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16. Abstract

Recommendations are given to improve design and construction of asphalt concrete overlays containing a fabric interlayer installed to reduce the severity or to delay the occurrence of reflection cracking. Improvements in specifications for fabrics and overlays are suggested. Realistic criteria for fabrics, overlays and construction procedures are given. Methods of determining life cycle costs and selecting the appropriate pavement rehabilitation alternative are discussed.

Research is continuing under Study 433, "Evaluation of Fabric Test Pavements," and final results and recommendations will be made under Study 433.

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FABRICS IN ASPHALT OVERLAYS--
Design, Construction and Specifications

by

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PREFACE

This is the third and final report issued under Research Study 2-9-79-261, "Evaluation of Fabric Underseals".

The first report (261-1) entitled "Laboratory Evaluation of Selected Fabric for Reinforcement of Asphaltic Concrete Overlays" by D. Pickett and R. L. Lytton was issued in May, 1981 and dealt primarily with the development of a technique to analyze laboratory data using fracture mechanics and finite element theory. These methods were applied to test results from the "overlay tester", a device for quantifying a pavement system's relative resistance to thermal cracking. Significant findings are presented regarding optimum location of a fabric within a pavement system and optimum tack coat associated with a fabric.

The second report (261-2) entitled "Evaluation of Fabric Interlayers" by J. Button and J. Epps was issued in November, 1982. It describes construction and early performance of several pavement test sections installed in Texas and gives results of laboratory tests on construction materials. Recommendations are given regarding special design and construction procedures which should be followed when a fabric is used in concert with an asphalt concrete overlay. Supplement 1 to Report 261-2 updates the performance data obtained on the field test pavements to August, 1984.

Monitoring of the field test pavements is continuing under Study 433, "Evaluation of Fabric Test Pavements". Final results and recommendations will be made upon completion of the field evaluation.

DISCLAIMER

IMPLEMENTATION STATEMENT

Analysis of laboratory and field research indicate that certain engineering fabrics have the potential to reduce the severity or delay the appearance of reflection cracks in an asphalt concrete overlay. However, reliable cost-benefit ratios for fabrics have not been established. Presently, based on results of five year old field tests performed under this study, cost-benefit ratios for fabrics appear questionable. Items that have been shown by this research to be of particular importance are 1) overlay design procedures, 2) materials selection and 3) construction operations.

This document provides information to aid the paving engineer responsible for designing an asphalt concrete overlay containing a fabric interlayer installed to reduce or delay reflection cracking. It also contains guidelines to aid personnel responsible for construction of such pavements. Specifications and materials test methods from several states are discussed to aid in preparation of special provisions or upgrading of standard specifications. Improved performance-based specifications need to be developed. Techniques are suggested for use in determining life-cycle costs of pavement overlays and selection of a rehabilitation alternative.

METRIC CONVERSION FACTORS

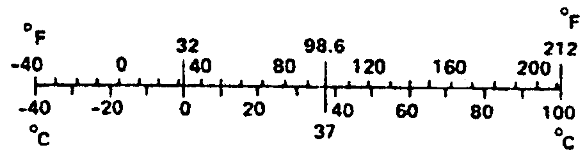
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

Asphalt concrete overlays are extensively utilized for rehabilitation of our nations highways. One of the major problems with overlays is reflection cracking*. The use of fabrics in asphalt concrete overlays is one of several methods that have been used in an attempt to prevent, reduce the severity and/or delay the occurrance of reflective cracks.

Design and construction guidelines and typical specifications for paving fabrics are presented in this report. These guidelines and specifications are based on research conducted at Texas A&M University (3, 4 and 5) as well as a review of the published literature of which references 6, 7 and 8 present the best summary of information.

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*Reflection cracks are fractures in an overlay (AC or PCC) that are the result of, and reflect, the crack or joint pattern in the underlying layer, and may be either environmental and/or traffic induced. (1,2)

FABRICS IN ASPHALT OVERLAYS

Fabrics are only one of a number of techniques that have been tried with varying degrees of success to solve the reflection cracking problem. Available methods usually fall under one or more of three categories as described below:

1. Reinforcement of the overlay:
   a. Thicker overlays of dense graded asphalt concrete
   b. Fabric interlayer within the new overlay
   c. Fibers in asphalt concrete overlay
   d. Reinforcing steel or wire mesh within the new overlay
   e. Low rubber content mixtures or plant mixed seals (open graded friction course)
2. Insulation of overlay from high stress areas (cracks):
   a. Fabric-asphalt interlayer
   b. Fiber-asphalt cement interlayer
   c. Asphalt rubber chipseal
   d. Unstabilized aggregate interlayers
   e. Stone dust bond breakers
   f. Thick overlays of large maximum size open-graded asphalt stabilized interlayers
3. Restrengthening of cracked pavement prior to overlaying:
   a. Heater-scarification
   b. Spray applications of asphalt cement softening agent.

The use of thick overlays, heater-scarification, asphalt cement bound chip seals, asphalt-rubber bound chip seals and fabrics are the methods which are most commonly used.

Reflection cracking can be caused by several mechanisms including:

1. Differential vertical movement at a crack or slab joint in the pavement upon which the overlay is placed,

2. Horizontal movement at a crack or slab joint in the old pavement upon which the overlay is placed,

3. High tensile stresses in the asphalt concrete overlay caused by stress concentration which occurs directly over discontinuities in the pavement upon which the overlay is placed and

4. Combinations of 1, 2 and 3 as stated above.

It is apparent from this limited discussion that both traffic and non-traffic and/or environmentally related loads are responsible for reflection cracking.

The effectiveness of fabrics in preventing, reducing the severity and/or delaying the occurence of reflective cracking is not well defined. Numerous field test pavements have been placed and reports have been prepared (3,4,5,6 and 7). Unfortunately, the field installations often do not contain the required amount of preconstruction, construction and long term post-construction performance information. In addition, comparison of findings from tests sections in various environmental areas of the country often leads to conflicting results. However, the following general conclusions appear to be emerging from these field studies.

Fabrics appear to be most effective in reducing the rate of reflective cracking when:

1. Thick overlays of asphalt concrete are utilized,
2. Differential vertical movements across cracks or joints are small,
3. Differential horizontal movements across cracks or joints are small,
4. Climates are warm.

These field results indicate that fabrics are not effective substitutes for asphalt concrete thickness. That is, they appear to act only as limited reinforcement when the pavement is subjected to traffic loads. Asphalt concrete overlay thicknesses should be designed for future traffic load considerations and the thickness should not be reduced when a fabric is used. For a situation where overlay design procedures suggest that a relatively thin overlay of asphalt concrete is adequate, a minimum thickness of asphalt concrete of the order of one-half the thickness of the existing asphalt pavement should be considered if the rate of reflection cracking is to be controlled.

Virginia and California have developed techniques to measure vertical displacement across joints in portland cement concrete. Virginia data suggest that when differential deflections are greater than about 0.002 inch*, reflection cracking will form rapidly (8). California has developed a method for measuring differential displacements with the Dynaflect but has not established a criteria.

Pavements in warm climates are usually subjected to lower environmentally related stresses and strains than pavements placed in the colder climates. In addition, the properties of the fabric interlayer and asphalt concrete overlay at evaluated temperatures are such that they can accept a larger strain prior to fracture.

Theory and practice, to a degree, have both indicated that fabrics should be placed on top of an asphalt concrete leveling course rather than on the existing cracked pavement. This practice is particularly true for asphalt concrete overlays on portland cement concrete where an overlay thickness of a minimum of 3 to 4-inches is used.

Fabrics have proven to be ineffective when used in combination with thin overlays on jointed portland cement concrete pavements and with thin overlays on asphalt concrete pavements exhibiting transverse temperature related cracks. Some evidence exists which suggests that cracks which have reflected through pavements which contain fabrics are less severe and require less maintenance. Published information to support the observation is difficult to locate.

The benefits of asphalt saturated fabrics in retarding penetration of water have been recognized by some agencies, but the results have not been quantified. A California report (9) suggests that permeability of a fabric-asphalt interlayer is no better than a conventional sealcoat.

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*Benkelman Beam used to make measurements.

DESIGN CONSIDERATIONS

According to Majidzadeh (10), the structural requirements must be satisfied before the beneficial effects of the fabric can be demonstrated. Other research data primarily from highway test pavement evaluations appear to substantiate this conclusion.

When designing an asphalt concrete overlay containing a fabric several items need to be considered. They include fabric selection, asphalt tack coat, asphalt type and quantity, and overlay thickness. In addition, the probability of potential problems such as overlay slippage and moisture damage at the pavement-fabric interface need to be minimized.

Fabric Selection

A number of different types of fabrics have been used as interlayers in asphalt concrete overlays (3,7, and 11). Several types are listed in Table 1 along with the name of the manufacturer and the current in-place cost. Properties of selected fabrics are listed in Table 2. The type of fabric most commonly used in overlay applications is nonwoven and composed of either polypropylene or polyester.

Polypropylene begins to melt at a temperature of 300°F. Therefore, when using polypropylene fabrics, the temperature of the paving mixture should not be greater than 300°F when it contacts the fabric.

Fabric shrinkage upon exposure to heat should be quantified. Fabrics which exhibit free shrinkage in excess of 5 percent upon exposure to 300°F for 30 minutes can cause hairline cracks to appear during construction at wrinkles or insufficiently overlapped cuts in the fabric (12).

Fabrics with a somewhat fuzzy surface next to the asphalt tack offer more resistance to slippage under tires of construction equipment than smoother surfaced fabrics (3). It follows then that fabrics with fuzzy surfaces would be less likely to exhibit slippage of a finished overlay during periods of hot weather.

Thick absorbent fabrics which hold comparatively large quantities of asphalt exhibit greater resistance to cracking during fatigue tests (12). Although no proof is available, thicker asphalt-soaked fabrics should also provide better waterproofing membranes. No data has been generated to show what fabric thickness provides the optimum economic benefits. At this time, a fabric weight of 4 ounces per square yard is the minimum recommended for use with overlays. This should afford absorbency, allow reasonable variation in tack, and provide the tensile strength required during construction and service.

Tack Coat

The appropriate viscosity grade of asphalt cement to utilize as a fabric tack coat for a particular job should be based on the maximum laydown temperature of the overlay, range of ambient temperatures, solar radiation, traffic volume and weight, and magnitude of expected shear forces. It should be as soft as possible to allow proper functioning of the strain-relieving interlayer while providing adequate adhesive and shear strength between layers. Grade AC-10 is recommended for moderate to low temperature environments and AC-20 is recommended for high temperature environments (Figure 1) (13). Generally, one should use the same grade as used in the overlay mixture.

Insufficient asphalt tack can result in failures due to slippage at the fabric interface, especially in areas of high shear forces during periods of hot weather. Excessive tack, on the other hand, can migrate to the pavement surface due to action of traffic and appear as flushing in the wheelpaths. Low viscosity asphalts are more susceptible to this "bleed through" than higher viscosity materials.

Asphalt saturation content of a fabric is dependent upon thickness and absorbency of the fabric and should be quantified prior to designing a pavement containing fabric. Two methods of estimating asphalt retention of a fabric have been adopted by Texas and California. These test methods are included in Appendix A. The proper quantity of asphalt tack is dependent not only on fabric properties but also on the condition of the old pavement surface.

Equation 1 may be used to obtain pavement tack coat quantities:

$$Q_d = 0.08 \pm Q_c + Q_s \qquad \text{Equation 1}$$

where

Q_d = design tack quantity, gal/yd^2

Q_s = fabric asphalt saturation content, gal/yd^2 and

Q_c = correction based on asphalt demand of old surface, gal/yd^2.

The 0.08 is an average value based on field experience for overlays with no fabric.

Emulsified asphalts have been successfully used as tack for fabrics. However, they develop bond strength more slowly than asphalt cement and, as a result, fabric debonding on windy days has been reported. Emulsified asphalts are most suitable to secure overlaps at construction joints. Cutback asphalts should never be used as tack or to secure fabric overlaps. The petroleum-based solvents in cutbacks are damaging to most synthetic fabrics.

Overlay Thickness

Overlay thickness design should, of course, consider projected traffic weight and volume, condition of old pavement (type of cracking, roughness, etc.), strength of subgrade and pavement deflection (Dynaflect, Falling Weight Deflectometer, Benkelman beam, etc.). If a relatively thick overlay is required by standard design procedures, it should not be reduced when a fabric is employed. If a relatively thin overlay is sufficient, a thickness of one half the underlying asphalt concrete pavement should be considered a minimum for significantly reducing or delaying reflective cracking. If a very thin overlay is determined to be adequate, a thickness of 1 1/2-inches should be considered a minimum to prevent slippage during hot weather and provide an effective moisture barrier.

Slippage

Several factors work together to resist slippage in a layered asphalt pavement system: interfacial adhesion, mechanical interlock at the interface, and tensile, compressive and shear strength of the uppermost layer. Nevertheless, during periods of hot weather, slippage has been observed on several commercial airfields and even a few highways particularly in areas of high shear stress. Slippage cracks are typically crescent shaped with the arched end of the crack pattern pointed in the direction opposite that of vehicle travel (Figure 2).

Laboratory tests (12,14) have shown that a fabric will decrease interfacial shear strength of an asphalt mixture at temperatures below 100°F; however, shear strength is not normally a pavement problem at these temperatures (Figure 3). Fabrics have less effect on the interfacial shear strength at temperatures above 100°F where shear strength in a pavement becomes critical. Shear strength appears to be directly related to surface texture of fabrics and somewhat dependent on tack coat quantity. Fabrics should not be expected to compound slippage problems when properly installed to prevent reflection cracking in overlaid pavements.

Slippage should not be confused with problems resulting from unstable overlay pavement mixtures. Distress due to low stability will appear as plastic deformation within the surface course such as rutting, shoving, corrugations, etc. Cracking is not normally associated with mixtures of low stability. Fabrics should not be blamed for these types of distresses.

Water Susceptibility

Moisture in the form of vapor can move through the soil pore structure in the old pavement until it encounters an impermeable layer such as an asphalt-fabric interlayer. Evidence indicates that moisture can, under certain conditions, accumulate at the underside of a fabric interlayer and after a period of time significantly reduce the bond strength between the fabric and the old pavement. Horizontal components of stresses imparted by repetitive vertical wheel loads and other shear forces can eventually result in fatigue-related pavement distress or slippage.

Thin overlays are difficult to adequately compact which, of course, results in comparatively high air voids. Water can penetrate this permeable layer until it reaches the asphalt-impregnated fabric interlayer. The water may remain near the bottom of the new overlay for extended periods depending on the weather. This moisture can weaken the overlay by stripping (often near the bottom of the layer) or by freeze-thaw cycling. Distress will develop first in the wheelpaths due to repetitive loading of traffic on the weakened pavement layer.

For high traffic volume facilities, an overlay where fabric is used should consist of at least 1 1/2-inches of dense graded, well compacted asphalt concrete.

CONSTRUCTION CONSIDERATIONS

Fabrics have been used in numerous overlay rehabilitation projects in recent years. Standard specifications and special provisions to specifications have been developed to define fabrics and to guide construction crews. A summary of the more important features of the construction operations are given below.

General Considerations

Performance of overlays containing fabrics is primarily dependent upon the following three factors:

1. Proper saturation of the fabric with asphalt cement,
2. Proper bond of the saturated fabric to the old pavement,
3. Proper bond of the saturated fabric to the overlay.

The design method described above provides for establishing the correct quantity of asphalt cement to saturate the fabric and sufficient excess to provide for bond to both the old pavement and the new overlay.

The construction sequence involves the spray application of asphalt cement, placement of the fabric then placement and compaction of the asphalt concrete overlay. Complete fabric saturation does not occur until the asphalt concrete overlay is placed on the fabric. Heat from the asphalt concrete overlay lowers the viscosity of the asphalt cement for a sufficient length of time to allow the asphalt to migrate through the fabric. The pressure created during the compaction process also aids the migration of the asphalt.

Cores removed from pavements containing fabrics have confirmed that fabric saturation takes place during construction. Fabric saturation is normally not evident prior to overlay; however, on hot days and with certain relatively permeable materials, fabric saturation will occur in the wheel tracks of construction equipment.

Fabric

Fabric is most often shipped to the job site in rolls that are typically 300 feet in length and 12.5 feet in width. However, different dimensions can be specified. During shipment and storage, the fabric should be protected from direct sunlight and water. Some fabric will degrade upon prolonged exposure to sunlight. Water soaked fabric will be cumbersome and may not readily adhere to an asphalt tack.

Preparation of Old Pavement

As a minimum, the old pavement should be thoroughly cleaned. If the fabric is to be placed directly on the old asphalt concrete pavement, all cracks greater than about 1/4-inch should be filled. Asphalt-rubber binders have been used for this purpose with reasonably good success. Potholes and other areas of localized severe distress should be patched prior to the placement of the fabric and overlay (Table 3). If a leveling course is to be placed prior to the fabric installation, the cracks in the old pavement may not have to be filled. Best results, however, will be achieved if cracks are filled.

When fabric overlay systems are placed on Portland cement concrete pavements, measures should be taken to minimize joint and crack movements. Depending upon the magnitude of the movement; undersealing, cracking and seating or the placement of a leveling course may be required. The fabric should not be placed directly on the old jointed Portland cement concrete.

Tack Coat Distribution

The tack coat type and quantity should be determined by the design method described above. The tack coat is normally applied by an asphalt distributor such as those which are conventionally used for chip seals. Equipment check out procedures and quality control procedures are identical to those used for chip seals. (Tables 3, 4, 5, and 6) (15).

Tack coat distribution should be performed such that relatively long shot lengths are utilized. Start and stop operations of the order of 50 to 100 feet cause highly variable asphalt application rates. Shot lengths equal to fabric roll lengths (300 feet) are convenient for some contractor operations. Greater lengths are encouraged provided the freshly sprayed asphalt does not become contaminated with dust or other foreign material.

Relatively short shot lengths may have to be used on cold and/or windy days to insure that the fabric will adhere to the roadway for a sufficient period of time to allow placement of the overlay. When short shots are required, starting and stopping on paper will reduce the buildup of asphalt at these overlapping sites.

Fabric Placement

A crew of three, using a small tractor rigged for handling fabric rolls, is normally required for fabric placement. The fabric can be placed manually but this is usually undesirable except for small projects.

The supply of fabric for the laydown operation is normally maintained on a truck which follows the laydown tractor. An extra crew member may be required to drive the truck depending upon the speed of the laydown operation.

As the fabric is rolled onto the asphalt tack coat, it must be aligned and smoothed to remove wrinkles and folds. Folds that result in a triple thickness must be cut with a knife and lapped (16).

When fabric is applied on hot days (say 90°F and above), pavement temperatures of the order of 130 to 150°F may prevail. These temperatures can be sufficiently high to keep the asphalt liquid enough to partially saturate the fabric during laydown and fully saturate the fabric in the wheelpaths of the construction vehicles. Tires of asphalt concrete haul trucks can become coated with asphalt and will often pick up the fabric.

The amount of asphalt tack coat should not be reduced to solve this problem. The following corrective measures should be considered:

1. Hand spread a small amount of asphalt concrete on top of the fabric in the wheelpath of the haul vehicles.
2. Change to a "heavier" grade of asphalt cement for the tack coat material.
3. Minimize the number of vehicles on the fabric.
4. Shorten the distance between fabric placement and the paving machine.
5. Application of sand is the least desirable choice as sand will absorb some of the asphalt which defeats its purpose.

If sand is used the quantity should be minimized and the grading should be coarse.

Cool weather construction may require the use of a rubber tired roller to properly attach the fabric to the tack coat. Rolling is preferred over short shot length to solve the cool weather fabric adhesion problem.

A four to six-inch overlap is suggested at all longitudinal and transverse fabric joints. It is desirable to apply additional asphalt tack at these locations to insure proper saturation and bonding. For this purpose, emulsified asphalt can be applied using a brush or mop.

Fabric installed to reduce reflection cracking should not be unnecessarily exposed to traffic and the elements. Exposure can only serve to damage the fabric and thus reduce its effectiveness even though the fabric may not appear to be damaged. Traffic will abrade fibrous material to varying degrees depending upon the type of fabric. Tires will pinch or wear holes in the fabric at the peaks of the larger aggregate in the old surface. Furthermore, from a skid resistance standpoint, a dangerous situation could develop on exposed fabric, particularly during periods of wet weather. Exposure of fabric to prolonged rainfall and traffic action immediately after installation can adversely affect the fabric-to-pavement bond. In severe cases, isolated areas of fabric may become completely separated from the pavement. A highly textured pavement surface such as a chip seal an open graded friction course will aggravate this situation.

Placing and Compacting the Asphalt Concrete

An asphalt concrete overlay can be placed over a fabric using conventional equipment and techniques. If in-place density specifications are met, heat and rolling will have taken place to allow for fabric saturation.

On hot days it may be necessary to place a thin layer of asphalt paving mixture in front of the laydown machine in the paths of the tracks or rubber wheels to prevent fabric "pick-up".

Table 7 contains an inspector checklist for placing fabric.

SPECIFICATIONS

A number of states have prepared standard specifications and/or special provisions to standard specifications for fabrics in pavement overlays. States currently with specifications include: Alabama, California, Colorado, Georgia, Kansas, Florida, Hawaii, Illinois, Iowa, Nebraska, Nevada, New Hampshire, New Mexico, North Carolina, Oklahoma, Oregon, Tennessee, Texas, Virginia, and Washington. Typical requirements for overlay fabrics contained in these specifications are given below:

1. weight (ASTM D 1910)
2. thickness (ASTM D 461)
3. grab tensile strength (ASTM D 1117, D 1682)
4. elongation at break (ASTM D 1117, D 1682)
5. length of roll
6. width of roll
7. asphalt retention (Georgia, Texas, California, North Carolina, Oklahoma, Washington, Corps of Engineers)
8. Mullin Burst (ASTM D 75)
9. color
10. melt point
11. shrinkage

Many of the test methods and criteria are those suggested by fabric manufacturers and thus are based on the fabrics use in other than pavement overlays (filters, clothing, packaging, etc.). Asphalt retention requirements and shrinkage tests are two tests that have been developed by state departments of transportation.

Improved performance-based specifications need to be developed. An outline of such a specification is shown on Table 8. This table indicates that tests should be used for both asphalt saturated and unsaturated fabric samples and that specialized testing equipment will be required. A specification of this nature will require additional testing and field verification.

Specifications contained in Appendix B from Texas and California are suggested for use at the present time.

ECONOMIC SPECIFICATIONS

Highway engineers have a number of rehabilitation alternatives which are suitable for eliminating or reducing the occurrence of reflection cracking. Overlays and reconstruction including the concepts of materials recycling are commonly used. The most successful overlay systems for reducing reflection cracking on old asphalt concrete pavements are thick overlays or asphalt-rubber chipseals, heater-scarification and fabrics in combination with an asphalt concrete overlay. Methods for reducing reflection cracking from old Portland cement concrete pavements include the use of thick overlays or asphalt-rubber chip-seals, fabrics and cracking and seating all in combination with an asphalt concrete overlay. Cost comparisons of these alternatives on both a first cost and life cycle basis are of interest to the engineer and should be considered when selecting the optimum rehabilitation alternative for a particular segment of pavement.

First costs for a number of rehabilitation and maintenance alternatives are shown in Table 9. These cost data are intended to be illustrative only. Relative costs can be expected to vary depending on location which will influence cost of materials, cost of labor, cost and availability of equipment and productivity. For a particular project, the engineer is encouraged to obtain and utilize local cost information.

As noted in Table 9 the first costs of the fabric interlayers ($1.00 per square yard) and heater-scarification ($0.90 per square yard) are nearly identical. The first cost of one inch of asphalt concrete is about $1.70 per square yard. In the last four years, the cost of fabric interlayers has decreased about 25 to 35 cents per square yard. This cost reduction is primarily a result of fabric costs rather than tack coat, labor and equipment cost reductions.

Engineering decisions based on economic considerations should not only include first cost comparisons but also life cycle cost comparisons. Figures 4 and Tables 10, 11, and 12 provide a method for making life-cycle types of comparisons.

Figure 4 can be used to obtain a quick estimate of the relationship between first cost and life-cycle cost. For example, if the first cost of an overlay system is $1.00 per square yard and it normally performs for a period of 5 years, a competitive system that cost $1.20 per square yard must last 6 years. A competitive system that cost $1.60 must last 8 years and a system that cost $2.00 must last 10 years. This simplified approach assumes no maintenance costs and a zero percent rate of return and is appropriate for a general comparison only.

Tables 10, 11, and 12 show comparisons for specific rehabilitation alternatives based on representative first costs shown in Table 9, no maintenance costs and 4 percent rate of return. Table 10 uses a 1.5-inch asphalt concrete overlay as the basis of comparison and estimated life cycles of 4, 8 and 12 years. Table 11 uses a 3-inch asphalt concrete overlay as the basis of comparison and estimated life cycles of 4, 8 and 12 years. Table 12 uses a 4.5-inch asphalt concrete overlay as the basis of comparison and estimated life cycles of 4, 8 and 12 years.

For a particular pavement rehabilitation project, the design engineer may have experience showing that a 3-inch asphalt concrete overlay will last 8 years. With first costs as shown on Table 9, a fabric with a 3-inch overlay would have to last 9.9 years to have equal annual costs. Numerous other comparisons are possible by using these tables.

Reference 17 describes a method for determining life-cycle costs of rehabilitation alternatives. Tables 13 and 14 illustrates the use of the approach.

Five rehabilitation strategies have been proposed for a rural interstate highway in west Texas. This four lane roadway is expected to carry one million equivalent 18,000 pound axle loads over the next 20 years. The existing pavement has moderate alligator cracking over 30 percent of its area, 1 to 4 moderate transverse cracks per station and less than 100 feet of moderate longitudinal cracks per station. According to an overlay thickness design procedure, a 3-inch overlay will be required to carry the traffic for the next 20 years. First costs and calculated life-cycle costs are shown on Table 13. First costs, rehabilitation and maintenance costs for the five alternatives upon which the life-cycle costs are based are shown on Table 14.

Utilizing this type of analysis framework, it is possible to perform "what if games". For example:

1. "What if" the life of the fabric reinforcement plus 2-inch overlay (alternate 3) were 15 years rather than 10 years.
2. "What if" the first cost of the fabric reinforcement plus 2-inch overlay were $3.75 rather than $4.50.

These types of "what if" analyses can be performed to determine competitive costs of new products, provided the competition and its cost is identified and the life of the competition and new product can be obtained or predicted.

Life-cycle cost techniques as described above should be utilized prior to selection of a rehabilitation alternative. Information is provided which will allow the engineer to quickly determine the increase in life required for various alternatives as compared to the more conventional techniques. Field performance information should be used to verify that the difference in life cycles are practical. Computer prediction models as described in Reference 18 can also be used for prediction of life of interlayer systems containing fabrics.

TABLES AND FIGURES

Table 1. General Information on Fabrics Used in Asphaltic Concrete Overlays

Product Name	Type of Fabric	Manufacturer Name and Address	Average Cost in Place/sq.yd.
Amopav	Nonwoven needle-punch, polypropylene	Amoco Fabrics Company 550 Interstate N. Parkway Atlanta, Georgia 30099	No information
Bidim Type: C-22 C-34	Needle punched, spun-bonded polyester, continous filament	Monsanto Textile Co. 800 N. Lindbergh Blvd. St. Louis, MO 63166 (note: Product no longer marketed by Monsanto. A similar fabric is now manufactured by Hoechst Fibers Industries, Spartanburg, S.C.)	1979 - $1.92 1980 - $1.12
Bithuthene	Waterproofing membrane. Rubberized asphalt and heat resistant high strength polypropylene mesh	W. R. Grace and Company 62 Whittmore Ave. Cambridge, MA 02140	1979 - $5.22 1980 - $4.95
Burlington Glass Fabric	Woven glass yarns made up of continuous filaments	Burlington Glass Fabrics, Co. 110 Andrews Street Greensboro, N.C. 27406	Oregon - $1.60 (1975) North Carolina materials cost - 0.65 (1974)
Cerex	Spun bonded nylon nonwoven continuous filaments self bonded (No longer sold for pavement applications)	Monsanto Textile Co. 800 N. Lindbergh Blvd. St. Louis, MO 63166	Not available

Table 1. (Continued)

Product Name	Type of Fabric	Manufacturer Name and Address	Average Cost in Place/sq.yd.
Duroglass	Non-reinforced fiberglass mat	Johns-Manville Ken-Caryl Ranch P.O. Box 5108 Denver, CO 80217	No information
Extrudamat	Short length polypropylene fibers applied as an asphalt slurry	Hercules Inc. Hercules Plaza Wilmington, DE 19899	
Fibertax 200	Nonwoven, spunbonded polypropylene, needle punched	Crown-Zallerbach Corp. Nonwoven Fabrics Div. P.O. Box 877 Camas, Washington 98607	1980 - $1.28
Foss 55	Nonwoven needle - punched polyester	Foss Manfacturing P.O. Box 175-T Haverville, MA 01830	No information
Glass Fabric	Woven glass fibers	Burlington Glass Co. 1345 Ave. of the Americas New York, New York 10105	No information
Mirafi 140 Mirafi 900X	Nonwoven combination of polypropylene and nylon	Celanese Fibers Marketing, Co. P.O. Box 1414 Charlotte, N.C. 28201	1979-1980 $1.00
Nicofab B50	Unknown	Nicolon	No information
Paveprep	High density asphalt mastic between two layers of nonwoven polypropylene fabric	McAdams Manufacturing Co.,Inc. Cincinnati, Ohio 45241	Penn. Mtrl. - $4.48 in place - $6.48 1981

Table 1. (Continued)

Product Name	Type of Fabric	Manufacturer Name and Address	Average Cost in Place/sq. yd.
Petromat	Nonwoven needle punched polypropylene	Phillips Fibers Corp. Greenville, S.C. 29602	1979 - $1.53 1980 - 1.51
Petrotac	Nonwoven polypropylene fabric precoated with rubberized asphalt	Phillips Fibers Corp. Greenville, S.C. 29602	Penn - Mtrl. - $2.97 In Place - $4.23
P66-Margel	No information	No information	No information
P.P.G. Fiberglass	Nonwoven - Multiple length chopped glass strands bonded with water-soluble polyester resin	Pittsburg Plate Glass Co. P.P.G. Industries, Inc. P.O. Drawer A Delaware, OH 43015	Arizona - $1.26
Polyguard	Woven polypropylene mesh laminated with rubberized asphalt	Polyguard Pipeline Prod., Inc. P.O. Box 27 Pryor, OK 74361	Georgia - $4.95 Penn. - $2.70 Alabama - $5.40
Prepave	Two layers of nonwoven spun-bonded polypropylene in an asphalt mastic	The Logan Long Co. 1200 South Main St. Franklin, OH 45005	N. Carolina - $1.00 Tennessee - $5.40(79) 6.26(80)
Protecto-wrap	Bituminous resin modified with a synthetic resin and reinforced with a fabric	Protecto-wrap Co. 2255 S. Delaware St. Denver, CO 80223	No information
Q-Trans-50	No information	Quline	No information

Table 1. (Continued)

Product Name	Type of Fabric	Manufacturer Name and Address	Average Cost in Place/sq.yd.
Reepav	Nonwoven spunbonded polyester with continuous filaments thermally bonded	E. I. DuPont De Nemours Co., Inc. 1007 Market St. Wilmington, DE 19895	No information
Roadglas	Woven fabric made of "Fiberglas" coated with a polymeric hot asphalt	Owens/Corning Fiberglass Corp. Highway Systems 821 Granville, OH 43023	\$9.00 - \$13.50
Royston 10AR & 108	Impregnated fiberglas mesh sandwiched between layers of polymer modified asphalt with a top surface of woven polypropylene	Royston Laboratories, Inc. 128 First St. Pittsburg, PA 15238	Penn. - \$4.32
Structofors	Woven polyester	American Enka Corp. Enka, N. C. 28728	Florida - \$0.26 Labor and equipment N.C. - \$2.52
Trans-Guard 250	Nonwoven needle punched polyproylene	Griffolyn Co.	No information
Truetex MG 75 & MG 100	No information (Apparently these fabrics have been withdrawn from the market)	Oneida Manufacturing Box 1533 Ogden, Utah 84403	California MG 75 - \$0.73 MG 100 - \$1.43

Table 1. (Continued)

Product Name	Type of Fabric	Manufacturer Name and Address	Average Cost in Place/sq.yd.
Typar	Nonwoven spunbonded continuous 100% polypropylene filaments	E. I. DuPont De Nemours & Co., Inc. Textile Fibers Dept. Wilmington, DE 19898	Mtrl. Cost - $0.70 (1978) N. Hampshire - $1.29 (1978) Vermont bid price $3.50
Varistrate	Unknown	3M Company St. Paul, MN 35144	No information

After references 3, 7, 11.

Table 2. Fabric Properties.

Fabric (Manufacturer)	Weight (oz/yd^2)	Thickness(a) (mils)	Grab Tensile(b) (mils)		Elongation(b) (%)	
			Mach.	Cross	Mach.	Cross
True Tex MG100	6.5	88	174	114	94	116
True Tex MG75 (True Temper)	6.5	56	170	98	96	97
Duraglass B-65 (Johns-Manville)	9.8	77	126	116	3	3
Q-Trans-50 (Quline)	7.0	105	93	142	173	107
Fibretex 200 (Crown-Zellerbach)	6.0	73	183	126	145	175
Petromat	4.5	40	81	132	85	74
Petromat (Phillips Fibers)	8.4	-	300+	300+	71	71
Bidim C-22	3.2	51	125	98	90	98
Bidim C-28	6.5	-	162	113	83	91
Bidim C-34 (Monsanto)	9.6	77	178	151	57	73
Reepav 376 (Dupont)	3.0	14	110	79	63	64
Repave (Dupont)	5.1	-	117	112	140	161
Nicofab B50 (Nicolon)	4.9	68	80	133	100	79
Amoco 4545 (Amoco)	6.6	40	142	147	73	104
Trevira 1115	4.5	85	130	110	85	95
Trevira 1120	6.0	100	175	155	85	95
Trevira 1127 (Hoechst)	8.0	125	260	225	85	90
Mirafi 900x (Mirafi Inc.)	4.9	-	102	76	58	47

After references 9 and 3

Table 3. Preparation of Existing Asphalt Pavement Surface for Fabric Overlay

Key Steps of Operation	Action To Be Taken
Pot Holes: Broken	Chip out broken material, leaving vertical sides. Clean, prime and patches, complete at least 30 days before asphalt shot is scheduled. For cold patch material, allow 60 days minimum.
Raveling: Streaking	If severe, fill depressions with slurry seal about 30 days prior to application of fabric.
Cracks-Longitudinal and transverse	Fill large cracks with crack sealing material.
Slippage	Remove all slipped material and replace with suitable patching material.
Bleeding Asphalt	If severe, remove excess asphalt with heater-planer or cold milling machine or heat surface and roll-in hot aggregate.
Rutting and Corrugations	If greater than 3/4 inch remove with heater planer or cold milling machine.
Alligator Cracking	If severe remove and replace with suitable patching material.
Pavement Edge	Remove grass and debris build up from edge of pavement and patch raveled edge as required. Proper drainage should be maintained.
Cleaning	Clean surface immediately prior to asphalt shot; remove mud and other foreign matter; sweep thoroughly with power broom; flush with clean water if necessary and allow to dry.

After reference[15]

Table 4. Inspectors Checklist for Equipment

Asphalt Distributors

1. Do distributors assigned to the job meet specifications requirements?

2. Are heaters and pumps in good operating condition?

3. Are certified calibrations for tank, tachometer and other measuring devices available?

4. Are spray bars and nozzles in good condition, clean and correctly adjusted?

5. Have all other adjustments been made in accordance with manufacturers instructions?

6. Has rate of application (including transverse and longitudinal variation) been checked?

7. Will spray bar height adjustment give required double-lap or triple-lap spray pattern with nozzle set as installed?

8. Does distributor have a means of maintaining constant spray bar height? Is it in good operating condition?

Aggregate Spreaders

1. Do spreaders assigned to the job meet specification requirements?

2. Has spreader operation been checked, including spread rate and transverse and longitudinal variation?

3. Can aggregate trucks assigned to the job be connected quickly and positively to the spreader?

4. Have all other adjustments been made in accordance with manufacturers instructions?

After reference 15

Table 5. Inspectors Checklist for Distribution Operation

1. Is stringline or centerline in place for all distance of shot? Is distributor guideline marker correctly in place?

2. Is asphalt temperature in distributor tank at correct value?

3. Is sufficient quantity of asphalt in the distributor tank to make the full shot?

4. Are pump pressures and travel speed set to produce specified asphalt application rate?

5. Are all nozzles open and set at correct angle?

6. Is spray bar set at correct height?

7. Is paper in place at beginning and end of shot? Is it held down so it will not be disturbed by wind or distributor passage?

8. As shot begins and throughout the shot, visually check flow for uniformity over full width. If streaks appear, stop distributor and correct the trouble. Streaking is usually caused by improper spray bar height adjustment, improper asphalt temperature, or worn or clogged nozzles. Use of worn or clogged nozzles should not be tolerated. Nozzles should only be cleaned by soaking in kerosene or other solvent and air blowing. Nozzles should not be cleaned by insertion of a wire into the orifice.

9. Does outside edge of application coincide with stringline or centerline over full length of shot?

10. Make sure that flow of asphalt is cut off as soon as distributor crosses paper at end of the shot and that distributor is backed up so that any nozzle drip will fall on paper.

11. After gaging tank at end of shot, calculate average spread (R) corrected back to 60°F. If this value does not coincide with design (A), within specified limits, make necessary adjustments so correct spread rate is delivered on subsequent shots.

After reference 15

Table 6. Asphalt Application

Key Step of Operation	Action To Be Taken
Equipment Check	Before work begins inspect distributor for operating condition (Inspectors Checklist Table 4 and 5).
Alignment	Place string-line along road edge or use center line to guide driver of the distributor.
Travel speed	Determine distributor speed (S_f) for spray bar output in gallons/minute (G_t), width of shot in feet (W) and rate of binder application in gallons/square yard (R). $S_f = \frac{9G_t}{WR}$, feet/minute
Length of Shot	Determine length of application (shot) (L_A) to balance aggregate availability (number of loaded trucks), size of tank, type of asphalt, allowable time delays and traffic control. Total quantity of asphalt to be shot (T) is measured in gallons. $L_A = \frac{9T}{WR}$, feet
Nozzle Adjustment	Adjust angle between long axis of nozzle orifice and spray bar longitudinal axis to value specified by distributor manufacturer (normally between 15 and 30 deg.) Adjust end nozzles to greater angle or use a deflector nozzle. Replace clogged or damaged nozzles.
Spray-Bar Height	Adjust height accurately to produce exact double-lap or triple-lap pattern determined by distributor calibration and test. (Double-check height control).
Spraying Temperature	Set tank heater to control temperature to give correct viscosity for type and grade of asphalt being shot.

Table 6. Continued

Key Step of Operation	Action To Be Taken
Transverse Joints	Avoid overlap by starting and ending the shot applied by the distributor on building paper.
Longitudinal Joints	Overlap preceeding shot by 1/2 width of spray from end nozzle. Accurate alignment by distributor driver is essential. If a good driver is available better performance can be obtained by using a deflector nozzle. If possible keep joint at edge of lane (centerline of 2-lane highways).
Asphalt Distribution Rate	1. On first shot, then periodically during job, measure transverse variation in rate by catching spray on cotton pads spaced across pavements. Transverse variation in rate should be less than 15 percent for asphalt emulsions and less than 10 percent for asphalt cements and cutbacks. 2. On first shot, then periodically during job, measure longitudinal variation in spray rate by catching asphalt in 12 in. x 12 in. shallow paper-lined pans placed at 100 to 150 ft. intervals along the direction of travel. The longitudinal variation in rate should be less than 10 percent. 3. By gauging tank before and after shot, determine total asphalt applied (T) and calculate distribution on a gallons per square yard basis. $R = \frac{9T}{WL}$ gal/yd^2 (After Reference 15)

Table 7. Inspection Checklist for Fabric Placement

Preliminary Work

1. Sample fabric, and send to Materials and Test Division.
2. Store fabric in area protected from sun and water.
3. Determine the brand and grade of asphalt to be used, for binder and obtain a sample.
4. Determine the rate of application of tack coat.

Preparation of Old Pavement

1. Sweep surface clean.
2. Seal larger cracks, or place leveling course.
3. Repair large spalls and chuckholes (see Table 3).

Application of Asphalt Binder

1. Check application rate and temperature of asphalt and obtain a sample.
2. Watch for poor asphalt spread practices such as:
   a) frequent stops and starts
   b) spread overlaps
   c) nonuniform spread

Fabric Laydown

1. Watch for wrinkles, folds, and bubbles.
2. Prevent excessive overlaps.
3. Insure that fabric follows proper alignment.
4. If bleeding occurs, broadcast asphalt concrete on fabric to prevent tires sticking.

Overlay Paving

1. Discourage lengthy windrows of asphalt concrete.
2. Check temperature of asphalt concrete behind paver.
3. Encourage expenditious, thorough rolling of asphalt concrete overlay.

(Based on reference 16)

Table 8 . Suggested Specification Tests and Acceptance Criteria for Overlay Fabrics

FUNCTION	PURPOSE	SUGGESTED TESTS	SUGGESTED ACCEPTANCE CRITERIA
Design	Determine Tack Coat Quantity	Caltrans Fabric Saturation Texas A&M Fabric Saturation Texas DOT Fabric Saturation	Information Only
Construction	Prevent Fabric Pick-up by Construction Traffic	Texas A&M Peel Strength Fabric Saturation Caltrans	Minimum Load/Unit of Fabric Width Select Proper Tack Coat Quantity and Type
	Place Fabric with Minimum of Difficulty (folds, wrinkles, around corners)	Direct Tension	Elastic Modulus or Stiffness at _________ Strain
	Prevent Fabric From "Ripping" During Construction	Direct Tension	Stress at ________ Strain Stress at Failure
Performance	Shrinkage Upon Application of Hot Mix Overlay	Texas A&M Fabric Shrinkage Upon Soaking in Asphalt at 275, 300, 325°F	Maximum Length Change of ____ Upon Soaking at ____°F
	Prevent Crack Propagation (Horizontal and Vertical Movements)	Direct Tension on Soaked Fabric Direct Tension on Unsoaked Fabric	Min. & Max. Stiffness at _____% Strain Min. & Max. Stress at _____% Strain Min. & Max. Strain at _____% Stress
		Texas A&M or Similar Crack Reflection Machine Flexural Fatigue Test	Number of Cycles to Fracture Rate of Crack Propagation Fracture Mechanics Parameters

Table 8. (Continued)

FUNCTION	PURPOSE	POSSIBLE TESTS	POSSIBLE ACCEPTANCE CRITERIA
Performance	Prevent Crack Propagation	Fabric Saturation: Cal Trans, Texas A&M	Min. & Max. Fabric Saturation
	Prevent or Limit Water From Passing Through Fabric	Water Permeability Under a Constant or Falling Head (Saturated Fabric)	Maximum Value of _______.
	Prevention Slippage of Overlay	Shear Strength at Interface Texas A&M, Caltrans	Min. Shear Strength at interface at some temperature, deformation rate and vertical loading & at optimum asphalt content. Min. Thickness of Overlay
		Friction of Cloth Surfaces	Coefficient of Friction

Table 9. Representative Prices of Pavement Rehabilitation Alternatives

Rehabilitation Alternative	In-place costs, dollars/yard^2	
	Range	Representative
Asphalt Concrete-Asphalt Cement Binder	1.40-1.95*	1.70*
Asphalt Concrete-Sulphur, Chemkrete or or polymer modified binder	1.80-2.50*	2.20*
Asphalt Concrete-Asphalt-Rubber Binder	2.50-3.50*	3.00*
Aggregate Base	0.30-0.45*	0.37*
Pavement Recycling-hot and cold	1.10-1.60*	1.40*
Chip Seal-Asphalt Cement Binder	0.60-1.10	0.85
Chip Seal-Asphalt-Rubber Binder	1.50-2.25	1.85
Heater Scarification	0.50-1.50	0.90
Fabric (conventional) includes tack coat	0.65-1.50	1.00
Cracking & Seating PCC	0.25-0.75	0.50
PCC Joint Repair	3.00-4.50	3.75
Pot Hole Repair	0.25-0.45**	0.35**
Dig out and Repair	0.50-1.00***	0.75***

* Dollars per square yard per inch thickness.

** One percent of area repaired 4-inches thick. Prices are for square yards of surface maintained.

*** Five percent of area repaired 6-inches thick. Prices are for square yards of surface maintained.

Table 10. Comparison of Asphalt Concrete Overlay Rehabilitation Alternatives*

Rehabilitation Alternative	First Cost, $/yd.^{2}	Life for Equal Annual Cost, yrs.		
Asphalt Concrete-Asphalt Cement Binder (1.5 in.)*	2.55	4.0	8.0	12.0
Asphalt Concrete-Asphalt Cement Binder (3.0 in.)	5.10	8.7	19.7	38.5
Asphalt Concrete-Asphalt Cement Binder (4.5 in.)	7.65	14.5	40.0	40.0
Asphalt Concrete-Sulphur, Chemkrete, polymer (1.5 in.)	3.30	5.3	11.0	16.9
Asphalt Concrete-Sulphur, Chemkrete, polymer (3.0 in.)	6.60	12.0	28.7	40.0
Asphalt Concrete-Asphalt Rubber Binder (1.5 in.)	4.50	7.5	16.4	27.7
Asphalt Concrete-Asphalt Rubber Binder (3.0 in.)	9.00	18.3	40.0	40.0
Pavement Recycling (1.5 in.)	2.10	3.3	6.3	9.5
Pavement Recycling (3.0 in.)	4.20	6.9	14.9	24.7
Pavement Recycling (4.5 in.)	6.30	11.3	28.0	40.0
Heater Scarification + 1.5 in. Asphalt Concrete	3.45	5.6	11.6	18.1
Heater Scarification + 3.0 in. Asphalt Concrete	6.00	10.6	25.6	40.0
Fabric + 1.5 in. Asphalt Concrete	3.55	5.8	12.9	18.9
Fabric + 3.0 in. Asphalt Concrete	6.10	10.8	26.3	40.0

Table 10. (Continued)

Rehabilitation Alternative	First Cost, $/yd.^{2}	Life for Equal Annual Cost, yrs.		
Chip Seal-Asphalt Cement Binder + 1.5 in. Asphalt Concrete	3.40	5.5	11.4	17.7
Chip Seal-Asphalt Cement Binder + 3.0 in. Ashpalt Concrete	5.95	10.5	25.2	40.0
Chip Seal-Asphalt Rubber + 1.5 in. Asphalt Concrete	4.40	7.3	15.9	26.5
Chip Seal-Asphalt Rubber + 3.0 in. Asphalt Concrete	6.95	12.9	33.7	40.0
Cracking & Seating + 1.5 in. Asphalt Concrete	3.05	4.9	9.9	15.2
Cracking & Seating + 3.0 in. Asphalt Concrete	5.60	9.7	22.9	40.0
Cracking & Seating + 4.5 in Asphalt Concrete	8.15	15.9	40.0	40.0

*Basis of Comparison 1.5-inches of Asphalt Concrete. Calculated using first costs shown in Table 9, no maintenance costs and 4 percent rate of return.

Table 11. Comparison of Asphalt Concrete Overlay Rehabilitation Alternatives*.

Rehabilitation Alternative	First Cost, $\$/yd.^2$	Life for Equal Annual Cost, yrs.		
Asphalt Concrete-Asphalt Cement Binder (1.5 in.)	2.55	1.9	3.8	5.3
Asphalt Concrete-Asphalt Cement Binder * (3.0 in.)	5.10	4.0	8.0	12.0
Asphalt Concrete-Asphalt Cement Binder (4.5 in.)	7.65	6.3	13.2	21.1
Asphalt Concrete-Sulphur, Chemkrete, polymer (1.5 in.)	3.30	2.6	4.9	7.0
Asphalt Concrete-Sulphur, Chemkrete, polymer (3.0 in.)	6.60	5.5	11.0	16.9
Asphalt Concrete-Asphalt Rubber Binder (1.5 in.)	4.50	3.5	6.9	10.2
Asphalt Concrete-Asphalt Rubber Binder (3.0 in.)	9.00	7.6	16.4	27.7
Pavement Recycling (1.5 in.)	2.10	1.7	3.0	4.3
Pavement Recycling (3.0 in.)	4.20	3.3	6.4	9.5
Pavement Recycling (4.5 in.)	6.30	5.4	10.3	15.9
Heater Scarification + 1.5 in. Asphalt Concrete	3.45	2.7	5.1	7.4
Heater Scarification + 3.0 in. Asphalt Concrete	6.00	5.2	9.8	14.8
Fabric + 1.5 in. Asphalt Concrete	3.55	2.8	5.5	7.7
Fabric + 3.0 in. Asphalt Concrete	6.10	5.3	9.9	15.2
Chip Seal-Asphalt Cement Binder + 1.5 in. Asphalt Concrete	3.40	2.7	5.1	7.3
Chip Seal-Asphalt Cement Binder + 3.0 in. Asphalt Concrete	5.95	5.2	9.5	14.7
Chip Seal-Asphalt Rubber + 1.5 in. Asphalt Concrete	4.40	3.4	6.7	10.0
Chip Seal-Asphalt Rubber + 3.0 in. Asphalt	6.95	5.7	11.7	18.3
Cracking & Seating + 1.5 in. Asphalt Concrete	3.05	2.4	4.5	6.5
Cracking & Seating + 3.0 in. Asphalt Concrete	5.60	4.5	9.0	13.5
Cracking & Seating + 4.5 in. Asphalt Concrete	8.15	6.7	14.3	23.4

*Basis of Comparison 3.0-inches of Asphalt Concrete. Calculated using first costs shown in Table 9, no maintenance costs and 4 percent rate of return.

Table 12. Comparison of Asphalt Concrete Overlay Rehabilitation Alternatives*.

Rehabilitation Alternative	First Cost, $/yd.^{2}	Life for Equal Annual Cost, yrs.		
Asphalt Concrete-Asphalt Cement Binder (1.5in.)	2.55	1.4	2.5	3.4
Asphalt Concrete-Asphalt Cement Binder (3.0in.)	5.10	2.7	5.1	7.3
Asphalt Concrete-Asphalt Cement * Binder (4.5in.)	7.65	4.0	8.0	12.0
Asphalt Concrete-Sulphur, Chemkrete, polymer (1.5in.)	3.30	1.8	3.2	4.5
Asphalt Concrete-Sulphur, Chemkrete, polymer (3.0in.)	6.60	3.4	6.7	10.0
Asphalt Concrete-Asphalt Rubber Bind. (1.5in.)	4.50	2.4	4.5	6.4
Asphalt Concrete-Asphalt Rubber Bind. (3.0in.)	9.00	4.8	9.8	14.9
Pavement Recycling (1.5in.)	2.10	1.1	2.0	2.9
Pavement Recycling (3.0in.)	4.20	2.2	4.1	5.9
Pavement Recycling (4.5in.)	6.30	3.3	6.4	9.5
Heater Scarification + 1.5in. Asphalt Concrete	3.45	1.8	3.3	4.7
Heater Scarification + 3.0in. Asphalt Concrete	6.00	3.1	6.0	8.9
Fabric + 1.5in. Asphalt Concrete	3.44	1.9	3.4	4.9
Fabric + 3.0in. Asphalt Concrete	6.10	3.2	6.2	8.9
Chip Seal-Asphalt Cement Binder + 1.5in. Asphalt Concrete	3.40	1.8	3.3	4.7
Chip Seal-Asphalt Cement Binder + 3.0in. Asphalt Concrete	5.95	3.1	6.0	8.8
Chip Seal-Asphalt Rubber + 1.5in. Asphalt Concrete	4.40	2.3	4.3	6.2
Chip Seal-Asphalt Rubber + 3.0in. Asphalt Concrete	6.95	3.6	7.2	10.8
Cracking & Seating + 1.5in. Asphalt Concrete	3.05	1.7	2.9	4.2
Cracking & Seating + 3.0in. Asphalt Concrete	5.60	2.9	5.7	8.2
Cracking & Seating + 4.5in. Asphalt Concrete	8.15	4.3	8.6	13.0

*Basis of Comparison 4.5-inches of Asphalt Concrete. Calculated using first costs shown in Table 9, no maintenance costs and 4 percent rate of return.

Table 13. Example Life Cycle Anaylsis.

Description of Project

Location: Southwestern U.S.

Type of Highway: Rural Interstate

ADT: 12,000 on 4 lanes

Eq. 18 kip Axle Loads: 1,000,000 on Design Lane

Existing Pavement: 4" Asphalt Concrete
10" Untreated Base
12" Select Subbase
Subgrade CBR = 7

Condition of Pavement

Condition Survey: Alligator Cracking, Moderate, >30%
Transverse Cracks, Moderate, 1-4 Per Station
Longitudinal Cracks, Moderate, <100 Ft. Per Station

Deflection: 0.017 Benkelman Beam

Serviceability Index: 3.1

Skid Number: 37

Required Overlay Thickness: 3-inches AC for 20 Year Life

Rehabilitation Alternatives	First Cost $/yd^2	Life Cycle Cost $/yd^2	First Energy BTU,yd^2	Life Cycle Energy BTU/yd^2
1. Asphalt rubber chip seal to delay overlay	1.25	7.31	6,200	139,300
2. 3-inch asphalt concrete overlay	4.95	9.88	83,400	189,800
3. Heater-scarification + 2-inch overlay	4.20	7.32	76,600	156,100
4. Asphalt-rubber interlayer + 2-inch overlay	5.15	7.36	61,800	115,500
5. Fabric interlayer + 2-inch overlay	4.50	7.62	58,100	137,600

Table 14. Life Cycle Costs Associated with Various Rehabilitation Alternatives (Values given in dollars).

Year	Rehabilitation Alternatives				
	1 A-R Chip Seal	2 3" AC	3 HS + 2" AC	4 A-R + 2" AC	5 Fabric + 2" AC
Initial	1.85	4.95	4.20	5.15	4.50
1					
2		0.10			
3	0.25	0.15			
4	4.95	0.20			
5		0.20	0.10		0.10
6		0.25	0.10		0.10
7		2.50	0.10		0.10
8			0.15	0.11	0.15
9		0.10	0.25	0.10	0.25
10		0.15	2.50	0.10	2.50
11	0.10	0.20		0.15	
12	0.10	0.20		0.25	
13	0.15	0.25		2.50	
14	0.25	2.50	0.10		0.10
15	2.50		0.15		0.15
16		0.10	0.25		0.25
17		0.15	2.50	0.10	2.50
18		0.20		0.15	
19	0.10	0.20		0.25	
20	0.15	0.25		2.50	
Salvage Value	0.71	0.36	1.43	2.50	1.43

AC = \$1.65/sq. yd.-in. A-R = \$1.85

HS = \$0.90 Fabric = \$1.00

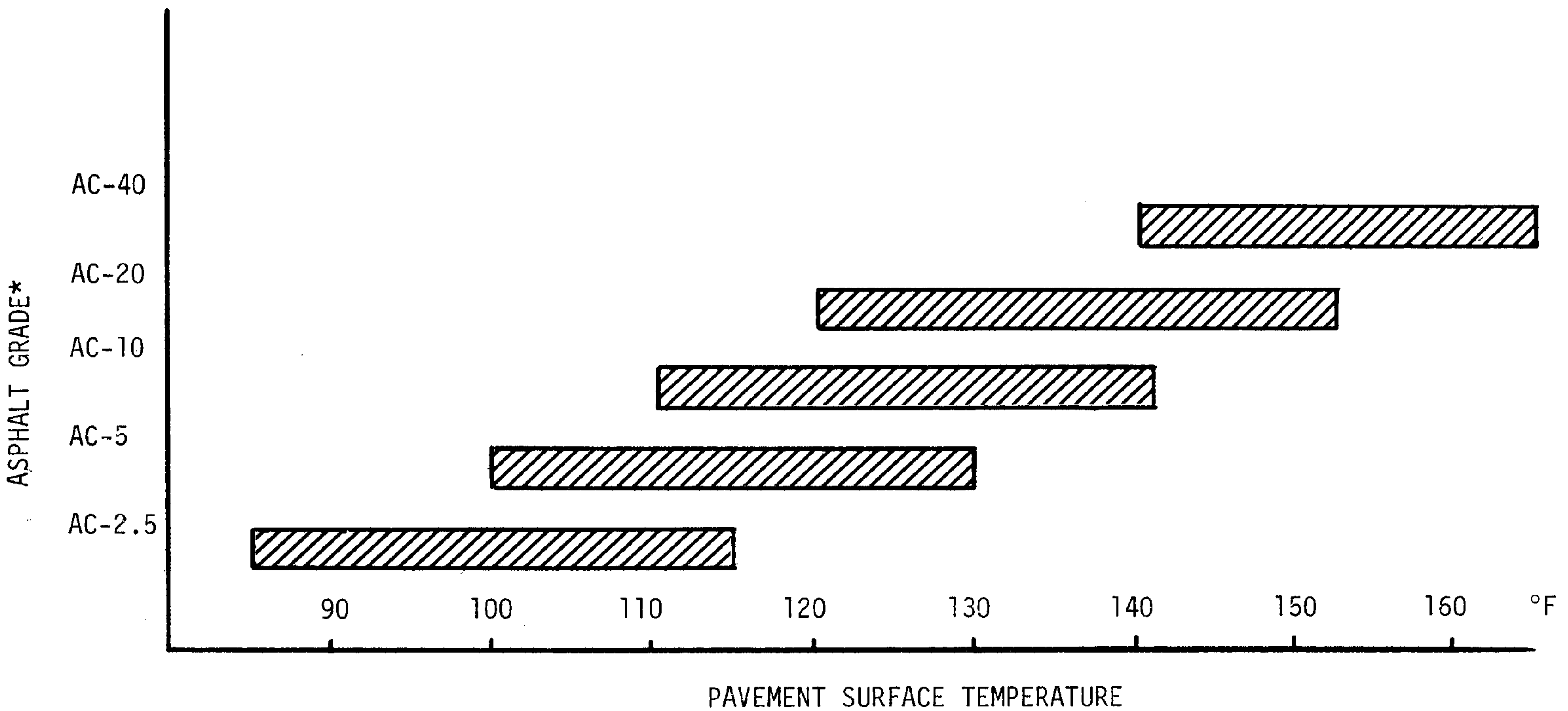
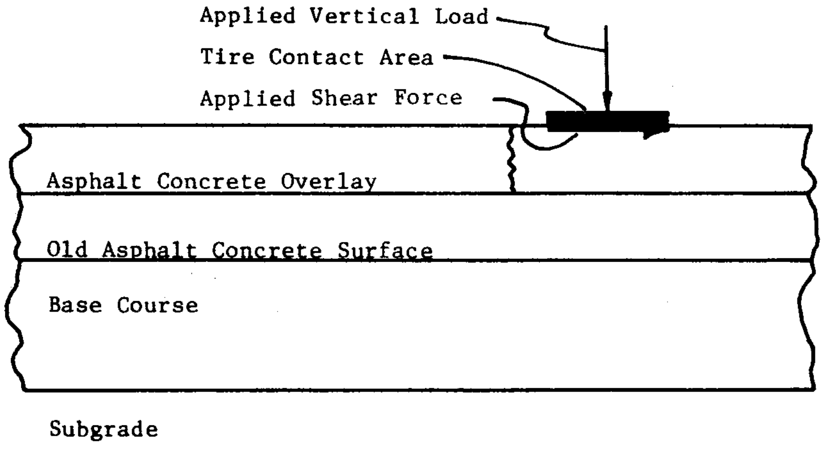


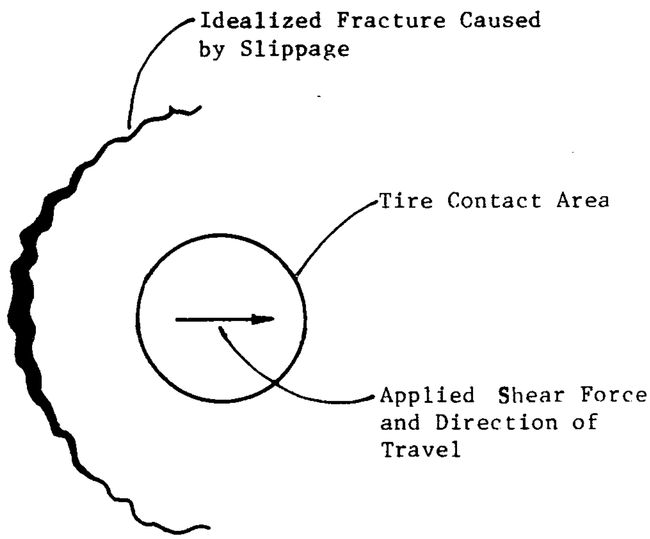
Figure 1. Asphalt Type and Serviceability Range Corresponding to Pavement Surface Temperature.

* From AASHTO 226-73

After Reference 13



a. Side View



b. Top View

Figure 2. Typical Slippage Failure.

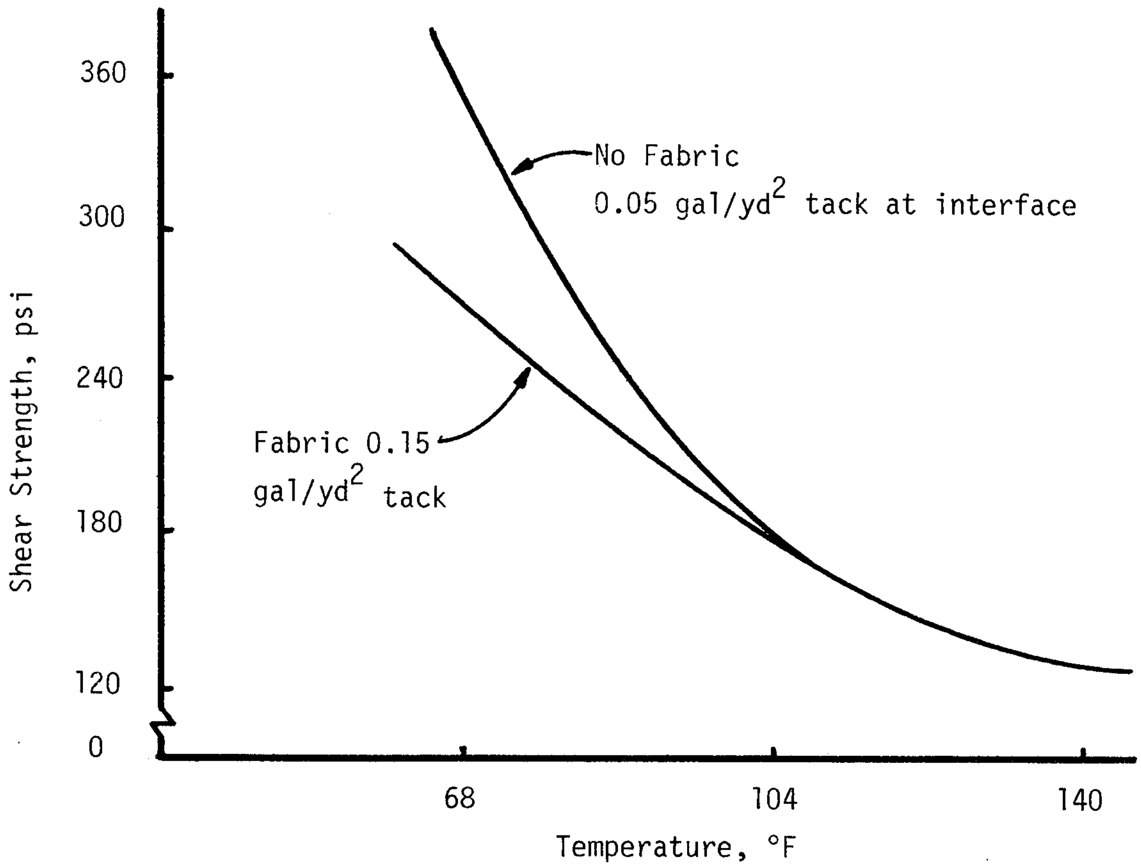


Figure 3. Shear Strength as a Function of Temperature.
After References 12 and 14.

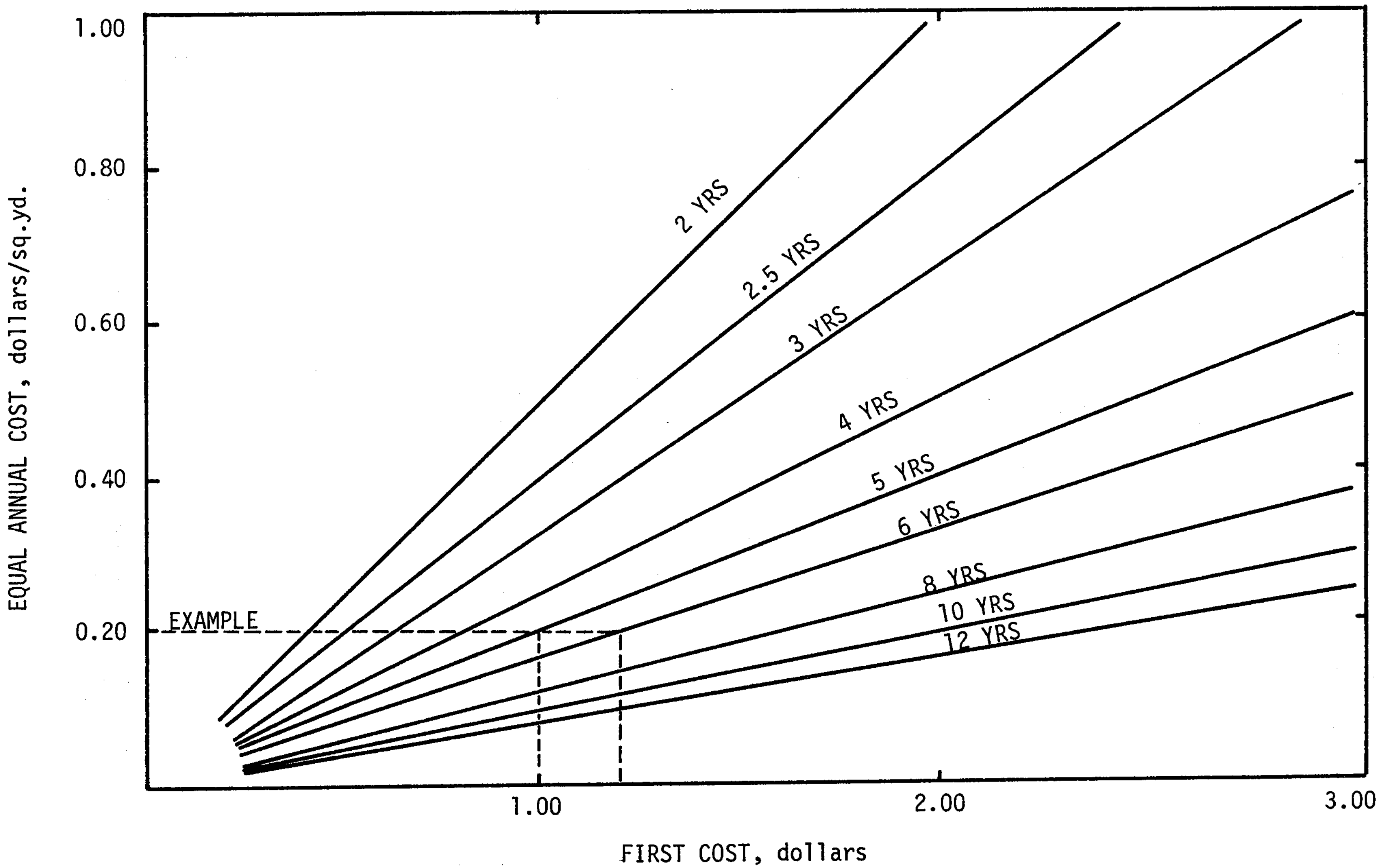


Figure 4. Simplified Relationship Between Equal Annual Cost and First Cost. (After Reference 12.)
Assumptions: No maintenance costs - 0 percent rate of return

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APPENDIX A

Test Methods to Determine Asphalt Retention of a Fabric

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

ASPHALT RETENTION TEST*

Asphalt retention and potential change of area of the fabric shall be determined as follows:

Three warp-wise specimens of four by eight inch dimension and three filling-wise specimens of like dimension shall be selected at random from the individual one foot wide by roll width test sample. These test specimens shall be individually weighed to the nearest 0.1 gram and then submerged for 30 minutes in the specified asphalt cement maintained at a temperature of 275 ± 4°F in a mechanical convection oven. After the required submersion the test specimens shall be removed and hung to drain in the oven for an additional 30 minutes at 275 ± 4°F. The samples shall then be removed from the oven and allowed to drain for one hour at a temperature of 76 + 4°F.

The asphalt cement used for this test shall meet the detailed requirements for viscosity grade AC-10 of the 1982 Texas State Department of Highways and Public Transportation Specification Item, "Asphalts, Oils and Emulsions" with the additional requirement that the viscosity at 275°F shall be within the range of 2.3 to 2.8 stokes. After the one hour of 76 ± 4°F the asphalt coated specimens shall be weighed to the nearest 0.1 g and then placed in naphtha heated to 110 ± 5°F for 30 minutes. Fresh naphtha contained in trays at the specified temperature may be alternated as necessary during the 30 minute period to effect removal of the asphalt cement from the specimens. Specimens will be blotted with paper towels and allowed to air dry to effect naphtha removal. The area of the specimens will then be measured for the determination of percent change in area. Asphalt retention and change in area will be calculated as follows:

asphalt retention, oz./sq.ft. =

$$\frac{\text{wt. in grams asphalt} \times 0.0352739}{\text{area of specimen after test in in}^2 \div 144}$$

---

*From special specification, Item 3099.

change in area,

$$\% = 100 - \left[\frac{\text{area of specimen after test in in}^2 \times 100}{\text{original area of specimen in in}^2}\right]$$

Specimens which have been previously subjected to the 275°F Asphalt Retention Test and Asphalt Removal procedures shall be centered in the jaws of the tensile testing machine. The 3-inch jaw separation will be maintained. If the original 4 x 8-inch specimen has expanded or shrunk in size, the required fabric spacing around the jaws will of necessity not be maintained. Specimens will be centered and 3-inch jaw separation maintained.

Estimation of Tack Coat Requirements (9)

In order for any pavement interlayer system to be successful, it must achieve satisfactory bonding with both the overlay and the existing pavement or underlayer. In the case of a fabric interlayer, this proper bonding should depend on the tack coat that penetrates the fabric from its underside and provides sufficient excess on the fabric's top surface to effect proper bonding with the underside of the overlay. In order for this situation to be realized, three things must occur:

1. The tack coat must be made liquid (melted) enough to enable it to invade the fabric,
2. The tack coat must stay liquid long enough for its migration through the fabric to occur, and
3. External compressive load must be applied to the system when the tack asphalt is still liquid in order to provide a sponging effect on the fabric.

For this situation to occur, it is apparent that inputs of heat and pressure are necessary. The heat demand must be meat by heat from the overlay mix that is adjusted for the overlay thickness, the temperature of the underlayer, and the air temperature and wind during paving. The required pressure will be supplied from the deadweight of the overlay and the compactive effort on the overlay.

Testing Discussion. In designing a routine laboratory test for a fabric's asphalt saturation potential (ASP), it is prudent to simulate the probable worst-case field conditions, namely:

1. Low temperature of existing pavement = 40°F;
2. Thin overlay = 0.1 ft;
3. Relatively cool overlay mix = 250°F;
4. Minimal rolling effort = 3 passes of a 12-ton roller; and
5. Heat availability and dwell time = 5 min.

The details of this test cannot be presented here, but basically the test involves placing a 250°F AC briquette (4 in. in diameter) on top of a fabric, under which is an asphalt (AR-4000) film of known thickness (which represents a known tack-coat rate). The briquette is loaded to simulate rolling forces, and the fabric is inspected for degree of saturation.

Recommended tack coat rates for the fabric's tested are given in the table below:

Fabric	Lightest Tack-Coat Rate Found to be Acceptable (gal/yd^2)
Amoco 4545	0.35
Bidim C-22	0.25
Bidim C-34	0.35
TrueTex MG75	0.30
TrueTex MG100	0.35
Trevira 1117	0.30
Nicofab B50	0.30
Petromat	0.25
Reepav 376	0.15
Q-Trans-50	0.35
FibreTex 200	0.30

An investigation was made of possible correlations that might exist between the recommended tack rate (from melt-through testing) and various fabric properties. It was hypothesized that the tack-coat demand of a fabric would depend largely on two fabric properties: weight and thickness. After unsuccessful attempts to establish a meaningful correlation with either of these properties individually, a reasonably valid (r^2 = 0.83) correlation was observed to exist with their product (weight x thickness). This relation is given in Equation 1 and shown in Figure A1:

$$RTC = 0.055TW^{0.30} \qquad (1)$$

where

RTC = recommended tack-coat rate (gal/yd^2),

T = fabric thickness (mils), and

W = fabric weight (oz/yd^2).

Note that the RTC values calculated from fabric weight and thickness by using Equation 1 should be taken as estimates, and values should be rounded to the nearest 0.05 gal/yd^2 to be consistent with the precision of field application techniques.

Other Tests for Estimating Tack Coat Requirements. Recognizing the need for a simpler test than the one just described, an investigation was made of a test developed earlier by the Texas State Department of Highways and Public Transportation (7).

The asphalt retention values obtained by using the Texas test had satisfactory correlations with TransLab RTC determinations, as shown in Figure A2. However, the Texas method for determing tack-coat rate, although simple, was not considered an acceptable test method because it did not simulate field conditions. For example, some of the fabric samples shrunk as much as 50 percent in their linear dimensions while in the 285°F oven. This is not comparable to field conditions, where the fabric would be restrained from shrinking. Also, the Texas test did not consider role of roller pressure or AC mix weight and heat in accomplishing the saturation. It was, therefore, decided that TransLab should develop its own simple test, with an objective being that any such test should have satisfactory correlation with RTC values obtained from the melt-through test.

The TransLab motor oil retention test was developed to meet this need. In this test, a piece of the fabric is soaked in 20W motor oil at 70°F for 2 min, then removed and placed on an inclined (7.5°) surface. Next, a 3350 gram steel cylinder is rolled down the incline six times to remove some of the excess oil on the fabric (Figure A3). The weight of the oil retained in the fabric is determined and a recommended tack rate is estimated by using the TransLab correlation shown in Figure A4. (Note that in Figure A4 the tack-coat rate includes 0.05 gal/yd^2 to fill voids in the surface that receives the tack coat).

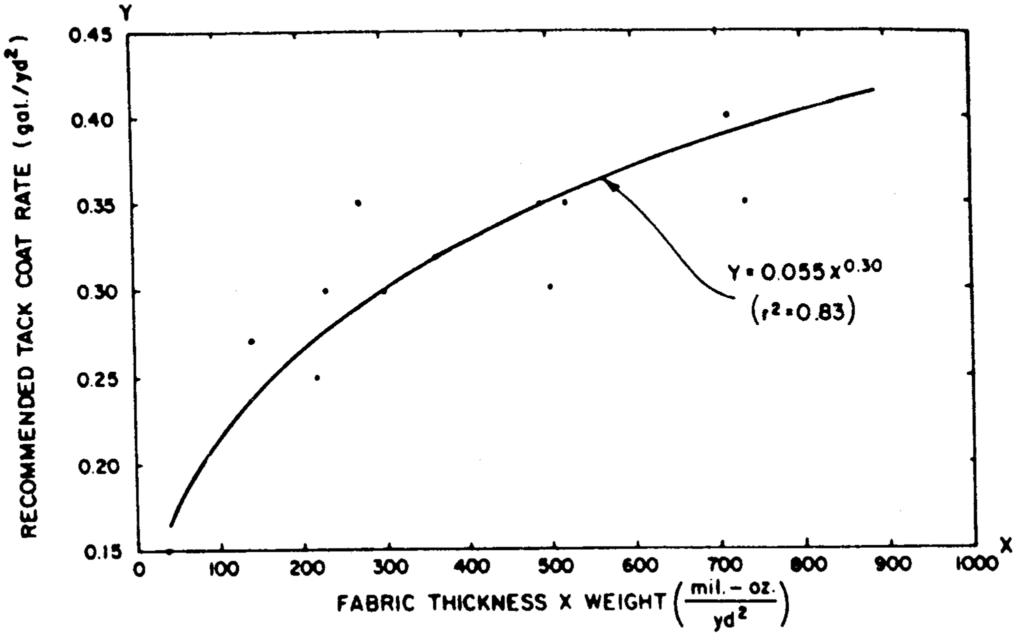


Figure A1 . Recommended Tack Coat Rate Versus Fabric Weight and Thickness.

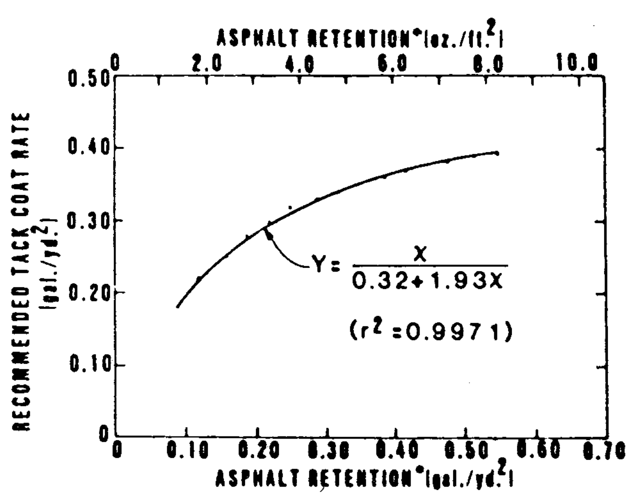


Figure A2 . Recommended Tack Rate Versus Asphalt Retention.

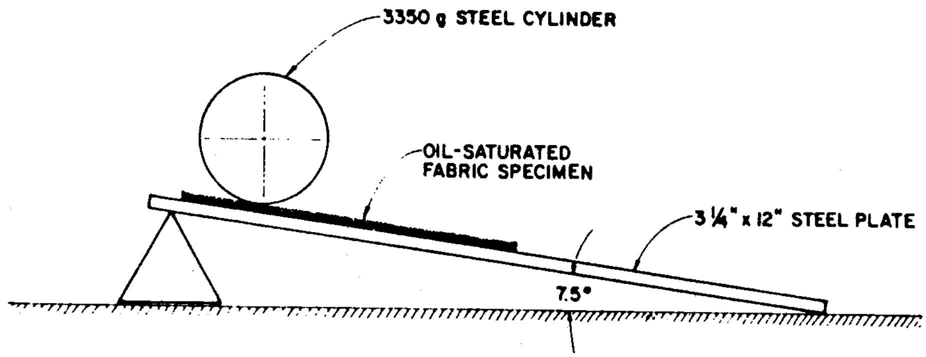
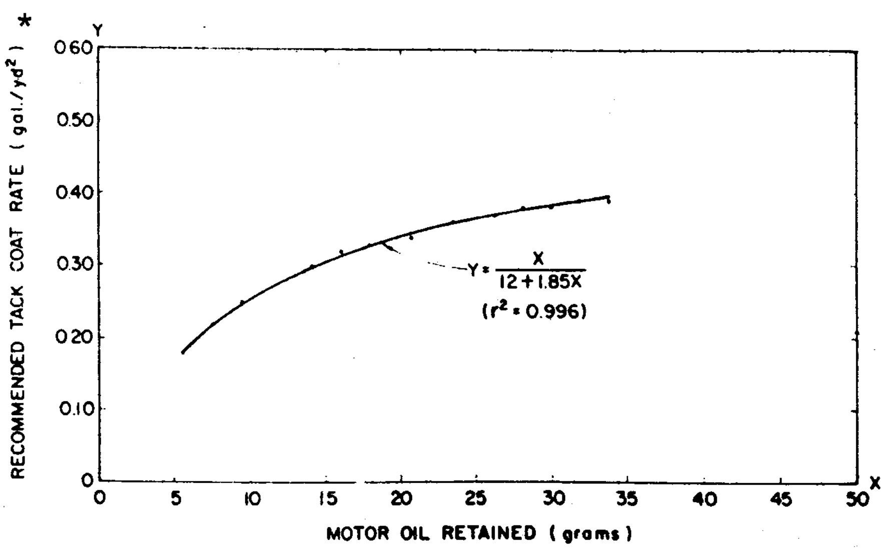


Figure A3. Motor Oil Retention Test Setup.



* Includes 0.05 gals/sq. yd. to satisfy surface hunger

Figure A4. Recommended Tack Coat Rate Versus Motor Oil Retention.

APPENDIX B

Paving Fabric Specifications from Texas,*

California and New Mexico

*This study was initiated in 1978 and the test pavements were built under the 1972 Texas Standard Specifications. The advent of the 1982 Texas Standard Specifications required the renumbering of certain specifications. Special Specification, Item 3099 was renumbered and is now Item 3002. The wording is, however, the same.

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SPECIAL SPECIFICATION

ITEM 3099

FABRIC UNDERSEAL

1. DESCRIPTION. This item shall consist of furnishing and placing a fabric underseal in accordance with the details shown on the plans and the requirements of these specifications. This underseal shall consist of a single application of asphalt covered with one layer of the fabric with or without sand or screenings.

2. MATERIALS. The woven or non-woven fabric furnished shall be constructed exclusively of man-made thermoplastic fibers. These fibers may be oriented in the fabric in either a random or an aligned orientation and the fibers may be either continuous or discontinuous throughout the fabric. The fabric itself shall be mildew resistant, rot-proof and shall be satisfactory for use with asphalt cements.

   a. Physical Requirements. The fabric supplied shall meet the following additional requirements when sampled and tested in accordance with the methods specified.

TEST Original Physical Properties:	METHOD	REQUIREMENT Minimum	 Maximum
(1.) Fabric weight, oz./sq.yd.:	ASTM D 1910 paragraph 37 or 38	4.0	9.0
(2.) "Apparent elongation" at "breaking load" on warp-wise specimens, percent:	ASTM D 1682, Grab Method G as modified by paragraph F. Testing Requirements of this specification.	50	150
(3.) "Apparent elongation at "breaking load" on filling-wise specimens, percent:	" " "	50	150
(4.) "Breaking load," on warp-wise specimens, pounds:	ASTM D 1682, Grab Method G as modified by paragraph F. Testing Requirements of this specification.	45	---
(5.) Breaking load," on filling-wise specimens, pounds:	" " "	80	---

(6.) Asphalt retention, oz./sq.ft.	paragraph F. Testing Requirements of this specification.	0.5	8.5
(7.) Change in area caused by asphalt retention test & subsequent asphalt removal. Reported as change in area of specimen measured after test as compared to area of specimen prior to test, percent:	paragraph F. Testing Requirements of this specification.	---	± 15

(8.) Physical Properties After 275°F. Asphalt Retention Test & Subsequent Asphalt Removal: Fabric samples so treated shall when tested in accordance with the methods prescribed for tensile and elongation tests comply with the minimum and maximum strength requirements as set forth for "as-received" samples under "Original Physical Properties" with a 10% tolerance allowed.

b. Packaging Requirements. The fabric shall be packaged in standard-width rolls of specified length. The fabric itself shall be uniformly wound onto suitable cylindrical forms or cores to aid in handling and unrolling. Each roll of fabric and the form or core upon which it is rolled shall be packaged individually in a suitable sheath, wrapper or container to help protect the fabric from damage due to ultra-violet light and moisture during normal storage and handling.

c. Identification Requirements. Each roll shall be labeled or tagged in such a manner that the information for sample identification and other quality control purposes can be read from the label without opening the roll packaging. Each roll shall be identified by the manufacturer as to lot number or control numbers, date of manufacture, tare weight of core plus wrapper, width and length of fabric on the roll plus the gross weight of the entire package which is to include fabric, core, wrapping sheath or container tags, etc.

d. Sampling Requirements. Each roll may be subject to a fabric-weight determination on a per-roll basis. In addition, individual test samples shall be cut from at least one roll selected at random from each 100 rolls or fraction thereof representing each shipment. Individual samples shall be no less than one foot in length by full-roll width.

e. Basis for Rejection. Should any individual roll fail to meet the fabric-weight requirement when the entire roll is weighed then that roll is subject to rejection. Should any individual sample selected at random from 100 rolls (or fraction thereof) fail to meet any specification requirement, then that roll shall be rejected and two additional samples shall be taken, one from each of two other additional rolls selected at random from the same 100-roll lot (or fraction thereof). If either of these two additional samples fail to comply with any portion of the specification, then the entire quantity of rolls represented by that sample shall be rejected.

f. Testing Requirements. Fabric-weight determinations may be made upon complete rolls of fabric. In addition the individual test samples selected in accordance with the sampling procedure outlined may be used for fabric-weight determination. If individual test samples are used for fabric-weight determination, then all 19 of the 4 X 8 inch specimens required for testing of a roll shall be selected from the one-foot by roll-width test sample and the 19 individual test specimens shall be weighed and the average weight expressed in ounces per square yard and calculated and reported on that basis.

The determination of the "breaking load" and the "apparent elongation" at "breaking load" shall be made in accordance with ASTM D 1682 entitled "Standard Methods of Test for Breaking and Elongation of Textile Fabrics" using Grab Method G with a constant rate of traverse so that the breaking load is reached in 20 seconds plus or minus three seconds. Modified jaws are to be used in which the 1 inch x 2 inch jaw faces are serrated with approximately 0.5 millimeter deep serrations in a horizontal direction when the jaws are pulled vertically. The continuous teeth or serrations are to be pointed slightly upward on the jaw faces as the jaws are positioned in the testing machine. Original Physical Property test specimens as placed in the testing machine shall be rectangular and measure four by eight inches. When placed in the 1 inch x 2 inch modified jaws the fabric shall extend one-half inches on either side of the one-inch wide by two-inch high jaws.

Five individual specimens shall be chosen for determination of original physical properties, tensile and elongation testing in the warp-wise direction and eight individual specimens shall be chosen for testing in the filling-wise direction. It is important that these specimens be chosen at random from each individual test sample of at least one foot in length by full-roll width selected at random in accordance with the prescribed sampling procedure. The average test value obtained on the five specimens and the average test value for the eight specimens tested shall be reported as the final test values for those tests in the warp and fill directions respectively. Additional individual specimens shall be selected for those tests involving hot asphalt.

Asphalt retention and potential change of area of the fabric shall be determined as follows:

Three warp-wise specimens of four by eight inch dimension and three filling-wise specimens of like dimension shall be selected at random from the individual one foot wide by roll width test sample. These test specimens shall be individually weighed to the nearest 0.1 gram and then submerged for 30 minutes in the specified asphalt cement maintained at a temperature of 275 $\pm$ 4 F. in a mechanical convection oven. After the required submersion the test specimens shall be removed and hung to drain in the oven for an additional 30 minutes at 275 $\pm$ 4 F. The samples shall then be removed from the oven and allowed to drain for one hour at a temperature of 76 $\pm$ 4 F.

The asphalt cement used for this test shall meet the detailed requirements for viscosity grade AC-10 of the Texas State Department of Highways and Public Transportation Specification Item, "Asphalts, Oils and Emulsions" with the additional requirement that the viscosity at 275 F. shall be within the range of 2.3 to 2.8 stokes. After the one hour at 76 $\pm$ 4 F. the asphalt coated specimens shall be weighed to the nearest 0.1 g and then placed in naphtha heated to 110 $\pm$ 5 F. for 30 minutes. Fresh naphtha contained in trays at the specified temperature may be alternated as necessary during the 30 minute period to effect removal of the asphalt cement from the specimens. Specimens will be blotted with paper towels and allowed to air dry to effect naphtha removal. The area of the specimens will then be measured for the determination of percent change in area. Asphalt retention and change in area will be calculated as follows:

$$\text{asphalt retention, oz./sq.ft.} = \frac{\text{wt. in grams asphalt} \times 0.0352739}{\text{area of specimen after test in in}^2 \div 144}$$

$$\text{change in area, \%} = 100 - \left[\frac{\text{area of specimen after test in in}^2}{\text{original area of specimen in in}^2} \times 100\right]$$

Load test specimens which have been previously subjected to the 275 F. Asphalt Retention Test and Asphalt Removal procedures shall be centered in the jaws of the tensile testing machine. The three inch jaw separation will be maintained. If the original 4 X 8 inch specimen has expanded or chrunk in size the required fabric spacing around the jaws will of necessity not be maintained. Specimens will be centered and 3 inch jaw separation maintained.

3. <u>CONSTRUCTION METHODS</u>. The area on which the underseal is to be placed shall be clean of dirt, dust or other deleterious material by sweeping or other approved methods. Asphaltic materials of the type and grade shown on the plans shall be applied on the clean surface by an approved type of self-propelled pressure distributor so operated as to distribute the material in the quantity specified, evenly and smoothly under a pressure necessary for proper distribution. The Contractor shall provide all necessary facilities for determining the temperature of the asphaltic material and all of the heating equipment and in the distributor for determining the rate at which it is applied and for securing uniformity at the junction of two distributor loads. The distributor shall have been recently calibrated and the Engineer shall be furnished an accurate and satisfactory record of such calibration.

This underseal shall not be applied when the air temperature is below 60 F and is falling, but it may be applied when the air temperature is above 50 F and is rising, the air temperature being taken in the shade away from artificial heat. Neither the asphalt nor the fabric shall be placed when general weather conditions, in the opinion of the Engineer, are not suitable.

After beginning the work, should the yield on the asphaltic material appear to be in error, the distributor shall be calibrated in a manner satisfactory to the Engineer before proceeding with the work.

Asphaltic material shall be applied ahead of the placement of the fabric in widths 10 inches wider than the fabric. The asphaltic material shall be applied at the approximate rate shown on the plans or as directed by the Engineer.

String lines will be set for alignment as required by the Engineer.

Immediately upon application of the asphalt, the fabric shall be aligned and carefully broomed and/or rolled into the asphalt with equipment approved by the Engineer. In the event the initial alignment is not satisfactory and causes the fabric to wrinkle during placement, the fabric shall be cut and realigned overlapping the previous material and proceeding as before. All transverse joints shall be overlapped a minimum of 6 inches. In lapping joints, the top fabric shall be folded back to allow application of a light coat of asphalt. The top fabric is then folded back onto the asphalt and broomed and squeegeed out smoothly. Rolling and/or brooming the fabric into the asphalt at the joints shall be accomplished in such a way that the air bubbles which form under the fabric will be removed. This may be accomplished by brooming from the center of the fabric toward the outer edges. The fabric shall be neatly cut and contoured at all joints as directed by the Engineer.

If the edges of the fabric tend to be displaced because of air currents, the Engineer may require that the edges be secured to the pavement at 15-foot intervals. In the event this procedure does not prove satisfactory, then work will be suspended until conditions are more favorable.

Adjacent panels of the fabric shall overlap a minimum of 4 inches. Additional asphalt shall be applied to make these longitudinal joints.

Turning of equipment shall be gradual and kept to a minimum to avoid damage to the fabric. On typical sections not receiving a seal coat, the surface of the underseal fabric shall be covered with a thin layer of clean sand or clean crusher screenings at a rate sufficient to absorb the excess asphalt. The sand and/or crusher screenings shall be approved by the Engineer. On typical sections to be seal coated only sufficient sand shall be spread ahead of the tires to prevent sticking.

All storage tanks, piping, retorts, booster tanks and distributors used in storing or handling asphalt material shall be kept clean and in good operating condition at all times, and they shall be operated in such a manner that there will be no contamination of the asphaltic material with foreign material. It shall be the responsibility of the Contractor to provide and maintain, in good working order, a recording thermometer in the storage heating unit at all times.

The Engineer will select a temperature of application based on the temperature viscosity relationship that will permit application of the asphalt within the limits recommended in the item, "Asphalts, Oils and Emulsions". The recommended range for the viscosity of the asphalt is 50 seconds to 60 seconds Saybolt Furol. The Contractor shall apply the asphalt at a temperature within 15 F of the temperature selected.

4. MEASUREMENT. Asphaltic material will be measured at the point of application on the road in gallons at the applied temperature. The quantity to be paid for shall be the number of gallons used as directed in the accepted underseal.

The fabric underseal shall be paid for by the square yard based on the calculated quantity shown on the contract plans with no allowance made for overlapping at joints.

5. PAYMENT. The work performed and materials furnished, as prescribed by this item, and measured as provided under "Measurement", will be paid for at the unit prices bid for "Asphalt" and "Fabric Underseal", which price shall each be full compensation for cleaning and preparing the existing pavement; for furnishing, preparing, hauling and placing all materials, including sand or crusher screenings; for all freight involved; for all manipulation, including rolling and brooming and for all labor, tools, equipment and incidentals necessary to complete the work.

Where a seal coat is proposed, "Aggregate" and "Asphalt" for the seal coat will be measured and paid for under the Item, "Seal Coat".

Where an asphaltic concrete pavement is proposed, "Aggregate" and "Asphalt" for the asphaltic concrete pavement will be measured and paid for under the appropriate asphaltic concrete pavement item.

CALTRANS

CALIFORNIA DEPARTMENT OF TRANSPORTATION

STANDARD SPECIAL PROVISION 39.20

for

PAVEMENT REINFORCING FABRIC

10-1._____ PAVEMENT REINFORCING FABRIC.--Pavement reinforcing fabric shall be placed where shown on the plans, and at locations designated by the Engineer.

Pavement reinforcing fabric shall be nonwoven polyester, polypropylene, or polypropylene/nylon materials conforming to the following when tested in conformance with the listed ASTM Designation:

Weight, Oz./sq.yd., ASTM Designation: D 1910	3.0 to 8.0
Grab Tensile Strength (1-inch grip), Pounds, ASTM Designation: D 1117	90 min.
Elongation at Break, Percent, ASTM Designation: D 1117	40 min.
Fabric Thickness, ASTM Designation: D 461	12 to 100 mils.

Pavement reinforcing fabric shall be accompanied with a Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

The fabric shall be protected from exposure to ultraviolet rays and kept dry until placed.

Before spreading asphalt binder, large cracks, spalls and chuckholes shall be repaired as directed by the Engineer, and such repair work will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications.

Asphalt binder for pavement reinforcing fabric shall conform to the provisions of Section 92, "Asphalts," of the Standard Specifications and shall be Grade AR-4000 unless otherwise ordered by the Engineer.

Asphalt binder for pavement reinforcing fabric shall be applied at an approximate rate of 0.25-gallon per square yard of surface covered. The exact rate of application will be determined by the Engineer. The width of the asphalt binder spread shall be the width of the fabric mat plus 3 inches on each side.

The fabric shall be stretched, aligned, and placed with no wrinkles that lap. The test for lapping shall be made by gathering together the fabric in a wrinkle. If the height of the doubled portion of extra fabric is 1/2 inch or more, the fabric shall be cut to remove the wrinkle, then lapped in the direction of paving. Lap in excess of 2 inches shall be removed.

Pavement reinforcing fabric shall be omitted for the portion of conform tapers that are less than 0.08' thick.

If manual laydown methods are used, the fabric shall be unrolled, stretched, aligned, and placed in increments of approximately 30 feet.

Adjacent borders of the fabric shall be lapped 2 to 4 inches. The preceding roll shall lap 2 to 4 inches over the following roll in the direction of paving at ends of rolls or at any break. At fabric overlaps, both tack coat and fabric shall lap the previously placed fabric by the same amount.

Seating of the fabric with rolling equipment after placing will be permitted. Turning of the paving machine and other vehicles shall be gradual and kept to a minimum to avoid damage.

A small quantity of asphalt concrete, to be determined by the Engineer, may be spread over the fabric immediately in advance of placing asphalt concrete surfacing in order to prevent fabric from being picked up by construction equipment.

Public traffic shall not be allowed on the bare reinforcing fabric, except that public cross traffic shall be allowed to cross the fabric, under traffic control, after the Contractor has placed a small quantity of asphalt concrete over the fabric.

Care shall be taken to avoid tracking binder material onto the pavement reinforcing fabric or distorting the fabric during seating of the fabric with rolling equipment. If necessary, exposed binder material shall be covered lightly with sand.

Full compensation for advance spreading of asphalt concrete over the fabric shall be considered as included in the contract prices paid per ton for aggregate (asphalt concrete) and paving asphalt (asphalt concrete) and no additional compensation will be allowed therefor.

Pavement reinforcing fabric will be measured and paid for by the square yard for the actual pavement area covered.

Paving asphalt used as binder will be measured and paid for by the ton as paving asphalt (paint binder).

The contract price paid per square yard for pavement reinforcing fabric shall include full compensation for furnishing all labor, materials (except binder), tools, equipment and incidentals, and for doing all the work involved in furnishing and placing pavement reinforcing fabric, including lapping, complete in place, as shown on the plans, as required by the Standard Specifications and these special provisions, and as directed by the Engineer.

NEW MEXICO STATE HIGHWAY DEPARTMENT

SPECIFICATION FOR

PAVING FABRIC

413.01 DESCRIPTION.

413.011 This work shall consist of placing a paving fabric as part of a pavement rehabilitation project in substantial compliance with the plans, specifications and these special provisions and as directed by the Project Manager.

413.012 The Contractor shall furnish all materials, labor, tools, equipment and any other appurtenances necessary to complete the work.

413.013 The Contractor shall provide to the Project Manager the following information 30 days prior to fabric placement and shall provide certified test results for fabric properties listed in 413.21.

(a) Project number
(b) Project location
(c) Fabric manufacturer
(d) Fabric type
(e) Fabric quantity
(f) Asphalt source
(g) Asphalt grade
(h) List of roll numbers

413.02 MATERIALS.

413.021 Fabric Properties. The fabric shall consist of woven or nonwoven polypropylene and/or polyester material meeting the following requirements when tested in conformance with the respective test method:

PROPERTY	ASTM DESIGNATION TEST*	VALUE	UNITS
Weight (Full Roll)***	D 3776-79, Option A	3.5 to 8.0***	oz./sq. yd.
Weight (Specimens)***	D 3776-79, Option C	3.5 to 8.0**	oz./sq. yd.
Grab Tensile Strength	D 1117-80	80.0 min.	pounds
Elongation at Break	D 1117–80	50.0 min.	percent
Fabric Thickness***	D 1777-64	.030 min.**	inches
Asphalt Retention	None	0.10 min.	gal./sq. yd.

*Information about unique procedures for each of the tests is included in paragraphs 413.025 through 413.02.10.

**Maximum allowable coefficient of variation is 12.5% where coefficient of variation = (standard deviation/mean) × 100%.

***For spun-bonded fabric these minimum values are to be: Thickness, 0.015 inches and asphalt retention, 0.07 gal. sq. yd.

413.022 Packaging. The fabric shall be packaged in rolls with each roll wound onto a suitable cylindrical form or core to aid in handling and placing. Each roll and the form or core upon which it is rolled shall be packaged in a suitable wrapper which is defined to include a sheath or container to protect the fabric from damage due to ultraviolet light and moisture during storage and handling.

413.023 Identification. Each roll shall be labeled or tagged in such a manner that the information for sample identification and other quality control purposes can be read from the label without opening the wrapper. Each roll shall be numbered by the manufacturer and further identified as to lot number or control number, date of manufacture, tare weight of core plus wrapper, width and length of fabric and gross weight of the entire roll which includes fabric, core, wrapper, tags, etc.

413.024 Sampling. Test samples will be cut at the project from rolls selected at random and shall be no less than three feet in length by the full width of the roll. Nothing in this section shall negate the Department's right to take additional samples in accordance with the provisions of Section 100.

The samples will be taken according to the following frequency:

SQUARE YARDS	NO. OF SAMPLES
0–50,000	8
50,000–150,000	16
100,000–300,000	24
Over 300,000	32

413.025 Testing. Specimens will not be conditioned for testing. One-half of the above samples will be tested initially; if the average test results indicate the material meets specification requirements no additional testing will be done. If the test results indicate the material does not meet specification requirements, the contractor will be notified and the remaining samples will be tested. These additional test results will be combined with the first set.

413.026 Weight (Full Roll). Weight determinations will be made using procedures described in ASTM D 3776-79, paragraph 7 (Option A). The Contractor shall provide scales and move the roll to said scales for this purpose. Net weight of the fabric is total weight minus the weights of the core, wrapper, tags, etc.

413.027 Weight (Specimens). Specimen weight determinations will be made using procedures described in ASTM D 3776-79 paragraph 9 (Option C). Each specimen taken for the strength/elongation test and the asphalt retention test will be weighted to the nearest 0.1 gram.

413.028 Strength and Elongation. The "breaking load" will be determined in accordance with ASTM D 1117-80, Grab Method, using constant rate of traverse of 12 ± 0.5 inches per minute and 1-inch (wide) $\times$ 2-inch (long) smooth-faced jaws. Test specimens will be rectangular and measure four by eight inches. When placed in the jaws, the fabric will project one-half inch at each end and 1.5 inches on each side.

Twenty individual test specimens will be taken at random for tensile and elongation testing, ten with the long dimension in the machine direction and ten with the long dimension in the cross-machine direction. No test specimens will be taken from either edge of the roll which is defined as within the outer one-tenth of the width. Ten specimens (five in each direction) will be tested for breaking load and elongation.

The average test values for the machine-wise and the cross-machine specimens will be reported separately as the final test values.

413.029 Thickness. Using ASTM D 1777-64, thickness will be determined using a 0.5-inch-diameter foot exerting 45 grams per square centimeter pressure onto a 1.1-inch-diameter anvil. Five thickness measurements will be made on each specimen used in the strength/elongation tests and asphalt retention test: one measurement in the vicinity of each corner and one in the center.

413.02.10 Asphalt Retention. Two machine-wise test specimens and two cross-machine specimens each three by fifteen inches will be selected from the full-width sample in the same manner as described in Subsection 413.028. Each test specimen will be weighed to the nearest 0.1 gram, saturated in asphalt cement maintained at 150° ±4°F, placed between sheets of newspaper and pressed with a hot iron to remove excess asphalt. (Presence of excess asphalt is evidenced by a glossy appearance.) The saturated specimen will be weighted to the nearest 0.1 g, then placed in naphtha heated to 110° ±5°F for 30 minutes. Fresh naphtha at the specified temperature will be alternated as necessary during the 30-minute period to effect removal of the asphalt cement from the specimen. The specimen will be blotted with paper towels and allowed to air dry to effect naphtha removal, then measured. Asphalt retention will be calculated as follows:

$$\text{asphalt retention (oz./sq. yd.)} = \frac{\text{(weight with asphalt} - \text{weight initial) gms} \times 0.0352739\ \text{oz./gm.}}{\text{(area of specimen after test, sq. in.)/1296 sq. in./sq. yd.}}$$

413.02.11 Basis for Rejection. If a roll fails to meet the weight requirements when it is weighed in accordance with Option A, that roll will be rejected. If the average of the test results shows that the material does not meet specification requirements for any property, the provisions of Section 100 of these specifications shall apply.

413.02.12 Testing Time Requirement. Testing may require up to 20 working days. Paving fabric from a shipment shall not be placed until testing from the shipment is complete.

413.02.13 Tack Coat. The tack coat shall be composed of paving grade bituminous material of the type and grade specified by the manufacturer of the fabric and shall meet the requirement of Section 407—Tack Coat. The tack coat application rate shall consist of the total of the mean optimum asphalt content required by the fabric as determined by the Materials Lab Bureau plus an amount to satisfy the "surface hunger" of the existing pavement as determined by the Project Manager.

413.03 CONSTRUCTION REQUIREMENTS.

413.031 Weather Limitations. Paving fabric and tack coat shall not be placed if paving is not permitted and if the ambient air temperature is not at least 50°F and rising or at least 55°F.

413.032 Fabric Handling Equipment. Mechanical laydown equipment shall be capable of laying the fabric smoothly without excessive wrinkles or folds.

413.033 Surface Preparation.

413.034 Crack Sealing. Prior to tack coat application, all cracks wider than 0.50 in. shall be sealed in accordance with Special Provisions for Asphalt Rubber Crack Sealant, Section 412-C or Section 412-D.

413.035 All joints shall be cleaned out and sealed as specified on the plans.

413.036 Application and Placement of Materials.

413.037 Tack Coat. The tack coat shall be applied in accordance with Section 407—Tack Coat except paragraph 407.031.

Tack coat width shall be equal to the fabric width. Additional tack coat equal to the optimum asphalt content required by the fabric shall be uniformly applied on the overlapped fabric joints.

413.038 Paving Fabric. If the Contractor does not have personnel satisfying Section 108.05 Character of Workmen, Methods and Equipment, the Contractor shall have qualified, manufacturer-trained representatives to supervise placement of the paving fabric.

The paving fabric shall be stretched, aligned and placed entirely on the tack coat with a minimum of wrinkles and folds. Hand and mechanical brooming shall be effected to maximize the fabric contact with the tacked roadway surface. If folds in excess of 1/2 inch occur, the fabric shall be slit to remove the fold or wrinkle then overlapped in the direction of the paving.

All cutting or slitting of paving fabric shall be effected by a method approved by the Project Manager. When cutting or slitting is employed, the Project Manager will determine the additional amount of tack coat to be applied, to assure adhesion of the double fabric layer.

If manual placement methods are used, the fabric shall be unrolled, stretched, aligned, and placed in increments not exceeding 30 feet.

The fabric shall be rolled when required to seat the fabric to prevent movement and assure fabric saturation. Care shall be taken to avoid tracking plant mix bituminous pavement material onto fabric and to avoid distorting the fabric during rolling.

If necessary, a small quantity of plant mix bituminous pavement material may be spread over the top of the fabric immediately in advance of the paving operation to prevent the fabric from being picked up by construction equipment.

No vehicle shall be allowed on the fabric, except rolling equipment (if fabric seating is necessary), equipment needed to spread the small quantity of plant mix bituminous pavement material on top of the fabric, paving equipment and cross traffic. Prior approval by the Project Manager shall be received before cross traffic is permitted.

413.39 Paving operations shall follow placement of the paving fabric within an hour or within 1/4 mile whichever is less.

413.03.10 BASIS OF ACCEPTANCE.

413.03.11 Paving fabric not rejected under Subsection 413.02.11 Basis of Rejection will be accepted.

413.04 METHOD OF MEASUREMENT.

413.041 The paving fabric will be measured by the square yard. Tack coat is incidental.

413.05 BASIS OF PAYMENT.

413.051 The accepted quantities of Paving Fabric will be paid for at the contract unit bid price per square yard complete in place.

Payment will be made under:

Pay Item	Pay Unit
Paving Fabric	Square Yard

413.052 The cost for retesting a lot will be at the Contractor's expense. Retesting will be accomplished in a testing facility selected by the Materials Lab Bureau.