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EVALUATION OFINTERFACE BOND CONDITION BETWEEN TWO BITUMINUOS LAYERS

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ABSTRACT

This study is to evaluate the bonding shear stress between asphalt pavement layered structures with emulsion and cutback asphalt as tack coat materials. A simple direct shear test device is set up for testing the shear force of the pavement composite interface. The test results show that the shear force decreases with an increase in temperature. It had a maximum value at optimum application rate and the emulsion asphalt used exhibited higher shear force than that of cutback asphalt. The shear stress model represented by exponential equations between shear stress and temperature is reasonable and is not significantly different to the shear stress from experimental field test, in accordance with the statistic of analysis of variance test. The shear stress modeling developed in this paper provides a valuable method to simulate the shear stress of a different nominal aggregate gradation and tack coat material.

Keywords: Tack coat materials, emulsion asphalt, Shear stress model.

1. INTRODUCTION

The bonding of asphalt layers is a significant factor that directly influences the strength and durability of pavements. This bonding of asphalt layers is influenced by the size of aggregates used in asphalt mix, by the type of asphalt mix and binder, by the quantity of bitumen emulsion, and by the type of construction technology used. Due to insufficient bonding between asphalt layers, the upper asphalt layer may be displaced, under the effect of shear force, parallel to the asphalt binder, and the asphalt binder can be displaced parallel to the asphalt base layer. In that case, the asphalt pavement structure is affected by corrugation, slippage and transverse cracking. The pavement distress usually occurs at the acceleration/deceleration and turning zones. The asphalt pavement life span decreases because of insufficient bonding of asphalt layers. The necessary bearing capacity, strength, and durability of pavement structures can be obtained if the bond between asphalt layers is appropriate. If bonding is sufficient, all asphalt layers in pavement act as a monolithic structure, and the largest stress from wheel load is concentrated at the bottom of asphalt base course. In such a case the cracking also starts from the asphalt base course. When the bonding is insufficient, each asphalt layer operates separately from the others, and the maximum stress is concentrated at the bottom of each asphalt layer.

The bonding between asphalt layers is conditioned by the friction and interlocking of layers. The friction is reduced by an excessive quantity of binder between the layers, when a binder coat is formed, which doesn't allow the contact between separate asphalt layers. The bonding between asphalt layers depends on friction, bonding, and interlocking of layers. There are three types of asphalt layer bonding.

1. **Sufficiently bonded** – asphalt layers act as a monolithic structure. A large shear stress is created and no deformations (displacements) are developed. However, this is a theoretical model, because in practice the bonding plane of asphalt layers is always represented by a smaller or larger deformation.
2. **Partially bonded** – depends on the interlocking strength. The shear stress and deformations (displacements) of various sizes occur between layers. In case of strong interlocking, the large shear stress and small deformations are registered. Conversely, if the interlocking is weak, the shear stress is small and the deformation is substantial.
3. **Insufficiently bonded** – the friction and bonding occur only as a result of the load and self-weight of layers. Small shear stresses and large deformations occur between the layers.

2. Objectives

The objectives of this study are as follows:

- Evaluate a new testing and data interpretation system developed to assess the effect of interface characteristics on pavement cracking performance.
- Present specimen preparation, testing and data interpretation methods.
- Evaluate the effect of interface bond conditions on top-down and reflective cracking.

3. Scope

This study primarily focused on the presentation of newly developed testing, evaluation and data interpretation method that allows for the characterization of the effect of bonded interfaces on top-down and reflective cracking . For top-down cracking, composite specimen interface cracking (CSIC) tests were performed on OGFC mixtures placed on dense graded mixture using both conventional tack coat and polymer-modified asphalt emulsion (PMAE). For reflective cracking, CSIC tests were performed on dense graded mixture placed on dense graded mixture using both conventional tack coat and PMAE. For both tests, one application rate was examined for each interface type, as this study was not meant to optimize application rate. All tests were conducted at one temperature, which has been determined in prior fracture research at the University of Florida to correlate well with cracking performance of pavements in the field.

4. Determination of asphalt layer bonding strength

The asphalt layer bonding strength can be determined by several methods. The shearing test is most often used in practice, while the pull–off and torque tests are less common (Figure 1). The shearing test is most often used in order to evaluate the bonding strength between asphalt layers. The shearing test can be performed either without normal stress (direct shear test), and with normal stress (simple shear test):

1. The direct shear test: the Leutner test, the parallel-layer direct shear test, the LBC test, the De Bondt test, the U.S. National Asphalt Technology Center Shearing test (NCAT), the FDOT test, the Iowa test, the Rommanoshi test, the Al-Qadi test, the Asher test, and the SST- Super pave Shear Test.
2. The simple shear test: the MCS trial, the ASTRA trial, and the SST trial.

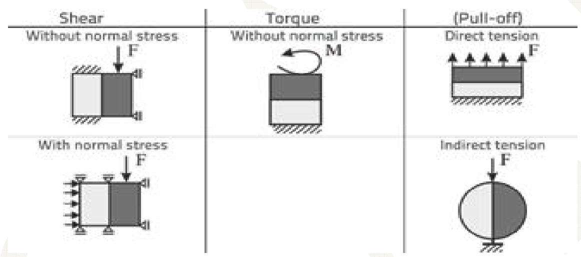

Figure 1: Methods used to determine bonding strength of asphalt layers

5. Test and Data Interpretation Methods

5.1. Overview

Currently, tests available for pavement layer interface evaluation mainly focus on interface shear resistance. In addition, most existing tests are performed in monotonic mode, which is not representative of the pavement interface loading conditions under traffic. Also, tests used to evaluate cracking resistance of interlayer materials require large specimens, which are relatively difficult to fabricate in the laboratory and more difficult to obtain from the field. Tests commonly used to the determine the tensile properties of asphalt mixture; e.g., Super pave Indirect Tensile Test and uniaxial tension test are designed to evaluate single asphalt mixture; they are not suitable for evaluating composite specimens normally composed of two types of asphalt mixtures with an interface in between. Therefore a new testing system, the CSIC test was designed to propagate a crack from one material layer through the interface to the other material layer(s), using easily obtained specimens, i.e. Super pave gyratory compacted specimens or cored field specimens.

5.2 Specimen Preparation and Test Method

Test specimens can be prepared from either super pave gyratory compacted specimens or cored field specimens. The laboratory preparation process involves compaction, cutting, gluing and grooving as shown in Fig 2. The test specimen consisted of two separately prepared composite specimens bonded together at the pavement surface for top-down cracking and at the bottom of the structural layer for reflective cracking. The top-down cracking specimens were composed of a 25 mm thick OGFC mixture compacted on dense graded mixture; whereas the reflective cracking specimens were composed of a 19 mm dense graded structural layer on a dense graded overlay. For both specimen types, a 19.05 mm diameter stress concentrator is cored at the specimen center. The final specimen was trimmed to 38 mm depth from the original 150 mm diameter composite specimen. The specimens curved ends were reinforced with carbon fiber to eliminate a potential bending failure.

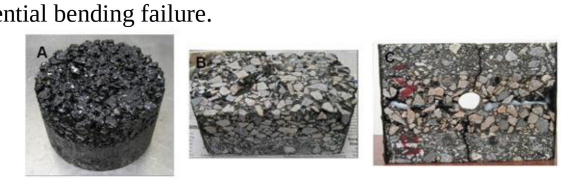

Fig 2: Composite specimen preparation process

The CSIC test was performed by applying a repeated have sine load for 0.1 second followed by a 0.9 second rest period by way of two split cylinder yokes inserted in the hole in the center of the specimen in Fig. 2. The radius of the two yokes was 9.5 mm, matching the radius of the stress concentrator in order to ensure uniform contact and to properly distribute the load. A seating load of 44 N was applied to ensure the specimen always in tension and that contact was never lost between the yokes and specimen. Four extensometers, two on each side of the specimen, were centrally mounted on gage points attached to the specimens at a distance of 19.1 mm from the composite specimen symmetrical plane. A plan view sketch of a specimen depicting load and measurement system is shown in Fig. 2 (dimensions in parentheses correspond to reflective cracking specimens).

5.3 Data Collection and Interpretation Method

Extensometer data was acquired at a rate of 5 samples per second and plotted to allow the operator to observe for abrupt changes in deformation as an indication of local damage evolution. If a sudden change 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 specimens total recoverable deformation.

The total 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. The specimen stiffness was calculated from the average of the total recoverable deformation of the four extensometers, and the average applied load for the six load cycles. Do not include headers, footers, or page numbers other than those already set in this manuscript. Note that the headers, footers or page numbers are different for the first page and the rest of the pages. Actual page numbers and other running heads will be modified when publications are assembled.

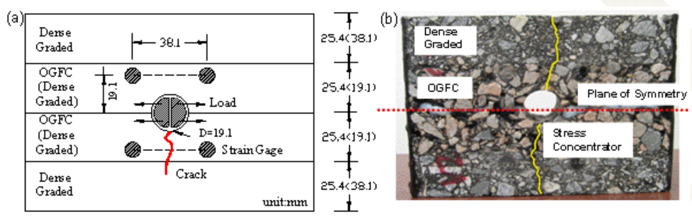

Figure 3: (a) Specimen loading and measurement system and (b) cracking mechanism.

The total number of load cycles required to break the composite specimen was used as a straightforward cracking resistance comparison parameter for specimens with different interface conditions subjected to the same loading conditions. However, this parameter provided only the fracture resistance of the whole specimen without any information regarding the damage evolution in the specimen.

It has been well recognized that damage induced in the specimen can be measured by the specimen's stiffness reduction. As indicated earlier, the total recoverable deformation measurement is inversely related to the stiffness, so the change in total recoverable deformation can be used to monitor damage. A typical total recoverable deformation versus time plot is shown in Fig. 5. As shown in this figure, the total recoverable deformation versus time curve can be divided into three stages: the initial stage, which is known to involve changes in temperature and local damage adjacent to the loading yokes; the second stage, which involves steady-state damage; and the final stage, when the crack propagates rapidly and the specimen breaks. The damage rate was defined as the slope of the steady state response portion of total recoverable deformation progression curve as shown by the line in Fig. 5.

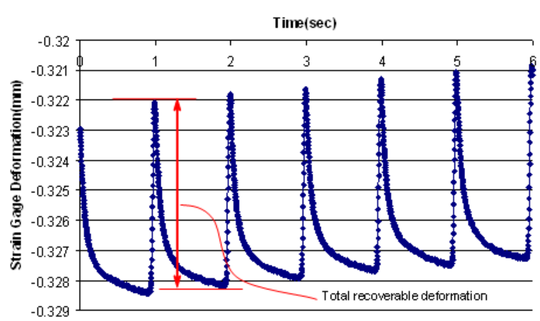

Figure 4: Total recoverable deformation

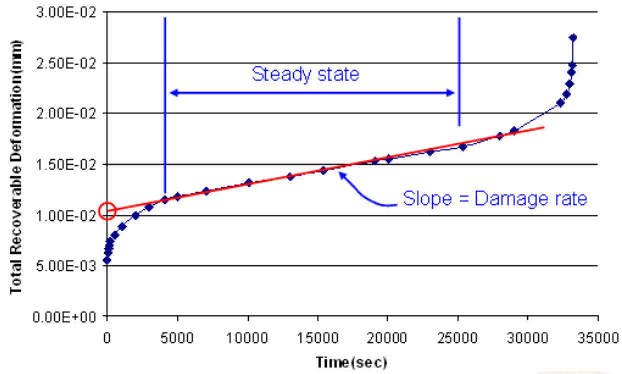

Figure 5: Typical total recoverable deformation and damage rate

6. Conclusion

In this study, it was shown that the newly developed CSIC test successfully distinguished effects of pavement layer interface characteristics on both top-down and reflective cracking performance. The following conclusions can be drawn from this study:

- This newly introduced test method can serve as tool for evaluating the cracking performance of interface materials on pavements.
- The total number of cycles to failure, and damage rate are two effective measurements of cracking performance for composite specimens with different interface conditions.
- Nova bond PMAE increased both top-down and reflective cracking performance of composite specimens by increasing the cracking resistance of materials near the interface and by dissipating the stresses at or along the interface.

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