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Influence of temperature on the cracking behavior of asphalt base courses with structural weaknesses

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A B S T R A C T

Asphalt pavement is known to be deteriorated by the repetitive traffic loading, climatic condition, aging of asphalt mixture etc. after opening to traffic. Crack plays a critical role in pavement deterioration. Several studies have been conducted to obtain a better understanding with respect to climate related pavement fracture behavior. However, the limitation of the previous researches was that most of them were conducted by laboratory experiment or numerical simulation. The main objective of this study is to determine the relationship between the continuously changed temperature and the relative crack opening in asphalt base course by analyzing the data collected from an in-service asphalt pavement. To achieve this objective, four artificial transverse cracks were first induced on the asphalt subbase of a test track, and then their temperatures and crack opening were recorded by monitoring systems. Diurnal and annual trends of temperature and relative crack opening as well as their relationship were investigated and discussed. In this study, a test track with defined asphalt layers was constructed, which was specially equipped with sensors that continuously monitored the temperatures and opening widths of structural cracks in the test track. On the basis of the findings obtained, it is possible for the first time to make direct statements about the deformation conditions occurring in an asphalt base layer as a result of temperature.

1. Introduction

Asphalt pavement is known to be deteriorated by the repetitive traffic loading, climatic condition, aging of asphalt mixture etc. after opening to traffic (Leng et al., 2008, 2017; Ling et al., 2017a,b; Liu et al., 2017b; Wagnoner et al., 2005; Zhang et al., 2001). As a major form of pavement deterioration, cracking has been recognized as a serious distress in flexible pavements and often leads to a shorter service life, poor durability, and higher long term maintenance and rehabilitation costs (Kim et al., 2008; Ling et al., 2017b). Crack plays a critical role in pavement fracture property. Bottom-up cracking, for instance, initiates at the bottom of the surface layer or stabilized base in the location of the highest tensile stress followed by propagating upward through the asphalt layer under traffic and climate loading (Castell et al., 2000; Hu et al., 2016, 2017;

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Ling et al., 2017b; Liu et al., 2015, 2017c,a). Thus, obtaining a good understanding of asphalt pavement cracking issues is necessary for addressing pavement deterioration (Song et al., 2006).

Numerous studies have been conducted to obtain a better understanding with respect to pavement fracture behavior, within these studies numerical model and laboratory experiment were two main methods (Liu et al., 2016b,a). In 1971, Majidzadeh et al. applied fracture mechanics in pavement fatigue analysis for describing the fracture behavior of asphalt mixture (Majidzadeh et al., 1971). Linear elastic fracture mechanics were employed by Monismith et al. to describe crack growth in asphalt concrete (Kim et al., 2008; Monismith et al., 1985). Based on the above studies, Abdulshafi and Majidzadeh applied *J*-integral as an approach of pavement concrete fatigue investigation and prediction (Abdulshafi and Majidzadeh, 1985). Quasi-static three-point bending tests were conducted at various low temperatures by Kim and El Hussein to evaluate toughness and fracture behavior of asphalt mixtures at low temperatures (Kim and El Hussein, 1995). Similarly, Li and Marasteanu proposed a Semi-Circular Bend (SCB) test method for low temperature cracking mechanism determination (Li and Marasteanu, 2004). Jacobs et al. investigated the effects of asphalt mixture components and loading conditions on the crack growth and crack resistance characteristics of asphalt mixtures (Jacobs et al., 1996). Ann et al. identified the mechanisms of pavement crack propagation and investigated the effects of stress state within the asphalt concrete pavement on the direction of crack propagation by combining finite element method (FEM) and fracture mechanics. According to that study, it was found that the traffic load position has a significant effect on crack propagation (Ann Myers et al., 2001). Based on the SCB test results, Li and Marasteanu found that the aggregate source and air void content of asphalt mixture and binder grade can significantly affect the fracture resistance of asphalt mixture (Li and Marasteanu, 2010). Gajewski used FEM and Artificial Neural Networks (ANN) to analysis the sensitivity of crack propagation of asphalt pavement (Gajewski and Sadowski, 2014). Mai et al. verified the validity of the time-temperature superposition principle for crack propagation in asphalt mixture using four-point bending test (Nguyen et al., 2013).

A very limited amount of work has been conducted to evaluate the climate related crack opening, although the significance of climate with relation to crack opening of asphalt pavement has been confirmed for many years (Wagoner et al., 2005). Dave et al. conducted numerical simulations using the FEM to investigate the mechanisms of cracking in asphalt concrete overlays under thermal and mechanical loads (Dave et al., 2007; Dave and Buttlar, 2010). Ceylan used Neural Network (NN) methodology to simulate the stress intensity factor (SIF) as cracks propagate upward an asphalt layer (Ceylan et al., 2010).

However, as aforementioned, the limitation of the previous researches was that most of them were conducted by laboratory experiment or numerical simulation. Specifically, although the fracture behavior can be simulated using numerical methodologies, the correlation between the calculated results and the real situation of asphalt pavement still need to be further discussed. Similarly, it is questionable to evaluate the crack opening of asphalt pavement under the loading resulting from traffic and continuous temperature changing using laboratory experiments. Therefore, the evaluation of the effects of continuous temperature changing on the crack opening based on in-service pavements is critically important.

The main objective of this study is to determine the relationship between the continuously changed temperature and the relative crack opening in asphalt base course by analyzing the data collected from an in-service asphalt pavement. To achieve this objective, four artificial transverse cracks were first induced on the asphalt subbase of a test track, and then their temperatures and crack opening were recorded by monitoring systems. Diurnal and annual trends of temperature and relative crack opening as well as their relationship were investigated and discussed.

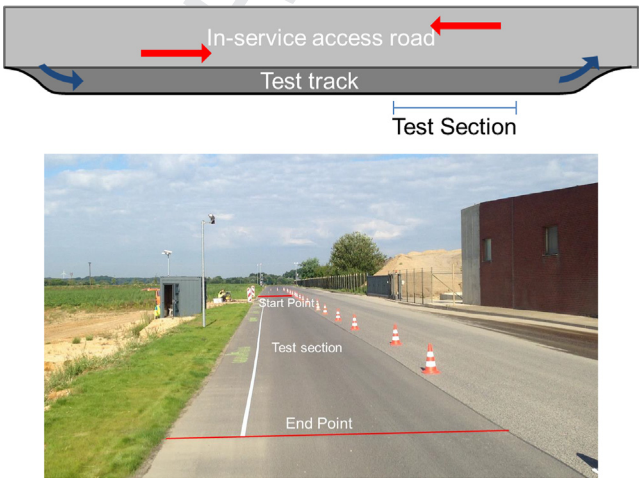

Fig. 1. Schematic of the test track.

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