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Review

Fracture properties of asphalt mixtures using semi-circular bending test: A state-of-the-art review and future research

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HIGHLIGHTS

- Presented current state-of-the-art regarding SCB test pertinent to asphalt mixtures.
- Discussed fundamental fracture assessment based on load-deformation characteristics.
- Documented analytical procedures to deduce fracture parameters for asphalt mixes.
- SCB test is a promising crack propagation assessment candidate for asphalt material.

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ABSTRACT

Although many fracture test procedures are available, the semi-circular bending (SCB) test has drawn a growing interest in the pavement community due to its simplicity, reproducibility, and flexibility in testing and evaluation. In this direction, fracture properties of asphalt mixtures are currently being evaluated using SCB test with the application of fracture mechanics to characterize low-temperature and fatigue fracture using the standard semi-circular bending protocols. However, several research studies have employed various sets of specifications suiting practical convenience that calls for a critical review of the procedures that have been followed to date. This review article presents the current state-of-the-art regarding the utilization of SCB test to evaluate fracture properties of different asphalt mixtures. The fundamental assessment of fracture through the SCB test, which was based on load-deformation characteristics of asphalt mixes, was discussed in detail. The analytical procedures employed to deduce fracture parameters for asphalt mixes to understand the fracture performance was also documented. Overall, the SCB test procedure was found to be a promising crack propagation assessment candidate to evaluate asphalt mix fracture properties. It was recommended that future studies must concentrate on developing cyclic SCB test to investigate the dynamic fatigue behaviour along with viscoelastic properties. Certainly, there exists scope for advancing the current state-of-the-art pertaining to the SCB test procedure that actually simulates the field performance characteristics in conjunction with mechanistic based flexible pavement designs.

Contents

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1. Introduction

Fracture forms an integral part of fatigue and low-temperature cracking mechanisms in flexible asphalt pavements. A robust and rational pavement design necessitates incorporation of an important fundamental property such as fracture to ensure its successful implementation in predicting long-term pavement performance. In this context, lower fracture performance of an asphalt material will entail diminished service life of the pavements, and eventually results in a premature failure.

The current flexible pavement design practices [1–7] fundamentally assess fracture of asphalt mixtures based on the limiting strain (for fatigue) and stress (for low-temperature cracking) criteria within the linear elastic regime. It has been a practice to use fracture mechanics principles to derive and analyze fracture properties such as fracture toughness and fracture energy parameters in the cracking processes. However, these successful design methodologies emphasize crack initiation and total failure stages through basic stress–strain analyses. Essentially, the processes do not directly account for the time-dependent viscoelastic properties and the associated fracture behaviour by targeting crack propagation phase.

Fracture phenomenon has been historically investigated through laboratory experimentations, numerical simulations, and field evaluation studies. In the last few decades, laboratory investigations along with analytical and numerical simulations have taken a major share in asphalt mix fracture characterization research. Currently, fracture characteristics of asphalt mixtures are being evaluated in the laboratory using: Single Edge Notch Beam (SENB); Disc-shaped Compact Tension (DCT); and Semi-Circular Bending (SCB) tests. Owing to the several merits such as repeatability, reproducibility, consistency, and simplicity in terms of specimen preparation and testing, the SCB test has received a growing interest by the research community to characterize fracture properties of asphalt mixtures. Furthermore, the success in generating the requisite parameters for fracture assessment has ensued in the development of an SCB standard protocol for monotonic loading conditions [8,9].

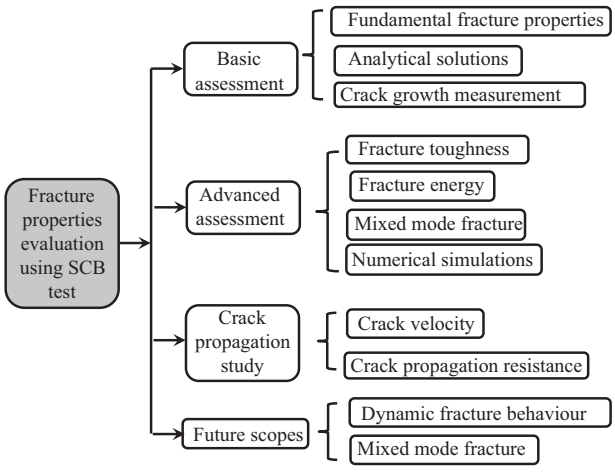

Fig. 1. Research review outline.

Due to its increasing popularity, monotonic SCB tests have been conducted extensively on different types of asphalt mixtures, and the obtained fracture properties have been analyzed using fracture mechanics principles to characterize fracture behaviour. Concurrently, studies have also used various other specifications as inputs for testing purposes and digressing from the standard protocols, which simply call for a critical review of the deviated procedures to assess if those findings can actually correlate with field performance. Thus, a consolidated discussion summary on the various test specifications used in conducting SCB test and its applications (findings) is needed. This collated review will help researchers and practitioners to comprehensively understand the tangibility of the test technique to assess fracture-cracking behaviour of asphalt mixtures. Moreover, it is also envisaged that this compilation will offer necessary inputs to further advance the state-of-the-art pertinent to fracture in asphalt mixtures so that new design practices can be developed incorporating SCB test parameters and associated mechanistic principles.

The main purpose of this research review paper was to assemble and present the current knowledge about the utilization of SCB test to evaluate fracture properties of asphalt mixtures, which is also aimed at taking forward this research area for implementation in flexible pavement designs. Although limited research is available regarding the SCB test and the associated findings on asphalt mixtures' fracture properties, it is envisaged that this methodology turns out to be a promising candidate test to assess fracture performance. Note that this review discussion focuses only on SCB test technique and other test procedures will not be discussed. Fig. 1 presents the review scope outline. The paper is divided into four major heads: (i) brief description of the SCB test background and standard protocol; (ii) fracture failure experimental and numerical investigation findings from the associated studies; (iii) advanced fracture resistance characterization using SCB test fracture parameters obtained during various investigations; and (iv) fracture crack propagation properties evaluation. A discussion summary regarding the current state-of-the-art is provided at the end of the review along with future prospects of the SCB test methodology that illustrate its worthiness of being a promising fracture properties assessor for asphalt mixtures.

2. Background to static SCB test

SCB test was first employed by material scientists as a means to determine fracture resistance of rock materials and reported in [10]. Later, it was adopted by pavement engineers to understand fracture characteristics of different asphalt mixtures, which led to the development of standard protocols for monotonic loading conditions. EN12697-44: 2010 [8] and AASHTO TP105-2013 [9]