Guidelines for Using Geosynthetics with HMA Overlays to Reduce Reflective Cracking

http://www.dot.state.tx.us/cst/technical_advisories.htm

Report 1777-P2
Project Number 0-1777
Research Project Title: Geosynthetics in Flexible and Rigid Pavement Overlay Systems to Reduce Reflection Cracking

BY
Joe Button
Senior Research Engineer
Texas Transportation Institute

Robert Lytton
Research Engineer
Texas Transportation Institute

SPONSORED BY
Texas Department of Transportation
U.S. Department of Transportation, Federal Highway Administration

PROJECT DIRECTOR
Gregory Cleveland
Bituminous Engineer
Texas Department of Transportation

EDITORIAL AND GRAPHIC SUPPORT
Information & Technology Exchange Center (ITEC)

April 2003
Texas Transportation Institute
Texas A&M University
College Station, Texas 77843-3135

Table of Contents

Introduction

1

No current pavement rehabilitation techniques have been shown to ***prevent*** reflective cracking. However, several techniques have demonstrated the ability to ***reduce*** reflective cracking. Application of geosynthetics is only one of a number of techniques. Available methods usually fall under one or more of three categories, shown in Figure 1.

1. Reinforcement of the overlay
- a. Thicker overlay
- b. Fiber-reinforced hot mix asphalt (HMA) overlay: polyester, polypropylene
- c. Modified asphalt in HMA overlay: tire rubber, neat rubber, polymer, sulfur, carbon black
- d. Compliant HMA mix: PFC w/crumb rubber or SMA
- e. High-modulus grid or composite: fiberglass or polymer

2. Stress relieving interlayers
- a. Stress absorbing membrane interlayer (SAMI): asphalt rubber seal coat
- b. Open-graded HMA interlayers
- c. HMA interlayer containing low-viscosity asphalt
- d. Stone dust bond breaker
- e. Fabric/asphalt interlayer
- f. Heavy-duty membrane

3. Restrengthening of cracked pavement before overlaying
- a. Heater scarification
- b. Spray applications of asphalt rejuvenator

Figure 1. Strategies for reducing reflective cracking.

Other methods to address reflection cracking might include: a seal coat applied to the existing pavement, thick large stone open-graded asphalt stabilized layer (Arkansas mix), saw and seal the HMA overlay, and cracking and seating or rubblizing of concrete pavements. These guidelines will deal strictly with geosynthetics for reducing reflection cracking.

Definition of Terms

"Geosynthetics" are defined herein as fabrics, grids, composites, or membranes. Grids and composites are newer generation materials developed for specific purposes by manufacturers.

Fabrics or geotextiles may be woven or nonwoven and are typically composed of thermoplastics such as polypropylene or polyester but may also contain nylon, other polymers, natural organic materials, or fiberglass. Filaments in nonwoven fabrics are typically bonded together mechanically (needle-punched) or by adhesion (spun-bonded, using heat or chemicals). Paving fabrics typically weigh about 4 to 8 ounces/yd^2. Technically, grids and composites are not geotextiles.[1] See Figure 2.

Figure 2. Different types of geosynthetics: 1) grid (protuding out of a paper envelope), 2) composites, 3) fabric.

Grids may be woven or knitted from glass fibers or polymeric (polypropylene or polyester) filaments, or they may be cut or pressed from plastic sheets and then post tensioned to maximize strength and modulus. Grids typically have rectangular openings from 1/4 inch to 2 inches wide. A grid may have a thin membrane laminated onto it that assists in construction (i.e., attaches to the asphalt tack coat) but is designed to melt and thus disappear when the hot HMA overlay is applied. Additionally, some grids have thin, permanent fiber strands partially filling the openings that adhere the grid to the tack coat without forming a waterproof barrier. Grids are designed to exhibit high modulus at low strain levels such that their reinforcing benefits begin before the protected pavement layer fails in tension.

Composites generally consist of a laminate of fabric onto a grid. For the composite, the fabric provides absorbency (primarily to hold asphalt) and a continuous sheet to permit adequate adhesion of the composite onto a pavement surface; whereas, the grid provides high strength and stiffness. Manufacturers custom design these third-generation products, based on laboratory and field research, to meet the needs of asphalt retention and high initial tangent modulus (i.e., high modulus at low strain levels).

Heavy-duty membranes are composite systems, usually consisting of a polypropylene or polyester mesh laminated on either one or both sides with an impermeable rubber-asphalt membrane. Membranes weigh about 50 to 100 ounces/yd^2. They are typically placed in strips over joints in concrete pavements or used for repair of localized pavement failures.

Advantages and Potential Disadvantages of Geosynthetics

Advantages

Moisture is frequently the main source of pavement damage and roughness. Asphalt-impregnated fabrics will control infiltration of surface water into a pavement. Fabrics may remain intact after the asphalt overlay has cracked and provide a moisture barrier. The fabric must be saturated with sufficient asphalt to provide a continuous moisture barrier; insufficient tack will diminish this waterproofing effect. Movement at cracks in some jointed concrete pavements may be large enough to rupture the fabric such that it no longer provides resistance to water flow. If a moisture barrier is justified, fabrics and composites offer this added benefit, but grids cannot.

Disadvantages

An asphalt-impregnated fabric or composite can trap water in a pavement. Any moisture barrier under a new overlay can be a detriment to its performance, particularly if the overlay is not compacted properly. Rapid premature failures have occurred when a moisture barrier (fabric, seal coat, etc.) was placed on an old pavement on which the overlay was insufficiently compacted such that it was permeable to water.[2] Surface water enters the permeable overlay and is trapped by the impermeable layer. Subsequent kneading and scouring action by traffic in the presence of the water causes rapid failure of the overlay. This problem is compounded when the overlay is also an inlay (sometimes termed the "bathtub" effect). One paper[3] stated, "The level of compaction is not as critical to achieving low permeabilities when a paving fabric moisture barrier is used." Based on personal observations, the authors disagree with this statement. Compaction of dense-graded HMA is always important for achieving proper density and minimum permeability. A permeable dense-graded HMA overlay over a moisture barrier can result in rapid failure, particularly during freeze-thaw conditions.[4]

In addition, water vapor rising from below due to evapo-transpiration can accumulate just under a moisture barrier and, if the HMA mixture in that vicinity is water susceptible, it can suffer significant damage. Distress will develop first in the wheelpaths due to repetitive loading by traffic on the weakened pavement layer and progress rapidly.

Fabrics have been found ineffective in reducing reflection of thermal cracks. Pavement overlay systems have had limited success in areas of heavy rainfall and regions with significant freeze-thaw cycles.[5]

When to Consider a Geosynthetic

2

General

The presence of cracks does not necessarily mean that ride quality is low. Cracks can be sealed and the pavement can continue to be used if ride quality is acceptable.

The economics associated with existing techniques for reducing reflection cracking indicate that a crack-treatment program for pavements having light to moderate levels of cracking is usually more cost effective than other available methods.[6]

Strategies including a geosynthetic, like all others, must be carefully engineered and are not quick, easy solutions suitable for all pavements.

Generally, however, geosynthetics will perform best when used to address load-related fatigue distress manifested by closely spaced random cracks or alligator cracks. To justify a full-coverage geosynthetic, significant random cracking should be prevalent on a significant portion of the project. No specific guidance is available. More widely spaced cracks and/or joints in Portland Cement Concrete Pavements (PCCP) can be addressed using a geosynthetic strip product (heavy-duty membrane). However, widely spaced transverse cracks and joints often exhibit large movements, making reflective cracking difficult to impede. See Figure 3.

Geosynthetics can be effective in retarding reflection cracking from low-severity and medium-severity alligator-cracked pavements.[7] Geosynthetics and other types of interlayers will typically perform considerably better in warm and mild climates than in cold climates.

1. from 0 to 0.03 inch, where no geosynthetic is needed;
2. from 0.03 to 0.07 inch, which is the effective range of geosynthetics; and
3. greater than 0.07 inch, which is an opening movement that geosynthetics cannot normally withstand.[8]

Figure 3. The three ranges of thermal crack opening.

Hot Mix Asphalt Concrete Pavements

In order for geosynthetics to perform satisfactorily, the flexible pavement on which they are placed must be structurally sound. The pavement should have a remaining life of greater than 5 years, as computed by the remaining life routine in Modulus 5.1. Pavements for which cracking can potentially be delayed by using a geosynthetic exhibit fatigue cracks that are not caused by base or subgrade failures or delamination of existing pavement layers. Surface cracks should be less than 1/8 inch wide.

Limitation Guidelines

- No improvement in performance is likely if cracks are greater than 3/8 inch wide.[9]
- Observations have shown that fabrics are not effective where wide transverse thermal and shrinkage cracks are present.[10]

- When an overlay and fabric are placed over an existing pavement, it often can no longer "breathe" and thus water may accumulate in the old pavement. It is prudent to evaluate the stripping potential of a pavement before placing a fabric/overlay system or any other sealing layer or interlayer. While the old pavement was able to "breathe," moisture susceptibility was not manifested.[11]
- Geosynthetic products should not normally be placed on a milled surface. A level-up course of HMA should be placed to provide a smooth surface on which to place the geosynthetic. A level-up course will also prolong the appearance of reflective cracking at the overlay surface. Theory[12] and practice[13] have shown significant benefits from placing a level-up course before placing the geosynthetic.

Portland Cement Concrete Pavements

If a geosynthetic is to be used on a jointed concrete pavement (JCP) or on continuously reinforced concrete pavement (CRCP), a level-up course of HMA should be placed to provide a smooth surface on which to place the geosynthetic and assist in reducing reflective cracking. Theory[14] and practice[15] have shown significant benefits from placing a level-up course before placing the geosynthetic.

Jointed Concrete Pavements

In order for geosynthetics to perform satisfactorily, the JCP on which they are placed must be structurally sound. Measures should be taken to minimize joint and crack movements. The load transfer efficiency factor (LTEF) at joints should be 80 percent or greater.

Lateral movements at joints and some cracks in JCP are often large, and stopping reflection of these joints/cracks in an overlay is particularly difficult. Cracks should be sealed before overlaying. Geosynthetic strips, which have a thick membrane, may provide an effective seal for several years even after the cracks appear at the overlay surface.

LTEF is computed as LTEF = $(d_u/d_l) \times 100$
where d_l = deflection on the loaded side
d_u = deflection on the unloaded side

Figure 4. Computing the load transfer efficiency factor (LTEF).

Limitation Guidelines

The 1993 AASHTO Design Guide advises that the effectiveness of geotextiles in controlling reflective cracking in HMA overlays over jointed plain concrete and jointed reinforced concrete pavements is questionable. If a geosynthetic is to be used on JCP, this guideline recommends a high-modulus product (such as fiberglass grid) be placed in strips only over the joints. Ideally, the geosynthetic should not be placed directly on the existing JCP.

The following should precede placement of the grid:

1. Cracks in the concrete larger than 1/8 inch should be filled with crack sealant.
2. A Grade 4 (~1/2-inch maximum size) seal coat (underseal) should be applied to promote good adhesion to the concrete and assist in sealing smaller cracks in the slabs.

Cracks in JCP greater than 3/8 inch should not be treated with fabrics without previous crack treatment. Cracks 3/8 inch or wider prevent asphalt tack from "wicking" into the fabric across a crack or joint. Thus, the crack or joint is left open to infiltration of surface water immediately after the old crack reflects through the overlay.[16]

Continuously Reinforced Concrete Pavements

In order for geosynthetics to perform satisfactorily, the rigid pavement on which they are placed must be structurally sound. Since crack spacing in CRCP is usually small, slab movement at the cracks is usually small, and reflective cracks through an HMA overlay are not usually serious problems. Therefore, geosynthetics are not normally needed to reduce reflective cracking in an HMA overlay over CRCP.

HMA-Overlaid Concrete Pavements

Geosynthetics are routinely used with new overlays on previously HMA-overlaid PCCP, where the original pavement was JCP, JRCP, or CRCP. In addition to controlling reflective cracking, an asphalt-impregnated geotextile can help control surface water infiltration into the pavement and thus minimize associated damage. Moisture can cause loss of bond between AC and PCC, stripping in the AC layers, progression of D-cracking or reactive aggregate distress (in pavements with these problems), weakening of the base and subgrade,[17] and frost heave.

Selecting, Ordering, and Storing a Geosynthetic Product

3

Selecting a Geosynthetic Product

Geosynthetics currently available include fabrics, grids, composites, and membranes. There are several widely varying products to consider within each of the four categories.

Fabrics

Fabrics made using polypropylene or polyester are most common. Fabrics have been made of other products (nylon, glass, combinations of materials) but they are usually more expensive. Polypropylene begins to melt at a temperature of about 325°F. Therefore, when using polypropylene products, the temperature of the paving mixture should not exceed 325°F when it contacts the geosynthetic.

Nonwoven Paving Fabrics

Nonwoven paving fabrics typically exhibit relatively low moduli and thus can mobilize only limited stress at low strain levels. Fabrics have demonstrated mixed results in reducing reflective cracking by acting as a stress-absorbing interlayer. There is evidence that an asphalt-impregnated fabric will resist intrusion of surface water into the base even after reflective cracks appear at the pavement surface. Some Department engineers believe this reduction of water in the base/subgrade reduces localized swell and thus helps maintain pavement smoothness.

Thicker Fabrics

In theory, using a thicker fabric should result in lower stresses at the tip of a crack than using a thinner one. Therefore, the thicker layer should be more effective in delaying reflection cracking. The full thickness of the nonwoven fabric must be saturated with asphalt. Clearly, asphalt retention rate is an important property. Asphalt retention should be at least 0.2 gallons/yd^2; it is directly related to the fabric weight and thickness. When used as a stress-relieving interlayer, the fabric should generally have a minimum weight of 4.1 ounces/yd^2.[18] Both theory and limited evidence indicate that a thicker fabric with a greater asphalt retention may delay cracking longer than a thinner fabric. Additionally, heavier fabric will reduce bleed through during construction and reduce the effect of any damage by construction traffic. The maximum practical weight for a paving fabric is about 6 ounces/yd^2 to allow proper asphalt saturation in the field.

Lightweight Fabrics

Manufacturers may recommend certain lightweight fabrics as having appropriate qualities. In these instances, advice should be sought from the Materials and Pavements Section, Construction Division.

Full-Width Fabrics

Full-width fabrics should be limited to use on flexible pavements where there is extensive random cracking and waterproofing of the pavement is needed and justified. Widespread alligator cracking often indicates structural failure, which must be addressed by major rehabilitation efforts. A fabric/seal coat or fabric/overlay to address structural problems should be considered only a short-term solution. If widespread alligator cracking is due to surface aging of asphalt and not structural failure, full-width fabric may be an inappropriate treatment; rejuvenation or surface recycling may be more appropriate. Strip fabrics are recommended for use on widely spaced cracks and joints where a prolonged waterproofing interface is desired. Waterproofing may limit base and subgrade movement due to freeze-thaw action or expansive soils. Fabrics have not demonstrated good success in reducing reflection of thermal (transverse) cracks in flexible pavements and joints in concrete pavements.

Grids

Grids typically exhibit much higher moduli than fabrics and logically should take on more stress at low strain levels. Grid systems serve primarily as a reinforcing interlayer. To act as overlay reinforcement, a grid must be tightly stretched or slightly pretensioned, and it must have sufficient stiffness. Typical grids used as overlay reinforcement exhibit stiffnesses varying from 80 to >1000 lb/inch. However, only the stiffest grids can act as overlay reinforcement.[19]

Some grids contain a thin, continuous sheet, designed to assist in installation (i.e., adhere to the tack coat) that melts when the hot overlay is applied. Other grids have thin, permanent fiber strands partially filling the openings that adhere the grid to the tack coat. Neither of these products forms a waterproof barrier. These products should be considered as grids and not composites.

Composites

Composites may offer benefits of both fabrics (stress-relieving interlayer) and grids (reinforcement). Composites are recommended for use on pavements where both reinforcement and waterproofing are desired.

Membranes

Heavy-duty membranes should serve as both a waterproofing membrane and a stress-relieving interlayer. The mastic membrane should provide reduced permeability and be sufficiently soft and thick to act as a stress-relieving interlayer. Membranes are relatively expensive and are normally placed in strips over joints or cracks. In some systems, the membrane is bonded to the old pavement when temperatures exceed 70°F by simply removing a protective film on the back of the membrane and placing it over the prepared joint. In other systems, an adhesive tack coat must be applied to the pavement before placement of the membrane.

Ordering Synthetic Products

When ordering geosynthetic products, the contractor should specify width of rolls to accommodate pavement lane width or the plans for geosynthetic placement. Improper roll width can result in significant lost time, excessive construction joints, and waste of material. The contractor should also consider the maximum roll weight that the application equipment (typically a specially equipped small tractor) can handle. Excessive roll weight or length may cause the roll to sag thus producing wrinkles during geosynthetic placement. A stiff roll core should be used to avoid sagging rolls.

Storing Guidelines

Careful consideration should also be given to storage of geosynthetics. During storage, geosynthetics should be protected from precipitation, extended exposure to sunlight, temperatures exceeding 160°F, sparks/flame, and chemicals. Geosynthetics containing any polymer will degrade upon prolonged exposure to sunlight. They should be protected from direct sunlight even if the geosynthetic is marked UV stabilized. Water-soaked materials are cumbersome and may not readily adhere to an asphalt tack. If rolls have taken on water, the cardboard core may not be strong enough to support the geosynthetic during placement. Geosynthetics should be stored in such a manner to avoid misshapen rolls.

Cost Considerations

4

In-place Costs

The in-place costs of geosynthetics and other methods to address reflection cracking are influenced by: (a) the specific product used, (b) the quantity to be placed, (c) tack coat requirements, (d) local experience with its installation, (e) local labor costs, and (f) the general condition of the market place. The in-place cost of fabrics has fallen significantly since the early 1980s, apparently due to stiff competition and, perhaps, improved contractor experience and acceptance of geosynthetics. In 1991, NCHRP Synthesis 171 offered the following rule of thumb: The in-place cost of a full-width paving fabric is roughly equivalent to the cost of about 0.5 to 0.6 inch of asphalt concrete.[20]

Estimating Probability of Success

Under favorable conditions (many of which are described herein), some geosynthetic products can delay reflection cracking in an asphalt overlay about two to four years longer than a similar overlay without a geosynthetic. Reflection cracks are usually sealed through a maintenance program. Such maintenance costs and any delays by a geosynthetic are reasonably easy to quantify and should be considered when the cost of different design alternatives is analyzed. An estimate of the probability of success should be included in all economic analyses. NCHRP Synthesis 171 indicated that, under favorable conditions, the probability of success of a paving fabric will be about 60 to 65 percent. The use of geosynthetics and other techniques should, at a minimum, be compared with the cost of using an overlay of similar thickness with a crack-sealing program. Thicker overlays can also be used as a basis for comparison.

One should obtain realistic cost data for the particular situation and estimate a reasonable probability of success. A simple approach is to determine or estimate the performance equivalency between two alternatives and directly compare their costs. California DOT indicated a paving fabric interlayer may be equivalent to about 1.2 inches of HMA in retarding reflective cracking. Using typical in-place costs, a fabric interlayer is about 50 percent of the cost of 1.2 inches of HMA,[21] and this assumes a 100 percent success rate. Considering a 65 percent probability of success, the economic advantage of using paving fabrics appears to be somewhat less unless the potential benefits of reduced water infiltration and resultant improved ride quality are considered. Determination of cost effectiveness of products in pavements typically requires several years. As a result, information on cost effectiveness of the newer grids and composites is not currently available in the literature.

Cost Effectiveness of Heater Scarification

Heater scarification is an alternative for addressing reflective cracking. The decision to use a geosynthetic or heater scarification for controlling reflective cracking may come down to economic conditions for the particular project. The two procedures are not equivalent. Heater scarification may be used in conjunction with a geotextile to provide, for practical purposes, a 1-inch leveling course. In this case, heater scarification must compete with a new leveling course in order to be the most cost-effective alternative. When a pavement exhibits large spaces between thermal cracks (i.e., greater than about 15 to 20 feet, depending on the temperature regime), crack movement due to thermal variations and traffic is expected to exceed the capability of a fabric to effectively control reflective cracking. In this case, it seems reasonable to heater scarify the old pavement rather than or in addition to installing a geosynthetic. Again, heater scarification is competing with new overlay material. If heater scarification reduces the overlay thickness and/or maintains the required grade, it may be cost effective.

Pavement Design with a Geosynthetic

5

Overlay Thickness

Overlay thickness for both flexible and rigid pavements should be determined as if the geosynthetic interlayer is not present. Generally, overlay thickness should not be reduced from that determined by standard structural design methods when using a geosynthetic. When overlay thickness is reduced based on contributions of the geosynthetic, it should not be reduced to less than four times the size of the largest aggregate in the HMA overlay mixture nor less than 1.5 inches.

Avoid the use of thin (< 2 inches) or inadequately compacted overlays with fabric, particularly on high traffic volume facilities. Stage construction is not recommended. That is, a thin overlay should not be constructed with plans for placing another thin overlay in a few years. Data and experience suggest that a minimum overlay thickness of 2 inches should be used with or without paving fabrics.[22]

Overlays less than 1½ inch thick cool rapidly and, thus, are difficult to compact to the required density. A poorly compacted overlay may exhibit high permeability and allow water to become trapped on top of a fabric interlayer. Trapped water can lead to distress due to stripping and freeze-thaw damage in the overlay, which will appear prematurely as cracks in the wheel paths and will deteriorate rapidly.

Overlay Type

Normally, only dense-graded, well-compacted, low permeability HMA mixtures should be used as overlays over fabrics or composites. Beneath permeable HMA mixtures (e.g., PFC or OGFC), any waterproof layer must be placed at a drainable grade so that surface water drains out of the overlay. For milled inlays, proper drainage must be provided. Permeable overlays, such as poorly compacted mixtures with interconnected voids, should not be permitted, particularly in inlays. CMHB mixtures have shown significant permeability when first placed and, therefore, should not be used over a waterproofing fabric or composite. A poorly compacted overlay over a waterproof membrane (asphalt-impregnated fabric) can trap and hold water. Retained water can cause rapid failure of the overlay due to freezing and/or stripping of the asphalt. Overlay damage during or after freezing and while holding water is exacerbated by traffic loadings.

Design for Flexible Pavement Overlays

The recommended steps[23] in developing an overlay design for flexible pavements where a geosynthetic is a potential candidate are given below. Details have been modified to accommodate TxDOT circumstances.

1. Evaluate Pavement Condition

A general pavement condition survey is valuable in establishing the type, severity, and extent of pavement distress. Such information is needed to develop required repair strategies and the overlay design strategy. Candidate pavements should be divided into segments. Nondestructive surveys, including visual distress, ground penetrating radar (GPR), deflection (FWD), or seismic (SPA), are possible tools to establish where these divisions should be made. For each segment, determine extent and severity of cracking (longitudinal, transverse, alligator, block, random), rutting, patching, potholes, flushing, raveling, etc. Crack widths should be measured. TxDOT has existing systems for rating pavement condition.

A tentative conclusion should then be drawn as to whether a geosynthetic is a suitable candidate in the rehabilitation scheme. If a formal pavement condition survey is not performed, at a minimum, the type, extent, and level of cracking should be established.

2. Evaluate Structural Strength

Overall structural strength of the pavement should be evaluated, along its length, using the falling weight deflectometer (FWD). The pavement should have a remaining life of greater than 5 years, as computed by the remaining life routine in TxDOT's Modulus 5.1.

3. Identify Base/Subgrade Failures

Areas that have experienced base or subgrade failures should be identified. There should be no evidence of severe load associated distress (e.g., alligator cracking > 5 percent, deep ruts, or failures). When nondestructive testing devices are not available, proof loading of the pavement with a loaded truck has also been used to identify structurally weak areas. Reflection cracking will not be significantly delayed by geosynthetics in areas that have base/subgrade failures; however, a waterproof geosynthetic product can be used on affected areas to help keep surface water out of the base.

If base failure areas are limited, they should be repaired by removal and replacement. If base failure areas are extensive, rehabilitation alternatives other than geotextiles should be considered. If all failed base/subgrade areas are repaired and no other types of distress are present, geotextiles will probably not be cost-effective improvements in performance.

4. Develop Remedial Pavement Treatment

Results of the pavement condition survey and deflection measurements should be used to develop a pavement repair strategy for each segment.

5. Select Overlay Design

An adequate overlay thickness must be selected to ensure a reasonable overlay life. Using geosynthetics with thin, under-designed overlays, which lead to significant reflection cracking in three to five years or less, will not justify the use of a geosynthetic.

6. Monitor Performance

To develop a data bank of performance histories with geosynthetics, performance monitoring during construction and service of the overlay is highly desirable. Constructing a control section without the geosynthetic, with all other items equal, will provide valuable comparative data for future decisions. Without a control section, a so-called test pavement has no value.

Design for Rigid Pavement Overlays

The process[24] for determining candidate rigid pavements for rehabilitation with overlays incorporating a geosynthetic is generally similar to that previously described for flexible pavements. Vertical joint deflection surveys should be performed to determine if grout injection or joint repairs are necessary. Joint deflections can be conducted using FWD, Rolling Dynamic Deflectometer, or proof rolling with a loaded truck. Geosynthetics should not be used when vertical joint deflections exceed 0.008 inches unless corrective measures are taken to reduce joint movements.

Horizontal thermal joint movement should be less than about 0.05 inch. Because horizontal joint movement is approximately proportional to slab length, thermal joint movements will increase as joint spacing increases. Careful attention must be given to performing the required remedial measures, including joint cleaning and resealing, patching, grouting, joint repair, slab replacement, etc.[25]

Overlay thickness should not be reduced when a geosynthetic interlayer is employed.

Using FPS-19 Design Check for the Effect of Geosynthetics

6

A modification of the TxDOT flexible pavement design program, FPS-19, has been offered by TTI to permit a design check for the expected reflection cracking life of an overlay with and without selected generic reinforcing geosynthetics. If this design check is selected, the designer must put in the additional data shown in Figure 5.

1. The existing pattern of reflection cracking of the old pavement surface
2. The temperature variations in the area of the project
3. Whether a tack coat will be used with the geosynthetic
4. What the typical aggregate interlocking factor is expected to be from experience in the project area

Figure 5. Additional data for FPS-19 check.

The design check then uses the traffic and asphalt layer data that were originally input to the FPS-19 program to predict the life of the overlay to reach the medium severity level of reflection cracking.

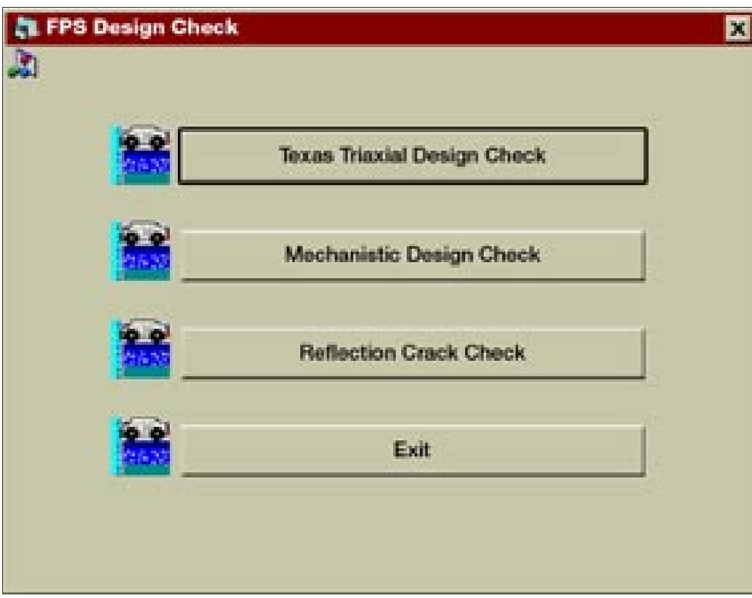

Figure 6. FPS-19 interface.

Selecting Aggregate Interlocking Factor

In the design check for reflection cracking, three levels of aggregate interlocking factor are used: high, medium, and low. Subjective rankings are used because measured data from a deflection survey may not always be available at the time the overlay is being designed. The load transfer efficiency factor (LTEF) from a deflection survey is directly related to the aggregate interlocking factor. The LTEF is the ratio of the deflection on the unloaded side of a crack divided by the deflection on the loaded side of the same crack. The relationship between the LTEF and the aggregate interlocking factor is shown in Figure 7.

Range of LTEF	Aggregate Interlocking Factor
0.80 – 1.00	High
0.50 – 0.80	Medium
0.00 – 0.50	Low

Figure 7. Relationship between the LTEF and the aggregate interlocking factor.

In the absence of any measured deflections on a prospective project site, a medium aggregate interlocking factor is a prudent choice.

Selecting Reinforcing Materials

Options that the designer will have in selecting reinforcing materials are:

- no reinforcing geosynthetic,
- woven/coated polyester grid with nonwoven fabric composites,
- woven/coated fiberglass grid with fabric woven composite,
- polypropylene non-woven fabric, and
- coated fiberglass grid.

The properties of these products that are used in the design check are averages of typical products that are commercially available in each category of material. As a result, the predicted reflection cracking life of the overlay is an approximate estimate of how each generic product will perform under the expected traffic and weather.

Default Data

The design check contains default data for each of the input data that the designer is required to provide. It is possible for the designer to simply accept the default data or to modify it as personal experience or judgment indicates. The default data are:

- annual average temperature: 72°F;
- daily temperature drop: 20°F;
- transverse crack spacing in old pavement: 10 feet;
- tack coat used with geosynthetic? Yes; and
- aggregate interlocking factor: Medium.

As a good rule, the overlay should be designed to last as long against reflection cracking as the FPS-19 program predicts it should last under the expected traffic while resisting fatigue cracking, rutting, and roughness (loss of serviceability index). In order to achieve this, the designer may need to experiment with the thickness of the overlay to achieve this balanced design.

Design Check Assumptions

There are many options for the design of overlays with reinforcing geosynthetics, most of which have been experimented with for decades. From both experience and analysis, it has been found that there are numerous construction and performance benefits to applying a ¾ to 1 inch thick leveling course on top of the old pavement before placing the geosynthetic and then placing the remainder of the designed thickness (but not less than 1½ inches) of the overlay on top of the geosynthetic. For this reason, the design check for reflection cracking automatically assumes that the geosynthetic will be placed on top of a 1-inch leveling course, and the reflection cracking life is calculated on that basis.

According to the design check, reflection cracks will begin to appear in a 2-inch thick overlay without any reinforcing in about 250 to 400 days, depending upon a number of factors such as traffic level, crack spacing in the existing pavement, aggregate interlocking factor, stiffness of supporting layers, and nightly temperature drops. Alternatively, initiation of reflection cracks in a similar overlay of the same thickness with reinforcing will occur in about 500 to 1200 days (a time increase of two- to three-fold), depending upon the product and the quality of its placement.

Overlay Construction with a Geosynthetic

7

Preparing the Surface

These recommendations are designed to ensure that the geosynthetic or level-up course will have continuous firm support, which will assist in proper compaction of the overlay and allow continuous tack coat application to uniformly saturate the geosynthetic product. See Figure 8.

1. Before application of a geosynthetic, thoroughly clean the existing pavement using a broom and/or compressed air.
2. Confirm that the existing pavement is dry.
3. Fill cracks exceeding 1/8 inch wide with appropriate crack sealant.
4. Fill cracks exceeding 1 inch wide with a fine-grained bituminous mixture.
5. Level faulted cracks or joints with vertical deformation greater than ½ inch; use a fine-grained bituminous mixture or other suitable material.
6. Properly repair potholes even with the existing pavement surface.
7. Allow crack filler and patching materials to cure prior to placement of the geosynthetic.

Figure 8. Preparing the surface.

Importance of a Leveling Course

Apply a leveling course to uneven, rutted, or extremely rough surfaces. For best results, place a level-up course (0.75 to 1 inch thick), whenever possible, before placing the geosynthetic. This will maximize performance of the geosynthetic by reducing reflective cracking. Both observation and analysis have shown that it is important to place a leveling course before placing a geosynthetic to further retard the appearance of reflection cracks. The leveling course does several important things to promote success of the overlay including providing a smooth surface on which to place a geosynthetic and a fresh, unoxidized surface to which the geosynthetic or new overlay can bond. The leveling course can also establish a drainable grade, when necessary, on which to place the geosynthetic.

Placing a geosynthetic (and particularly a fabric) directly on an old or even a milled surface can cause wrinkles, which can themselves reflect a crack upward to the surface of the overlay. Grids also benefit from being placed on a level-up course because the smooth surface:

- makes the installation much easier,
- provides maximum adhesion,
- allows the reinforcing strands to be placed flat to mobilize their strength and stiffness at small deformations, and
- provides new material both above and below the grid so that compaction will press aggregates down through the grid apertures to lock the grid in place.

Theory and practice indicate that the life of an overlay can be shortened by placing a grid directly on the old pavement surface, whether it is milled or not, and then placing the overlay on top of it. Typically, the life of the overlay is shortened if the overlay thickness is between 2 and 5 inches thick and no leveling course is used beneath the grid. In such cases, analysis shows that, in this range of total thickness of overlay, the use of a leveling course can provide an overlay reflection cracking life that is 20 to 100 times longer than it would be if a grid were placed directly on the old pavement surface.

Because the movement at cracks and joints in jointed concrete pavements is relatively large, a level-up course is highly recommended.

Tack Coat Selection and Application

Selection of proper tack material and application rate is one of the most important aspects in construction and performance of certain geosynthetic interlayers. One should consult the particular geosynthetic manufacturer's installation manual. Hot asphalt cement (AC) is usually recommended as tack for geosynthetics. Tack coat should be applied uniformly at the specified rate using a calibrated asphalt distributor truck. The tack coat should be sprayed approximately 4 inches wider than the geosynthetic. Common field problems with tack coat applications include proper temperature control, clogged or leaking spray bars or nozzles, application of too much or too little material, and nonuniform distribution.

Temperature Control

Tack application temperatures are generally about 290°F to a maximum of 325°F. Temperature of the tack when the geosynthetic is placed can be critical. Polypropylene may be damaged or shrink at temperatures above about 300°F.[26] Optimum temperature for embedment of fabric is 180°F to 250°F. One must install a geosynthetic while asphalt is still tacky. However, if a geosynthetic is embedded in asphalt that is much hotter than 180°F (particularly in hot weather), the geosynthetic may become prematurely saturated and cause construction problems (e.g., geosynthetic pick-up, slippage). A noncontact thermometer is useful in determining binder temperature.

Measuring Tack Rate

Tack rate should not be reduced to solve construction problems. Such reductions can cause subsequent system failure.

Weight tickets and tank gauges may not be sufficiently accurate for checking tack rate. Tack rate should be verified using preweighed, thin pans placed directly in the path of the distributor truck. The pans can be recovered after passage of the distributor truck and weighed to compute the tack application rate. If measured tack rate is different from specified rate, it should be appropriately adjusted before further use. Application spot checks should be conducted periodically and used to verify weight tickets and calibrated stick measurements.

Insufficient tack rate is the leading cause of poor fabric interlayer performance and failure.[27] Insufficient tack will result in unsaturated fabric, which can lead to overlay slippage and/or debonding and will not provide waterproofing.

Using Emulsified Asphalt as Tack

Emulsified asphalt is not normally recommended as tack for geosynthetics. If, however, emulsified asphalt is used, it should be allowed to break and set before the geosynthetic is placed. Placement should be followed immediately by pneumatic rolling to minimize disruption by wind or traffic. A larger quantity of emulsion is required as compared to AC (to yield the proper amount of residue) and the viscosity of emulsion is lower than AC (and stays lower longer). This may cause problems with runoff, particularly on sloped or undulating pavements. If emulsified asphalt is used as tack, it should not be diluted with water. The inspector should ensure the emulsion has not been diluted. When calculating tack coat shot rate, recall that emulsion is only about 65 percent asphalt, therefore, tack rate must be adjusted upward by dividing it by the asphalt content (percentage) of the emulsion: (e.g., emulsion shot rate = desired asphalt tack rate/0.65).

Tack Coats and Fabrics

The design tack coat application rate for a particular fabric is normally provided by the manufacturer/supplier. Type of tack should be hot-applied asphalt cement (not emulsion) of the same grade as that determined for the HMA overlay. Although emulsified asphalts have been successfully used as tack for fabrics, they develop bond strength more slowly than asphalt cement, and debonding on windy days has been reported. Cutback asphalts should never be used for fabric tack, because the solvent can remain for extended periods and weaken the polymer.

Tack coats for fabric application are relatively heavy and should be applied uniformly with a calibrated distributor truck. Insufficient or excessive asphalt tack applied for fabric adhesion can result in overlay failures due to slippage at the fabric interface, especially in areas of high shear forces during periods of hot weather. Excessive tack can cause slippage of the paving machine or subsequently migrate to the pavement surface and appear as flushing in the wheelpaths. Low-viscosity asphalts are more susceptible to this bleeding than higher viscosity materials.

Tack coat should be applied using relatively long shot lengths. Start-stop operations less than a few hundred feet yield highly variable asphalt application rates. Shot lengths equal to fabric roll lengths (about 300 feet) are convenient for some operations. Greater lengths are encouraged provided the freshly sprayed asphalt does not become contaminated with dust or other foreign material. Starting and stopping on paper will reduce the buildup of asphalt at the overlapping sites.

Tack Coats and Grids

Grids or mesh products often do not have enough continuous surface area to adhere tenaciously to an asphalt tack coat. Some grids are fastened to the existing pavement by methods other than asphalt tack. Some grid products have a self-adhesive backing. Therefore, tack may or may not be necessary to fasten a grid to the existing pavement. Generally, one should follow the manufacturer's recommendations for tacking grids. However, keep in mind that the interface between the existing pavement and the new overlay often needs tack to prevent delamination and thus slippage due to vertical and horizontal traffic loads. Placement of a light tack coat onto the mesh after installation should minimize potential slippage and/or debonding but may cause construction problems.

Placing a thin overlay without tack (particularly on a high-traffic facility) invites slippage and/or debonding problems. When placing a self-adhesive grid product for use with an overlay on an old pavement surface (i.e., not a new level-up course), a tack coat should be applied on top of the grid (i.e., after grid application) to ensure adequate adhesion at the interface. The appropriate quantity of tack is that normally used without a grid or slightly more. Type of tack should be hot-applied asphalt cement (not emulsion) of the same grade as that determined for the HMA overlay. If the grid is placed on a new level-up course, the tack coat may not be necessary.

Tack Coats and Composites

Typically, the tack coat selection and application guidelines for fabrics apply to composites.

Tack Coats and Membranes

Membranes may or may not require tack coat. If a tack is required, it may be a proprietary product.

Placement of Geosynthetics

An experienced crew using a small tractor rigged for handling geosynthetic rolls should be specified for geosynthetic placement. (See Figure 9.) Such a crew can move much faster than the paving train. To avoid placing traffic on the geosynthetic, no more geosynthetic should be placed than can be overlaid the same day. Manual placement should be disallowed except in small areas where equipment may have difficulty maneuvering.

Figure 9. Placing the geosynthetic roll.

Aligning and Smoothing

As the geosynthetic is spread onto the asphalt tack coat, it must be aligned and smoothed to remove wrinkles and folds. (See Figure 10.) Some wrinkling of geosynthetics during installation is unavoidable due to curves and undulations in the pavement surface. Folds that result in a triple thick-

Figure 10. Smoothing the surface.

ness must be slit with a knife and overlapped in a double thickness. Wrinkles can be a source of premature cracking in the overlay due to compaction without firm support or possibly due to shrinkage (polypropylene products).[28]

Handling Overlaps

A 4-inch to 6-inch overlap is suggested at all longitudinal and transverse joints. Transverse overlaps should be in the direction of paving to avoid fabric pick-up by sticky tires. It is necessary to apply additional asphalt tack at these locations to ensure proper saturation and bonding. For this purpose, emulsified asphalt can be applied using a hand sprayer, brush, or mop.

Controlling Traffic

Traffic will damage geosynthetics and may cause delamination from the pavement surface prior to overlay placement. Geosynthetics significantly reduce pavement surface friction and can present a skidding hazard, particularly during wet weather. Significant traffic should never be allowed on geosynthetics. If trafficking is necessary, speed should be strictly controlled to 25 mph. If significant trafficking is necessary, an alternative to geosynthetics should be considered.

Handling Equipment

To avoid displacement or damage to geosynthetics while turning construction equipment, turning should be gradual and kept to a minimum.

Parking of construction equipment on a completed geosynthetic/asphalt tack interlayer, even for short periods, should be avoided.

Dealing with Rain

Geosynthetics should not be placed during rainfall or when rain is expected. Rainfall before, during, or after placement can result in severe debonding and even loss of the geosynthetic. On highly textured surfaces (e.g., a milled surface), geosynthetics are more subject to damage by rainfall and traffic.

Highly Textured Surfaces

Geosynthetics can be successfully employed on highly textured surfaces such as freshly milled pavement. Milled surfaces may require additional tack coat; this can be accomplished by pretacking any milled surfaces (e.g., next to curbs). In urban areas subject to high shear forces (e.g., at intersections), a highly textured surface may help decrease the probability of slippage.

Placement of Fabrics

The bonded or glazed side of a fabric is better to drive on than the fuzzy side (i.e., less damage). The fuzzy side should be placed next to the tack coat. This practice will provide the highest bond strength and best slippage resistance.

When fabric is applied on hot days (>90°F), pavement surface temperatures near 160°F may prevail. These temperatures can be sufficiently high to keep the viscosity of asphalt tack low enough to partially saturate the fabric during placement and fully saturate the fabric in the wheelpaths of construction vehicles.

Tires of HMA 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 corrective measures shown in Figure 11 should be considered.

1. First, allow the tack to cool longer before placing fabric.
2. Alternatively, hand spread a small amount of HMA mix on top of the fabric in the wheelpath of the haul vehicles.
3. Application of sand is the least desirable choice, as sand will absorb some of the asphalt and defeat its purpose. If sand is used, the quantity should be minimized and the grading should be coarse.
4. Change to a “heavier” grade of asphalt cement for the tack coat material.
5. Shorten the distance between fabric placement and the paving machine.
6. Minimize the number of vehicles on the fabric.

Figure 11. Correcting fabric movement.

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

High winds can be problematic during application of fabrics particularly on a highly textured milled surface. Limited pneumatic rolling of a fabric immediately after application will maximize adhesive strength and minimize its disruption by wind and construction traffic.

Pneumatic rolling on a steep grade or cross slope can result in slippage at the pavement fabric interface if the asphalt tack is still hot.

Construction joints in fabrics should generally follow the manufacturer's instructions. Additional tack hand-applied on transverse fabric overlaps or applied by distributor on longitudinal overlaps can reduce disruption by wind and construction traffic. Emulsified asphalt is suitable for securing fabric overlaps at construction joints.

Placement of Grids and Composites

Placement of grids and composites are generally similar to placement of fabrics. They should be tensioned during placement using a specially equipped tractor or laid flat to maximize their reinforcement effects.

Placement of Membranes

Membranes are thicker and heavier than fabrics and grids and are usually placed by hand in strips along pavement joints or cracks.

Placement of HMA Overlay

An HMA overlay can be placed immediately after placement of a geosynthetic using conventional equipment and techniques. No cure time is necessary. The HMA mixture should be no less than 250°F nor greater than 325°F as it exits the paving machine. The minimum temperature is required to obtain adequate density of the overlay and pull the binder up through the geosynthetic. The maximum temperature is required to avoid damage to geosynthetics containing polypropylene. If in-place density specifications are met, typically, heat and rolling will have occurred to achieve geosynthetic saturation.

On hot days, premature saturation of the geosynthetic may occur. Therefore, it may be necessary to broadcast a thin layer of HMA mix in front of the paving machine in the wheelpaths of haul trucks and the paving machine to prevent geosynthetic "pick-up."

If the installed geosynthetic should get wet due to rainfall, the overlay should not be placed until all free water is removed. The geosynthetic surface may be slightly damp but one should not be able to squeegee any free water out of the geosynthetic. If an overlay is placed over excess moisture, the resultant steam will not permit adequate bond of the interlayer system and could lead to overlay problems.[29]

A minimum compacted overlay thickness of 1.5 inches is required as the first lift over a geosynthetic. If the thickness of the overlay is tapered toward the edges, at the thinnest point, it should not be less than 1.5 inches. Thinner overlays will not generate enough heat to draw the asphalt up into the paving geosynthetic to produce a well-bonded interlayer.[30]

Post-Construction Considerations

8

Project Inspection

Figure 12 contains a suggested generalized checklist for geosynthetic/overlay placement.

Initial Work

- ☐ Sample geosynthetic, and send to Materials and Tests Division.
- ☐ Store geosynthetic in area protected from sun and water.
- ☐ Determine grade of asphalt to be used for tack coat and obtain a sample.
- ☐ Determine the rate of application of tack coat.

Preparation of Old Pavement

- ☐ Sweep surface clean.
- ☐ Seal cracks larger than ⅛ inch or place leveling course.
- ☐ Fill cracks larger than 1 inch with fine graded asphalt mixture.
- ☐ Repair rough, uneven, or unstable areas, large spalls, and potholes.
- ☐ Place level-up course.

Application of Asphalt Tack

- ☐ Check application rate and temperature of asphalt and obtain a sample.
- ☐ Watch for poor asphalt spread practices such as:
  - a) frequent stops and starts
  - b) spread overlaps
  - c) nonuniform spread
- ☐ Test binder application rate on roadway using preweighed, thin pans.

Geosynthetic Placement

- ☐ Ensure minimal wrinkles or folds in geosynthetic (or bubbles in fabrics).
- ☐ Avoid excessive overlaps in geosynthetic; follow specifications or manufacturer's recommendations.
- ☐ Ensure that geosynthetic follows proper alignment.
- ☐ Geosynthetics have different characteristics on each side. Ensure it is placed with the proper side downward.
- ☐ If bleeding of tack coat occurs, broadcast small amount of asphalt concrete (not sand) on geosynthetic in wheelpaths to prevent construction vehicle tires from sticking.

Overlay Placement

- ☐ Discourage lengthy windrows of asphalt concrete.
- ☐ Ensure proper temperature of asphalt concrete behind paving machine.
- ☐ After compaction, displace HMA and expose some geosynthetic to confirm adequate saturation by tack coat (if appropriate).
- ☐ Encourage expeditious, thorough rolling of asphalt concrete overlay.
- ☐ Ensure specified density of overlay.

Figure 12. Inspection checklist for geosynthetic product placement.[31]

Potential Construction Problems

In hot weather (pavement temperatures > 120°F), asphalt tack may bleed through fabrics. Vehicles can splash asphalt onto their painted surfaces. Construction traffic can become sticky and pick up fabric and in severe cases wrap the fabric around the tires or axles (see Figure 11 for corrective measures.). Bleeding can be exacerbated by excessive pressure applied by the brush on the fabric application tractor.

Incomplete fabric saturation can occur due to insufficient tack application rate, overlay temperature, and/or overlay compaction.

If wet fabric is applied or if fabric is applied on damp pavement, blistering can occur due to vaporization of moisture underneath the asphalt-impregnated fabric. Pavement that has recently received rainfall but has a dry surface can retain enough moisture to cause blistering. If blisters appear, workers should eliminate them by using a lightweight rubber-tired roller before overlaying.

Wrinkles in geosynthetics can occur due to uneven pavement surface, improper alignment during placement, damaged rolls, and/or curves in the roadway. See Figure 13.

Figure 13. Wrinkles in the geosynthetic surface.

The following items are recommended for comprehensive inspection of geosynthetic interlayers:
• noncontact thermometer,
• geosynthetic knife,
• scale capable of 0.01- to 0.02-gram increments,
• calculator,
• tack coat calculator reference chart, and
• test pans (for measuring tack application rate).

Performance Monitoring

Performance monitoring during the construction period and service life of the overlay is highly desireable. This will allow development of a data bank of geosynthetic project performance histories. The primary areas of interest are reflective cracking and road roughness. Clearly, the most meaningful results will come from a special monitoring study where cracks in the old pavement are carefully mapped rather than depending on routine PMIS data.

Constructing a control section without the geosynthetic, with all other items equal, will provide valuable comparative data to assist future decisions. Without a control section, a so-called test pavement has no value and, in fact, can be misleading.

Milling/Recycling Pavements Containing Geosynthetics

A few problems have been reported when recycling pavements containing a geosynthetic interlayer. Hot milling and, particularly, heater scarification can cause problems when a geosynthetic is present; however, cold milling does not usually present problems. The cold pavement holds the geosynthetic while the milling machine tears it out in small pieces. Chisel milling teeth rather than conical teeth and slower forward speed can be used to produce the smallest geotextile pieces and thus maximize success. Thick fabrics or strong plastic grids may interfere with any milling process.

A typical 4-ounce/yd^2 polymeric fabric milled with HMA does not normally have a significant affect on mixture properties of the RAP, construction operations, or mix plant stack opacity.

References

9

[1] Holtz, R.D., B.R. Christopher, and R.R. Berg, "Geosynthetic Design and Construction Guidelines," *Publication No. FHWA HI-95-038*, NHI Course No. 13213, National Highway Institute, Federal Highway Administration, US Department of Transportation, April 1998.

[2] _______, "Issues Mount Over Paving Fabric Usage," *Better Roads*, Wm. O. Dannhausen Corporation, Des Plaines, Illinois, March 2000, pp. 17-20.

[3] Marienfeld, M.L. and T.L. Baker, "Paving Fabric Interlayer System as a Pavement Moisture Barrier," *Transportation Research Circular E-C006*, Transportation Research Board, Washington D.C., March 1999.

[4] Button, J.W., "Overlay Construction and Performance Using Geotextiles," *Transportation Research Record 1248*, Transportation Research Board, Washington, D.C., 1989, pp. 24-33.

[5] FHWA, "Pavement Rehabilitation Manual, Pavement Division," Office of Highway Operations, Federal Highway Administration, Washington, D.C., 1982.

[6] Barksdale, R.D., "Fabrics in Asphalt Overlays and Pavement Maintenance," *NCHRP Synthesis 171*, National Cooperative Highway Research Program, National Research Council, Washington, D.C., July 1991.

[7] Holtz et al., 1998.

[8] Lytton, R.L., "Use of Geotextiles for Reinforcement and Strain Relief in Asphalt Concrete," *Geotextiles and Geomembranes*, Volume 8, 1989.

[9] Barksdale, 1991.

[10] Barksdale, 1991.

[11] McKeen, R.G. and R.L. Lytton, "Development of a Generic Specification for Reinforcing Fabrics," New Mexico Engineering Research Institute, New Mexico State Highway Department, March 1982.

[12] Pickett, D.L. and R.L. Lytton, "Laboratory Evaluation of Selected Fabrics for Reinforcement of Asphalt Concrete Overlays," *Report No. FHWA-TX-84+261-1*, Texas Transportation Institute, College Station, Texas, 1983.

[13] Brewer, W.B. Jr., "Sand Anti-Fracture Mixture: I-35 Logan County," *Report No. 213, Research*, Development & Technology Transfer, Oklahoma Department of Transportation, Oklahoma City, Oklahoma, 1997.

[14] Pickett and Lytton, 1983.

[15] Brewer, 1997.

[16] Barksdale, R.D., July 1991.

[17] Holtz et al., 1998.

[18] AASHTO, Designation M288-00, "Geotextile Specification for Highway Applications," Part 1, *Standard Specifications for Transportation Materials and Methods for Sampling and Testing*, 21st Edition, American Association of State Highway and Transportation Officials, Washington, D.C., 2001.

[19] Barksdale, 1991.

[20] Barksdale, 1991.

[21] Holtz et al., 1998.

[22] Barksdale, 1991.

[23] Barksdale, 1991.

[24] Barksdale, 1991.

[25] Barksdale, 1991.

[26] Button, J.W., J.A. Epps, and R.L. Lytton, "Laboratory Evaluation of Fabrics for Reducing Reflection Cracking," Interim Report RF 3424-5, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1983.

[27] AIA, *Fabric Interlayer Guide*, Asphalt Interlayer Association, Sacramento, California, Issue dated June 6, 1999.

[28] Button et al., 1983.

[29] Marienfeld, M.L. and T.L. Baker, "Field Installation Guidelines for Paving Fabrics," Fabrics & Fibers Business Unit, Amoco Fabrics and Fibers Company, Austell, Georgia, 2001.

[30] Marienfeld and Baker, 2001.

[31] CalTrans, *Guidelines for Quality Control in Pavement Reinforcing Fabric Installation*, California Department of Transportation, Sacramento, California, January 1981.

May 2003

Information & Technology Exchange Center
Texas Transportation Institute
Texas A&M University
College Station, Texas 77843-3135

Texas Department of Transportation

ITEC.TXDT0355.0803.0000