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Assessing pavement interfacial bonding condition

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HIGHLIGHTS

- The modulus and interfacial bonding condition is an order on the deflection, and the strength and bonding condition take same effect on the structure deformation.
- With the interfacial friction coefficient decreasing, the deflection all increase, and the difference of interfacial radial stress gets larger.
- The interfacial friction coefficient has good relationship with the deflection basin index, and SCI/BCI and F_1/F_2 can be used to reflect the interfacial bonding condition.

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ABSTRACT

When analyzing the pavement structure, the interface condition is always supposed to be completely continuous, but it doesn't correspond to the reality. To deal with this situation and provide suggestions on pavement construction, the asphalt pavement will be studied further. Taking a practical project as an example, the mechanical response of the structure layer of asphalt pavement has been analyzed by finite element software ABAQUS with different interlayer friction coefficients. It shows that the interlayer friction coefficient has great influence on the surface deflection, the tensile stress at the bottom layer and the stress differences among radial stresses of the interface bonding position. Moreover, the deflection basin index has a good relationship with the interlayer friction coefficient. The relation between deflection basin index and interlayer friction coefficients is established, and a method of assessing the pavement interfacial bonding condition is suggested.

1. Foreword

As analyzing the pavement structure, the interfacial state of pavement structure is usually supposed to be completely continuous, i.e. "full friction" or "full bonding" between layers. However, the material characteristics and the construction qualities are difference, it will result in that the interfacial bonding condition, which is the contact state of the pavement structure layers, may vary from completely continuous to slip. In addition, for built roads, it is inevitable that its layer contact condition will change under the traffic load, temperature, moisture and other external environmental factors. It does not correspond to the assumed full bonding situation, and the result of theoretical analysis is not accurate [11]. In order to improve construction qualities, predict early defect and reduce maintenance and rehabilitation cost, the cohesive effect of interface in road construction should be ensured, and the rational evaluation should be performed in road service process [7].

Many methods such as shear box test [12], shear strength [10], modified Leutner test, torque test, impulse hammer test, have been used to test and evaluate the bonding condition between layers. Based on the testing data and theoretical analysis, some factors were put forward to represent its interfacial bonding status of pavement [2]. Salman et al. [8] presented a new fracture-energy based on Interface Bond Test (IBT), which could be used to evaluate the bonding between pavement layers as a practical method. The results of laboratory and field are demonstrated to distinguish the ability between samples produced with different tack coat application rates and modified versus unmodified tack coat materials. Results from the IBT test were also compared with direct tension, and it was found that the trend was similar [8].

The Falling Weight Deflectometer (FWD) is widely used for the pavement defect detection and residual life assessment. A new back-analysis method was suggested to assess the bonding condition between bituminous layers with the structure stiffness from FWD test results [1]. Mehta's studies showed that, surface

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layer modulus calculated from FWD data could be used to identify the lack of interlayer bonding in pavement, and the effect of slip between two asphalt layers of similar properties would be reflected by the modulus of the top layer lower than that of the bottom layer [13]. In addition, based on the elongated reflections in ground-penetrating radar Lech and Jacek [4], put forward the assessment of the interlayer bonding condition of the bituminous pavement by an impulse high-frequency Ground Penetrating Radar (GPR) [4]. Three-dimensional finite element simulations of the deflection under a standard axle load were carried out, and the pavement layers were considered to be linear elastic and the interface condition complied with three different hypotheses: perfectly bonded, perfectly smooth and frictional, and the numerical result showed that the first derivative of the deflection curve and the curvature radius beneath the wheel load provided suitable indications of the flaw presence and extension [9].

The FWD had become the key technology and equipment in pavement structure evaluation and rehabilitation, and was used to simulate the loading and record the deflections by pavement managements and testing organization all over the world [7]. In fact, the presence of some defects, such as rutting, stripping, cracking or debonding in the layers of flexible pavements, will contribute to the changes in deflection data. The deflection basin index deriving from combination of the different place's deflections had a good correlation with tensile stress at the bottom of surface layer and compressive stress at the top of the base, so it could be used to reflect pavement layer condition [3], and this avoids singularity and misconvergence of back-calculated modulus.

The pavement interfacial bonding condition evaluation by FWD is studied in this paper. The mechanical response of the structure layers under different interlayer friction coefficients is analyzed with software ABAQUS, and the stress and deformation are simulated. Moreover, the deflection basin and deflection basin index under different interlayer friction coefficient are calculated. Therefore, the relation between deflection basin index and the interlayer friction coefficient is established. According to the measured deflection, the deflection basin index is calculated, and based on the relation between the deflection basin index and the interlayer friction coefficient, the interlayer friction coefficient is obtained. Furthermore, samples are cored at selected positions in the tested road, and then shear test by triaxial shearing rheometer is adopted to examine the results, and the assessing method of pavement interfacial bonding condition is developed.

Table 1
Calculated results of different model.

Dimensions	The maximum deformation (μm)	The maximum compressive stress (kPa)	The maximum tensile stress (kPa)
5.5.3	278.4	692.3	69.6
5.5.5	294.5	685.0	67.5
8.8.8	298.6	682.5	64.2
10.10.10	300.3	679.9	62.1
12.12.12	300.4	679.4	62.1

2. Finite element analysis of pavement model

ABAQUS is common software for calculation and analysis, and its application in road engineering is an important field [5]. This software provides a powerful tool for deeply understanding of road defect problems, and it is taken as a platform of mechanical analysis in this paper.

3. Modeling

Based on the actual pavement structure, a 10 layers road structure model is established. In order to reduce the size effect, five models, whose length, width and height are separately 5.5.3, 5.5.5, 8.8.8, 10.10.10 and 12.12.12, are selected to check the structural response under the standard axle load. The results are shown in Table 1, in which the maximum deformation and the maximum compressive stress are acting at loading direction, and the maximum tensile stress is vertical to loading action direction. According to the calculated data in Table 1, when the model size is greater than 10.10.10, the result is almost the same, so considering the calculation cost, the 10.10.10 is adopted as the computed model.

The cube model is chosen in this paper, and the thickness of pavement structure is 1.36 m, and so is 8.64 m for the subgrade, which is shown in Fig. 1. In the model, X is width direction, and Y is driving direction, and Z is depth direction. Assumed that the subgrade bottom is completely fixed, the whole model boundary has no displacement at Y direction, and also has no displacement at X direction. The subdivision technique of linear hexahedron element C3D8R is used to grid the model, and the mesh generation is shown in Fig. 1.

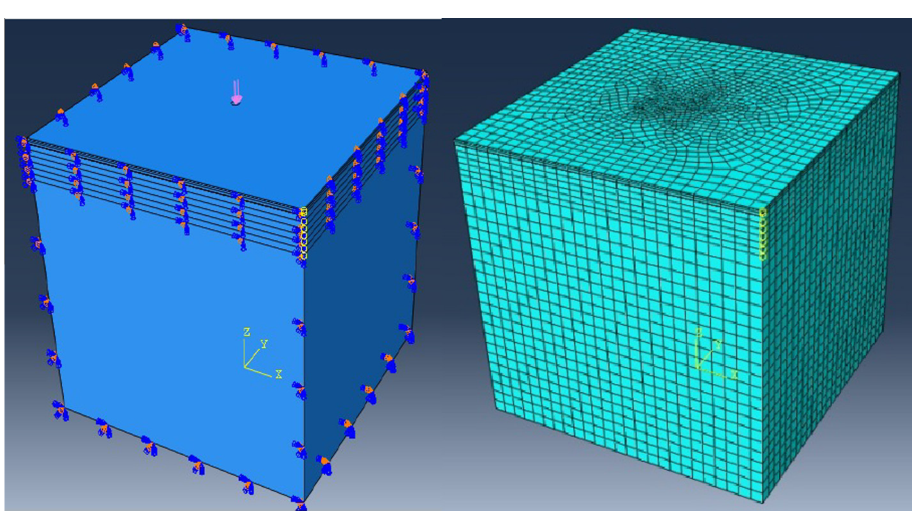

Fig. 1. Model and mesh.