Final Report

EVALUATION OF ASPHALT RUBBER MEMBRANCE INTERLAYER (ARMI) USING THE UNIVERSITY OF FLORIDA'S COMPOSITE SYSTEM INTERFACE CRACKING (CSIC) TEST

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background

The Florida Department of Transportation (FDOT) has been using Asphalt Rubber Membrane Interlayers (ARMI), intended to mitigate reflective cracking, since in the late 1970s. ARMI layers are constructed by spraying Asphalt Rubber Binder containing 20% rubber (ARB-20) at a rate of 0.6 to 0.8 gallons per square yard, and covering this asphalt layer with No.6 stone at a rate of 0.26 to 0.33 ft^3 per square yard, and rolling the stone into the asphalt layer with a pneumatic tire roller (ARMI layers also require a minimum overlay of at least 1.5 inches). This layer adds an additional high cost to the rehabilitation of pavements, when required by design.

Field reports are mixed as to the effectiveness of this system and FDOT districts have also reported that the ARMI layer may contribute to rutting. The FDOT State Materials Office recently completed a study titled “Evaluation of Asphalt Rubber Membrane Interlayer on Rutting and Reflective Cracking”. Initial tests indicated that thin overlays may be rut susceptible, corroborating the observations made by some FDOT Districts. This study included constructing pavements which were to undergo testing using the FDOT Heavy Vehicle Simulator (HVS). Control and experimental test sections were monitored for rutting performance. Results from these tests clearly show that the sections with ARMI rutted more severely, and more quickly, than those without ARMI.

Research at the University of Florida has revealed that pavement top-down cracking performance depends not only on the pavement layer material characteristics but also on the layer interface conditions. The interface conditions involve both the shear resistance along the interface and the cracking resistance across the interface provided by the interface bonding agents or materials. The currently available tests mainly focused on the pavement layer material properties and shear strength along the interface. When thick Polymer Modified Asphalt Emulsion (PMAE) was applied at the interface between Open-Graded Friction Course (OGFC) and dense graded structural layer, a bonded interface was formed by the PMAE migration into OGFC air voids. Shear strength tests, which can well characterize the adhesive film effect of interface bonding agents, cannot fully capture the effect of the bonded interface on pavement performance.

In order to simulate the crack initiation and propagation process and evaluate the effect of bonded interface conditions on top-down cracking performance, a Composite Specimen Interface Cracking (CSIC) test was developed (Chen et al. 2012). The developed system involves repeated tensile loading and monitoring of the rate of damage development (reduction in stiffness) on composite specimens specifically designed for this purpose. The number of loading cycles to failure and damage rate results from the proposed test on three different interface conditions clearly indicated that this test method can be used to optimize bonding materials and application rates for enhanced cracking performance.

It was proposed that this test method can be applied to any composite pavement systems, regardless of the interface type or construction, and therefore it was used in this study to evaluate the effects of ARMI layers on reflective cracking performance.

1.2 Objectives

The overall objective of this research was to evaluate the effect of ARMI layer on resistance to reflective cracking using the CSIC test. Specimens were obtained from cores taken from pavement sections constructed at FDOT’s State Materials Office which have been tested using the Heavy Vehicle Simulator. Cores were taken from control section constructed without an ARMI layer and from a section constructed WITH an ARMI layer. The purpose is to determine whether the ARMI layer contributes to a delay in reflective crack propagation through the pavement system using the CSIC test developed at the University of Florida.

Detailed objectives of this research are as follows:

- Take cores from the HVS test sections, with and without ARMI
- Construct CSIC test specimens using these cores
- Perform repeated load tests using the CSIC testing system
- Evaluate the effects of ARMI layer on reflective cracking using the data acquired during the test

1.3 Scope

This study primarily focuses on the evaluation of ARMI layer effects on pavement reflective cracking performance. CSIC tests were performed on control specimens (without ARMI layer) and specimens with ARMI layer. Specimens were produced from cores taken from sections constructed at FDOT's State Materials Office. All tests were conducted at one temperature (10°C), which has been determined in prior fracture research at the University of Florida to correlate well with cracking performance of pavements in the field.

CHAPTER 2
SPECIMEN PREPATATION AND TEST METHOD

2.1 Specimen Preparation

The FDOT State Materials Office cored the HVS pavement sections and recovered 10 cores from both the control (without ARMI) and experimental (with ARMI) sections in an area away from the distressed or tested regions. The cores were taken carefully as to not disturb or damage the pavement layers. The cores were transported to the testing laboratory at the University of Florida. Typical cores for both experimental and control sections are shown in Figure 2-1.

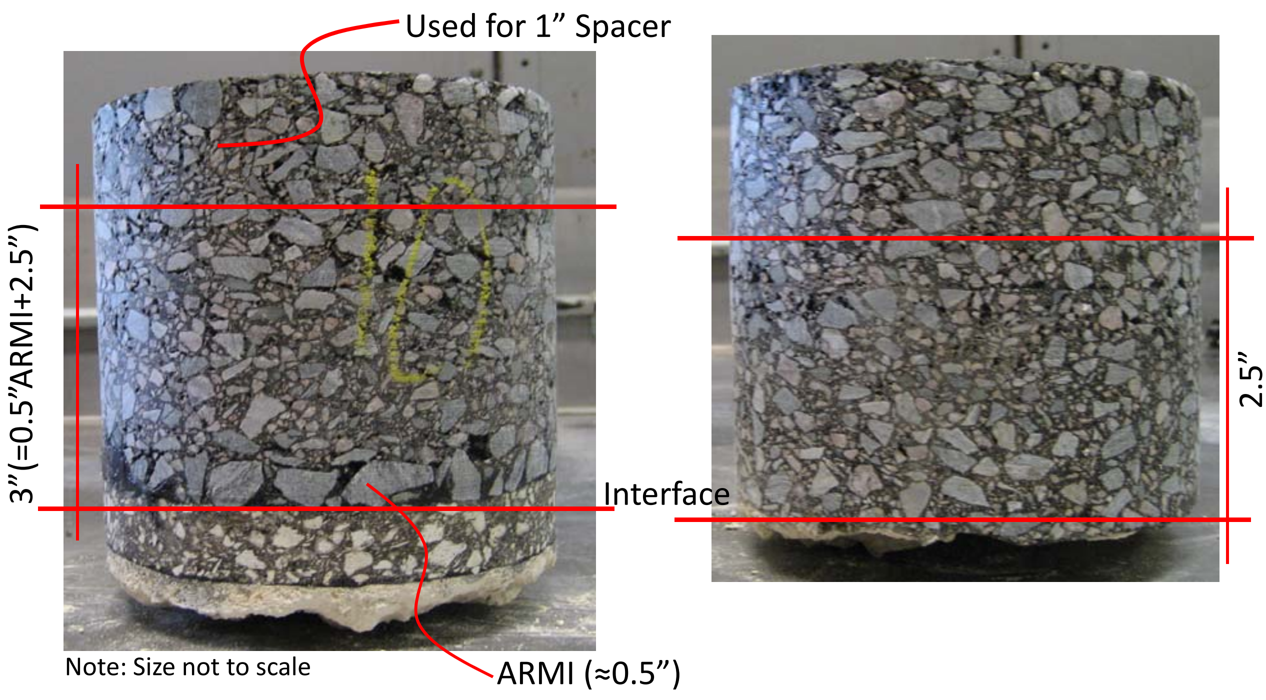

Figure 2-1. Typical cores from sections with ARMI layer (left) and without ARMI layer (right)

As also shown in Figure 2-1, previous pavement layers were trimmed off at the interface for both ARMI and control sections. ARMI layers were estimated to be 0.5-inch, and the top parts of both cores, whether with ARMI or without, were also trimmed, leaving 3.0-inch and 2.5-inch for cores with ARMI and without, respectively (See Figure 2-1). A 1.0-inch layer was retrieved from the top parts for both cores and used as central loading spacer. Two half specimens were expoxied to the central loading spacer to form a completely symmetrical composite specimen for testing (See Figure 2-2). Teflon spacer was introduced to represent an existing crack, which more effectively concentrated stress at the interface. A diamond-tip coring tool was used to introduce the 3/4-inch hole though which loading was applied. The specimen's curved ends were reinforced with carbon fiber to eliminate a potential bending failure. Five composite specimens each were prepared for both with ARMI and without ARMI.

Figure 2-2. Typical composite specimens with ARMI layer (left) and without ARMI layer (right) ready to be glued together with epoxy

2.2 Test Method

The CSIC test system included the environmental chamber, MTS loading system, cooling system, measurement, and data acquisition system. The test was performed in load control mode by applying a repeated haversine waveform load for a period of 0.1 second followed by a rest period of 0.9 seconds by way of two split cylinder yokes inserted in the hole in the center of the specimen. The radius of the two yokes is 3/8-inch, matching the radius of the stress concentrator in order to ensure uniform contact and to properly distribute the load. The load level was selected such that damage and fracture developed gradually (i.e. not catastrophically) to optimize the ability to identify the effects of ARMI layer on damage and fracture. A sketch of specimens depicting load and measurement system is shown in Figure 2-3. The test procedures are summarized in the following steps:

- Aluminum gage points were affixed with epoxy to prepared test specimens. Specimens were cooled at test temperature for at least 3 hours before the test.
- Four extensometers, two on each side of the specimen, were mounted at a gage-length of 1.5-inch.
- The test specimen was placed into the loading frame with specially designed loading yokes. A seating load of 10 to 30 lbs was applied to the test specimen to ensure proper contact between specimen and loading yokes.
- The specimen was then loaded by applying a repeated haversine load of 570 lbs, which was selected by performing several trials. If sudden changes in extensometer data occurred, or whenever desired, the operator recorded a burst of data for 6 consecutive loading cycles at a rate of 500 data points per second, which allowed for calculation of the specimen's total recoverable deformation.

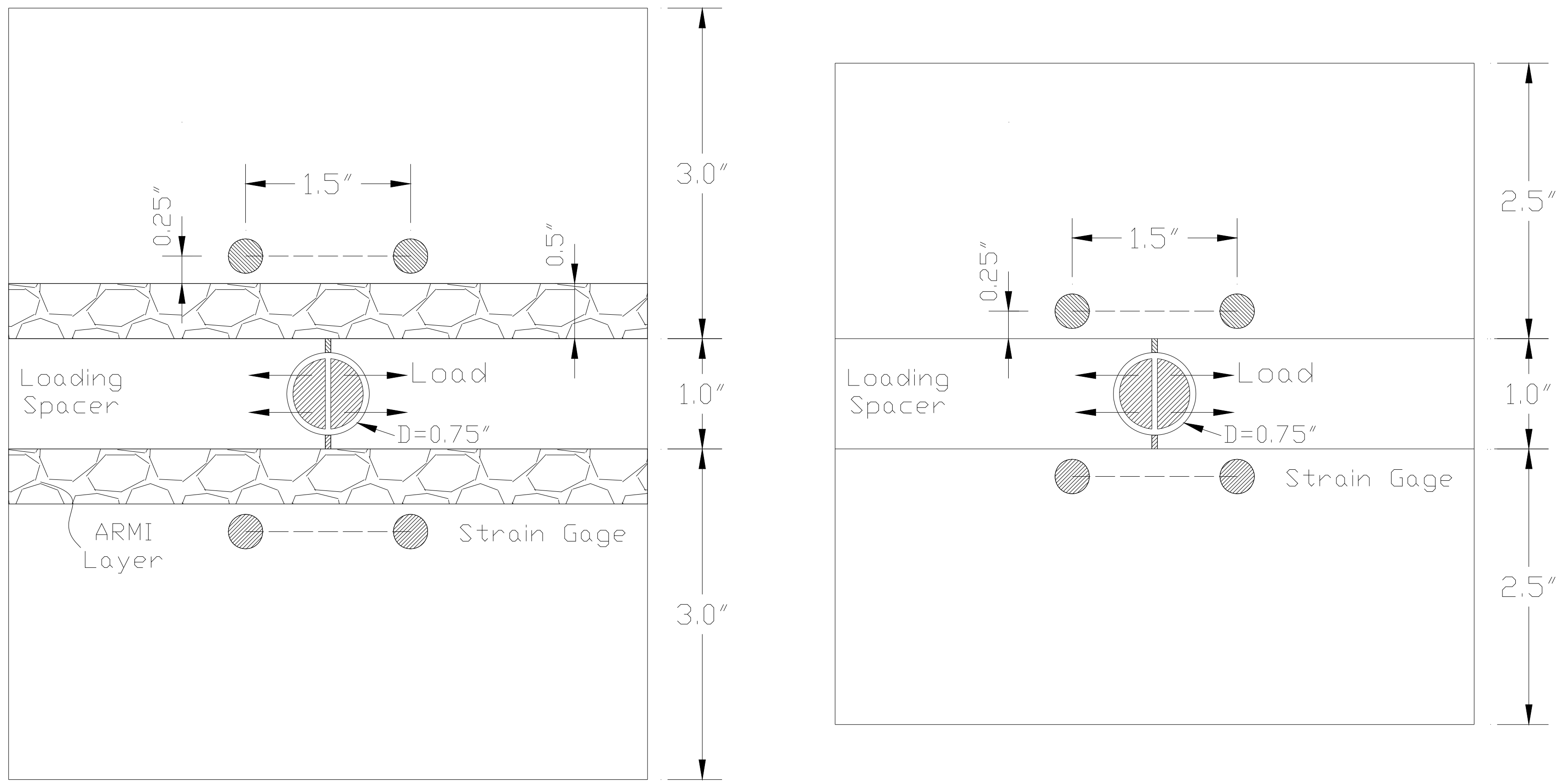

Figure 2-3. Sketches of composite specimens with ARMI layer (left) and without ARMI layer (right) and strain gauge measurement system

CHAPTER 3
TESTING RESULTS

3.1 Data Analysis

The recoverable deformation, which is inversely related to the specimen's stiffness, was calculated to facilitate comparison of the specimen's behavior and performance throughout the test. To eliminate specimen-to-specimen variations, recoverable deformation was normalized to its value at the beginning of the test.

The number of load cycles required to fail the composite specimen is a straightforward cracking resistance comparison parameter for specimens with different interface conditions subjected to the same loading conditions.

It has been well recognized that damage induced in the specimen can be measured by the specimen's stiffness reduction. As indicated earlier, the recoverable deformation measurement is inversely related to the stiffness, so the change in recoverable deformation can be used to monitor damage.

A typical recoverable deformation versus time plot is shown in Figure 3-1. As shown in this figure, the recoverable deformation versus time curve can be divided into three stages: the initial stage, which was known to involve changes in temperature and local damage adjacent to the loading yokes; the second stage, which involved steady-state damage; and the final stage, when the crack propagated rapidly and the specimen breaks. The damage rate is defined as the slope of the steady state response portion of recoverable deformation progression curve as shown by the line in Figure 3-1.

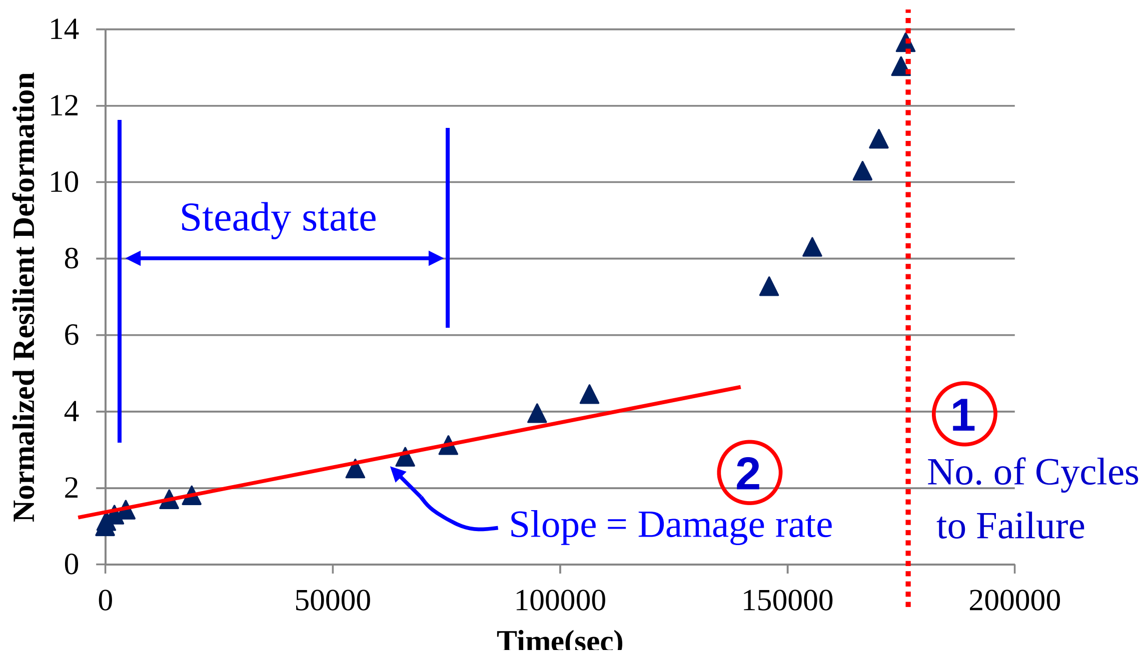

Figure 3-1. Typical recoverable deformation and damage rate

3.2 Test Results

Repeated load fracture tests were performed on three composite specimens each for both with ARMI and without ARMI under the same peak load. Number of load cycles to failure and damage rate were obtained for each test. Typical failure mode for both types of composite specimens is shown in Figure 3-2. The number of loading cycles to failure and damage rate results are presented in Figures 3-3 and 3-4, respectively.

Figure 3-2 clearly indicated that cracking did initiate within the ARMI and propagated through the ARMI and into overlays. This cracking process successfully simulated the reflective cracking mechanism with ARMI. Figures 3-3 and 3-4 clearly indicated that specimens without ARMI outperformed the specimens with ARMI in terms of reflective cracking resistance. It appears that ARMI not only cannot delay reflective cracking but to some extent reduces reflective cracking resistance. It indicates that asphalt rubber doesn't have the same capability of PMAE to dissipate stresses accumulated near the interface.

Figure 3-2. Typical failure mode of composite specimen

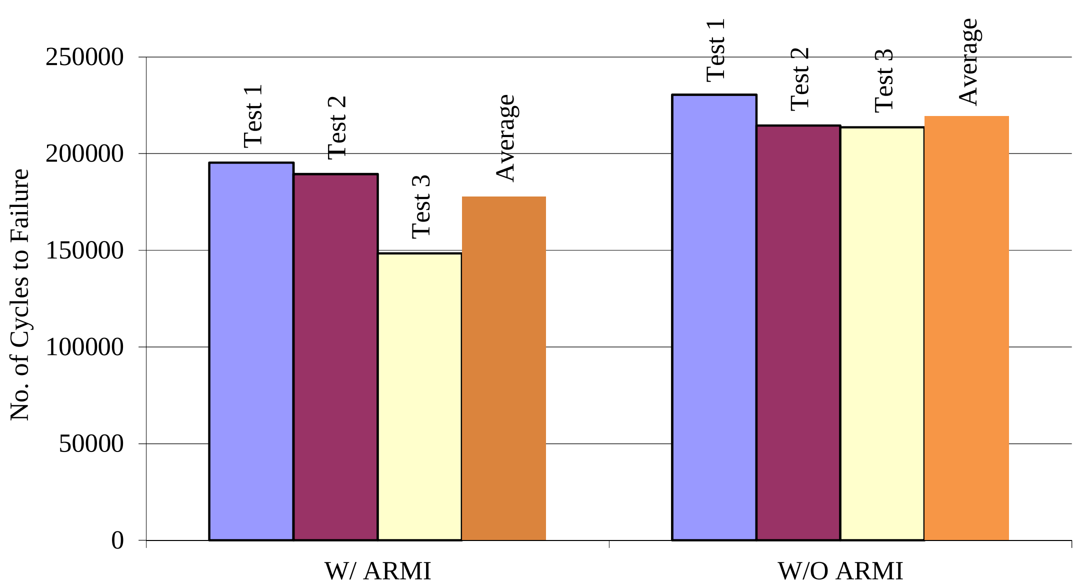

Figure 3-3. Number of cycles to failure

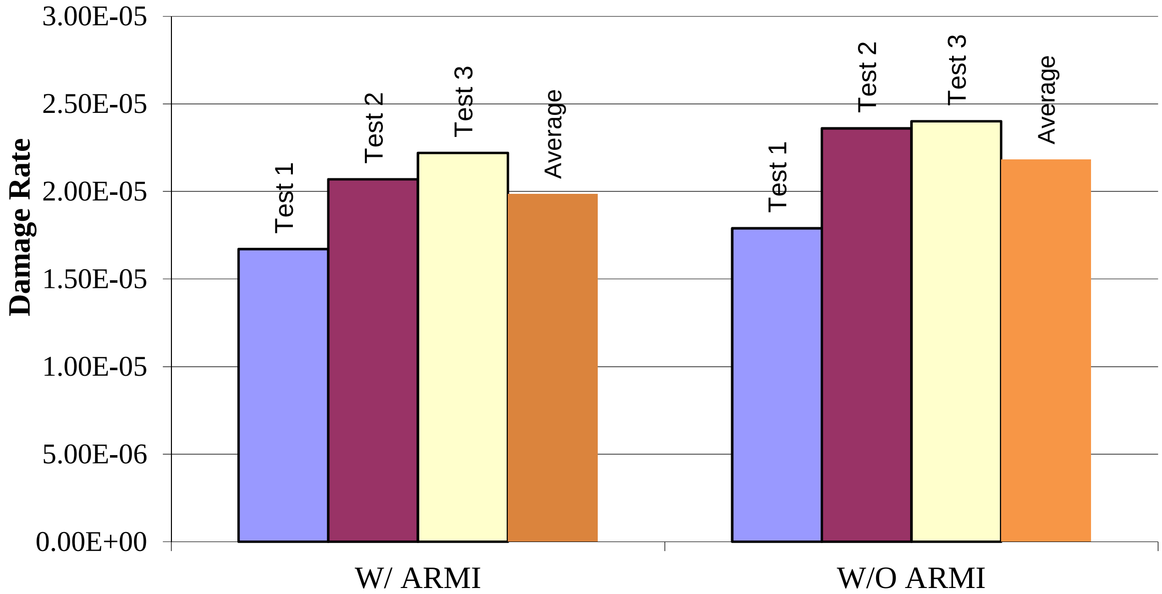

Figure 3-4. Damage rate

CHAPTER 4
CLOSURE

4.1 Summary and Conclusions

This study was conducted to evaluate the effects of asphalt rubber membrane interlayer (ARMI) on reflective cracking performance. Repeated load fracture tests were performed on three composite specimens each for both control (without ARMI) and ARMI specimens subjected to the same peak load. Number of cycles to failure and damage rate results were obtained for all tested specimens. Results indicate that specimens without ARMI outperformed the specimens with ARMI in terms of reflective cracking resistance. It appears that ARMI not only cannot delay reflective cracking but to some extent reduces reflective cracking resistance. It indicates that asphalt rubber doesn’t have the same capability of PMAE to dissipate stresses accumulated near the interface.

LIST OF REFERENCES

Y. Chen, G. Tebaldi, R. Roque, G. Lopp & Y. Su. (2012). " Effects of Interface Condition Characteristics on Open-Graded Friction Course Top-Down Cracking," Road Materials and Pavement Design, DOI:10.1080/14680629.2012.657051.