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Shear fatigue between asphalt pavement layers and its application in design

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HIGHLIGHTS

- Shear fatigue performance at the interface of asphalt pavement layers was investigated in this study by conducting indoor shear fatigue tests, and the shear fatigue failure mechanism of the tack coat materials and the factors affecting the shear fatigue life were analyzed. The results clearly show that the shear fatigue life of tack coat material is affected by stress level and temperature.
- The relationship between $\frac{N_{fT}}{N_{fT_0}}$ and $\frac{T}{T_0}$ was found to be a good power function, and the value of "m" of SBS-modification-emulsified asphalt was calculated by nonlinear fitting. Then, the temperature-modifying methods for the shear fatigue life prediction model as well as the calculation methods for the shear fatigue equivalent temperature of asphalt pavement of interlayer materials were proposed.
- The axle-load conversion method was established based on the equivalence principle of shear fatigue. The conversion coefficients (b/c) of the ESAL of the three types of tack coat materials were calculated to be 2.43, 2.13, and 2.24. The correction coefficient (K = 95) of the materials' actual shear fatigue life at the interface of asphalt pavement layers was also determined.
- The application results indicate that when the tensile fatigue stress and permanent deformation of asphalt pavement are used as the design standards, its contact status at the interface of asphalt pavement layers cannot satisfy the requirements of pavement shear fatigue. Therefore, in the design of asphalt pavement, it is recommended to add the shear fatigue stress at the interface of asphalt pavement layers as the design index.
- According to the asphalt pavement mechanics analysis and study of the shear fatigue characteristics of tack coat materials, an interlayer design method for asphalt pavement was proposed based on the shear fatigue failure at the interface of asphalt pavement layers, and this provides a scientific foundation for the design of asphalt pavements.

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ABSTRACT

The performance and usable life of an asphalt pavement mainly depend on the interlayer bonding state. To design an asphalt pavement, tensile fatigue stress of the asphalt layer and permanent deformation of the asphalt surface are commonly used as the design criteria in many countries. However, the shear fatigue damage at the interface of asphalt pavement layers is usually neglected; therefore, the study of shear fatigue in the interface of asphalt pavement layers and its application in design has some theoretical and practical importance. Based on the indoor shear fatigue test carried out using tack coat materials, in this study, the shear fatigue formula and prediction models of indoor shear fatigue life were established and modified as per the engineering experience and actual working conditions of tack coat materials in the asphalt pavement structure. Based on the material's shear fatigue failure at the interface of asphalt pavement layers, an interlayer design method for asphalt pavement was proposed. Using the traditional design method for asphalt pavement in China, the shear fatigue formula and prediction models were applied in the design example, and the results show that it is a rational approach. The results of this study provide a quantitative reference for the design of an asphalt pavement.

1. Introduction

Interlayer binding conditions of an asphalt pavement significantly affects the performance and durability of the entire

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structure. The study of Chun and Kim on interlayer binding conditions indicates that good interlayer binding conditions improve the usability of the road [1]. Diverse studies in this field also reveal that the early damage of a pavement is partially caused by poor interlayer binding conditions. Therefore, a reasonable design method asphalt pavement layers at the interface will play a vital role in the performance and durability of the road [2]. During the road service, the materials for the interlayer treatment of an asphalt pavement are applied under repeating shear stress conditions caused by traffic loads, which may result in the shear fatigue damage of interlayer materials [3].

According to the mechanics of materials, the fatigue damage of materials is caused by the accumulation of minor injuries [4]. To be specific, the minor damage to the interlayer material occurs as long as it is under the traffic loads. Once the cumulative effect of traffic load reaches a certain threshold, the interlayer shear stress caused by traffic loads exceeds the interlayer shear strength of materials [5], resulting in shear fatigue damage at the interface of asphalt pavement layers.

In practical engineering applications, because the interlayer is covered by a structural layer, it is difficult to observe the shear fatigue of the interlayer materials of asphalt pavement in the initial stage, which may lead to the neglect of the shear fatigue damage at the interface of asphalt pavement layers. Therefore, more attention should be paid to the study of shear fatigue properties of tack coat materials. However, the current asphalt pavement design usually considers only the tensile fatigue stress of asphalt layer and permanent deformation of asphalt surface as the design standards, and only a few studies investigated the shear fatigue damage at the interface of asphalt pavement layers. Theoretically, this may be responsible for some underlying problems of asphalt pavements [6].

In this study, four types of binding state at the interface of asphalt pavement layers were designed as follows: (i) without tack coat, (ii) with tack coat using SBS modification of an emulsified asphalt, (iii) with tack coat using SBS modified asphalt, and (iv) with tack coat using a high-viscous asphalt.

Indoor shear fatigue tests were carried out using the tack coat materials. To evaluate the shear fatigue properties and application of different interlayer materials, the following aspects were studied: (i) shear fatigue formula and prediction model of different interlayer materials under the standard temperature (25 °C), (ii) temperature-modifying method of prediction model, establishment of axle-load conversion method based on the equivalence principle of shear fatigue, (iii) calculation method for the cumulative number of equivalent single axle loads (ESALs) used as a design index for the shear fatigue damage of interlayer materials in asphalt pavement, (iv) correction coefficient of the materials' actual shear fatigue life at the interface of asphalt pavement layers, and (v) an interlayer design method for asphalt pavement based on the shear fatigue failure at the interface of asphalt pavement layers. The objective of this work was to first establish a shear fatigue formula and design index of different interlayer materials and then apply them in asphalt pavement design. The effects of binding conditions on the pavement performance and durability were also investigated. The experimental results show that the method can make the existing method for asphalt pavement design more practical and reasonable. Moreover, it can provide a theoretical and practical reference for the related design task in the future.

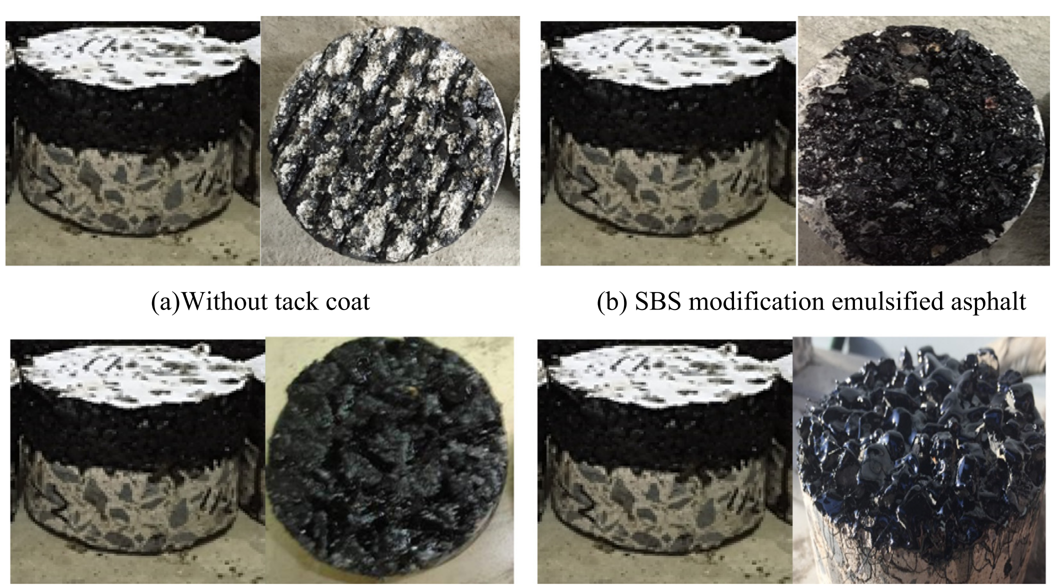
Table 1
Types and amount of tack coat material.

Types of tack coat material	Amount (kg/m^2)
Without tack coat	–
SBS modification emulsified asphalt	0.5
SBS modified asphalt	0.5
High-viscosity asphalt	0.4

2. Lab tests of shear fatigue between asphalt pavement layers

2.1. Test plans

The maximum shear stress occurs in the area between the surface and middle layers of asphalt pavement [7]. Therefore, when conducting the indoor shear fatigue test, the shear fatigue properties of the tack coat materials at this position will be mainly investigated. Because it has been proven that emulsified and original



(a)Without tack coat (b) SBS modification emulsified asphalt

(c)SBS modified asphalt (d) High-viscosity asphalt

Fig. 1. Asphalt pavement structure specimens of different tack coat materials.