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Dynamic response of concrete pavement structure with asphalt isolating layer under moving loads

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Abstract: A three-dimensional finite element model (3D FEM) is built using ABAQUS to analyze the dynamic response of a concrete pavement structure with an asphalt isolating layer under moving loads. The 3D model is prepared and validated in the state of no asphalt isolating layer. Stress and deflection at the critical load position are calculated by changing thickness, modulus of isolating layer and the combination between the isolating layer and concrete slab. Analysis result shows that the stress and deflection of the concrete slab increase with the increase of thickness. The stress and deflection of the concrete slab decrease with the increase of combination between the isolating layer and concrete slab. The influence of changing the isolating layer modulus to the stress and deflection of the concrete slab is not significant. From the results, asphalt isolating layer design is suggested in concrete pavement.

Key words: concrete pavement; asphalt isolating layer; moving loads; three-dimensional finite element

1 Introduction

Asphalt isolating layer is paved on the top base of concrete pavements, which can effectively avoid the pumping, fill void under the concrete slab, and ultimately avoid disruption due to concrete slab damage (Yao 2003; Deng 2005; Liao et al. 2010). Currently asphalt isolating layer is gaining more attention, but it is more challenging to properly pave it in concrete pavement. Chen et al. researched the mechanical properties of concrete pavement with different isolation layers on lean concrete base, and the wax was recommended as the isolation layer between concrete pavement slab and lean concrete base (Dziewański et al. 1980; Chen et al. 2009; Yao et al. 2012). Tarr et al. analyzed interlayer bonding conditions between different bond breaker media and concrete slabs and found bond breaker media had significant impacts

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on pavement stresses (Tarr et al. 1999; Fu 2004). There is lack of stress analysis under moving loads. In the existing design methods of concrete pavement, equivalently simplified vehicle load is commonly known as a static uniform load. Static uniform load is most commonly used on pavement structure for the mechanical analysis and calculation and that is basically reasonable on the condition of low speed and small load. In fact, moving vehicles on the road produce a complex vertical force and horizontal force to the pavement. Actually, there is a great difference between static loads mode and moving loads mode on pavement slab. Under the fast-moving vehicle loads, the response of concrete pavement structure cannot be described by the static mechanical characteristics (Hou et al. 2003; Kim and McCullough 2003; Yang 2005; Wang and Yang 2008; Liang 2011). For the concrete pavement with an asphalt isolating layer under the concrete slab, it is necessary to calculate and analyze the response of pavement structure under moving loads, and the results are benefitial to design the asphalt isolating layer in concrete pavement.

2 Establishment of 3D model

In this paper, the moving vehicle loads are considered as surface loads which have a certain speed. ABAQUS 3D finite-element analysis software is used to establish concrete pavement structure model with the asphalt isolating layer (Wang and Chen 2006; Liao and Huang 2008; Cao and Shi 2009; Zhuang et al. 2009; Wang and Fu 2010). The size of cement concrete slab is 4.50 m ×3.75 m, and the slab thickness is 22 cm. The thickness of asphalt isolating layer ranges from 0 to 3 cm. Subgrade depth is gradually expanding to 2.0 m, while the stress in the slab is convergence, and this size is used in the subsequent calculation, the whole pavement structure is shown in Fig. 1.

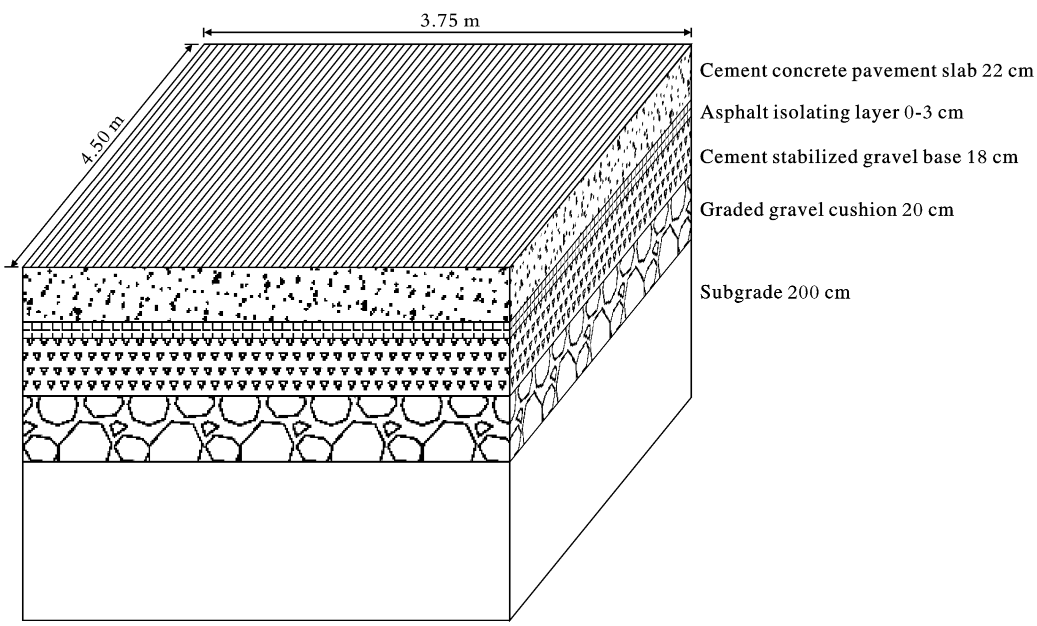

Fig. 1 Concrete pavement structure

2.1 Calculation parameters

Material parameters of each structure layer are determined by reference to the Specifications of Cement Concrete Pavement Design for Highway (JTG D40-2002), α and β are damping constants and the damping matrix C is calculated by using these constants to multiply the mass matrix M and stiffness matrix K.

$$C = \alpha M + \beta K \tag{1}$$

In this paper, the value of α and β are taken according to the research work of Liao and Huang (2008) and Liu (2010). As β is zero (Liu 2010), it is not listed in the table. Other parameters are shown in Tab. 1.