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# Fatigue Analysis of Asphalt Concrete under Indirect Tensile Mode of Loading Using Crack Images

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**ABSTRACT:** In this study, various fatigue criteria for indirect tensile (IDT) fatigue tests were evaluated and a new approach to identify the fatigue failure was proposed based on a crack-length criterion. The IDT fatigue tests were conducted to characterize the fatigue behavior of various asphalt mixtures, such as three warm mix asphalt mixtures and a polymer-modified asphalt mixture. During the IDT tests, digital cameras were mounted to monitor crack growth on the both faces of a specimen. Existing three fatigue failure criteria were evaluated regarding to fatigue-crack development. Then, a crack-length limit was proposed as a fatigue criterion. The IDT strength tests were also conducted to determine fracture energy of the mixtures. Based on the new fatigue criterion, a fatigue performance model was constituted with dissipated and fracture energy parameters. The fatigue model proposed in this study successfully predicted the fatigue lives of the mixtures with a high level of accuracy. The main advantage of this fatigue model is that it does not need a transfer function to convert the fatigue life to crack length or area, because fatigue-crack length is directly determined from the crack-length limit.

**KEYWORDS:** fatigue criterion, indirect tensile, crack image, dissipated energy, fracture energy, warm mix asphalt

## Introduction

Fatigue cracking is a primary distress in asphalt pavements. Tensile and/or shear stress induced by traffic loading diffused through the asphalt concrete layer initiate fatigue cracks at the bottom or surface layer. Because of this, numerous fatigue performance models, empirical, and mechanics-based models, have been developed to characterize the fatigue behavior of asphalt mixtures.

Empirical fatigue models are based on a simple relationship between initial tensile stress or strain and the number of load repetitions to failure. Dissipated energy is also used instead of stress or strain. However, this approach did not consider progressive material damage or crack development; it was valid only for specific materials under the same loading and environmental conditions [1,2]. To overcome the limits of the empirical models, continuum damage mechanics and fracture mechanics with or without viscoelasticity have been employed [3–7]. Continuum damage mechanics describe the fatigue behavior of asphalt concrete up to crack initiation, whereas fracture mechanics is appropriate for describing the crack propagation of materials.

Fatigue models require fatigue criteria to identify the fatigue lives of materials. For example, 50 % stiffness reduction has been used as a fatigue failure criterion for asphalt mixtures. This stiffness criterion has been successfully used for the controlled-strain mode of testing and adopted in many specifications, such as ASTM D7460-08 [8] and AASHTO TP8-94 [9]. Fatigue failure is defined in the controlled-stress mode of testing when 10 % of original modulus is reduced [10]. However, these fatigue criteria do not present material damage, especially crack development, because the criteria was defined arbitrarily [11].

An indirect tension (IDT) fatigue test is relatively simple to perform but has not been widely used compared to bending-beam fatigue testing because the states of stress and strain in a specimen are complex and the fatigue criterion is undefined. With this, different fatigue failure criteria have been considered by many researchers for IDT fatigue testing. Kim et al. [12] proposed 2.5 mm of total horizontal deformation as a failure criterion. Airey et al. [13] suggested 9.0 mm of total vertical deformation as a failure indicator. Wakabita et al. [14] defined the fatigue failure when a crack propagates fully across the diametral specimen. Khalid [15] proposed another criterion based on changes in the dissipated energy or energy ratio. However, once multiple cracks are developed in an IDT specimen at early stage of fatigue loading, the specimen does not follow a continuum behavior any more. Thus, the fatigue criteria based on continuum mechanics do not identify fatigue crack development in secondary and tertiary stages

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