Construction and Building Materials 179 (2018) 285–293

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Selection of a performance test to assess the cracking resistance of asphalt concrete materials

Shashwath Sreedhar *, Erdem Coleri, Sogol Sadat Haddadi

School of Civil & Construction Engineering, Oregon State University, OR 97331, USA

HIGHLIGHTS

- SCB and IDT tests are the most reliable tests to evaluate fatigue cracking.
- Flexibility index parameter is effective in differentiating cracking resistance.
- Mixing method does not have significant effect on measured cracking performance.
- Compaction method significantly affects the measured cracking resistance.

ARTICLE INFO

Article history:
Received 25 October 2017
Received in revised form 26 April 2018
Accepted 28 May 2018

Keywords:
Asphalt concrete
Cracking
Performance tester
Fatigue life
Recycled asphalt materials
Fatigue tests
Flexibility index

ABSTRACT

Cracking is a common failure mechanism in asphalt concrete pavement structures. It is one of the main reasons for large road maintenance and rehabilitation expenditures, as well as reduced user comfort and increased fuel consumption due to high road roughness. The resistance of the pavement to this distress mechanism is dependent upon the ductility of the asphalt pavement mixture. The use of recycled asphalt materials in asphalt mixtures are also becoming increasingly common. A drawback of this practice is a reduction in ductility of the asphalt mixture, which causes a significant reduction in the fatigue life of the pavement in many cases. In Oregon, asphalt pavements are commonly failing prematurely due to cracking-related distresses, necessitating costly rehabilitation and maintenance at intervals of less than half of the intended design lives in some cases. For this reason, it is necessary to accurately quantify the impact of increasing the recycled asphalt content in asphalt pavement on the structural cracking resistance of the pavement through the use of low-cost and efficient testing procedures that can be implemented easily. This study focuses on characterizing the cracking performance of asphalt pavements in Oregon by considering four tests commonly used to evaluate fatigue cracking resistance and proposing the implementation of the most cost-effective and efficient test procedure for agencies and contractors.

1. Introduction

Fatigue cracking is one of the most predominant modes of pavement distress. It occurs due to repeated traffic loading, particularly by heavy axle loads of trucks [1]. It has been observed that some of the pavements constructed in Oregon over the last two decades are failing prematurely by fatigue cracking [2]. The use of recycled materials, polymers and modified binders in the asphalt mix have altered the performance of the mixtures [3]. Hence, volumetric properties considered in the mix design stage are not sufficient on their own to evaluate the fatigue performance of asphalt mixtures. Therefore, a more comprehensive laboratory evaluation tool is necessary to understand the behavior of paving mixtures.

High surface tensile stresses for asphalt concrete layers (top-down), high near tire shear induced tension for thick structures (top-down), and high bending stresses at the bottom of the asphalt concrete layers (bottom-up) are the major causes of cracking [4]. Several researchers have come up with test procedures to evaluate fatigue cracking performance of asphalt concrete [5–11]. Based on a comprehensive literature review, four cracking tests were chosen in this research study as candidate experiments. According to the literature review, the Semi-Circular Bend (SCB) test, Indirect Tension (IDT) test, Bending Beam Fatigue (BBF) test and Direct Tension Cyclic Fatigue (DTCF) test are the most commonly used test methods used to evaluate the fatigue performance of asphalt mixtures. The four chosen tests were evaluated for:

* Corresponding author.
E-mail addresses: sreedhas@oregonstate.edu (S. Sreedhar), erdem.coleri@oregonstate.edu (E. Coleri), haddadis@oregonstate.edu (S.S. Haddadi).

https://doi.org/10.1016/j.conbuildmat.2018.05.258
0950-0618/

- Simplicity: Factors such as sample preparation, testing difficulty and required testing time;
- Sensitivity to mix design parameters: Ability of the tests to identify the impact of fundamental mixture properties, such as binder content, binder type, gradation, polymer modification and recycled materials, on measured performance;
- Correlations to field performance: Ability of the tests to identify field sections with high and low cracking performance;
- Test variability; and
- The cost involved in implementation.

In this study, the effectiveness of each laboratory experiment was first evaluated by comparing test results from PMFC (plant mixed and field compacted - cores from field sections) specimens to the measured in-situ cracking performance of roadway sections. Second, the agreement between the results of different experiments was determined. The major purpose was to determine the effectiveness of different testing methods in identifying the cracking performance of pavements with different mixture properties. Another purpose of this part of the study was to determine the cracking resistance of Mix 1 (PG70-22ER (ER:Elastomer)-Fine gradation), Mix 2 (PG70-22ER (ER:Elastomer)-Coarse gradation) and Mix 3 (PG70-22-Coarse gradation), which are asphalt mixtures that are now commonly used in Oregon for pavement construction. Finally, the impact of compaction [(field compaction and Superpave Gyratory Compactor (SGC)] and mixing (laboratory and plant mixing) on the results of the selected cracking test were determined.

The major objectives of this study are as follows:

- Determine the effectiveness of different testing methods in identifying the in-situ cracking performance of pavements with different mixture properties;
- Determine the cracking resistance of Mix 1 (PG70-22ER-Fine gradation), Mix 2 (PG70-22ER-Coarse gradation) and Mix 3 (PG70-22-Coarse gradation) asphalt mixtures that are now commonly used in Oregon for pavement construction;
- Determine the correlations between SCB, IDT, BBF and DTCF test results and measured field performance data;
- Select the most effective cracking experiment by considering testing time, cost, efficiency, complexity and practicality for use in district and contractor laboratories in Oregon; and
- Determine the effect of mixing (laboratory and plant mixing) and compaction method (field roller compaction and laboratory gyratory compaction) on the results of the selected cracking experiment.

2. Materials and methods

2.1. Materials

This section provides information about virgin binders, virgin aggregates and RAP aggregates used in this study. All the materials were obtained from local sources. In this study, three types of asphalt samples were used for testing and evaluation:

- Plant Mixed-Field Compacted (PMFC) samples: These are samples taken from various highway sections with close ages and used for laboratory specimen production. Parameters obtained from PMFC samples were expected to reflect actual field performance.
- Plant Mixed-Laboratory Compacted (PMLC) samples: Before construction, loose asphalt mixtures were collected from the local producer to prepare PMLC samples in the laboratory. Although PMFC samples are expected to provide more realistic test results reflecting actual in-situ performance, compaction variability and limited layer thickness for laboratory test specimen production required plant sampling of production mixtures and compaction in the laboratory for specimen production.
- Laboratory Mixed-Laboratory Compacted (LMLC) samples: The aggregates, virgin binders and RAP material used to produce asphalt mixtures for field construction were sampled from a local producer in Portland, Oregon. These materials were used to produce LMLC samples at the Asphalt Materials Performance Laboratory at Oregon State University. Although laboratory compaction and mixing methods are different from plant mixing and field compaction methods, the binder content, gradation, RAP content and air-void content can be accurately controlled to achieve target values for LMLC samples.

PMFC samples were collected from four different highway sections (Sections US20-U and OR99-U with no cracking and sections OR99W-C and OR99EB with severe cracking) to conduct different cracking experiments in order to determine the effectiveness of each experiment in identifying the cracking resistance.

For the PMLC samples, three different asphalt mixtures were used in this study. Mix 1 (M1) was comprised of 3/8″ nominal maximum aggregate size (NMAS) aggregates (fine gradation), 20% RAP and PG 70-22ER (polymer modified binder) grade virgin asphalt binder. The binder content of M1 was 6% by total weight. Mix 2 (M2) was comprised of 1/2″ NMAS aggregates (coarse gradation), 20% RAP and PG 70-22ER (polymer modified binder) grade virgin asphalt binder. The binder content of M2 was 5.3% by total mixture weight. Mix 3 (M3) was comprised of 1/2″ NMAS aggregates (coarse gradation), 20% RAP and PG 70–22 (no polymer modification) grade virgin asphalt binder. The binder content of M3 was 5.3% by total mixture weight.

2.2. Experimental program

2.2.1. Experimental design for plant mixed-field compacted specimens

In this part of the study, the effectiveness of each laboratory experiment was evaluated by comparing test results from PMFC-Old specimens to the measured in-situ cracking performance of roadway sections. For this purpose, test samples for laboratory testing were collected from two field sections with high cracking resistance (sections with no cracking) and two with low cracking resistance (sections with severe cracking). The general experimental design is given in Table 1. Field specimens were collected from the following sections: Sections US20-U and OR99-U with no cracking and sections OR99W-C and OR99EB with severe cracking. DTCF tests were not carried out with field specimens since it was not possible to obtain 6-inch-tall specimens from field sections due to limited layer thicknesses. All the field cores and samples were taken along the wheel path.

2.2.2. Experimental design for plant mixed - laboratory compacted specimens

In this part of the study, the agreement between the results of different experiments was determined. The major purpose was to determine the effectiveness of different testing methods in identifying the cracking performance of pavements with different mixture properties. Another purpose of this part of the study was to determine the cracking resistance of Mix 1 (PG70-22ER-Fine gradation), Mix 2 (PG70-22ER-Coarse gradation) and Mix 3 (PG70-22-Coarse gradation) asphalt mixtures that are now commonly used in Oregon for pavement construction. Table 2 shows the experimental plan followed in this study. In order to evaluate the effectiveness of each experiment, three mixes with different cracking performance (Mix 1, Mix 2 and Mix 3) were used. Loose asphalt mixtures were sampled from the plant and stored in air-tight