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Aggregate fatigue failure on macro texture polishing of asphalt pavement

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Abstract

The macro-texture of asphalt pavement greatly affects the traffic safety of driving. In this study, the 3D laser scanning data, which is captured from the pavements, is used for reverse modeling. FE software ANSYS is used to analyze the contact stress distribution of pavement macro-texture and tire. The results show that the macro texture will be affected by fatigue failure considering the size effect of coarse aggregate. The fatigue life distribution of pavements is analyzed using the fatigue analysis software FE-SAFE which is based on linear cumulative damage theory. The developing tendency of texture depth with respect to the number of loading times is obtained by analyzing the results of fatigue life. Compared with the results of accelerated loading test shows that the factor of fatigue failure has remarkably affected the macro texture under low loading times. This effect is gradually decreased with the increasing of cyclic loading times.

Keywords: Fatigue failure; Reverse modeling; FE simulation; Pavement macro-texture; Fatigue life analysis

1. Introduction

Nowadays, the asphalt pavement is the primary pavement type in road engineering, because of its great skid resistance performance which is a prerequisite for ensuring the safety and comfort of traffic. The skid resistance performance of asphalt pavement is closely related to the surface texture which is mainly determined by the shape, size, and distribution of asphalt aggregate. It can be divided into macro texture and micro texture according to different scales [1–6]. Analysis based on the energy loss of rubber tires shows that the higher the height of pavement macro texture, the greater the hysteresis energy loss of the tire with elastic deformation, resulting in a better pavement skid resistance performance [7]. Cairney [8] suggested that traffic accident rate will be raised, when the pavement macro texture was degraded to a lower level. Laganier [9] concluded that pavement roughness and surface macro texture would significantly affect the vehicle fuel consumption. Therefore, research on the resistance mechanism of the macro texture of asphalt pavement is of great importance.

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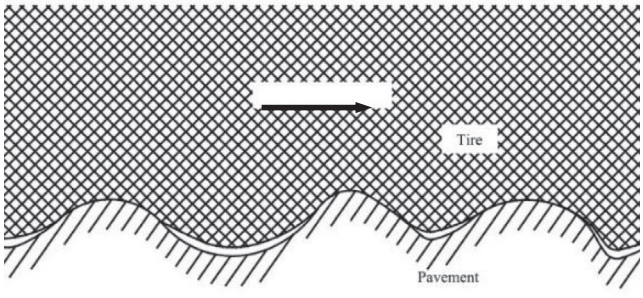
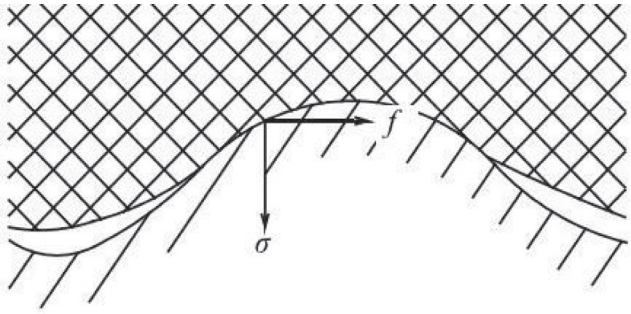
2. Fatigue failure mechanism of pavement macro texture

A large number of studies show that the damage of pavement macro texture is mainly influenced by the property of asphalt aggregate and traffic condition [10–13]. In actual use of the pavement, the contact surface of tire and pavement is an approximately elliptical rectangle, due to the vehicle load and the influence of the inner pressure of the tire [14,15]. The tire and the macro texture of pavement are in contact closely with this contact surface, which makes the tire to an elastic deformation of flexure in the vertical direction to wrap the rough edges of macro texture, as shown in Fig. 1(a). Meanwhile, micro slip phenomenon could occur between tire and pavement. Even if the contact condition is pretty good, the slip rate of the tire will still reach 5–10% [16]. Therefore, the macro texture of pavement will bear the vehicle load in the vertical direction and the friction force in the longitudinal direction, which is generated by the micro slip of the tire, as shown in Fig. 1 (b). With the repeated actions of the vehicle, the macro texture of pavement is under the cyclic stress constantly, resulting in a periodic disturbance of coarse aggregates exposed on the pavement surface.

The coarse aggregate used in asphalt pavement is mainly composed of rock material. As a kind of quasi-brittle material, the process of rock failure caused by cyclic loading is quite complicated [17–19]. There are a large number of micro cracks, pores, and other micro structures in natural rock when the rock is affected by external loading, these micro structures will increase and expand, and the cracks will also be connected with each other. After unloading, these micro structures will be closed till the cyclic loading is loaded again, the micro structures will expand continuously along the fractures, and the fractures gradually develop until rock failure [20]. Therefore, if the internal fatigue damage of exposed coarse aggregate of asphalt pavement is generated by the stress, then with the increase of cyclic times, the damage is continuously accumulated till failure.



(a)



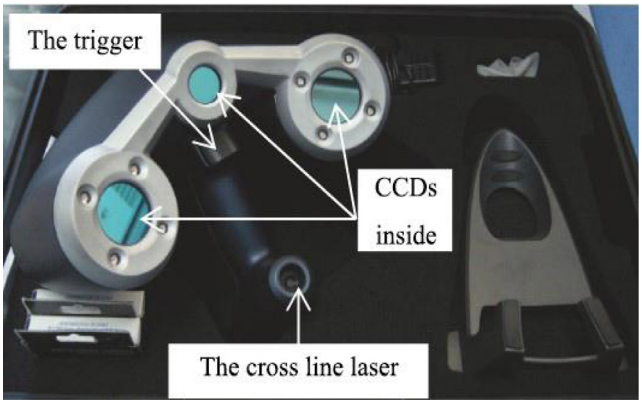
(b)

Fig. 1. The micro scale contact between tire and pavement.

3. Numerical simulation analysis

3.1. Establishment of the pavement macro texture model

In order to analyze the stress distribution of pavement macro texture accurately, reverse models based on real pavement is used for finite element analysis. This study uses hand-held high-resolution 3D laser scanner produced by Creaform Inc. to capture the spatial coordinates of macro texture from the real pavement, as shown in Fig. 2. The



(a) Hand-held 3D laser scanner

(b) Field acquisition of pavement macro texture

Fig. 2. Acquisition of the spatial coordinates of pavement macro texture.

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