Evaluation of FiberMat® Type B as a Stress Absorbing Membrane Interlayer to Minimize Reflective Cracking in Asphalt Pavements

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CHAPTER 1:

Introduction

Many hot mix asphalt (HMA) pavement overlays prematurely exhibit cracking patterns similar to that which existed in the old, underlying pavement. Cracking in the new overlay surface is due to its inability to withstand shear stresses and tensile stresses created by movements concentrated around preexisting cracks in the underlying pavement. This movement may be due to traffic loading causing differential deflections on each side of the cracks in the underlying pavement layers, expansion or contraction of subgrade soil due to moisture variations, or expansion and contraction of the pavement itself due to daily and seasonal changes in temperature. Movement of the pavement induced by any one or combination of the above phenomena create tensile and/or shear stresses in the new overlay. When these stresses exceed the tensile strength of the HMA overlay, a crack develops in the new overlay. These cracks grow wider and longer with time due to repetitive movement of the underlying pavement. Propagation of an existing cracking pattern from the old pavement into and through a new overlay is commonly known as “reflection cracking.”

Reinforcing HMA Pavements

Numerous methods for reinforcing asphalt pavement can be found that are used to reduce or delay the reflective cracks in HMA overlays. Roberts et al. (*1996*) summarized these methods in four basic categories:

1. Increasing the HMA overlay thickness,
2. Performing special treatments on the existing surface,
3. Treatments only on the cracks and/or joints, and
4. Special considerations of the HMA overlay design.

Crack Propagation in Reinforced HMA Pavement

Researchers (*Button, 1987*; *Lytton, 1989*) summarized three distinct failure modes associated with stress relief and reinforcement:

• Mode I - Stress Relief. A crack in the existing pavement attempts to move upward into a new overlay containing a stress-relieving interlayer. The crack stalls at the stress-relieving interlayer for a while, and then propagates from the top of the interlayer upward toward the surface.

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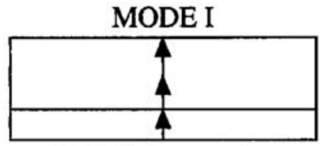
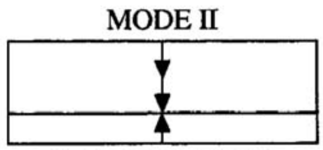


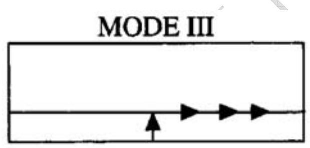
Mode I - Crack propagates from bottom to top

• Mode II - Stress Relief. A crack in the existing pavement attempts to move upward into a new overlay containing a stress-relieving interlayer. A crack then begins at the top of the overlay and propagates downward to the stress-relieving interlayer.



Mode II - Crack propagates up to reinforcement, then starts again from top of sample and propagates downward

• Mode III - Reinforcement. A crack in the existing pavement attempts to move upward into a new overlay containing a reinforcing interlayer. The crack then makes a right turn and moves along the interface between the reinforcement layer and underlying material (leveling course).



Mode III - Crack propagates to bottom of reinforcement and then is redirected horizontally

Performance Testing of HMA Overlay

In analyzing the treatments for delaying reflection cracking, it is essential to recognize the fundamental mechanisms associated with their behavior. A growing amount of evidence indicates that overlay reflection cracking and its reduction, when a stress-relieving interlayer or other technique is employed, is closely related to: (1) joint and crack movement in the underlying pavement caused particularly by traffic loads, temperature changes, and moisture, but also possibly caused by other factors such as expansive subgrade materials and frost action, (2) crack width, (3) overlay thickness, (4) climate, (5) traffic volume (*Cleveland, 2003*).

Stresses and strains in an overlay that are caused by simultaneous and/or sequential wheel loadings, short- and long-term temperature changes, and moisture gradients induce a complex stress state of cyclic bending, tension, and shear within the overlay.

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Objective of Study

FiberMat® alternately known as Fibredec® is a product of Colas, Inc. and marketed by Midland Asphalt Materials Inc. in the USA. FiberMat is a combination of polymer modified asphalt emulsion, chopped glass fibers, and aggregates. Together, they form a stress absorbing interlayer when placed between an original cracked pavement surface and an HMA overlay. There are two types of FiberMat; namely FiberMat Type A and FiberMat Type B. When they are used as an interlayer it is called FiberMat Type B; when they are used as crack reducing chip seal it is called FiberMat Type A. FiberMat is designed to significantly reduce or delay reflective cracking in HMA pavements and is a patented and proprietary process.

The objective of this research project was to quantify in the laboratory any benefits of FiberMat Type B when used as stress absorbing membrane interlayer for reducing reflective cracking and thus extending the service life of HMA overlays. The end result of this effort should be to provide evidence that FiberMat, when applied beneath HMA overlays, is an effective means to provide extended pavement overlay service life by reducing the severity of and/or delaying the appearance of reflective cracking.

Scope of the Report

This report summarizes the testing using laboratory compacted and field compacted specimens at Texas Transportation Institute (TTI) using TTI overlay testers and their results to evaluate the FiberMat system as a SAMI to reduce the severity and/or delay the appearance of reflective cracking in asphalt pavements. Chapter 2 discusses the materials used in this project to prepare specimens in the laboratory and associated specimen preparation techniques. Chapter 3 presents the test results in two phases, using the laboratory prepared and field compacted specimens.

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CHAPTER 2:

EXPERIMENTAL DESIGN

Introduction

The researchers evaluated FiberMat sandwiched between two layers of compacted HMA. The testing program examined different parameters (components) of FiberMat. Researchers utilized both the small and large overlay testers developed at the Texas Transportation Institute. The experiment design included similar HMA specimens with and without FiberMat. Specimens without FiberMat but with regular tack coat were termed “control” specimens. The performance of all specimens with different proportions of FiberMat and tack coat were tested using a TTI overlay tester and were compared with the performance of control specimens. Selected ingredients of FiberMat were varied during specimen preparation in order to determine the optimum rate that provided the best benefit. Further, testing was conducted at three different temperatures. At the initial stage of the testing, researchers focused on testing at 10°C. Three replicates were prepared and tested for any given test module.

Mixtures and Materials

Three ingredients of the FiberMat system were varied; they were:

- Tack or Bond Coat (amount and type)
- Cover Stone
- Fiber Glass

Only one type and size (medium length, 60 mm) of glass fibers were used to prepare the specimens. The control specimens used unmodified (CSS-1h, diluted emulsion to a nominally 30% asphalt content) tack and other specimens used polymer-modified bond coat (CRS-1p based on PG 52-28 grade asphalt) at various rates of applications.

Consulting with engineers from Midland Asphalt Materials Inc. (a subsidiary of Colas, Inc.), the researchers selected a relatively fine Superpave mixture typically used in the northeastern part of the USA as a wearing course. Accordingly, a 9.5-mm Superpave mixture design (designed by New York department of Transportation) was obtained for preparing both level-up (bottom layer) and overlay (top layer). This mixture was designed with 5.6 percent PG 64-28 binder. Midland Asphalt Materials Inc. provided all necessary materials (aggregate, binder, tack coats, and fiber) for this testing.

Specimen Preparation

Specimens for testing in the laboratory were prepared in three steps: compaction of 1-inch bottom layer (leveling course), application of FiberMat, and compaction of 2-inch top layer (overlay). TTI owns a linear kneading wheel compactor. This compactor

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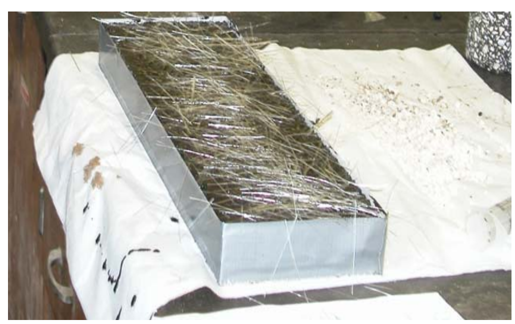
can effectively compact HMA slab specimens up to 18 inches long and 12.5 inches wide with thicknesses ranging from 0.5 to 4 inches.

To simulate field conditions, the compacted HMA specimens were maintained within 7±1 percent air voids. The bottom layer was compacted as a slab (18 × 6 × 1 inches) using the linear kneading compactor. The bottom slab was allowed to cool to room temperature and left for at least one day. Later, the slab was retrieved from the compaction chamber and encircled with duct tape to avoid tack coat spillage. An appropriate amount of emulsified tack coat was applied onto the top of bottom slab at room temperature. The tack or bond coat was applied using a hand held spray nozzle keeping the slab on top of a balance to ensure the correct amount. Immediately, the emulsion was spread with a paint brush ensuring that no emulsion was lost on the paintbrush.

Previously weighed chopped glass fibers were spread onto the freshly applied tack or bond coat. Cover stone was measured by weighing equal amounts passing sieves No. 4 and sieve No. 8 to cover the slab at a rate of 13 lb/yd^2 (7 kg/m^2). Cover stone was obtained from the same source as the Superpave mixture. The stone was uniformly spread manually and then rolled with a cylindrical HMA specimen to ensure bonding between the tack and loose stone.

After the emulsion set, some loose stones, which were not adhered to the bond coat, were swept away. In Phase 2 of laboratory specimen preparation, application of cover stone was followed by a final layer of tack coat application to provide better adhesion to the subsequent overlay and show the necessity to have an asphalt layer as per requirements in Superpave.



Overlay Testing with Lab Specimens

The overlay tester is a displacement controlled repetitive loading machine to initially produce a small crack (due to tension) at the base of a test specimen and then continue to induce repetitive horizontal displacements which causes the crack to propagate upward through the specimen. This process is intended to simulate the cyclic tensile stressing of pavements due to periodic thermal variations. Below is a schematic diagram of a typical overlay test set up.

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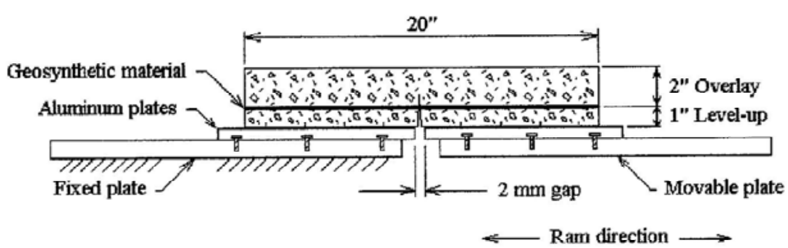

This overlay tester consists of two steel plates; one is fixed, and the other moves horizontally to simulate the opening and closing of joints or cracks in the old pavements beneath an overlay. The load is applied in a cyclic, triangular waveform with constant magnitude. The overlay test is usually performed at room temperature or 77°F (25°C) in a controlled displacement mode at a loading rate of one cycle per 10 seconds with a maximum displacement of 0.025 inches until failure occurs. This amount of horizontal movement is approximately equal to the displacement experienced by Portland Cement Concrete pavements undergoing 30°F (16.7°C) temperature changes in pavement temperature with a 15-foot joint or crack spacing (*Zhou and Scullion, 2003*).
In this test procedure, a composite beam is attached by epoxy to two rigid metal platens on the overlay tester. One platen is fixed, and the other is regulated to oscillate at a displacement of 0.025 inches and at a rate of six cycles per minute. Tests were performed

at 25, 10, and 0°C temperatures. Test temperature was achieved by changing the temperature of the environmental chamber containing the overlay tester.
Specimen failure is typically defined as that cycle at which the specimen cracks completely through. Ideally, complete failure would be defined as the cycle at which the load approaches zero; however, for those specimens containing geosynthetics or fibers, a measurable load is normally evident even after the asphalt concrete specimen is cracked completely through. Load and displacement as a function of time is recorded. The length of visible cracking is periodically measured on the two vertical sides of the specimens. Temperature is recorded throughout testing of each specimen.

Overlay Testing with Field Specimens

After experiencing mode III type crack propagation behavior with laboratory compacted small specimens, the researchers suggested testing with specimens obtained from a roadway. Accordingly, Midland Asphalt Materials Inc. provided specimens with the FiberMat system from a pavement. Large beam and 6-inch diameter core specimens were obtained from four different locations that had different layer configurations. All field specimens contained FiberMat as a SAMI. No control specimens were obtained for direct comparisons. Only the two top layers of these specimens were tested; other layers were trimmed from the bottom. Chapter 3 details the dimensions of specimens from the field. Small and large specimens from the field were tested using the small and large overlay testers, respectively.

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CHAPTER 3:

RESULTS AND DISCUSSION

General

Specimens with and without FiberMat were prepared in the laboratory for testing using the small and large overlay testers. Dimension of specimens for testing with large and small overlay testers were 2.5×5.5×17 inches and 2.5×2.5×8.5 inches, respectively. Stress-absorbing interlayer's were located between a 1-inch bottom layer and 1.5-inch upper layer (overlay). Laboratory prepared small specimens were tested in Phase 1 of this study. Additionally, samples sawn from four different pavements were tested using both overlay testers.

Phase 1 Laboratory Specimens

Most of the specimens were tested at 25°C or 10°C using 0.025 inches of peak displacement with loading and unloading achieved in 10-second cycles. (Specimens tested at 0°C were subjected to only 0.015 inches of peak displacement). During testing, the two major parameters, (e.g., displacement and load) were recorded every 0.1 seconds. Therefore, 100 data points were recorded for each load cycle. As the crack propagated into the specimen, the measured load decreased to maintain constant displacement.

During testing, a person was continuously present to record the crack propagation. Tests were continued until the crack propagated completely through the specimen. Typically, a crack will initiate at the bottom of the slab near the gap and propagate vertically from the bottom with no reinforcement or interlayer. However, specimens with FiberMat often the crack propagated in a different manner. Cracks propagated vertically until they reached the interlayer, then they turned horizontally along the interlayer – Mode III. Similar phenomenon was reported by a previous study conducted at Nottingham University (*Cooper et. al., 1987*). For large long specimens, these horizontal cracks stop at a certain point and then start moving vertically upward.

All control specimens were compacted in two layers, and there was only a small amount of tack coat at the interlayer. The control specimens failed quickly for all three test temperatures. They failed vertically. The photo overleaf shows a typical result from control specimens tested at three temperatures. As expected, they survived longer at higher temperatures.

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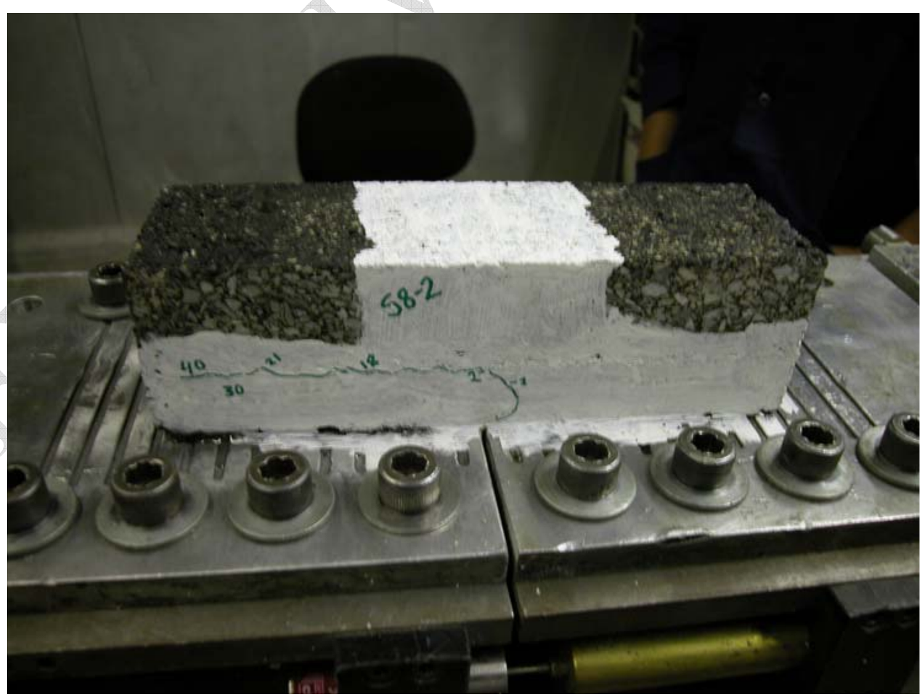
Specimens containing a complete FiberMat system (bond coat - fiber - bond coat - stone) mostly had cracks that propagated by means of horizontal cracks along the interlayer – see photo below. Before that, they survived much longer than the control specimens.



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Phase 2 Laboratory Specimens

Due to the propagation of cracks through the horizontal plane of the small specimens, large specimens were prepared in the laboratory and tested using the large TTI overlay tester. Large specimens were prepared following essentially the same protocol used for the small specimens. The specimen preparation sequence was slightly different in that the final layer of tack was applied onto the previously applied aggregate. As a result, bonding between the cover stone and overlay was improved. This result justifies the use of a final layer of tack on the cover stone.

Any variation of FiberMat improved crack resistance significantly as compared to that of the control samples. The overall trend was similar to the Phase 1 of study. The notable difference was that the bond coat-stone-fiber combination survived significantly longer (compared to the small samples) even though the crack propagated in a similar fashion (i.e., horizontal crack). Application of cover stone is primarily to accommodate the movement of construction traffic or temporary highway traffic over FiberMat during construction (*Gillespie*, *2000*).

Field Pavement Specimens

Cores and beams were obtained from the four different locations that had different layer thicknesses and mixture types. During testing, any material below the second HMA layer was trimmed off. The objective was to obtain a smooth bottom surface (to aid gluing) and a level-up - SAMI - overlay system and examine the performance in the overlay tester.

The field samples that were tested did not include any control samples for comparison. The pavement cores were trimmed on both sides to obtain a 3-inch width; the length was kept at 6 inches. The large beams were sawn to 15 inches in length and 6 inches in width. It should be noted that the field specimens from different locations varied widely in their layer thickness, material type, and construction history.
All of them were tested at 25°C and 0.025-inch displacement. For a given location, the larger specimens survived longer than the smaller ones. The small samples were more prone to crack propagation along the interlayer than their large counterparts. Both large and small samples from a particular site did not propagate even though testing was continued to 2000 cycles. In that case, vertical cracks reached the interlayer and did not progress passed it.

The small specimen from another project propagated via horizontal cracking at interlayer; whereas large specimen from the same location yielded more cycles to failure when tested with the large overlay tester and in that case, the mode was of type I vertical propagation instead of horizontal. Only one specimen from each roadway was available for testing.

Recently, in another TTI research project, field compacted specimens were tested using both the small and large overlay testers. Comparison of these results with results from the FiberMat field samples showed that the FiberMat samples have greater crack resistance.

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Conclusions and Recommendations

Hot mix asphalt concrete specimens with and without various forms of FiberMat were tested in the laboratory using the TTI overlay tester at 0, 10, or 25°C. Variations of FiberMat included specimens with and without cover stone as well as different amounts of unmodified and polymer-modified emulsified asphalt tack coat. Based on results of the laboratory tests, the following conclusions are made.

- Some of the laboratory prepared specimens, particularly the small specimens; crack propagation was along the horizontal plane through the FiberMat interface rather than by cracking vertically above the stressed band across the specimen. Because of these multiple modes of crack propagation it prevented a rational analysis of the data to predict relative field performance using a computer program as originally planned. Therefore, the complete potential of the FiberMat system could not be evaluated from this program at this time.
- However, specimens containing the various forms of FiberMat improved cracking resistance in the overlay tester when compared to cracking resistance exhibited by the control specimens. The small FiberMat samples survived 3 to 4 times more the number of load cycles than the corresponding control samples. The large FiberMat samples survived 14 times more than the number of load cycles compared to the corresponding control samples.
- For the small control specimens, the number of load cycles to propagation increased when polymer-modified bond replaced unmodified tack and when the tack coat rate was increased.
- For the small specimens (both control and FiberMat), the most significant improvement in the number of cycles until crack propagation was exhibited by the specimens fabricated with the medium-high rate of modified bond coat.
- All large specimens containing FiberMat or modified bond coat alone yielded more cycles to failure than the large control specimens. However, those specimens containing fibers exhibited horizontal cracking at the fiber-treated interface. The large specimens containing glass fibers and bond coat performed better than those specimens containing only bond coat.
- The FiberMat field specimens survived longer than the field compacted control specimens tested using the overlay tester on another project. This is for general information only.
- In the overlay tester, the large laboratory specimens are more likely to fail via vertical cracking; whereas, the small specimens are more likely to propagate via horizontal cracking along the reinforced interface. In the overlay tester (both large and small), propagation by horizontal cracking along the interface has most often been observed when very stiff (e.g., fiberglass) reinforcing materials have been applied at the interface between the “leveling course” and the “overlay.”

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