THEORETICAL ANALYSIS OF OVERLAID CEMENT CONCRETE PAVEMENT WITH CRACK

Y. GAO

Abstract—In this paper, overlaid Portland cement concrete (PCC) with crack subjected to vehicle load is considered based on theoretical analysis. In order to build efficient model, PCC is reduced to an elastic plate on Winkler foundation. Fourier integral transform, residue theorem and Lobatto-Chebyshev integration formula are used to obtain the analytical solutions on the stress and strain fields of the pavement and stress intensity factors of the crack tip. Stress intensity factors are numerically calculated. The stress intensity factors of the crack tips in the pavement with 10cm thickness overlay are reduced heavily, especially for I type crack. Overlay thickness is very significant factor that effect the value of stress intensity factor of I type crack, rather than II type crack. However, stress intensity factors are less affected by elastic modulus of overlay material.

Keywords—Cement concrete pavement; Crack; Pavement overlay; Fracture mechanics; Stress intensity factor.

I. INTRODUCTION

Portland cement concrete (PCC) is a common structure of pavement. Because of traveling load, seasonal temperature variations, shrinkage or chemical attack of cement concrete and so on, the damages in the form of cracks could be induced in the cement concrete pavement. It badly influences the safety and comfort of driving. The most common rehabilitation technique for deteriorated concrete pavement is the placement of an asphalt overlay on top of it. However, the reflection cracks always occur and reduce the service life of asphalt overlay. Therefore, the causes of the problems have to be well settled at the design stage. Some experts have implemented several methods to mitigate the development of reflection cracks. Most research began at 1990’s and focused on finite element method (Liu and Wang, 2011; Baek, 2010) and experimental study (Kim and Nelson, 2004; Doh et al., 2009; Li et al., 2014). Ghouch and Abou-Jaoude (2013) researched reflective cracks which appeared in asphalt overlays placed on top of a concrete pavement. Their papers research the effects of sub-grade and sub-base strengths, vehicle speed, overlay thickness, and pavement temperature to identify the parameters that deteriorate the overlay. Wu et al. (2014) developed a pavement crack propagation analysis tool, neural networks based on semi-analytical finite element analysis, to calculate the stress intensity factors (SIFs) at the crack tip for pavement crack propagation analysis. Qian et al. (2013) introduced Engineered Cementitious Composite which can extend the service life of pavement overlay with less thickness compared with concrete overlay proved by experimental testing on fatigue performance of ECC. Increasing the overlay thickness, rubblizing the concrete pavement, and placing stress relieving interlayer systems or geosynthetics (Khodaii et al., 2009; Kim and Buttlar, 2002) were adopt to alleviate the reflection crack.

Up to now, the problem of reflection cracks occurring shortly after pavement rehabilitation is still an issue for pavement designers and road managers. Thereby, theoretical analysis of overlaid cement concrete pavement with crack for understanding the mechanism of cracks propagation is still needed. Compared with the finite element method, the computational accuracy of the theoretical method is better. It can provide advices for pavement design and helpful for developing finite element software. In this paper, theoretical analysis of cement concrete pavement with an asphalt overlay based on fracture mechanics is conducted. In order to identify the parameters involved in the role of the overlay, the effects of load position, crack length, overlay thickness, and elastic modulus of overlay are investigated.

II. DESCRIPTION OF THE PROBLEM

Overlaid PCC with crack subjected vehicle load is considered as a plate on an elastic foundation shown in Fig. 1.

In Fig. 1, \( h \) is thickness of old cement concrete pavement, \( h_1 \) is thickness of overlay, \( x \) is depth direction of pavement, \( y \) is longitudinal direction of pavement, \( \gamma \) is foundation modulus, \( P(y) \) is vehicle load, \( L \) is range of load and \( l \) is horizontal distance between edge of vehicle load and crack. The crack emerges on the surface of the old concrete pavement as \( a=h_1 \). In this study, only the plane strain is concerned, thus the effect of volume force is ignored.

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\text{Fig.1. Model of cement concrete pavement with overlay containing crack}
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