APPLICATION OF ASPHALT RUBBER ON NEW HIGHWAY PAVEMENT CONSTRUCTION

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JANUARY, 1982

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ARIZONA DEPARTMENT OF TRANSPORTATION

PREPARED FOR PRESENTATION AT THE 61ST ANNUAL MEETING
OF THE TRANSPORTATION RESEARCH BOARD
ABSTRACT

Asphalt rubber has been utilized for many years as a Stress Absorbing Membrane (SAM) or Stress Absorbing Membrane Interlayer (SAMI) for both rigid and flexible pavement overlay systems in Arizona with satisfactory performance.

In 1977, a new experimental application of asphalt rubber was used to build a low volume highway pavement between Dewey and Interstate 17 on Highway 169. Several experimental pavement sections were placed. After four years of service only two sections are still in excellent condition with no cracks or ruts observed to date. One section consisted of cement treated base, the other lime-fly ash treated base. Each section received a SAMI and a one-inch wearing course. Other test sections failed and constant patching is required to maintain a minimal level of service. Generally, cement treated bases will always have shrinkage cracks which easily reflect through any asphalt concrete surface layer if without special treatment to retard crack propagation.

A Finite Element procedure was utilized as an aid in explaining why a SAMI can be used effectively to eliminate reflective cracks. It was found that SAMI's can significantly reduce crack tip stresses due to thermal and traffic loads and provide longer service life of the asphalt concrete surface layer.
INTRODUCTION

In the early 1960's, asphalt rubber was originally used as a patching material for alligator cracking type failures in Arizona (1, 2). Later it was developed as a Stress Absorbing Membrane (SAM) and Stress Absorbing Membrane Interlayer (SAMI) for rehabilitation and overlay of cracked pavements (3, 4, 5, 6, 7). Asphalt rubber has also been utilized as joint and crack seal material and as a waterproof membrane for control of expansive clay subgrades.

Coetzee and Monismith (8) investigated the effectiveness of a SAMI as an overlay system over rigid pavements by inducing thermal and symmetrical traffic loading across a crack. Results of this study concluded that a SAMI can reduce stresses in overlays and can also prolong the service life of a typical overlay.

Many field studies of SAM and SAMI have been undertaken by the Arizona Department of Transportation. In 1977, a new area for application of asphalt rubber was introduced in construction of a low-volume road with a cement treated base (CTB). This paper discusses this new asphalt rubber application.

CONSTRUCTION AND PERFORMANCE

The Dewey project, as it is often referred to, is on State Route 169, between milepost 4.8 and 14.5 and is located approximately 80 miles north of Phoenix. It was constructed as a new connecting highway between Dewey, Arizona and Interstate 17. The present Average Daily Traffic (ADT) is approximately 1000 with 6% trucks. The embankments and grades were constructed in 1976 and surfacing was placed in August, 1977. This project consisted of five test sections and one control section.
The original pavement design (before it was decided to build test pavements) called for stage construction of six inches of full depth asphaltic concrete with an open-graded asphaltic concrete friction course (ACFC) on the compacted subgrade. Initial surfacing was two inches and the remaining four inches was designated for future surfacing.

Subgrade material is primarily decomposed granite, clayey sand and gravel with a plasticity index ranging as high as 69. The average project elevation is approximately 4400 feet and winter months are often severe.

A description of the control section and the five test sections are as follows:

**Control Section - Station 262-520**

Subgrade was compacted to 100% of maximum density (36 foot width). Two inches of asphalt concrete was placed on the compacted subgrade. Asphalt concrete was made with an AR2000 asphalt.

**Test Section #1 - Station 520-555 - Lime-Fly Ash Treated Base**

Three percent quicklime and 12 1/2 percent fly ash (by weight of subgrade material) were added to inplace subgrade soil and thoroughly mixed to a depth of six inches and then compacted to 100% of maximum density. An asphalt-rubber membrane was placed across the entire roadway, shoulders and cut ditches. A one-inch asphaltic concrete friction course (ACFC) was placed as a wearing course.

**Test Section #2 - Station 555-590 - Cement Treated Base**

Four and one-half percent (by weight of subgrade material) Portland cement was added to the inplace subgrade soil. This was thoroughly mixed to a depth of six inches and then compacted to 100% of maximum density. An asphalt-rubber membrane was placed across the entire roadway, shoulders and cut ditches. One-inch ACFC was placed as a wearing course.
Test Section #3 - Station 590-640 and 670-765

The subgrade was compacted to 100% of maximum density. Asphalt-rubber then was placed across the entire roadway, shoulders and cut ditches. A one-inch ACFC was placed as a wearing course.

Test Section #4 - Station 640-670

Same treatment as Test Section #3 except an asphalt-rubber membrane was placed two feet down into the subgrade.

Test Section #5 - Station 765-780 - AR1000 - Enzymatic SS

The subgrade was compacted to 100% of maximum density using Enzymatic SS, a compaction aid. Two inches of asphalt concrete was placed on the subgrade as a wearing course. AR1000 asphalt was used in production of the asphalt concrete.

Test Sections one and two, the lime-fly ash and cement stabilized sections, have served perfectly with no visible problems or defects whatsoever, as shown in Figures 1 and 2. Several pavement cores were taken from these test sections - a typical core is shown in Figure 3. All other test sections, as well as the control section, have experienced some degree of distress; performance of even the best of which has been judged unacceptable. Examples of these sections are shown in Figures 4 and 5. The control section and the other three test sections experienced numerous construction difficulties. The intent was to encapsulate the pavement subgrade to prevent moisture change and, thereby, rely on the inherent strength of a cohesive soil molded at optimum density and moisture content. These sections might have performed better if
FIGURE 1. TEST SECTION #1 - LIME-FLY ASH SUBGRADE, SAMI AND ONE-INCH ACFC

FIGURE 2. TEST SECTION #2 - CEMENT TREATED BASE, SAMI AND ONE-INCH ACFC
FIGURE 3. PAVEMENT CORE AT STATION 540
different construction procedures were followed. The asphalt rubber membrane was placed directly on the compacted subgrade. During construction, asphalt concrete haul trucks were allowed to travel on the recently completed membrane and very often "picked-up" the membrane. These areas were never patched. As a result, a complete, intact membrane seal was never achieved. During the first winter (which was very wet) it became apparent these sections were doomed to failure. An asphalt-rubber membrane can be properly placed if construction procedures are controlled to prevent pickup of the membrane from the subgrade.

A great deal was learned from this test project. Although we know stabilized bases will crack, especially cement treated bases, both of these test sections (sections #1 and #2) remain crack free after four years service. The SAMI has effectively prevented transmission of the cracks in the stabilized base through to the one-inch thick surface course.

Asphalt-rubber has shown its effectiveness in preventing reflective cracking in overlays over existing pavements and it was expected a membrane would do the same on new construction with stabilized bases.

ANALYTICAL STUDIES

An analysis was conducted of the theoretical behavior of the structure to explore the basic reason why the asphalt-rubber prevented reflective cracking as well as to provide a method to determine the structural adequacy of the systems.

Several Finite Element Method (FEM) computer programs were utilized for the analysis of stresses and strains. The primary computer program used for this study was a slightly modified static analysis program for solid structures; namely, SOLID SAP by Wilson (9). The slight modification
of this program was in the calculation of the effective stress, which is
defined by using the normal and shear stresses in an orthogonal Cartesian
coordinate system as:

\[ S_{\text{eff}} = \frac{1}{r^2} \left[ (S_{11} - S_{22})^2 + (S_{22} - S_{33})^2 + (S_{33} - S_{11})^2 + 6(S_{12}^2 + S_{23}^2 + S_{31}^2) \right]^{\frac{1}{2}} \]  

It is considered to be a realistic determinant for fracture (cracking)
under the triaxial stress state existing in the overlay pavement.

In order to reduce the cost of computer time, a linear elastic plane
strain analysis was assumed with up to 685 nodes and 620 elements. The
general configuration of the pavement structure is shown in Figure 6.
The range of different layer properties are shown in Table 1. This does
not exactly model the pavement condition in Dewey. However, the objec-
tive of this paper is to provide an analytical explanation for the
apparent success of this new asphalt rubber application.

Computer runs were not arranged as a factorial matrix due to the
high cost of each run. Instead, several interesting variables were
studied separately.

(a) **Thermal Effects** - The general temperature profile shown in
Figure 7 was used. Results of this study indicate the horizon-
tal tensile stress near the crack tip reduced significantly as
a result of the SAMI as shown in Figure 8. The SAMI will not
reduce the overall horizontal stress in asphalt concrete
(AC) or an asphalt concrete friction course (ACFC) due to
thermal expansion or contraction, but will significantly reduce
stress concentration above the crack tip, minimizing reflec-
tive cracking.
FIGURE 6. GENERAL CONFIGURATION OF THE PAVEMENT STRUCTURE WITH CEMENT TREATED BASE AND A CRACK
<table>
<thead>
<tr>
<th></th>
<th>ELASTIC MODULUS</th>
<th>SHEAR MODULUS</th>
<th>POISSON RATIO</th>
<th>THERMAL COEFF.</th>
<th>THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>E (KSI)</strong></td>
<td><strong>G (KSI)</strong></td>
<td><strong>µ</strong></td>
<td><strong>α (PER °F)</strong></td>
<td><strong>t (IN.)</strong></td>
</tr>
<tr>
<td>AC OR ACFC</td>
<td>100-500</td>
<td>40-200</td>
<td>0.3</td>
<td>0.0000125</td>
<td>1-4</td>
</tr>
<tr>
<td>SAMI</td>
<td>0.2-2.0</td>
<td>0.08-0.8</td>
<td>0.35</td>
<td>0.000015</td>
<td>0.4</td>
</tr>
<tr>
<td>CTB</td>
<td>1000-4000</td>
<td>420-1680</td>
<td>0.2</td>
<td>0.0000039</td>
<td>6-10</td>
</tr>
<tr>
<td>SUBGRADE</td>
<td>10</td>
<td>4</td>
<td>0.48</td>
<td>0.00001</td>
<td>40</td>
</tr>
</tbody>
</table>

**TABLE 1. RANGE OF PAVEMENT LAYER PROPERTIES**
FIGURE 7. GENERAL INPUT PAVEMENT TEMPERATURE PROFILE
FIGURE 8. EFFECTS OF SAMI ON THERMAL HORIZONTAL STRESS NEAR THE CRACK TIP
(b) **Overlay Thickness** - Overlay thicknesses from one to four inches were studied. For an overlay without a SAMI, stresses reduce significantly due to increasing thickness (Figures 8 and 9). However, for an overlay with SAMI, stresses were only slightly reduced due to the increasing overlay thickness. This indicates, from an economical point of view, a thick overlay may not be justified for a reflective overlay design when SAMI is utilized.

(c) **Crack Width** - Only two different crack widths were investigated, 0.03" and 0.3". Results show when there is not a SAMI in the overlay system the stress concentration problem is more serious for smaller cracks than larger cracks (Figure 10). For overlays with a SAMI, stresses stay approximately the same no matter what the crack width. It is assumed there is no load transfer capacity across a crack, which is valid in most cases depending on the magnitude of the crack width and vertical differential movements.

(d) **Effects of Moving Traffic** - Traffic loading was represented by a 12" long, 100 psi load moving from one side of the crack to the other, as shown in Figure 6. Shear and effective stresses are at a maximum when the edge of this simulated traffic load just reaches the location of a crack as shown in Figures 11 and 12. This study also revealed that a SAMI can reduce effective stress and more importantly, shear stress in the surface layer which many researchers believe is one of the major factors causing reflective cracking.
FIGURE 9. EFFECTS OF SAMI ON EFFECTIVE STRESS NEAR THE CRACK TIP
FIGURE 10. INFLUENCE OF CRACK WIDTH ON STRESSES
FIGURE 11. INFLUENCE LINE OF EFFECTIVE STRESS NEAR THE CRACK TIP DUE TO MOVING LOAD
**FIGURE 12. INFLUENCE LINE OF SHEAR STRESS NEAR THE CRACK TIP DUE TO MOVING LOAD**

A graph showing the shear stress above a crack tip in PSI, with positive and negative shear regions indicated. The graph includes lines for conditions with and without SAMI at the bottom of the crack, and a traffic loading case indicated by points A through A'.
SUMMARY

1. SAMI can be used for overlay of flexible and rigid pavements, for new construction or anywhere else that stress concentration around a crack needs to be reduced.

2. SAMI can reduce stresses due to thermal changes as well as vertical shear stresses due to moving traffic loads.

3. SAMIs can retard (or eliminate) reflective cracks by reducing crack tip stresses. In many cases, crack tip stresses drop to 10% or less of the original stresses.

4. A three dimensional finite element analysis with more realistic time and temperature dependent material properties will provide better results. However, computer time required may increase 10 to 20 times. The primary purpose of this dissertation is to report a new area for the application of asphalt rubber as a SAMI in construction of new pavement and try to provide analytical explanations for the apparent success of this new approach in pavement design.

5. During the analytical study, it was assumed there is no load transfer capability across a crack. This is especially true when the ratio of crack width to vertical differential movement of a crack is high. Results of this study imply that a SAMI will perform even better if there is some load transfer capacity through a crack.

6. A better understanding of SAMI properties is needed through laboratory testing.

7. When a SAMI is utilized, the thickness of overlay becomes less critical. This may result in very economical approaches to overlay design.
REFERENCES


