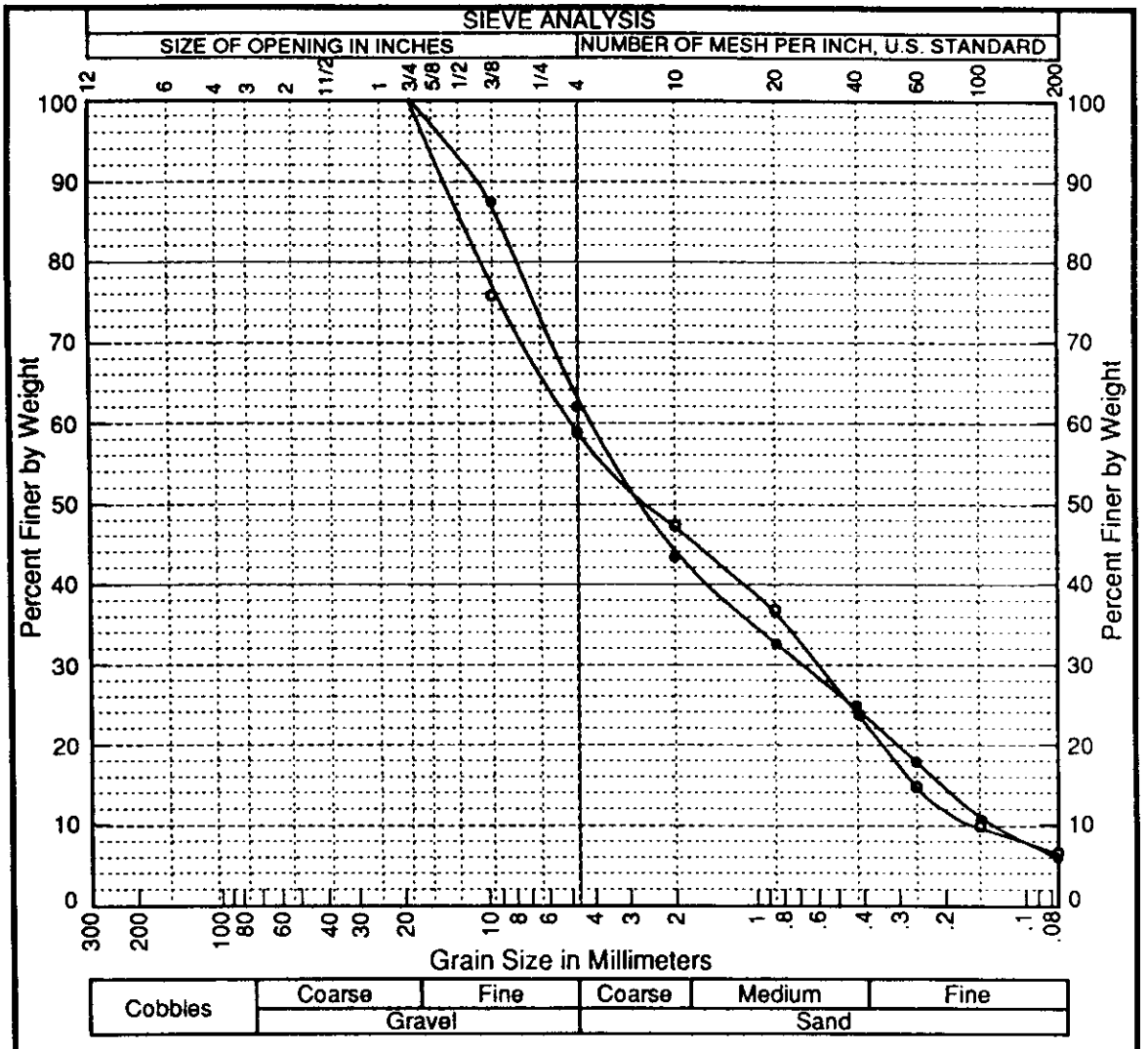
5.3 Summary of Test Results

5.3.1 Grain Size Distributions

Grain-size distribution curves are presented in Fig. 5.2 through Fig. 5.9. Curve sets comparing gradation of aggregate samples from different elevations above the geotextile are presented in Fig. 5.3 through Fig. 5.7 and Fig. 5.9. Fig. 5.2 and Fig. 5.8 present grain size distributions for subgrade and basecourse material at the Colville Vicinity site and the Rocky Butte to Bridgeport Bar site. No grain-size distributions of basecourse material obtained from different elevations above the geotextile were accomplished due to the presence of fill below the geotextile at the Colville Vicinity site (Fig. 5.2) and the presence of cobble-sized pit-run gravel at the Rocky Butte site (Fig. 5.8). The results of the grain-size distribution tests on basecourse material from the other sites (Fig. 5.3 through Fig. 5.7 and Fig.5.9) generally show a slightly higher (0.1 percent to 4 percent) fines content in the basecourse material from 0 in. to 4 in. above the geotextile as compared to the fines content from higher up. The increase in the fines content is equal to the difference between the percent fines content in the lower material and that from the higher up material.

As discussed in Section 4.3, a second site visit was made to the Fallon to Palouse project site and no geotextile was encountered in the test pit at milepost 14.00. A sample of the basecourse was obtained in this test pit from 0 in. to 3 in. above the contact with the subgrade. Figure 5.3 shows that the amount of fines in the basecourse aggregate from 0 in. to 3 in. above the subgrade at the milepost 14.00 test pit, was 11.5 percent. The same type of basecourse aggregate collected from 0 in. to 4 in. above a geotextile in the test pit at milepost 11.35 of this project contained approximately 5 percent to 8 percent fines content It appears therefore, that the presence of the geotextile separator may have resulted in a lower amount of fines in the basecourse aggregate at milepost 11.35. This assumes that the increased amount of fines at the milepost 14.00 site was a result of subgrade pumping or some other form of fines migration from the subgrade and not a result of variability of the basecourse aggregate itself or aggregate crushing during placement which would also increase the fines fraction.

The small amount of fines increases in the first lift above the geotextile as compared to higher up lifts are relatively small and cannot be attributed to upward migration of fines from the subgrade.

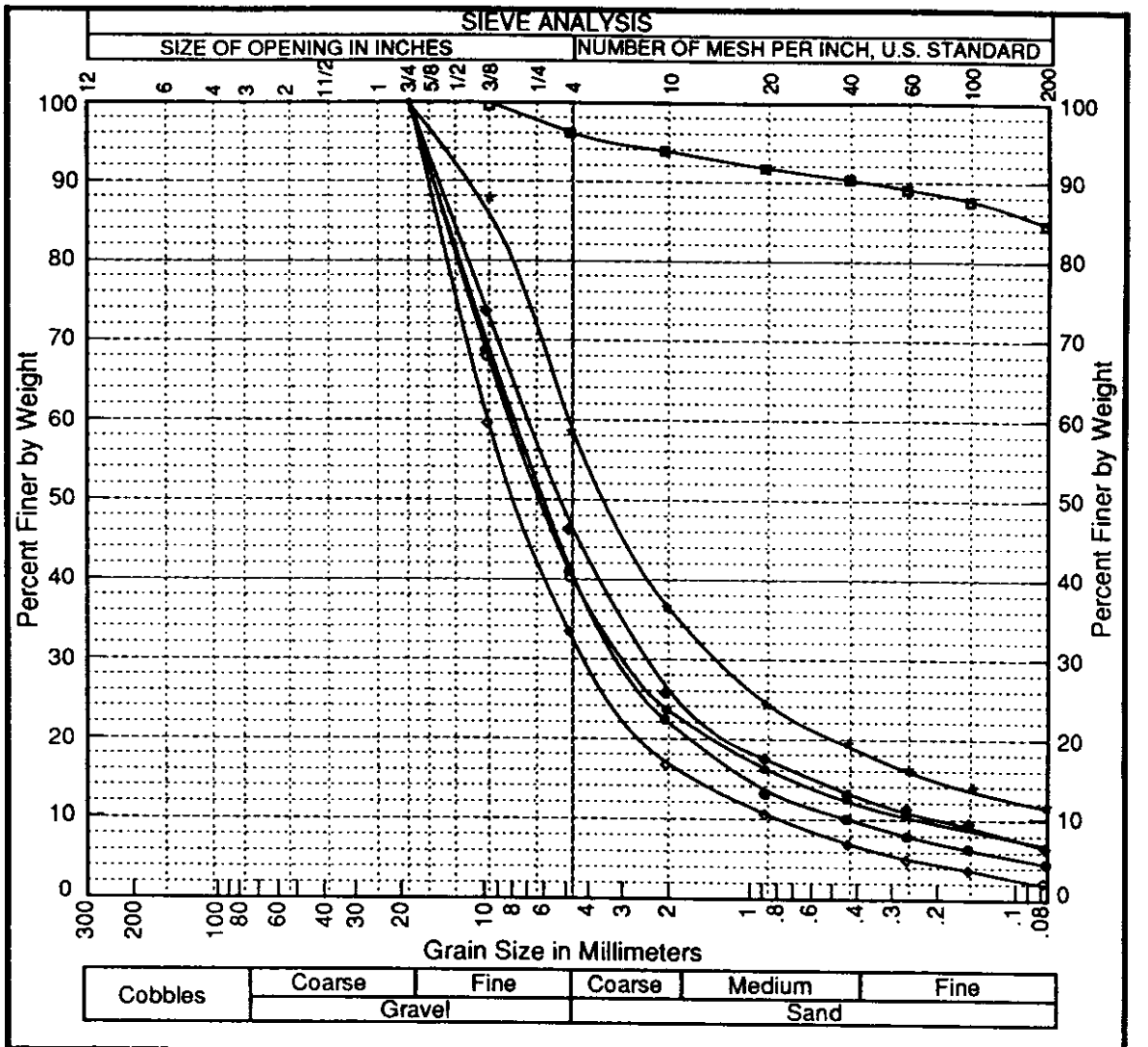


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
●	1	Base course from 0 to 5 in. above geotextile	Very dense, light gray, brown and white, slightly silty, gravelly sand; moist (1/2 in. minus, angular, crushed rock, mostly quartz)	6.2	3.2
○	2	Fill below geotextile	Dense, brown, slightly silty, sandy gravel; moist, (pit run gravel up to ~5 in. diameter)	6.7	3.0

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).
2. Additional grain size analyses not performed since geotextile was not placed directly on subgrade at this site.

Figure 5.2 - Grain Size Distribution for Colville Vicinity, SR395, C3331

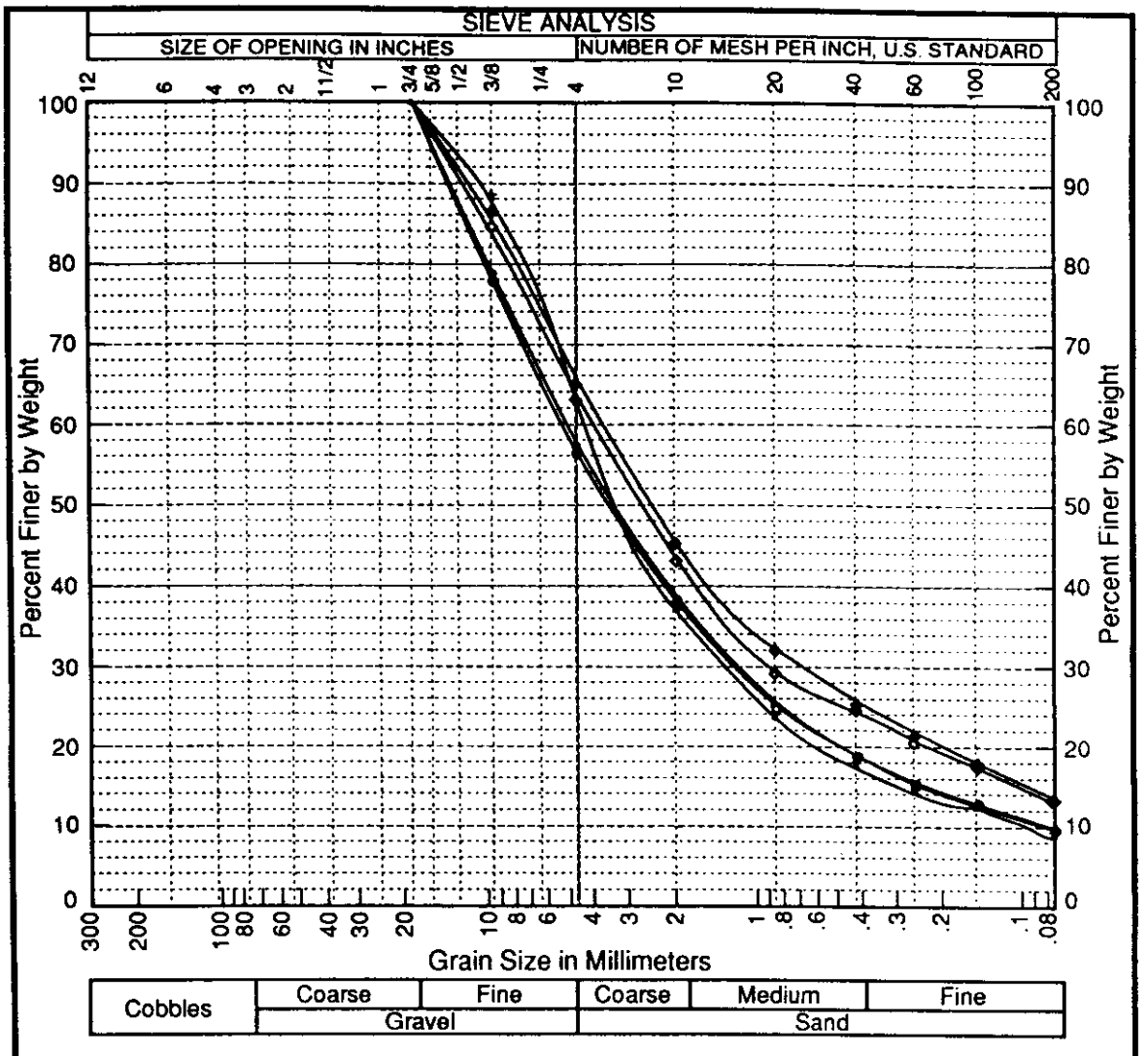


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
●	1	Crushed Surfacing Base Course From 0 - 4 in. above geotextile	Very dense, gray, slightly silty, sandy gravel; moist (angular, vesicular, crushed basalt)	4.9	7.9
⊖	2	" "	" "	7.8	7.9
◇	3	Crushed Surfacing Base Course From 4 - 8 in. above geotextile	" "	2.5	7.4
◆	4	" "	" "	7.6	7.4
*	5	Crushed Surf. Base Course 0-3 in. above subgrade, MP 14+00	" "	11.5	6.6
◘	6	Subgrade from 0-2 in. below geotextile	Hard, dark gray, slightly sandy, clayey silt; moist, trace of gravel, organic odor	84.6	19.9

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).
2. Sample No. 5 taken from test pit at MP 14 +00 during second site visit, no geotextile found.

Figure 5.3 - Grain Size Distribution for Fallon To Palouse, SR27, C2364

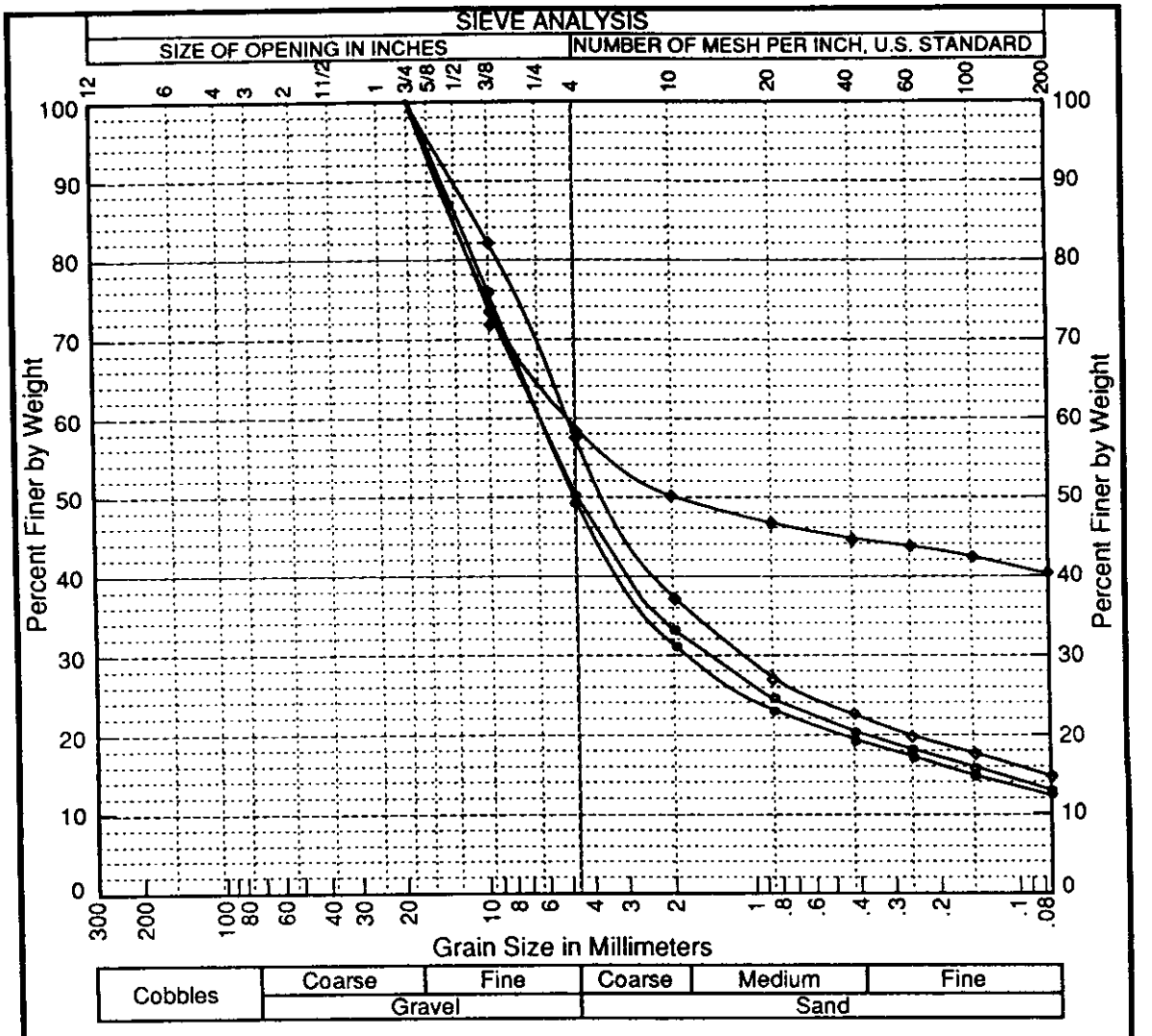


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
●	1	Ballast from 10 - 14 in. above geotextile	Very dense, gray, slightly silty, sandy gravel; moist (angular, vesicular, 1.5 in. minus, crushed basalt)	9.5	5.2
●	2	" "	" "	9.5	5.2
◇	3	Ballast from first 5-in. lift above geotextile	Very dense, gray, silty, sandy gravel; moist (angular, vesicular, 1.5 in. minus, crushed basalt)	13.4	6.8
◆	4	" "	" "	13.1	6.8
*	5	Cr. rock below geotextile	Very dense, gray, slightly silty, sandy gravel; moist (angular, vesicular, 1.5 in. minus, crushed basalt)	8.7	8.6

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).

Figure 5.4 - Grain Size Distribution for SR270 To Albion Road, SR195, C2550

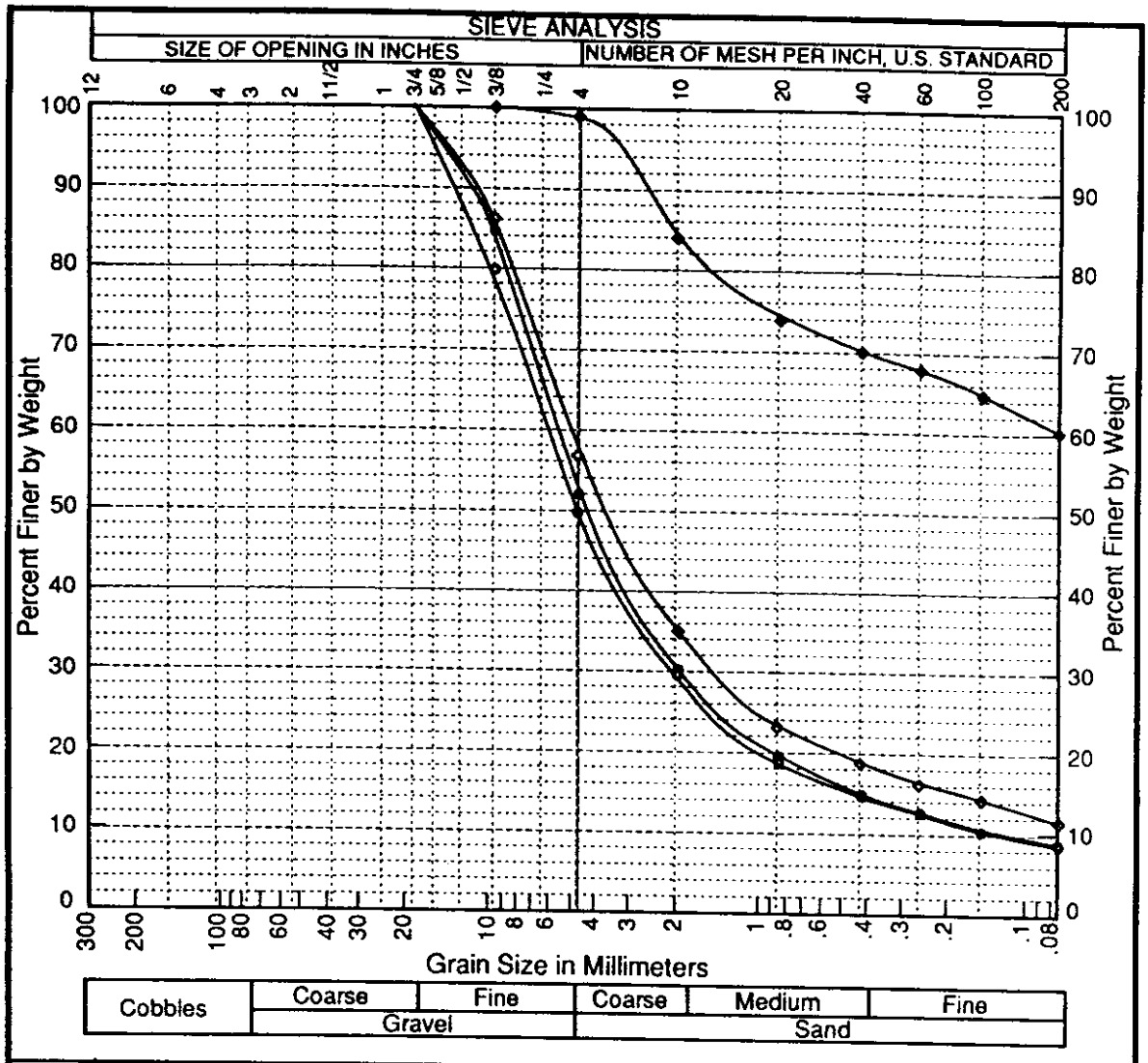


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	W %
●	1	Ballast From 2 - 6 in. above geotextile	Very dense, gray and brown, silty, sandy gravel; moist (angular, 1.5 in. minus, crusher-run basalt)	12.4	6.0
○	2	" "	" "	12.9	6.0
◇	3	Ballast From 0 - 1 in. above geotextile	" "	14.9	7.5
◆	4	Subgrade from 0 - 3 in. below geotextile	Hard, dark gray, sandy, clayey silt; moist, occasional gravel and asphalt chunks	40.6	14.6

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).

Figure 5.5 - Grain Size Distribution for Albion Road To Parvin Road, SR195, C2990

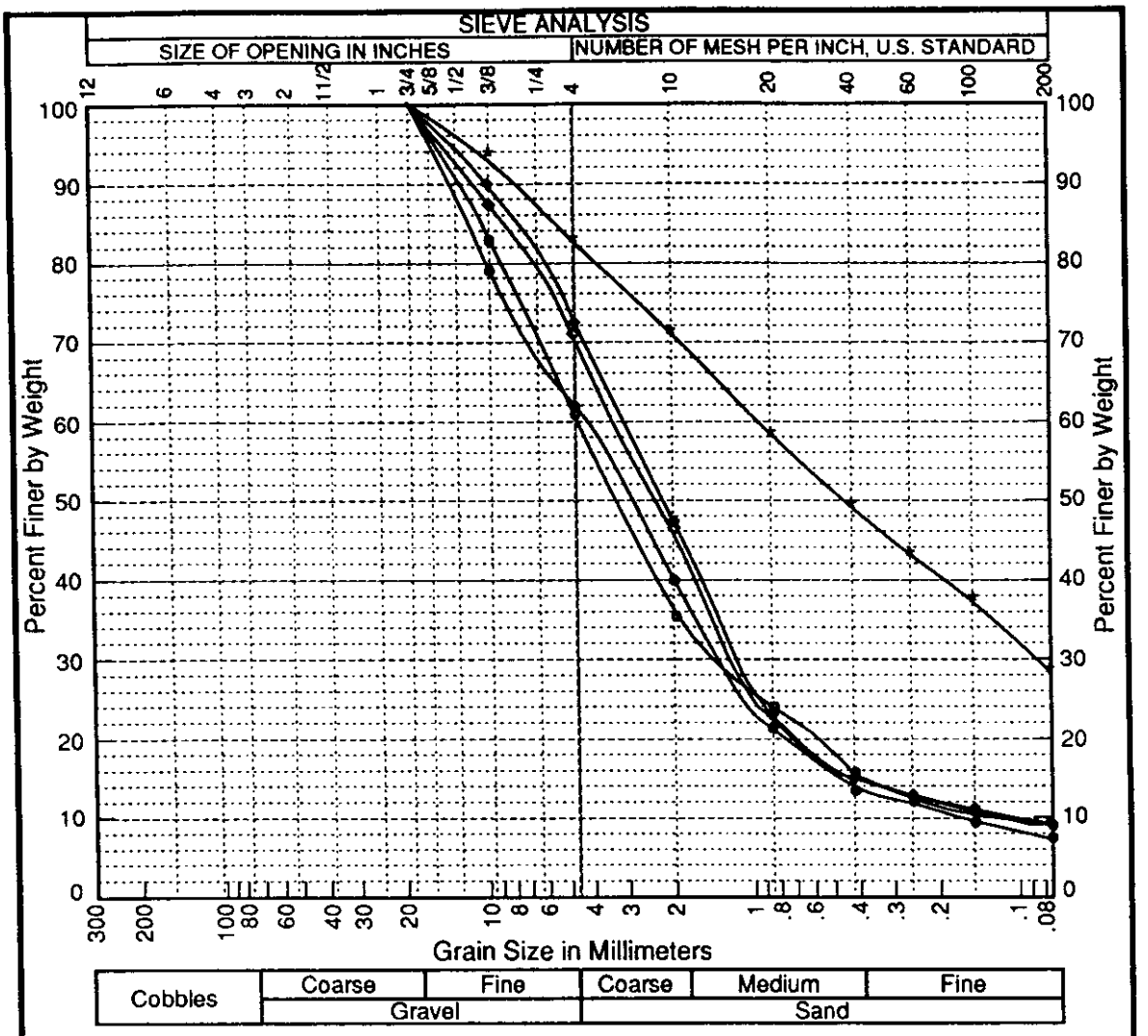


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
●	1	Crushed Surf. Top Course, 0 -1 in. above geotextile	Very dense, gray, slightly silty, sandy gravel; dry (angular, 1 in. minus, crusher-run basalt)	8.7	1.2
○	2	Crushed Surf. Top Course, 17 in. above geotextile	" " "	8.6	1.5
◇	3	Crushed Rock below geotextile	" " "	11.8	1.6
◆	4	Subgrade below crushed rock, 7 in. below geotextile	Hard, brown, sandy, clayey silt; moist	60.5	13.7

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).

Figure 5.6 - Grain Size Distribution for Ritzville To Tokio And Weigh Stations, SR90, C3503

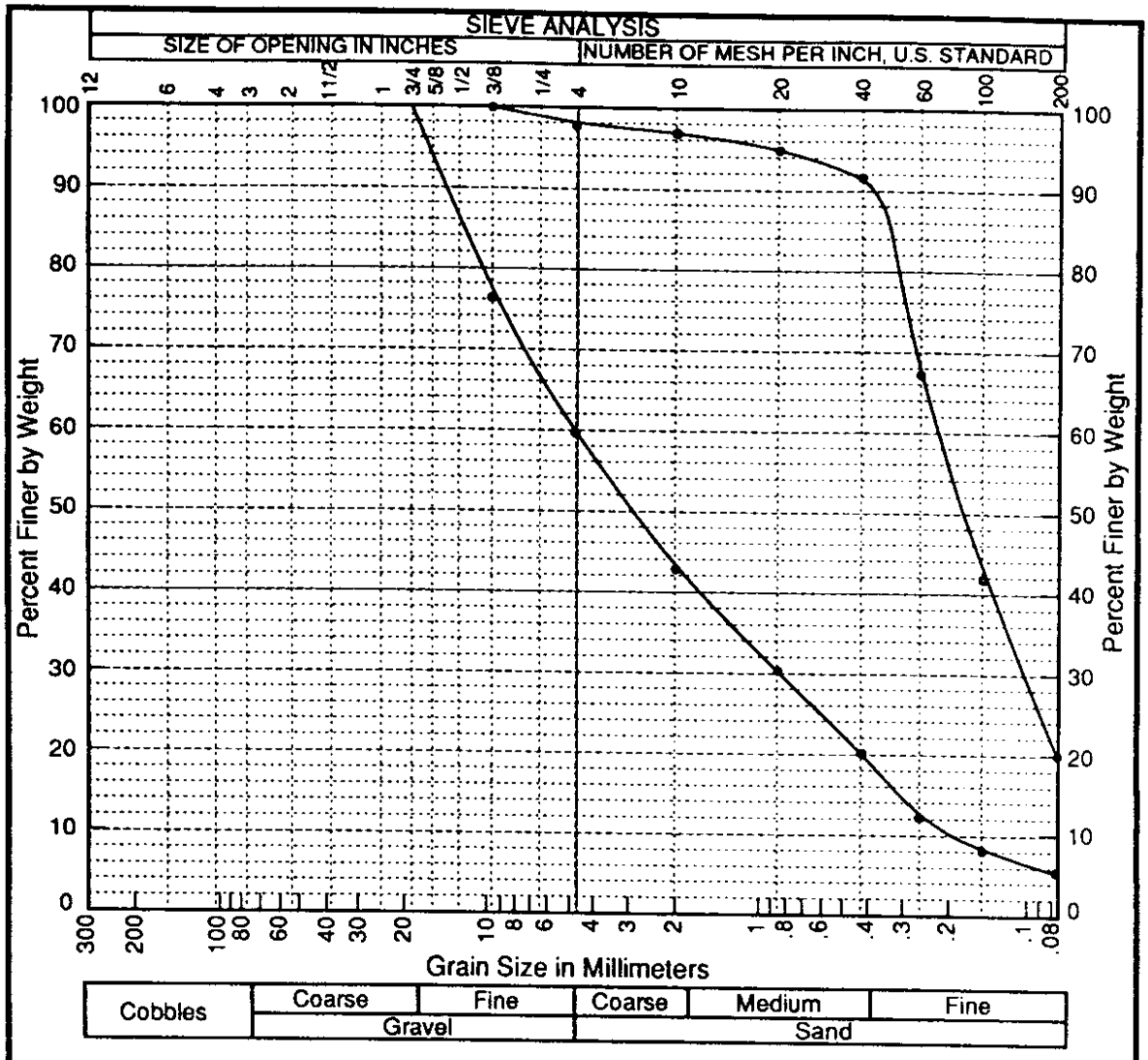


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
●	1	Ballast 3 -6 in. above geotextile	Very dense, brown, slightly silty, gravelly sand; dry (rounded, 1-1/2 in. minus)	7.7	3.8
○	2	Ballast 3 -6 in. above geotextile	" "	8.7	3.8
◇	3	Ballast 0 -2 in. above geotextile	" "	9.1	4.8
◆	4	Ballast 0 -2 in. above geotextile	" "	9.1	4.8
*	5	Subgrade below geotextile	Dense, brown, slightly gravelly, silty sand; moist	29.2	7.6

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).

Figure 5.7 - Grain Size Distribution for Aeneas Valley Road To Wauconda Summit, SR20, C3582

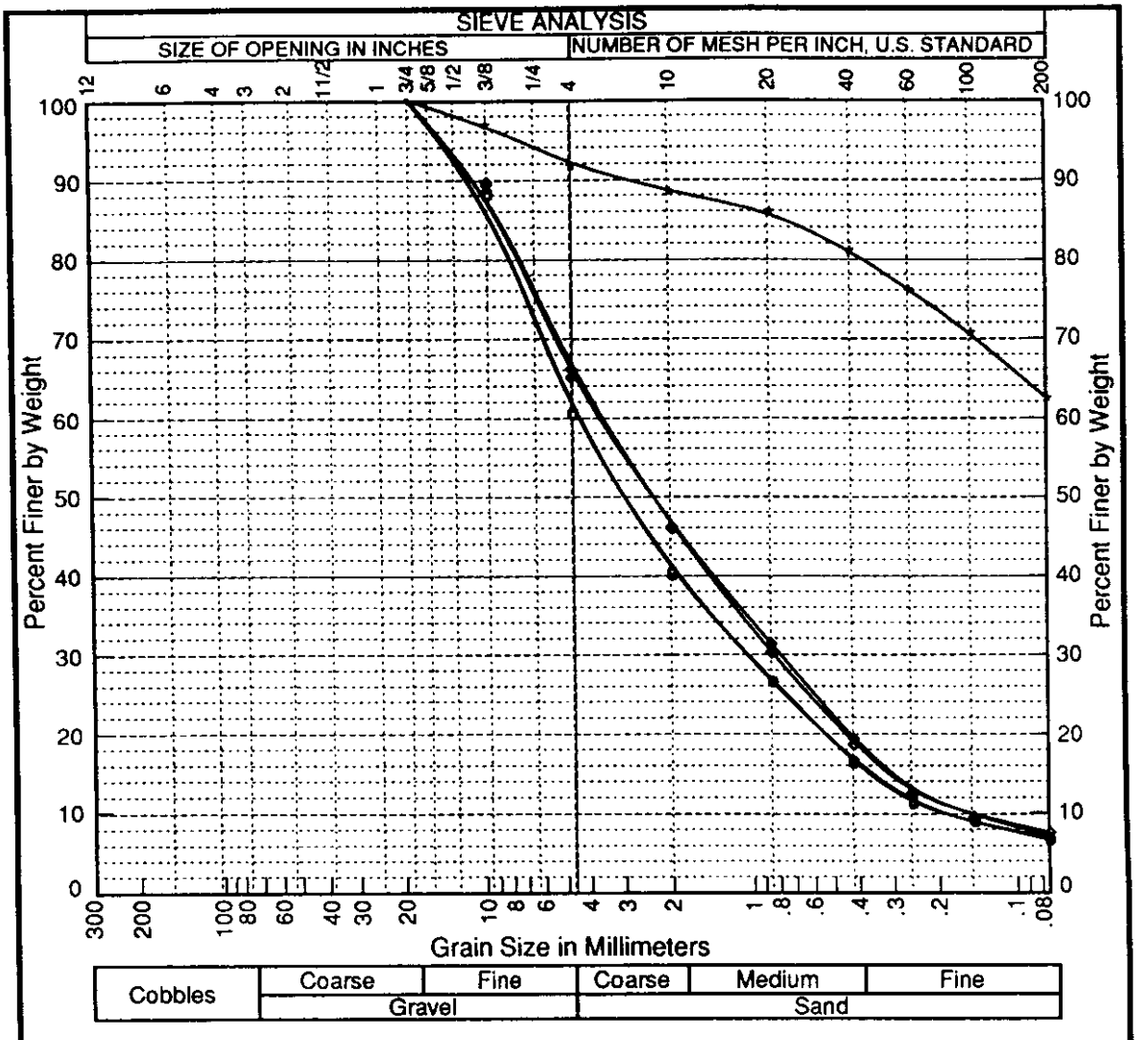


Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
•	1	Ballast from 0 - 3 in. above geotextile	Very dense, brown, slightly silty, sandy gravel; dry, cobbles up to 5-in. diameter (pit-run gravel)	5.8	3.3
•	2	Subgrade below geotextile	Dense, brown, slightly gravelly, silty sand; moist	19.8	6.2

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).

Figure 5.8 - Grain Size Distribution for Rocky Butte to Bridgeport Bar, SR173, C3057



Symbol	Sample No.	Description	Classification	Percent Passing No. 200 Sieve	w %
●	1	Crushed Surf. Top Course from 3 - 6 in. above geotextile	Very dense, gray, slightly silty, sandy gravel; moist, sub-angular (crushed pit-run gravel)	6.7	3.9
○	2	" "	" "	6.6	3.9
◇	3	Crushed Surf. Top Course from 0 - 2 in. above geotextile	" "	7.5	3.9
◆	4	" "	" "	7.3	3.9
*	5	Subgrade below geotextile	Dense, brown, sandy silt; moist	62.6	15.9

NOTES

1. Laboratory analyses of bulk samples used to determine grain-size distributions of fraction finer than 3/4 in. (19 mm).

Figure 5.9 - Grain Size Distribution for SR2/Farmer To 5NW Road, SR172, C3369

5.3.2 Permittivity Tests

The permittivity test data is presented on Tables B.1 through B.13 in Appendix B. The tables present both permittivity (sec^{-1}) determined by the tests and permeability (cm/sec) which was calculated based on a nominal thickness for each geotextile. The nominal thickness used was based on manufacturer's published values for the specific geotextile used. Permeability is included in Appendix B because it is often referred to in the literature and is used as an acceptance criteria by WSDOT instead of permittivity.

The unwashed permittivities were determined by testing the geotextiles without any prior cleaning. Disturbance of the geotextiles was kept to a minimum to preserve the degree of clogging that was found in-situ. Washed permittivity was determined after the unwashed test was completed by cleaning the specimen to the extent possible with a high-pressure spray of water. During the unwashed test many of the geotextiles which were only slightly clogged or had no apparent clogging, essentially became washed due to the flow of water through them during the test. These specimens were not tested for washed permittivity because it was expected that there would be no change in the permittivity. The results of the permittivity tests are summarized in Table 5.1.

As shown on Table 5.1, unwashed permittivity tests were conducted on all the geotextile samples. Washed permittivities were conducted only on the Fallon to Palouse, Albion Road to Parvin Road and SR2/Farmer to 5NW Road sites. The permittivity values for the clean geotextiles (those not tested for washed permittivity) ranged from 0.030 sec^{-1} to 0.66 sec^{-1} for the woven slit films and 1.05 sec^{-1} for the nonwoven geotextile from the Colville Vicinity site. The permittivity determined for the Ritzville to Tokio site was over 7 times greater than the manufacturer's published value

For the three geotextiles which had washed permittivity tests completed the average unwashed permittivities were 0.02 sec^{-1} (Fallon to Palouse), 0.08 sec^{-1} (SR2/Farmer to 5NW Road) and 0.49 sec^{-1} (Albion Road to Parvin Road). These same geotextiles had average washed permittivities of 0.41 sec^{-1}, 0.11 sec^{-1} and 0.74 sec^{-1} respectively. These values represent increases in permittivity after washing of 1,950 percent, 38 percent, and 51 percent respectively. Clearly the Fallon to Palouse geotextile suffered the most loss of permittivity due to blinding and clogging in-situ than any other geotextile.

Table 5.1 - Summary of Permittivity Test Results

Site	Geotextile Type*	Unwashed Permittivity (avg.) sec^{-1}	Washed Permittivity (avg.) sec^{-1}	Manufacturer's Published Permittivity sec^{-1}	Percent Permittivity Retained** %
Colville Vicinity	8-NP	1.05	n/a	1.23[a]	85
Fallon to Palouse	4-SF	0.02	0.41	0.03[b]	67
Albion to Parvin	5.3-NP	0.49	0.74	0.72[c]	68
Ritzville to Tokio	4-SF	0.66	n/a	0.09[d]	>100
Aeneas Valley	4.5-SF	0.03	n/a	0.04[e]	75
Rocky Butte	4-SF	0.08	n/a	0.09[f]	89
SR2/Farmer	4-SF	0.08	0.11	0.09[g]	89

* 8-NP indicates weight of geotextile (8 oz/yd^2) and type; i.e., nonwoven needlepunched (NP) or woven slit film (SF).

** Percent retained = unwashed permittivity divided by manufacturer's published permittivity.

[a] Based on manufacturer's 1987 permeability value divided by typical geotextile thickness of 0.2032 cm.

[b] Based on manufacturer's 1983 permeability value divided by typical geotextile thickness of 0.0584 cm.

[c] Based on manufacturer's 1982 permittivity value.

[d] Based on manufacturer's 1988 permeability value divided by typical geotextile thickness of 0.0533 cm.

[e] Based on manufacturer's 1989 permittivity value.

[f] Based on manufacturer's 1988 permeability value divided by typical geotextile thickness of 0.0584 cm.

[g] Based on manufacturer's 1988 permeability value divided by typical geotextile thickness of 0.0584 cm.

For comparison purposes, four specimens of washed geotextile from the Fallon to Palouse site were sent to the WSDOT Materials Laboratory for permittivity testing. The results, as shown on Table B.4 of Appendix B, indicate that the WSDOT determined permittivity ranged from 0.05 to 0.11 sec^{-1}. This can be compared to values ranging from

0.45 to 0.67 sec^{-1} (Table B-3) for the same geotextile tested with the apparatus shown on Fig. 5.1 (UW apparatus).

The permittivity test results for a control specimen of nonwoven geotextile (Polyfelt TS600) are presented in Tables B.12 and B.13 of Appendix B. The average permittivity, as measured with the UW apparatus, is 1.34 sec^{-1} while the average obtained at the WSDOT laboratory is 2.54 sec^{-1}. The manufacturer's published permittivity value for this material is 2.0 sec^{-1}. The reasons for this discrepancy are not clear. Some of the difference may be explained by the inherent material variability which is quite common for all geotextiles. As shown on Table B-13 of Appendix B, the thickness of the control sample specimens varied between 0.098 cm and 0.216 cm. These specimens were all cut from a sample measuring approximately 3 ft by 4 ft

The difference between the results obtained with the UW apparatus, the WSDOT apparatus and by the manufacturer may be due to the different equipment and procedures used; however, this should not be the case since all apparatus meet the requirements of ASTM 4491. Additional studies should be undertaken to attempt to clarify the cause of the discrepancy.

5.3.3 Index Strength Tests

Index strength tests were performed on geotextile specimens from all of the test sites with the exception of the SR270 to Albion Road site. In general, four specimens were tested for each of the four index strength tests. The results were averaged and are presented in Table 5.2 as percent strength retained. The percent strength retained is a measure of the average strength after burial as compared to average values obtained from manufacturer's published data. The complete data is presented in Tables 6.1 through 6.8 in Chapter 6 of this report. In general, the number of specimens tested was limited to four rather than the standard of ten, which is normal for ASTM and WSDOT testing procedures, because of the limited size of the geotextile sample obtained from the test pits and the need to avoid testing specimens with noticeable damage, such as puncture holes and/or fraying. Samples from the Colville Vicinity site and Ritzville to Tokio site yielded six specimens for each index test because of the relatively good condition of these geotextiles after they were exhumed from the test pits.

The data shown in Table 5.2 indicates that all of the geotextiles appear to have survived reasonably well with the exception of the material from the Aeneas Valley Road to Wauconda Summit. The reason for this exception is not clear.

Table 5.2 - Summary of Index Strength Test Results - Percent Strength Retained

Site	Grab Tensile %	Trap. Tear %	Puncture %	Burst %	Avg. %
Colville Vicinity	80	99	100	99	95
Fallon to Palouse	87	61	100	81	82
Albion to Parvin	100	100	100	66	92
Ritzville to Tokio	76	41	100	67	72
Aeneas Valley	38	29	73	41	45
Rocky Butte	100	96	100	99	99
SR2/Farmer	62	61	100	63	72

5.3.4 Falling Weight Deflectometer

Falling weight deflectometer (FWD) testing and analysis was performed by WSDOT personnel at six of the sites investigated in this study. The tested sites were selected based on the amount of roadway structural information available (personal communication, N. Jackson, 1990). The FWD tests were generally completed within 50 ft of the test pit locations. In general, the FWD test results indicate that the strength of the pavement structure varies considerably; however, the test results do not present conclusive evidence that the strength of the structure is influenced by the presence or absence of the geotextile separator any more than by the thickness of the basecourse and other structural characteristics of the roadway.

As shown in Table 5.3, the data on the Fallon to Palouse project indicates that the location where no geotextile was found had a somewhat lower subgrade modulus. This may be related to the absence of the geotextile; however, the test pit that was excavated at that location, MP 14.00, encountered only 16 in. of crushed surfacing and ballast below the pavement whereas the section at MP 11.35 contained 18 in.. At the Ritzville to Tokio site

only one test pit was excavated and a geotextile was found. According to the the project inspector, geotextile was only used in a short stretch of this acceleration ramp widening project. At the location where the geotextile was not used the FWD data seems to indicate a sharp drop in the subgrade modulus. Verification of this condition would require excavation of an additional test pit to determine if the geotextile is actually present and if the road structure is the same as that encountered at the test pit location where the higher modulus has been found.

Table 5.3 - Results of FWD Testing

Site Name	Deflection (mil)	Area (mil^2)	Basecourse Thickness (in.)	Subgrade Modulus (ksi)
Colville Vicinity	20	21	17.5	13
Fallon to Palouse				
(MP11.35, with geotextile)	40	16	18	11
(MP 14.00, without geotextile)	41	17	16	10
SR270 to Albion Rd.	12	19	32	26
Albion Rd. to Parvin Rd.	31	16	17	14
Ritzville to Tokio				
with geotextile	28	13	29.5	24
without geotextile (?)	26-39	19-17	n/a	13-12
SR2/ Farmer to 5 NW	65	12	9.5	12

6.0 ANALYSIS OF RESULTS

A total of eight site visits yielded information which, to varying degrees, is useful for the purposes of this study. Results from five of the sites yielded information on survivability, clogging, retained strength and general performance of the geotextiles. The results from the other three sites yielded very little information on anything other than survivability under the specific conditions in which they were installed but did provide information on construction practices in the field.

The qualitative information obtained from the site visits and the data obtained from laboratory testing are summarized for each of the eight sites in Tables 6.1 through 6.8. In general, all of the roadways appeared to be in very good condition with no visible signs of premature failure. All of the geotextiles, with the exception of the lightweight nonwoven from SR270 to Albion Road, appeared to have survived construction reasonably well although several showed signs of minimal to moderate construction damage, mainly in the form of puncture (Table 4.1). Later analysis of retained strength indicated that the geotextiles did survive as well as would be expected, with the exception of the Aeneas Valley Road to Wauconda Summit geotextile which showed an unusually low retained strength (Table 5.2). This material did not appear to be excessively damaged when it was exhumed although it did display numerous small holes as can be seen in Fig. 4.39.

As mentioned earlier, a small increase in the fines content of basecourse aggregate from immediately above the geotextile separator was observed in most of the test sites. Because the increase in the amount of fines in all cases is so small, it is not possible to say with certainty that the fines migrated into the basecourse aggregate through the geotextile from the underlying subgrade. Fines may also have been deposited in the lower portion of the basecourse layer during construction. At any rate, the lack of excessive fines in the basecourse indicates that migration of fines through the geotextile was probably not a significant problem at the sites investigated in his study. As shown in Fig. 5.3, a comparison of the percent fines in the initial lift of basecourse aggregate from the roadway with geotextile (Samples 1 and 2) and the roadway without geotextile (Sample 5) indicates that the presence of the geotextile may have prevented the increase of over 6 percent fines in the initial lift of basecourse.

Table 6.1 - Data Summary Sheet For Colville Vicinity

Contract Number C3331

Name Colville Vicinity Investigation Date 4/19/90

Site Location Approximately MP 228.7 of SR395. Southbound lane, from fog at shoulder to 63 in. into driving lane.

Subgrade Type Native subgrade consisted of silt; howver, this was overlain by imported, slightly silty, sandy gravel (pit-run up to ~5 in. diameter)

Geotextile 8 oz/yd Nonwoven needlepunched, Supac 8NPUV Date Installed 10/87

Base Material Slightly silty, gravelly sand (1/2-in. minus, angular crushed rock)

ConstructionNotes: Road section consisted of 0.15 ft. asphalt wearing course, 0.15 ft. asphalt leveling course, 0.30 ft. crushed surfacing top course (CSTC), 1.00 ft. crushed surfacing base course (CSBC), geotextile, 6 in. to 8 in. pit-run gravel, native subgrade. 12 in. to 18 in. minimum lift thickness above geotextile specified.

Performance Notes: Pavement appears to be in good condition. Geotextile appeared in good condition with no holes or clogging. Some indentations of geotextile due to fill material below; however, no permanent damage visible.

Test Results :

TEST	Published* Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permeability (cm/sec)	0.25	4	3	0.38	0.19 - 0.25	50-66	Compared to new measured value
						76-100	Compared to published value
Grab Strength (lb)	250	10	6	376	300	80	MD
Grab Elong. (%)	65	10	n/a	n/a	n/a	n/a	
Tear (lb)	125	10	6	130	129	99	X-MD
Puncture (lb)	125	10	7	138	148	100	
Burst (psi)	430	10	10	423	417	99	

* Manufacturer's certified values, October 22, 1987.

New measured value is the WSDOT compliance test value before installation.

Table 6.2 - Data Summary Sheet For Fallon To Palouse

Contract Number C2364

Name Fallon to Palouse Investigation Date 5/8/90

Site Location Approximately MP 11.35 of SR27 (Station 565 + 84). Northbound lane out of Pullman. From edge of shoulder to ~3 ft. into driving lane.

Subgrade Type Slightly sandy , clayey silt

Geotextile 4 oz/yd woven slit film, Mirafi 500X Date Installed 9/83

Base Material Slightly silty, sandy gravel (angular, vesicular, crushed basalt)

Construction Notes: Road section consisted of 3 in. bituminous surface treatment (BST), 6 in. CSTC, 12 in. CSBC, geotextile separator, native subgrade.

Performance Notes: Pavement was in good condition. Geotextile appeared to have no holes or other construction damage; however, it appeared to be clogged and blinded with clay and silt particles which were adhered to the underside. Geotextile had mottled brown and rust colored zones of less clogged material with iron-oxide staining around the outside of the zones.

Test Results :

TEST	Published* Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permeability (cm/sec)	0.002	0	3	n/a	0.0007 - 0.0018	35 - 90	unwashed
					0.006 - 0.039	100 +	washed
Grab Strength (lb)	200**	0	5	n/a	174	87	
Grab Elong. (%)	30	0	0	n/a	n/a	n/a	
Tear (lb)	115	0	5	n/a	70	61	
Puncture (lb)	85	0	4	n/a	103	100+	
Burst (psi)	400	0	6	n/a	322	81	

* Manufacturer's published values for 1983

** This value based on Test Method CFMC-GET-2 by Mirafi on July 26, 1983.

No compliance tests completed prior to installation.

Table 6.3 - Data Summary Sheet For SR270 To Albion Road

Contract Number C2550

Name SR 270 to Albion Road Investigation Date 5/9/90

Site Location Approximately MP 25.5 of SR 195 (Station 203). Northbound lane out of Pullman. From approximately 2 ft. outside shoulder fog line to approximately 2 ft. into driving lane

Subgrade Type Native subgrade consisted of clayey silt; however, 8 in. of crushed rock was placed above subgrade below geotextile.

Geotextile 3.5 oz/yd nonwoven heat-bonded, (Maybe Mirafi 140NL) Date Installed 10/83

Base Material Silty, sandy gravel (angular, vesicular, crushed basalt)

Construction Notes: Road section consisted of 2.5 in. asphalt wearing course, 2.0 in. asphalt levelling course, 24 in. ballast, geotextile, 8 in. crushed rock fill, clayey silt subgrade. First lift above fabric was 6 in. thick. Vibratory roller used.

Performance Notes: Pavement appears to be be in good condition. Geotextile was in very poor condition with severe construction damage; approximately 1 to 2 holes up to 1/4-in. diam. per square inch. Mottled coloration visible with some apparent clogging.

Test Results :

TEST	Published* Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permeability (cm/sec)	0.3	0	0	n/a	n/a	n/a	No permeability or strength tests performed due to damaged condition of geotextile
Grab Strength (lb)	100	0	0	n/a	n/a	n/a	
Grab Elong. (%)	50	0	0	n/a	n/a	n/a	
Tear (lb)	n/a	0	0	n/a	n/a	n/a	
Puncture (lb)	n/a	0	0	n/a	n/a	n/a	
Burst (psi)	200	0	0	n/a	n/a	n/a	

* Based on 1989 published value for Mirafi 140NL.

No compliance tests completed prior to installation.

Table 6.4 - Data Summary Sheet For Albion Road to Parvin Road

Contract Number C2990

Name Albion Road to Parvin Road Investigation Date 5/9/90

Site Location Approximately MP 34.35 of SR195. Test pit located in northbound lane, approximately 2 ft. of shoulder and 2 ft. into driving lane

Subgrade Type Clayey silt with numerous crushed rock and gravel

Geotextile 5.3 oz/yd nonwoven needle-punched, Supac 5NP Date Installed 9/85

Base Material Silty sandy gravel (1.5 in.-minus, angular, crushed basalt, Ballast)

Construction Notes: Roadway section consisted of 4 in. asphalt, 8 in. CSTC, 9 in. Ballast. Geotextile underlain by clayey silt subgrade. No minimum lift thickness specified - only that eqipment not operate directly on geotextile; however, first lift was probably full depth of ballast; ie., 9 in.

Performance Notes: Pavement appeared to be in good condition. Geotextile was in good condition; approximately 1 to 2 puncture holes up to 1/4-inch diameter per square foot, mottled coloration due to subgrade intrusion where base course aggregate came in contact with subgrade. Geotextile was wet, some minor clogging evident.

Test Results :

TEST	Published * Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permittivity (1/sec)	0.72	0	3	n/a	0.38-0.59	53-82	unwashed
					0.62-0.87	86-100	washed
Grab Strength (lb)	165	0	4	n/a	173	100	
Grab Elong. (%)	65	0	0	n/a	n/a	n/a	
Tear (lb)	55 **	0	4	n/a	79	100	** 1989 value
Puncture (lb)	95	0	4	n/a	94	100	
Burst (psi)	345	0	4	n/a	226	66	

* Based on 1982 published value for Supac 5NP

No compliance tests completed prior to installation.

Table 6.5 - Data Summary Sheet For Ritzville To Tokio And Weigh Stations

Contract Number C3503

Name Ritzville to Tokio and Weigh Stations Investigation Date 6/28/90

Site Location Approximately MP 231.51on eastbound Tokio acceleration ramp to I-90. Test pit located approximately 200 ft. east of luminar, at eastbound MP 231.51 or Station 863 + 48, mainline stationing. Shoulder of acceleration ramp.

Subgrade Type Fine sandy silt overlain by 6 in. to 7 in. crushed rock

Geotextile 4 oz/yd woven slit film, Mirafi 500X Date Installed 7/89

Base Material Base course consisted CSTC (1-in. minus, angular, crushed basalt)

Construction Notes: Roadway consisted of 2 in. asphalt pavement, 29.5 in. CSTC, geotextile underlain by 6 in. to 7 in. CSTC over a clayey silt subgrade. No minimum lift thickness was specified; however inspector indicated initial lift was 6-in. and was compacted w/ double drum vibratory roller. Geotextile was supposed to have been placed directly on subgrade but was not. Dump trucks reportedly operated on geotextile.

Performance Notes: Pavement surface was in good condition. Geotextile was virtually undamaged and unclogged. Only one small (~1/4 in. diam.) hole attributed to construction damage.

Test Results :

TEST	Published * Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permeability (cm/sec)	0.005	0	3	n/a	.035	>100	No washed specimen tested since geotextile was washed clean during unwashed test
Grab Strength (lb)	185	0	5	n/a	141	76	
Grab Elong. (%)	30 max	0	0	n/a	n/a	n/a	
Tear (lb)	95	0	5	n/a	39	41	
Puncture (lb)	75	0	5	n/a	105	100+	
Burst (psi)	400	0	5	n/a	274	69	

* Values based on 1988 data published by Mirafi Inc. for Mirafi 500X.

No compliance tests completed prior to installation.

Table 6.6 - Data Summary Sheet For Aeneas Valley Road to Wauconda Summit

Contract Number C3582

Name Aeneas Valley Road To Wauconda Summit Investigation Date 8/15/90

Site Location Approximately MP 283.24 of SR20 (Station 1131+50). Eastbound lane, shoulder of road and approximately 3 feet into driving lane.

Subgrade Type Slightly gravelly, silty sand

Geotextile 4.5 oz/yd woven slit film (Amoco 2002) Date Installed 6/89

Base Material Slightly silty, gravelly sand (1-1/2-in. minus pit-run gravel)

ConstructionNotes: Raodway consisted of 1 in. BST, 4 in. CSTC, 13 in. ballast, geotextile and subgrade

Performance Notes: Road was in good condition. Geotextile had 3 small holes (approx. 1/4-1/2 in. diam.) where subgrade rocks had punctured upwards and several smaller holes. No significant clogging was visible.

Test Results :

TEST	Published * Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permittivity (1/sec)	0.04	4	3	0.247	.031	78 **	** Compared to published value
Grab Strength (lb)	200	10	4	255/291	96	38	MD/X-MD
Grab Elong. (%)	15	0	0	n/a	n/a	n/a	
Tear (lb)	75	10	4	110/132	32	29	MD/X-MD
Puncture (lb)	90	10	4	118	86	73	
Burst (psi)	400	10	4	455	185	41	

* Based on minimum average roll value reported in manufacturer's certification on 1/7/89.

New measured value is the WSDOT compliance test value before installation.

Table 6.7 - Data Summary Sheet For Rocky Butte to Bridgeport Bar

Contract Number C3057

Name Rocky Butte To Bridgeport Bar Investigation Date 9/16/90

Site Location Approximately MP 8.24 of SR173 (Station 444+00). Southbound lane, shoulder of road and approximately 3 feet into driving lane.

Subgrade Type Slightly gravelly, silty sand

Geotextile 4 oz/yd Woven slit film, Mirafi 500X Date Installed 4/86

Base Material Pit-run gravel ballast up to 10 in. diameter.

ConstructionNotes: Raodway consisted of 1 in. BST, 12 in. ballast, 36 in. pit-run gravel with cobbles up to 10 in. diameter, geotextile and subgrade.

Performance Notes: Pavement was in good condition. Geotextile was in good condition. No holes or clogging were evident. Subgrade was smooth and had no protrusions.

Test Results :

TEST	Published * Value	No. of Tests		Measured Value		Percent Retained	Comments
		New	Exhumed	New	Exhumed		
Permeability (cm/sec)	0.005	0	3	n/a	.003-.006	60-100	No washed permeabilty test was performed because geotextile was washed clean during the unwashed test
Grab Strength (lb)	185	0	4	n/a	201	100	
Grab Elong. (%)	30 max	0	0	n/a	n/a	n/a	
Tear (lb)	95	0	4	n/a	91	96	
Puncture (lb)	75	0	4	n/a	115	100	
Burst (psi)	400	0	4	n/a	398	99	

* Values based on 1988 data published for Mirafi 500X.

No compliance tests completed prior to installation.

Table 6.8 - Data Summary Sheet For SR2/Farmer to 5NW Road

Contract Number C3369

Name SR2/Farmer to 5 NW Road Investigation Date 9/6/90

Site Location MP 4.36 of SR 172 (Station 240 + 10)
Northbound lane, shoulder of road and 2 feet into driving lane

Subgrade Type Sandy silt with occasional gravel

Geotextile 4 oz.yd woven slit film, Mirafi 500X Date Installed 7/88

Base Material Slightly silty, sandy gravel (sub-angular, crushed pit-run)

ConstructionNotes: Road section consisted of 2 in. BST, 9.5 in. CSTC, geotextile, separator, native subgrade. Four inch initial lift thickness specified. Some installation problems reported with wind blowing geotextile around, occasional tearing during blading operations and pumping subgrade during paving operations.

Performance Notes: Shoulder pavement separation due to slippage along geotextile overlap on exist. pavement. Pavement appears to be in good conditon. Geotextile over subgrade was in good condition; 4-5 holes attributed to construction damage, numerous holes in overlap above existing pavement.

Test Results :

TEST	Published * Value	No. of Tests		Measured Value		Percent ** Retained	Comments
		New	Exhumed	New	Exhumed		
Permeability (cm/sec)	0.005	4	3	0.0055	0.0046	84	Unwashed
					0.0056	100	Washed
Grab Strength (lb)	185	10	4	257	115	62	
Grab Elong. (%)	30 max	10	0	21	n/a	n/a	
Tear (lb)	95	10	4	194	58	61	
Puncture (lb)	75	10	4	111	78	100	
Burst (psi)	400	10	4	467	253	63	

* Values based on 1988 data published by Mirafi Inc. for Mirafi 500X.

** Based on exhumed value/published value.

New measured value is the WSDOT compliance test value before installation.

Blinding was observed to varying degrees in three of the geotextiles with the worst blinding observed in the woven slit film from the Fallon to Palouse site. Laboratory permittivity tests indicate that the washed permittivity of the Fallon to Palouse geotextile is 1,950 percent greater than that of the unwashed material. For the other geotextiles, which showed some signs of clogging and blinding, the increase in permittivity after washing was less than about 70 percent.

It should be noted that the permittivity values, presented in Tables B.2, B.3 and B.4 of Appendix B, generally show an increasing trend between successive trials on each geotextile specimen, the only exception being trials No. 2 and No. 3 on Table B.3. This trend is believed to be an indication that each successive trial contributed to the washing of clogged soil particles from the weave of the geotextile. This would have the effect of clearing the openings between filaments resulting in an apparent increase of permittivity in the next trial. This phenomena was observed in most other geotextile specimens which had displayed visible signs of blinding and clogging in the field. The Aeneas Valley to Wauconda Summit geotextile (woven slit film) showed increases of 71 and 153 percent for two of the tests, although this material did not appear to be clogged in the field. It is apparent that, for the woven slit film geotextiles, only a small amount of contamination of the material by fine grained soil particles is required to cause a significant drop in permittivity.

A large amount of variation was observed in the degree of clogging of the geotextiles and in the amount of washing; i.e., increase in permittivity between successive trials, as is indicated in the data in Appendix B. The variation may be partly due to sample preparation and testing procedures; however, most of the observed variability is probably due to the fact that clogging in the field was not a uniform occurrence. This is clearly evidenced by the mottled patterns observed in several of the geotextiles, especially the sample from the Fallon to Palouse site (Fig. 4.10).

Tables 6.1 through 6.8 generally present the published and measured values of permeability of the various geotextiles instead of permittivity, with the exception of Tables 6.4 and 6.6 (Albion Road to Parvin Road and Aeneas Valley to Wauconda Summit sites) which present permittivity values. The reason for this is that the manufacturers of the geotextiles used on the latter two projects only published permittivity values for those

products, rather than permeability, in the years in which those products were used. In later years the manufacturer's permeability values may have been published; however, it is well known that property values for most products on the market have changed markedly over the years while the names of the products remain the same. In any case, the most meaningful data presented in Tables 6.1 through 6.8 is the percent of retained permeability or permittivity based on the published value at the time of construction. Unfortunately, only three out of the eight sites had compliance test records of geotextile properties prior to use on the project.

As can be seen in Tables 6.1 through 6.8, the percent of original permeability or permittivity retained, based on published values, in the geotextiles which were utilized over clayey silt subgrades ranged from 35 to 90 percent for the woven slit film and 53 to 82 percent for the nonwoven. In the case of the woven slit film it is more meaningful to compare the values obtained before and after washing. When this is done it can be seen that the percent retained permeability of the unwashed specimen, based on the washed value of the same specimen, is about 3 to 28 percent. The same analysis yields values of 59 and 97 percent for the nonwoven geotextile.

The data indicates that over a sandy silt subgrade, the geotextile from the SR2/Farmer to 5 NW Road site retained approximately 92 to 100 percent of its published permeability. When the washed permeability, determined with the UW apparatus, instead of the published value is considered to be the original value, the unwashed geotextile appears to have retained 68 to 83 percent of its original permeability. For comparison purposes this may be a more meaningful number since it is based entirely on the data produced by the same apparatus.

For the two geotextiles which were placed over silty sand subgrades, the retained permeabilities or permittivities, based on the manufacturer's data, ranged from 75 to 77 percent for the Aeneas Valley site and 60 to 100 percent for the Rocky Butte site. No washed permittivity tests were performed on these specimens because they appeared to be relatively clean in-situ and were quite clean after the first (unwashed) permittivity tests.

As mentioned in section 5.3.2, the permittivity of the control specimen (TS600, a 6 oz/yd^2 nonwoven needlepunched geotextile) was measured with the apparatus shown in Fig. 5.1 (the UW apparatus) as well as with equipment at the WSDOT laboratory. The test results indicate that the UW apparatus produced permittivity values which were 53 percent lower than the WSDOT apparatus and, in this case, 33 percent lower than the manufacturer's published value. The WSDOT and the manufacturer's results were obtained with the falling head method; however, the use of the falling head method or the constant head method should not produce significantly different results. The reasons for the discrepancy are unclear. For purposes of comparing washed permittivity to unwashed permittivity the UW apparatus is satisfactory.

As can be seen in Tables 6.1 through 6.8, the permeability or permittivity obtained with the UW apparatus was, in all cases, very close to the value published by the manufacturer at the time that the geotextile was installed in the roadway. For three of the sites in this study, WSDOT had performed acceptance testing on the geotextile prior to its use in the project. As shown in Tables 6.1 and 6.6, for the Colville Vicinity and Aeneas Valley sites, the measured permeability or permittivity values obtained on new geotextile specimens with the WSDOT apparatus were 52 to 500 percent higher than the manufacturer's published value which was presented on certification statements accompanying the geotextile at the time of delivery. The permeability value obtained by WSDOT for the geotextile from the SR2/Farmer project was closer to the manufacturer's published value, as shown in Table 6.8.

No damage was observed in the geotextiles from the Colville Vicinity, Fallon to Palouse or Rocky Butte to Bridgeport Bar sites. At these three sites the subgrades, geotextiles, and basecourse materials were all very different and, therefore, a comparison of the influence of these factors on geotextile survivability is not possible. Damage was observed in the geotextiles from the SR270 to Albion Road, Albion Road to Parvin Road, Ritzville to Tokio, Aeneas Valley Road to Wauconda Summit, and SR2/Farmer to 5NW Road sites.

A comparison of the Fallon to Palouse installation to the Albion Road to Parvin Road installation indicates that both were installed at the same time of year over roughly the same type of subgrade. The Albion Road site appeared to contain slightly more angular gravel

and debris at the surface of the subgrade; however, both subgrades were very soft at the time the geotextile was installed. As shown in the photographs (Fig. 4.9 and 4.19) and discussed in this report (Sections 4.3 and 4.4), the Fallon to Palouse geotextile appeared to have suffered no construction induced damage while the Albion Road geotextile did. This may be due to the presence of the gravel and debris below the Albion Road geotextile but it is also important to note that the index strength values for the Albion Road site were generally lower than the Fallon to Palouse site (with the exception of the burst strength).

It is possible to compare the SR270 to Albion Road site with the Ritzville to Tokio site. In both cases the geotextile was sandwiched between layers of angular crushed rock and, based on discussions with the project inspectors, the initial lift of basecourse was about 6 in. thick and was compacted with a vibratory roller. The SR270 to Albion Road geotextile was severely damaged; however, the Ritzville to Tokio geotextile was only slightly damaged. The reason that the SR270 material was so badly damaged is obviously because it was such a lightweight material (3.5 oz/yd^2) which does not meet current design standards. This amount of damage would be expected. The woven slit film from the Ritzville to Tokio site meets the current WSDOT standards for high survivability geotextile, however even this material did not emerge unscathed from the installation operation.

The Aeneas Valley to Wauconda Summit installation and the Rocky Butte to Bridgeport installation both involved over-excavations of 2 or more ft of soft subgrade before the geotextile could be placed. The basecourse material was similar at these two sites in that both consisted of rounded, pit-run gravel ballast. The Rocky Butte installation involved much larger particles which ranged from sand and gravel sizes to cobbles up to 10 in. in diameter. Both sites used 4 oz/yd^2 nonwoven geotextiles with similar strength values although the Aeneas Valley geotextile had a reported grab tensile elongation at failure of 15 percent (Table 6.6) as compared to 30 percent for the geotextile at the Rocky Butte site (Table 6.7).

One significant difference between these two sites was the difference in the subgrade soils. At the Aeneas Valley site the subgrade consisted of a slightly gravelly, silty sand with approximately 50 percent of the particles falling within the fine gravel to medium sand range, based on wet sieving the minus 3/4-in. size fraction of the bulk sample. Considerably larger gravel particles were observed in the subgrade and are visible in Figs. 4.33 and 4.34. These materials were not included in the grain-size distribution analysis.

As shown in Fig. 4.38, it was primarily this gravel material which caused most of the puncture damage observed in the geotextile sample. At the Rocky Butte site the subgrade consisted of a slightly gravelly, silty sand with only 2 percent of the bulk sample consisting of fine gravel, 6 percent coarse to medium sand, 72 percent fine sand and 20 percent fines. No coarse gravel was observed in the test pit, Fig. 4.46, and Fig. 4.41 indicates that no gravel was encountered in the overexcavation during roadway construction.

It is apparent therefore that the damage observed in the geotextile from the Aeneas Valley site, as indicated in Fig. 6.6, was due to the presence of sub-angular gravel at the surface of the subgrade. As shown in Figs. 4.33 and 4.34, the subgrade was compacted and smoothed by a roller prior to placement of the geotextile. Apparently, when ridges of uncompacted subgrade material remained the contractor hand shoveled the material to create a smoother surface upon which to place the geotextile. By doing this he scattered gravel-sized particles over the surface of the compacted subgrade. It is probable that, since the underlying subgrade was dense and unyielding, it forced the loose gravel remaining on top to protrude upward through the geotextile and into the initial lift of basecourse.

If the above analysis is correct, the amount of damage observed in the geotextile at this site may have been avoided by the use of a material with a higher grab elongation (strain) at failure or a higher puncture or burst strength. By comparison, the nonwoven geotextile utilized at the Colville Vicinity site survived remarkably well even though it had been placed over a dense fill layer which contained numerous large gravel and sharp stones (high survivability). This material had a reported grab elongation of 65 percent.

With regard to the effect of traffic and climate on the performance of geotextile separators, the sites investigated in this study did not provide evidence that these two factors have an influence. It would seem logical, however, that climate, with respect to the presence or absence of rainfall during installation of the geotextile, would influence the performance in that subgrade strength properties would certainly be affected by the addition of moisture during a rainy period. Additionally, the season in which roadway construction is being accomplished will affect the amount of groundwater present at locations where a geotextile might be used. Often, if construction is held off until the dry part of the year, the necessity for a geotextile could probably be eliminated.

7.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

This research involved field investigations and laboratory testing to evaluate the properties and overall performance of geotextiles from eight different locations in eastern and central Washington. Both nonwoven and woven geotextiles were exhumed from the roadways at the eight locations and samples of the geotextile were brought to the laboratory for index strength and permittivity testing. Samples of the basecourse and subgrade soils were analyzed for grain-size distribution. The results of the investigations and testing indicated that all of the geotextiles performed the separation function adequately although three of them were not installed directly against the subgrade soil as intended. Damage to the geotextiles varied considerably with the type of material and the installation conditions; however, this was not shown to have affected the performance of the separator. The conclusion is reached that the slit film woven geotextile would be adequate for separation applications over most subgrade soils; however, they tend to become blinded more readily than the nonwovens when used over clayey silt subgrades. The use of a heavier geotextile with high grab elongation will help to minimize the damage during installation.

7.2 Conclusions

Based on the damage observed in the geotextile from the SR270 to Albion Road site, it is concluded that a lightweight (3.5 oz/yd^2) nonwoven geotextile should not be used for any separation application, regardless of the subgrade type or initial basecourse lift thickness.

Puncture holes were observed in many of the woven slit film geotextiles where gravel-sized particles were present on the subgrade surface. Several puncture holes were also observed in the 5.3 oz/yd^2 nonwoven geotextile from the Albion Road to Parvin Road site. No damage was observed in the 8 oz/yd^2 geotextile from the Colville Vicinity site which was obviously a "high survivability" installation. It can be concluded therefore, that the use of a relatively heavy geotextile (say 8 oz/yd^2 or more) which meets the high survivability strength criteria and has a high grab elongation will help to minimize the damage which may occur during installation.

On the other hand, the use of a heavier geotextile will likely increase the initial cost of the installation. At all of the sites investigated in this study the existing roadway appeared to be

performing quite well. No signs of premature failure were visibly or physically detected. There is no evidence that the presence of moderate construction damage to the geotextile separator significantly affected the performance of the roadway.

It is difficult to formulate conclusions regarding clogging tendencies of geotextiles based on the limited amount of data obtained in this study. However, visual observations supported by the results of permittivity tests indicate that woven slit film geotextiles tend to become blinded more readily than nonwoven geotextiles when used over clayey silt subgrades. This conclusion is supported by the data in Appendix B and summarized in Table 5.2, which indicates that permeability of the woven slit film geotextile from the Fallon to Palouse site increased by an order of magnitude (1,950 percent) after the adhered clay and silt particles had been washed away while the nonwoven geotextile had an increase in permeability of 4 percent to 70 percent after washing, depending on the initial degree of clogging.

In the projects where the geotextile was used properly to separate the weak subgrade soils from the initial lift of basecourse aggregate, it is apparent from the fact that the roads were successfully constructed after the geotextile was installed, that the use of a geotextile separator effectively serves to expedite the construction process. Whether the geotextile becomes damaged or blinded during that process has not been proven to be detrimental to the performance of the roadway.

7.3 Recommendations for Changes To WSDOT Specifications

Based on discussions with WSDOT district personnel, and from observations during a site visit to a roadway project during construction, it is apparent that there are several instances where the geotextile is being used merely to comply with the contract specifications. It is recommended that the contract specifications be written in such a way that the project engineer may evaluate the subgrade conditions at the time of construction to determine whether the geotextile is needed. If the geotextile is not needed, the contractor should not be made to use it. An alternative approach would be to allow the use of the geotextile only in the case of a change order which would be decided by the project engineer during construction.

At several of the sites investigated in this study, the geotextile was installed after a layer of imported fill had been placed over the weak subgrade soils. This type of installation is obviously incorrect. It is recommended that WSDOT inspectors and project engineers involved with projects where geotextiles are to be used be instructed in the proper methods of installation. Furthermore, those inspectors should be required to keep accurate records of the installation, including type of geotextile, subgrade condition, initial lift thickness, method of compaction and any observed occurrence of damage or other problems with the geotextile.

There is a potential for complete blinding and clogging with subsequent buildup of pore pressures below a woven slit film geotextile installed as a separator over a clayey silt subgrade. The test results indicate that the degree of blinding and clogging of a nonwoven geotextile over a clayey silt subgrade is less than that of a woven slit film geotextile. Based on these results it is recommended that current WSDOT specifications require that a nonwoven geotextile which meets the current strength criteria be used where the subgrade consists of clayey silt or sandy silt.

7.4 Recommendations For Future Studies

The site investigations completed for this study were very useful for evaluating the performance of geotextile separators in eastern and central Washington. Many interesting and unexpected observations relating to performance and installation practices were made. It is recommended that similar site investigations be carried out at additional sites in western Washington to evaluate performance and installation practices in this area. Different soil, climate, traffic and installation conditions could have a significant impact on the performance of geotextile separators in western Washington and would be worth investigating.

The low subgrade modulus indications of the FWD data at the Ritzville to Tokio site, should be investigated. A second test pit should be excavated at the location where no geotextile was used and the FWD data indicates a weak subgrade may be present. This area coincides roughly with the section between Station 875 + 09 to 881+ 09 (mainline stationing on I-90).

There appears to be considerable discrepancy between the permeability and permittivity values obtained with the UW apparatus versus the WSDOT apparatus. The UW apparatus

seems to produce results which are more in agreement with manufacturer's published values. The cost of the UW apparatus makes it a desirable tool for use in similar studies of this kind; however, it would be useful to have a reliable correction factor which would correlate the results obtained with the two different apparatus. Additional studies should be performed which would address the discrepancies observed in this study.

As a way to fully document the performance of geotextile separators in the short and long term, it is recommended that a program be designed and implemented which would involve observation and long term study of all future geotextile installations completed by the state. This program would include full documentation of the type of geotextile, subgrade conditions, basecourse material and thickness, compaction effort, and all other pertinent parameters influencing the performance of the geotextile. After a specified period of time, perhaps related to the number of vehicular wheel loads passing over the site, the geotextile could be exhumed from the roadway and examined for signs of distress. Additionally, the basecourse aggregate and subgrade could be examined for changes.

LIST OF REFERENCES

Ayres, D.J. and McMorrow, J.C. (1980). "Discussion - The filtration behaviour of construction fabrics under conditions of dynamic loading", Geotechnique, Vol. 30, No. 1, pp. 87-88.

Barenberg, E.J., Dowland, J.H. and Hales, J.H. (1975). "Evaluation of soil-aggregate systems with Mirafi fabrics," The Highway Research Laboratory, University of Illinois, UILU-Eng-75-2020

Bell, J.R., Hicks, R.G., et. al. (1980). "Evaluation of test methods and use criteria for geotechnical fabrics in highway applications," (Draft Copy) U.S. Federal Highway. Administration, Washington, D.C., Report FHWA-RD-80, 97 pp.

Bell, A.L., McCulllough, L.M., and Snaith, M.S. (1982). "An experimental investigation of sub-base protection using geotextiles", Proceedings of the 2nd International Conference on Geotextiles, Vol. 2, Las Vegas, pp. 435-440.

Billing, J.W., Greenwood, J.H. and Small, G.D. (1990). "Chemical and mechanical durability of geotextiles," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 621-626.

Bonaparte, R., Ah-Line, C., and Charron, R. (1988). "Survivability and Durability of a nonwoven geotextile," Geosynthetics for Soil Improvement, Geotechnical Special Publication No. 18, ASCE, pp. 68-91.

Brorsson, I. and Eriksson, L. (1986). "Long-term properties of geotextiles and their function as a separator in road construction," Proceedings of the 3rd International Conference on Geotextiles, Vienna, pp.93-98.

Carroll, R.G. (1983). "Geotextile filter criteria," Transportation Research Record 916, Transportation Research Board, pp. 46-53.

Christopher, B.R. (1983). "Evaluation of two geotextile installations in excess of a decade old," Transportation Research Record 916, Transportation Research Board, pp. 79-88.

Christopher, B.R.and Holtz, R.D. (1985). "Geotextile engineering manual," U.S. Federal Highway Administration, Washington, D.C., FHWA-TS-86/203, 1044 pp.

Dawson, A. (1986). "The role of geotextiles in controlling sub-base contamination," Proceedings of the 3rd International Conference on Geotextiles, Vienna, pp. 593-598.

Dierickx, W. and van der Sluys, L. (1990). "Research into the functional hydraulic properties of geotextiles," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 285-288.

Fischer, G.R., Christopher, B.R. and Holtz, R.D. (1990). "Filter criteria based on pore size distribution," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 289-293.

Giroud, J.P. (1981). "Designing with geotextiles," Materiaux et Constructions, Vol. 14, No. 82, pp. 257- 272.

Hoare, D.J. (1982[a]). "A laboratory study into pumping clay through geotextiles under dynamic loading," Proceedings of the 2nd International Conference on Geotextiles, Las Vegas, pp. 423-428.

Hoare, D.J. (1982[b]). "Synthetic fabrics as soil filters: a review," Journal. of the Goetechnical Engineering Division., ASCE, Vol. 8, No.GT10, pp.1230-1245.

Ingold, T.S. and Crowcroft, P. (1984). "The notion of geotextiles as separators in roads," Ground Engineering, January 1984, pp. 27-34.

Koerner, R.M. and Ko, F.K. (1986). "Laboratory studies on long-term drainage capability of geotextiles," Proceedings of the 2nd International Conference on Geotextiles, Las Vegas, pp. 91-95.

Koerner, R.M. and Koerner, G.R. (1990). "The installation survivability of geotextiles and geogrids," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 597-602.

Koerner, R.M. and Wayne, M.H. (1989). "Geotextile specifications for highway applications," U.S. Federal Highway Administration, Washington, D.C., Report FHWA-TS-89-026.

Laier, H. and Brau, G. (1986). "The use of geotextiles in road constructions under intensive dynamic loading," Proceedings of the 3rd International Conference on Geotextiles, Vienna, pp. 995-1000.

Lafleur, J., Rollin, A.L. and Mlynarek, J. (1990). "Clogging of geotextiles under pumping loads," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 189-192.

McGown, A., Kabir, M.H. and Murray, R.T. (1982). "Compressibility and hydraulic conductivity of geotextiles," Proceedings of the 2nd International Conference on Geotextiles, Las Vegas, pp. 167-172.

McMorrow, J. (1990). "Filtering action of nonwoven geotextiles under dynamic loading," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 233-238.

Prapaharan, S., Holtz, R.D., and Luna, J.D. (1989). "Pore size distribution of nonwoven geotextiles," Geotechnical Testing Journal, ASTM, Vol. 12, No. 4, pp. 261-268.

Raumann, G. (1982). "Inplane permeability of compressed geotextiles," Proceedings of the 2nd International Conference on Geotextiles, Las Vegas, pp. 55-60.

Richardson, G. N. and Behr, L. H. (1990). "Survivability of subgrade separators," Geotechnical Fabrics Report, Industrial Fabrics Association International, May/June 1990, pp. 22-26.

Rollin, A.L. (1988). "CGSB filtration opening size: its importance in geotextiles selection," Reprint Volume: Third Canadian Symposium on Geosynthetics, Canadian Geotechnical Society, Ontario, Canada, pp. 1-7.

Rosen, W.J. and Marks, B.D. (1975). "Investigation of filtration characteristics of a nonwoven fabric filter," Transportation Research Record No. 532, Transportation Research Board, pp. 87-93.

Sato, M., Yoshida, T., and Futaki, M. (1986). "Drainage performance of geotextiles," Geotextiles and Geomembranes, No.4, pp. 223-240.

Saxena, S.K. and Hsu, T.S. (1986). "Permeability of geotextile-included railroad bed under repeated load," Geotextiles and Geomembranes, No. 4, pp. 31-51.

Schneider, H. and Puhringer, G. (1986). "The separation function of geotextiles," Third International Conference on Geotextiles, Vienna, pp. 1235-1239.

Scullion, T. and Chou, E. (1986). "Field evaluation of geotextiles under base courses," U.S. Federal Highway Administration, Washington, D.C., Report FHWA-TX-86/62+414-1F (Supplement), 56 pp.

Snaith, M.S. and Bell, A.L. (1978). "The filtration behaviour of construction fabrics under conditions of dynamic loading," Geotechnique, Vol. 28, No. 4, pp. 466-468.

Sprague, C.J. and Cicoff, G. (1989). "Permanent road stabilization: construction survivability of lightweight geotextiles," Geotechnical Fabrics Report, July/August 1989, pp. 26-31.

Task Force 25 (1989). "Guide specification for geotextiles in separation applications," as found in: Christopher, B.R. and Holtz, R.D. (1989). "Geotextile design and construction guidelines," National Highway Institute, U.S. Federal Highway Administration, Washington, D.C., Report FHWA-HI-90-001, pp. 123-127.

Werner, G. (1986). "Design criteria for the separation of geotextiles on the basis of mechanical test procedures," Proceedings of the 3rd International Conference on Geotextiles, Vienna, pp. 979-983.

Williams, N.D. and Luettich, S.M. (1990). "Laboratory Measurement of geotextile filtration characteristics," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, pp. 273-278.

APPENDIX A

PERMITTIVITY TEST PROCEDURES

In summary, the testing procedure is as follows (refer to Fig. 5.1):

1. Geotextile specimens are obtained from the sample exhumed from the roadway. The specimens are cut to a circular shape with a minimum diameter of 2.15 in. For very thin geotextiles, such Mirafi 500X, the diameter should be approximately 2.25 in. to minimize leakage of water during the test.

2. The specimens are immersed in water for a period of at least 1/2 hr prior to the test.

3. The apparatus is separated at the slip coupling by unscrewing the screw-down clamp. Deaired water is then poured slowly, with minimal turbulence, into the apparatus at the overflow port until the water level rises to the top of the slip coupling.

4. The specimen is placed on top of the lower half of the coupling while the water level is maintained such that the specimen is immersed.

5. The standpipe with the upper half of the coupling is lowered slowly onto the lower half and the screw-down clamp is tightened. The specimen must not be dislodged from the center of the apparatus during this step.

6. Deaired water is poured into the overflow port until the level rises to the top. The cap is placed on the overflow port until it is snug. During placement of the cap it is tapped downward quickly to force water through the specimen and to dislodge any air bubbles that may have collected there during filling.

7. Deaired water is then poured slowly into the standpipe from the top with the rubber stopper removed. The standpipe is filled to a point just above the top of the scale.

8. The rubber stopper is replaced with the lower end of the air supply tube at a point 2 in. above the top of the overflow port. This maintains the constant 2 in. gradient on the specimen during the test.

9. With a finger over the top of the air supply tube, the cap is removed from the overflow port. By lifting the finger slightly the air in the air supply tube is allowed to fall to the bottom of the tube where it will form a small bubble.

10. The water level in the standpipe is adjusted to a suitable starting point by slowly releasing air bubbles from the end of the air supply tube.

11. The drop in the water level is initiated by simultaneously starting the stopwatch and raising a finger off the top of the air supply tube. The drop is terminated by simultaneously stopping the stopwatch and placing a finger over the air supply tube. The net drop in water level is then read directly from the ruler attached to the side of the standpipe.

12. The values of time, drop in water level and temperature are recorded. At least five readings per specimen are obtained and an average value of permittivity per specimen is determined. ASTM D 4491 recommends 4 specimens be tested, however, with the apparatus shown in Fig. 5.1, five tests can be completed with minimal additional effort.

APPENDIX B

PERMITTIVITY TEST DATA

Table B.1 Results of Permittivity Tests for Colville Vicinity,SR395,C3331
Nonwoven Geotextile (Supac 8NP) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	3.25	1.39	22	80.93	1.07	0.22
	3.69	1.59	22	79.54	1.06	0.22
	2.63	1.43	22	62.95	0.84	0.17
	5.13	2.54	22	69.20	0.93	0.19
	3.38	1.62	22	71.45	0.96	0.19
				Average	0.97	0.20

	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	2.50	1.23	22	69.71	0.93	0.19

Additional tests discontinued due to leaking aparatus

				Average	0.93	0.19

	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	K (cm/sec)
3	6.13	2.15	22	97.70	1.31	0.27
	2.63	0.91	22	98.94	1.32	0.27
	3.56	1.38	22	88.54	1.18	0.24
	5.13	1.88	22	93.49	1.25	0.25
	2.00	0.81	22	84.68	1.13	0.23
				Average	1.24	0.25

* No permeability tests perfomed on washed specimens since geotextile was clean in-situ.

** Permeability based on nominal geotextile thickness of 0.2032 cm.

Table B.2 Results of Permittivity Tests for Fallon To Palouse, SR27, C2364 Woven Slit Film Geotextile (Mirafi 500X) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	2.00	30.77	21	2.23	0.030	0.0018
	1.88	26.27	21	2.45	0.033	0.0019
	1.19	14.87	21	2.74	0.021	0.0012
	2.13	25.41	21	2.87	0.038	0.0022
	2.38	30.01	21	2.71	0.036	0.0021
				Average	0.03	0.002
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	2.00	43.02	21	1.59	0.021	0.0012
	2.94	43.34	21	2.32	0.031	0.0018
	1.88	27.77	21	2.32	0.031	0.0018
	2.75	40.63	21	2.32	0.031	0.0018
	2.94	39.32	21	2.56	0.034	0.0020
				Average	0.03	0.002
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	2.00	102.62	21	0.67	0.0089	0.0005
	2.09	122.80	21	0.63	0.0078	0.0005
	1.63	89.13	21	1.12	0.0084	0.0005
	2.44	74.77	21	1.24	0.0150	0.0009
	2.69	73.98	21	1.27	0.0167	0.0010
				Average	0.01	0.001

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.0584 cm.

Table B.3 Results of Permittivity Tests for Fallon To Palouse, SR27, C2364 Woven Slit Film Geotextile (Mirafi 500X) Washed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	3.69	3.53	21	35.83	0.479	0.0280
	4.81	3.07	21	53.77	0.718	0.0419
	8.38	5.31	21	54.09	0.724	0.0423
	8.19	4.70	21	59.75	0.799	0.0467
	4.88	3.64	21	45.93	0.615	0.0359
				Average	0.67	0.039
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	3.38	14.20	21	8.15	0.109	0.0064
	4.00	17.70	21	7.75	0.104	0.0061
	4.44	21.51	21	7.07	0.095	0.0055
	3.50	14.63	21	8.20	0.110	0.0064
	3.19	14.67	21	7.45	0.100	0.0058
				Average	0.10	0.006
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	7.69	7.46	21	35.34	0.473	0.0276
	5.13	5.40	21	32.55	0.436	0.0255
	6.56	6.89	21	32.66	0.436	0.0255
				Average	0.45	0.026

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.0584 cm.

Table B.4 Results of WSDOT Permittivity Tests for Fallon To Palouse, SR27, C2364 Woven Slit Film Geotextile (Mirafi 500X) Washed*

Test No.	Falling Head Drop H (cm.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (sec^{-1})	Thickness (cm)	Permeability (cm/sec)
1	6.00	20.39	22	0.0702	0.0710	0.0050
	6.00	13.10	22	0.1093	0.0710	0.0078
	6.00	11.92	22	0.1201	0.0710	0.0085
	6.00	11.31	22	0.1266	0.0710	0.0090
	6.00	10.94	22	0.1308	0.0710	0.0093
			Average	0.1114		0.0079
	H (cm.)	T (sec)	t (deg. C)	Ψ (sec^{-1})	(cm)	(cm/sec)
2	6.00	16.71	22	0.0857	0.1020	0.0087
	6.00	14.81	22	0.0967	0.1020	0.0099
	6.00	13.57	22	0.1055	0.1020	0.0108
	6.00	13.20	22	0.1084	0.1020	0.0111
	6.00	12.74	22	0.1124	0.1020	0.0115
			Average	0.1017		0.0104
	H (cm.)	T (sec)	t (deg. C)	Ψ (sec^{-1})	(cm)	(cm/sec)
3	6.00	46.46	22	0.0308	0.0980	0.0030
	6.00	31.49	22	0.0455	0.0980	0.0045
	6.00	28.43	22	0.0503	0.0980	0.0049
	6.00	22.56	22	0.0634	0.0980	0.0062
	6.00	22.33	22	0.0641	0.0980	0.0063
			Average	0.0508		0.0050
	H (cm.)	T (sec)	t (deg. C)	Ψ (sec^{-1})	(cm)	(cm/sec)
4	6.00	30.39	22	0.0471	0.0860	0.0041
	6.00	23.45	22	0.0610	0.0860	0.0052
	6.00	19.47	22	0.0735	0.0860	0.0063
	6.00	18.29	22	0.0783	0.0860	0.0067
	6.00	17.28	22	0.0828	0.0860	0.0071
			Average	0.0685		0.0059

* These specimens were washed before testing in the WSDOT laboratory.

Note: Test conducted with Falling Head Method

Table B.5 Results of Permittivity Tests for Albion Rd. To Parvin Rd., SR195, C2990
Nonwoven Needlepunched Geotextile (Supac 5NP) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	4.06	6.0	22	23.22	0.310	0.043
	3.50	5.0	22	24.01	0.321	0.045
	4.53	5.6	22	27.75	0.371	0.052
	5.41	5.8	22	31.97	0.427	0.060
	2.44	2.5	22	33.44	0.447	0.062
				Average	0.38	0.052
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	2.44	2.59	22	32.28	0.4319	0.060
	2.75	2.35	22	40.13	0.5365	0.075
	4.06	3.19	22	43.68	0.5835	0.082
				Average	0.52	0.072
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	5.00	5.01	22	34.23	0.4576	0.064
	6.25	4.39	22	48.80	0.6528	0.091
	5.88	3.98	22	50.13	0.6774	0.095
				Average	0.59	0.083

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.1397 cm.

Table B.6 Results of Permittivity Tests for Albion Rd. To Parvin Rd., SR195, C2990
Nonwoven Needlepunched Geotextile (Supac 5NP) Washed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
2	3.03	1.59	22	65.39	0.874	0.122
	4.75	2.46	22	66.22	0.885	0.124
	4.75	2.45	22	66.49	0.889	0.124
	4.44	2.34	22	65.04	0.870	0.122
	8.19	4.45	22	63.10	0.844	0.128
				Average	0.87	0.122
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	3.81	3.31	22	39.50	0.528	0.074
	7.13	5.95	22	41.07	0.549	0.011
	7.69	5.04	22	52.31	0.699	0.098
	4.00	2.70	22	50.81	0.679	0.095
	2.50	1.81	22	47.37	0.633	0.088
				Average	0.62	0.086

Note: washed permeability not determined for specimen No. 1 due to damage caused to the specimen during washing

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.1397 cm.

Table B.7 Results of Permittivity Tests for Ritzville To Tokio, SR395, C3503 Woven Slit Film Geotextile (Mirafi 500X) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	2.75	2.14	22	44.07	0.589	0.031
	2.38	2.13	22	54.35	0.512	0.027
	3.63	2.34	22	53.13	0.711	0.038
	3.16	1.99	22	53.86	0.728	0.039
	3.50	2.16	22	55.57	0.743	0.040
				Average	0.66	0.035
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	2.38	1.64	22	49.67	0.665	0.036
	2.50	1.70	22	50.44	0.674	0.036
	2.81	1.73	22	55.76	0.745	0.039
	2.16	1.24	22	58.77	0.799	0.043
	2.75	1.62	22	58.22	0.778	0.042
				Average	0.73	0.039
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	1.56	1.12	22	47.85	0.638	0.034
	1.50	1.12	22	45.93	0.614	0.033
	2.00	1.19	22	38.32	0.512	0.027
	2.00	1.45	22	47.31	0.632	0.034
	1.43	1.12	22	44.02	0.585	0.031
				Average	0.59	0.032

* No permeability tests perfomed on washed specimens since geotextile was clean in-situ.

** Permeability based on nominal geotextile thickness of 0.05334 cm.

Table B.8 Results of Permittivity Tests for Aeneas Valley To Wauconda, SR20, C3582
Woven Slit Film Geotextile (Amoco 2002) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	2.06	3.02	22	23.42	0.313	0.018
	2.25	3.33	22	23.17	0.309	0.017
	0.88	1.25	22	24.00	0.323	0.018
	2.38	3.52	22	23.14	0.310	0.017
	2.75	3.66	22	25.77	0.344	0.019
				Average	0.319	0.018

(This test was affected by frayed edges of specimen)

	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	1.25	45.60	22	0.94	0.013	0.0007
	1.38	17.08	22	2.25	0.037	0.0020
	1.38	16.75	22	2.30	0.038	0.0021
	1.19	14.82	22	2.75	0.037	0.0021
	1.63	22.35	22	2.49	0.033	0.0019
				Average	0.0316	0.0018

	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	1.06	23.34	22	1.57	0.021	0.0011
	1.25	21.84	22	1.96	0.026	0.0014
	0.94	12.63	22	2.54	0.034	0.0019
	1.56	21.21	22	2.53	0.034	0.0019
	1.00	12.64	22	2.71	0.036	0.0020
				Average	0.030	0.0017

* No permeability tests perfomed on washed specimens since geotextile was clean in-situ.

** Permeability based on nominal geotextile thickness of 0.0560 cm.

Table B.9 Results of Permittivity Tests for Rocky Butte To Bridgeport, SR173, C3057
Woven Slit Film Geotextile (Mirafi 500X) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	1.75	7.99	20	7.51	0.1004	0.0059
	1.56	7.06	20	7.59	0.1013	0.0059
	1.56	6.78	20	7.90	0.1055	0.0062
	1.81	7.60	20	8.18	0.1092	0.0064
	1.44	6.07	20	8.12	0.1088	0.0064
				Average	0.105	0.006
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	1.50	8.69	20	5.92	0.0791	0.0046
	1.56	8.44	20	6.32	0.0847	0.0049
	1.44	8.03	20	6.14	0.0822	0.0048
	1.19	6.32	20	6.44	0.0863	0.0050
	1.69	9.00	20	6.38	0.0861	0.0050
				Average	0.084	0.005
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	1.13	10.22	20	3.78	0.0507	0.0030
	1.13	10.45	20	3.69	0.0496	0.0029
	1.56	15.21	20	3.52	0.0470	0.0027
	1.31	13.13	20	3.43	0.0457	0.0027
	1.13	10.27	20	3.76	0.0504	0.0029
				Average	0.049	0.003

* No permeability tests perfomed on washed specimens since geotextile was clean in-situ.

** Permeability based on nominal geotextile thickness of 0.0584 cm.

Table B.10 Results of Permittivity Tests for SR2/Farmer To 5NW Rd., SR172, C3369
Woven Slit Film Geotextile (Mirafi 500X) Unwashed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (g/m/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	1.25	5.92	20	7.24	0.0968	0.0057
	1.19	5.99	20	6.79	0.0911	0.0053
	1.63	8.14	20	6.85	0.0918	0.0054
	1.31	7.10	20	6.34	0.0846	0.0049
	1.38	6.56	20	7.19	0.0965	0.0056
				Average	0.092	0.005
	H (in.)	T (sec)	t (deg. C)	Ψ (g/m/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	0.81	5.71	20	4.88	0.0652	0.0038
	0.94	5.91	20	5.44	0.0727	0.0042
	0.88	4.65	20	5.26	0.0863	0.0050
	1.00	5.54	20	6.19	0.0828	0.0048
	0.69	3.71	20	6.36	0.0850	0.0050
				Average	0.078	0.005
	H (in.)	T (sec)	t (deg. C)	Ψ (g/m/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	1.19	7.32	20	5.58	0.0744	0.0043
	1.06	6.49	20	5.62	0.0751	0.0044
	0.88	5.34	20	5.62	0.0751	0.0044
	1.06	5.93	20	6.15	0.0822	0.0048
	1.25	6.49	20	6.60	0.0883	0.0052
				Average	0.079	0.005

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.0584 cm.

Table B.11 Results of Permittivity Tests for SR2/Farmer To 5NW Rd., SR172, C3369
Woven Slit Film Geotextile (Mirafi 500X) Washed*

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	1.45	5.02	20	9.82	0.1324	0.0077
	1.25	4.23	20	10.14	0.1355	0.0079
	1.13	3.67	20	10.51	0.1412	0.0082
	1.19	3.95	20	10.31	0.1381	0.0081
	1.45	5.06	20	9.82	0.1314	0.0077
				Average	0.136	0.008
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	1.19	5.86	20	6.95	0.0931	0.0054
	1.25	6.17	20	6.95	0.0929	0.0054
	1.19	5.35	20	7.61	0.1020	0.0060
	1.19	5.59	20	7.29	0.0974	0.0057
	1.63	8.41	20	6.63	0.0889	0.0052
				Average	0.095	0.006
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	1.19	5.95	20	6.84	0.0915	0.0053
	1.13	5.32	20	7.25	0.0970	0.0057
	1.13	5.17	20	7.46	0.0998	0.0058
	1.19	6.06	20	6.72	0.0898	0.0052
	1.25	5.78	20	7.42	0.0992	0.0058
				Average	0.096	0.006

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.0584 cm.

Table B.12 Results of Permittivity Tests for Control Specimen
Nonwoven Needlepunched Geotextile (Polyfelt, from factory roll)

Test No.	Drop in Water Level H (in.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ ((gal/min/ft^2)	Permittivity Ψ (sec^{-1})	Permeability** (cm/sec)
1	3.75	1.32	20	97.43	1.302	0.273
	2.68	0.94	20	98.06	1.310	0.275
	3.50	1.23	20	97.59	1.305	0.274
	2.94	0.99	20	101.76	1.360	0.286
	3.68	0.90	20	140.52	1.870	0.393
				Average	1.43	0.300
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
2	3.375	1.20	20	96.46	1.289	0.271
	2.875	0.97	20	101.69	1.359	0.285
	3.312	1.19	20	95.48	1.276	0.268
	2.750	1.06	20	88.97	1.189	0.249
	3.250	1.11	20	100.42	1.342	0.282
				Average	1.29	0.271
	H (in.)	T (sec)	t (deg. C)	Ψ (gal/min/ft^2)	Ψ (sec^{-1})	(cm/sec)
3	1.75	0.77	20	77.97	1.042	0.219
	2.75	0.96	20	98.25	1.313	0.276
	3.38	1.13	20	102.44	1.369	0.288
	2.88	0.95	20	103.79	1.387	0.291
	2.80	0.92	20	104.39	1.395	0.293
				Average	1.30	0.273

* Each specimen was tested before and after washing to remove clogging soil particles.

** Permeability based on nominal geotextile thickness of 0.2100 cm.

Table B.13 Results of WSDOT Permittivity Tests for Control Specimen Nonwoven Needlepunched Geotextile (Polyfelt, from factory roll)

Test No.	Falling Head Drop H (cm.)	Time For Drop T (sec)	Temp. t (deg. C)	Permittivity Ψ (sec^{-1})	Thickness (cm)	Permeability (cm/sec)
1	6.00	0.48	22	2.9821	0.2040	0.6083
	6.00	0.47	22	3.0455	0.2040	0.6213
	6.00	0.47	22	3.0455	0.2040	0.6213
	6.00	0.48	22	2.9821	0.2040	0.6083
	6.00	0.47	22	3.0455	0.2040	0.6213
			Average	3.0201		0.6161
	H (cm.)	T (sec)	t (deg. C)	Ψ (sec^{-1})	(cm)	(cm/sec)
2	6.00	0.56	22	2.5561	0.1020	0.5572
	6.00	0.55	22	2.6025	0.1020	0.5674
	6.00	0.56	22	2.5561	0.1020	0.5572
	6.00	0.56	22	2.5561	0.1020	0.5572
	6.00	0.56	22	2.5561	0.1020	0.5572
			Average	2.5654		0.5592
	H (cm.)	T (sec)	t (deg. C)	Ψ (sec^{-1})	(cm)	(cm/sec)
3	6.00	0.65	22	2.2021	0.0980	0.5043
	6.00	0.67	22	2.1364	0.0980	0.4892
	6.00	0.64	22	2.2365	0.0980	0.5122
	6.00	0.64	22	2.2365	0.0980	0.5122
	6.00	0.68	22	2.1050	0.0980	0.4820
			Average	2.1833		0.5000
	H (cm.)	T (sec)	t (deg. C)	Ψ (sec^{-1})	(cm)	(cm/sec)
4	6.00	0.58	22	2.4679	0.2160	0.5331
	6.00	0.60	22	2.3856	0.2160	0.5153
	6.00	0.60	22	2.3856	0.2160	0.5153
	6.00	0.60	22	2.3856	0.2160	0.5153
	6.00	0.60	22	2.3856	0.2160	0.5153
			Average	2.4021		0.5189

Note: Tests conducted with Falling Head Method

APPENDIX C

GENERAL SPECIAL PROVISIONS DIVISION 8

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION SPECIFICATIONS FOR CONSTRUCTION GEOTEXTILE

CONSTRUCTION GEOTEXTILE
October 23, 1989

Description
The Contractor shall furnish and place construction geotextile in accordance with the details shown in the Plans.

Materials
Geotextile and Thread for Sewing
The material shall be a woven or non-woven geotextile consisting only of long chain polymeric filaments or yarns formed into a stable network such that the filaments or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the long chain polymers shall be polyolephins, polyesters, or polyamides. The material shall be free from defects or tears. The geotextile shall conform to the properties as indicated in Tables 1, 2, and 3 for each specified use. The geotextile shall be free of any treatment or coating which might adversely alter its physical properties after installation.

Thread used shall be high strength polypropylene, polyester, or Kevlar thread. Nylon threads will not be allowed. The thread used to sew permanent erosion control geotextiles must also be resistant to ultraviolet radiation.

Geotextile Properties
Table 1: Geotextile for underground drainage.

Geotextile Property	Test Method	Geotextile Property Requirements: Low Survivability	Geotextile Property Requirements: High Survivability
AOS	WSDOT Test Method 922	.21 mm max. (#70 sieve)	.21 mm max. (#70 sieve)
Water Permeability	WSDOT Test Method 924	.08 cm/sec min.	.08 cm/sec min.
Tensile Strength, min. in machine and x-machine direction	WSDOT Test Method 916	90 lbs min.	180 lbs min.
Seam Breaking Strength	WSDOT Test Method 918 and WSDOT Test Method 916 (Grab Test)	80 lbs min.	160 lbs min.
Burst Strength	WSDOT Test Method 920	140 psi min.	290 psi min.

Puncture Resistance	WSDOT Test Method 921	40 lbs min.	80 lbs min.
Tear Strength, min. in machine and x-machine direction	WSDOT Test Method 919	30 lbs min.	60 lbs min.

Table 2: Geotextile for soil stabilization.

Geotextile Property	Test Method	Geotextile Property Requirements
AOS	WSDOT Test Method 922	.42 mm max. (#40 sieve)
Water Permeability	WSDOT Test Method 924	.005 cm/sec min.
Tensile Strength, min. in machine and x-machine direction	WSDOT Test Method 916	180 lbs min.
Seam Breaking Strength	WSDOT Test Method 918 and WSDOT Test Method 916 (Grab Test)	160 lbs min.
Burst Strength	WSDOT Test Method 920	290 psi min.
Puncture Resistance	WSDOT Test Method 921	75 lbs min.
Tear Strength, min. in machine and x-machine direction	WSDOT Test Method 919	50 lbs min.

Table 3: Geotextile for permanent erosion control.

Geotextile Property	Test Method[2]	Geotextile[1] Property Requirements Low Survivability[3]	High Survivability
AOS	WSDOT Test Method 922	.30 mm max. (#50 sieve)	.30 mm max. (#50 sieve)
Water Permeability	WSDOT Test Method 924	.04 cm/sec min.	.04 cm/sec min.
Tensile Strength, min. in machine and x-machine direction	WSDOT Test Method 916	130 lbs min.	270 lbs min.
Strain at Failure	WSDOT Test Method 916	15% min.	15% min.
Seam Breaking Strength	WSDOT Test Method 918 and WSDOT Test Method 916 (Grab Test)	110 lbs min.	240 lbs min.
Burst Strength	WSDOT Test Method 920	200 psi min.	430 psi min.
Puncture Resistance	WSDOT Test Method 921	60 lbs min.	110 lbs min.
Tear Strength, min. in machine and x-machine direction	WSDOT Test Method 919	40 lbs min.	80 lbs min.
Ultraviolet (UV) Radiation Stability	ASTM D 4355-84	70% Strength Retained min.	70% Strength Retained min.

[1] All geotextile properties in Tables 1, 2, and 3 are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

[2] WSDOT test methods 916, 919, and 924 are in conformance with ASTM geotextile test procedures, except for geotextile sampling and

specimen conditioning. Copies of all WSDOT geotextile test methods are available at the Headquarters Materials Laboratory in Tumwater.

[3] Low and high survivability for geotextiles used for underground drainage and permanent erosion control are defined in this Special Provision under the respective subsections.

Aggregate Cushion for Permanent Erosion Control Geotextile

The gradation requirements for aggregate cushion are as follows:

% Passing 2 1/2 inch square opening	80-100
% Passing 1/4 inch square opening	25-100
% Passing U.S. No. 100 sieve	0-5

All percentages are by weight.

Geotextile Approval And Acceptance

Geotextile properties and Test Methods

Properties of geotextiles shall be determined by the following test methods:

Geotextile Property	Test Method and Title
AOS	WSDOT Test Method 922: Apparent Maximum Opening Size of Geotextiles
Water Permeability	WSDOT Test Method 924: Water Permeability of Geotextiles by Permittivity
Tensile Strength and Strain at Failure	WSDOT Test Method 916: Breaking Load and Elongation of Geotextiles (Grab Method)
Seam Breaking Strength	WSDOT Test Method 918: Failure in Sewn Seams of Geotextiles; and WSDOT Test Method 916: Breaking Load and Elongation of Geotextiles (Grab Method)
Burst Strength	WSDOT Test Method 920: Diaphragm Bursting Strength of Geotextiles
Puncture Strength	WSDOT Test Method 921: Puncture Strength of Geotextiles
Tear Strength	WSDOT Test Method 919: Trapezoid Tearing Strength of Geotextiles
Ultraviolet (UV) Radiation Stability	ASTM D 4355-84, after 500 hours in weatherometer

Source Approval

The Contractor shall submit to the Engineer the following information regarding each geotextile proposed for use:

Manufacturer's name and current address,

Full product name, and
Proposed geotextile use(s).

If the manufacturer of the proposed geotextile(s) has not previously submitted a geotextile for initial source approval for the proposed use and obtained approval, a sample of each proposed geotextile shall be submitted to and approved by the Headquarters Materials Laboratory in Tumwater. After the sample and required information for each geotextile type have arrived at the Headquarters Materials Laboratory in Tumwater, a maximum of 14 calendar days will be required for this testing. Source approval will be based on conformance to the applicable values from Tables 1, 2, and 3. Each sample shall have minimum dimensions of 1.5 yards by the full roll width of the geotextile. A minimum of 6 square yards of geotextile shall be submitted to the Engineer for testing. The geotextile machine direction shall be marked clearly on each sample submitted for testing. The machine direction is defined as the direction perpendicular to the axis of the geotextile roll.

The geotextile samples shall be cut from the geotextile roll with scissors, sharp knife, or other suitable method which produces a smooth geotextile edge and does not cause geotextile ripping or tearing. The samples shall not be taken from the outer wrap of the geotextile roll nor the inner wrap of the core.

Acceptance Samples

Samples will be randomly taken by the Engineer at the jobsite to confirm that the geotextile meets the property values specified.

Approval will be based on testing of samples from each lot. A "lot" shall be defined for the purposes of this specification as all geotextile rolls within the consignment (i.e., all rolls sent to the project site) which were produced by the same manufacturer, and have the same product name. After the samples and manufacturer's certificate of compliance have arrived at the Headquarters Materials Laboratory in Tumwater, a maximum of 14 calendar days will be required for this testing. If the results of the testing show that a geotextile lot, as defined, does not meet the properties required for the specified use as indicated in Tables 1, 2, and 3, the roll or rolls which were sampled will be rejected. Two additional rolls from the lot previously tested will then be selected at random by the Engineer for sampling and retesting. If the retesting shows that either or both rolls do not meet the required properties, the entire lot will be rejected. All geotextile which has defects, deterioration, or damage, as determined by the Engineer, will also be rejected. All rejected geotextile shall be replaced at no cost to the State.

Acceptance will be by manufacturer's certificate of compliance without sampling if one or both of the following two conditions are met:

(1) The quantities of geotextile proposed for use in each geotextile application are less than or equal to the following amounts:

Application	Geotextile Quantity
Underground Drainage	500 sq. yd.
Soil Stabilization	1500 sq. yd.
Permanent Erosion Control	1000 sq. yd.

(2) the geotextile samples previously tested for the purpose of source approval came from the same geotextile lot as defined which is proposed for use at the project site, provided that the number of samples submitted and tested meet the requirements of WSDOT Test Method 914 "Practice for Sampling of Geotextiles for Testing".

The manufacturer's certificate of compliance shall include the following information about each geotextile roll to be used:

Manufacturer's name and current address,
Full product name,
Geotextile roll number,'
Proposed geotextile use(s), and
Certified test results.

Approval of Seams

If the geotextile seams are to be sewn in the field, the Contractor shall provide a section of sewn seam before the geotextile is installed which can be sampled by the Engineer.

The seam sewn for sampling shall be sewn using the same equipment and procedures as will be used to sew the production seams. If production seams will be sewn in both the machine and cross-machine directions, the Contractor must provide sewn seams for sampling which are oriented in both the machine and cross-machine directions. The seams sewn for sampling must be at least 2 yards in length in each geotextile direction. If the seams are sewn in the factory, the Engineer will obtain samples of the factory seam at random from any of the rolls to be used. The seam assembly description shall be submitted by the Contractor to the Engineer and will be included with the seam sample obtained for testing. This description shall include the seam type, seam allowance, stitch type, sewing thread tex ticket number(s) and type(s), stitch density, and stitch gage.

Construction Requirements

Shipment and Storage

During periods of shipment and storage, the geotextile shall be kept dry at all times and shall be stored off the ground. Under no circumstances, either during shipment or storage, shall the material be exposed to sunlight, or other form of light which contains ultraviolet rays, for more than five calendar days.

General Construction Requirements

The area to be covered by the geotextile shall be graded to a smooth, uniform condition free from ruts, potholes, and protruding objects such as rocks or sticks. The geotextile shall be spread immediately ahead of the covering operation. The geotextile shall not be left exposed to sunlight during installation for a total of more than five calendar days. The

geotextile shall be laid smooth without excessive wrinkles. Under no circumstances shall the geotextile be dragged through mud or over sharp objects which could damage the geotextile. The cover material shall be placed on the geotextile in such a manner that a minimum of 12 to 18 inches of material, depending on the survivability of the geotextile, will be between the equipment tires or tracks and the geotextile at all times. Construction vehicles shall be limited in size and weight such that rutting in the initial lift above the geotextile is not greater than 3 inches deep, to prevent overstressing the geotextile. Turning of vehicles on the first lift above the geotextile will not be permitted. End-dumping the cover material directly on the geotextile will not be permitted. Compaction of the first lift above the geotextile shall be limited to routing of placement and spreading equipment only. No vibratory compaction will be allowed on the first lift.

Pegs, pins, or the manufacturer's recommended method shall be used as needed to hold the geotextile in place until the specified cover material is placed.

Should the geotextile be torn or punctured or the overlaps or sewn joints disturbed, as evidenced by visible geotextile damage, subgrade pumping, intrusion, or roadbed distortion, the backfill around the damaged or displaced area shall be removed and the damaged area repaired or replaced by the Contractor at no cost to the State. The repair shall consist of a patch of the same type of geotextile placed over the damaged area. The patch shall overlap the existing geotextile a minimum of 2 feet from the edge of any part of the damaged area.

If geotextile seams are to be sewn in the field or at the factory, the seams shall consist of two parallel rows of stitching. The two rows of stitching shall be 0.5 inch apart with a tolerance of ±0.25 inch and shall not cross, except for restitching. The stitching shall be a lock-type stitch. The minimum seam allowance, i.e., the minimum distance from the geotextile edge to the stitch line nearest to that edge, shall be 1.5 inches if a flat or prayer seam, Type SSa-2, is used. The minimum seam allowance for all other seam types shall be 1.0 inch. The seam, stitch type, and the equipment used to perform the stitching shall be as recommended by the manufacturer of the geotextile and as approved by the Engineer.

The seams shall be sewn in such a manner that the seam can be inspected readily by the Engineer or his representative. The seam strength will be tested and shall meet the requirements stated in this Special Provision.

Specific Construction Requirements

The construction requirements which follow shall apply in addition to the general construction requirements previously stated.

Underground Drainage

The geotextile shall either be overlapped a minimum of 1 foot at all longitudinal and transverse joints, or the geotextile joints shall be sewn. In those cases where the trench width is less than 1 foot, the minimum overlap shall be the trench width. Either low survivability or high survivability geotextile shall be used, meeting the property requirements specified in Table 1. Low survivability geotextile may be used in trench drains if the trench walls are smooth, stable, and less

than 10 feet in depth. High survivability geotextile shall be used if the trench depth is greater than equal to 10 feet.

An area drain is defined as a geotextile layer placed over or under a horizontal or near-horizontal layer of drainage aggregate. The geotextile shall be overlapped a minimum of 2 feet at all longitudinal and transverse joints in an area drain, or the geotextile joints shall be sewn together. The minimum initial lift thickness over the geotextile shall be 18 inches if low survivability geotextile is used and shall be 12 inches if high survivability geotextile is used.

Soil Stabilization
The geotextile shall either be overlapped a minimum of 2 feet at all longitudinal and transverse joints, or the geotextile joints shall be sewn together. The initial lift thickness shall be 12 inches or more.

Permanent Erosion Control
Unless otherwise specified in the Plans, the geotextile shall either be overlapped a minimum of 2 feet at all longitudinal and transverse joints, or the geotextile joints shall be sewn together. If overlapped, the geotextile shall be placed so that the upstream strip of geotextile will overlap the next downstream strip. Where placed on slopes, each strip shall overlap the next downhill strip.

Placement of aggregate, riprap or both on the geotextile shall start at the toe of the slope and proceed upwards. The geotextile shall be keyed at the top and the toe of the slope as shown in the Plans. The geotextile shall be secured to the slope, but shall be secured loosely enough so that the geotextile will not tear when the riprap is placed on the geotextile. The geotextile shall not be keyed at the top of the slope until the riprap is in place to the top of the slope.

All voids in the riprap face that allow the geotextile to be visible shall be backfilled with quarry spalls or other small stones, as designated by the Engineer, so that the geotextile is completely covered. When an aggregate cushion between the geotextile and the riprap is required, it shall have a minimum thickness of 12 inches.

An aggregate cushion will be required to facilitate drainage when hand placed riprap, sack riprap, or concrete slab riprap, as specified in Sections 9-13.2, 9-13.3, or 9-13.4, respectively, is used with the geotextile.

Either low survivability or high survivability geotextile shall be used, meeting the property requirements specified in Table 3. Low survivability geotextile shall be used if a 12 inch thick aggregate cushion is placed between the geotextile and the riprap and the geotextile is placed on a slope of 2:1 or flatter. High survivability geotextile shall be used if an aggregate cushion is not used or if the geotextile is placed on a slope steeper than 2:1.

Grading of slopes after placement of the riprap will not be allowed if grading results in stone movement directly on the geotextile. Under no circumstances shall stones weighing more than 100 pounds be allowed to roll downslope. Stones shall not be dropped from a height

greater than 3 feet above the geotextile surface. Lower drop heights may be required if geotextile damage from the stones is evident, as determined by the Engineer. If the geotextile is placed on slopes steeper than 2:1, the stones shall be placed on the slope without free-fall for both low survivability and high survivability geotextiles.

Temporary Silt Fences

The Contractor shall be fully responsible to install and maintain temporary silt fences at the locations shown in the Plans. A silt fence shall not be considered temporary if the silt fence must function beyond the life of the contract. The silt fence shall prevent soil carried by runoff water from going beneath, through, or over the top of the silt fence, but shall allow the water without soil to pass through the fence. The minimum height of the top of the silt fence shall be 30 inches above the original ground surface. Damaged and otherwise improperly functioning portions of silt fences shall be repaired or replaced by the Contractor at no cost to the State, as determined by the Engineer.

Sediment deposits shall either be removed when the deposit reaches approximately 1/2 the height of the silt fence, or a second silt fence shall be installed, as determined by the Engineer.

Measurement

Construction geotextile, with the exception of silt fence geotextile and underground drainage geotextile used in trench drains, will be measured by the square yard for the ground surface area actually covered. Silt fence geotextile will be measured by the linear foot of silt fence installed. Underground drainage geotextile used in trench drains will be measured by the square yard for the perimeter of drain actually covered.

Payment

The unit contract prices per square yard for "Construction Geotextile For Underground Drainage", "Construction Geotextile For Soil Stabilization", and "Construction Geotextile For Permanent Erosion Control", and per linear foot for "Construction Geotextile For Silt Fence" as are included in the proposal shall be full pay to complete the work as specified.

Sediment removal behind silt fences will be paid by force account. If a new silt fence is installed in lieu of sediment removal, as determined by the Engineer, the silt fence will be paid for at the unit contract price per linear foot for "Construction Geotextile For Silt Fence".