The Deterioration Laws of Flexible Base Asphalt Pavement Performance under 1/3 Scale Accelerated Loading Test

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Abstract. To study the fatigue characteristics and the deterioration laws of asphalt layer under the repeated action of wheel loading, by using 1/3 proportional scale accelerated loading equipment to test the structure of graded crushed stone base asphalt pavement that was paved, tracking, monitoring and collecting the bottom strain of asphalt layer with different wheel loading times. The results show that the bottom strain of asphalt layer undergoes a change course of first compression, then tension and finally stabilization in the process of driving wheel load rolling. Under the repeated rolling action of wheel load, the change of bottom strain of asphalt layer is basically the same as that of temperature. When the asphalt layer is damaged, the bottom tensile strain curve deviates from the temperature curve with the wheel load times. The change of asphalt bottom strain and pavement temperature slope are taken as the basis to judge whether the asphalt bottom cracks or not, which is a beneficial supplement to the long-term performance observation of asphalt pavement.

Keywords. Road engineering, fatigue property, deterioration laws, 1/3 proportional scale accelerated loading test.

1. Introduction

Under the coupling effect of factors such as large flow rate, large axle load, high tire pressure, high speed and environment, the internal mechanical response characteristics and fatigue decay law of asphalt pavement structure are still urgent problems to be solved by road researchers [1-5]. Shaoxing Chen built a full size grading macadam base asphalt concrete pavement test road, which knew the change of the fatigue damage of asphalt concrete layer through the ALF accelerated loading test, but did not observe and analyze the pavement structure mechanics response changing with the load times, did not put forward the judgment of fatigue cracking of asphalt concrete layer [6]. Hupeng [7] studied the flexible base pavement fatigue forecast model by introducing the concept of equivalent loading times, transformed the loading times under different strain conditions, analyzed the relationship between and among strain-loading times-temperature, established the equations of two kinds of pavement structure fatigue equation that lack of a real engineering case validation. Yali Ye [8] carried out accelerated loading fatigue test, bending and sinking test through the gradation gravel base full scale APT test road construction, and put forward the technical means of fatigue test about asphalt pavement, however, did not study the mechanical properties of pavement structure further during the whole life span.

None of the literature above had clearly come up with the judgment basis for judging the fatigue cracking of flexible asphalt pavement surface layer, and had not studied and verified the fatigue damage change of asphalt pavement structure performance further in the whole life cycle. For all, this...
article uses the completely independent intellectual property rights of 1/3 proportional scale to accelerate the load testing machine, through the thin asphalt layer of grading macadam flexible base pavement structure to simulate overloading transportation damage and to analyze the bottom strain of asphalt layer and the pavement temperature change at the middle depth of asphalt layer under different times of wheel loading. It provides an effective foundation for the performance observation of asphalt pavement with long life in the future.

2. Accelerated Loading Test Scheme

2.1. Pavement Structure and Sensor Layout

APT test road can be divided into four pavement structures according to the thickness of asphalt layer and the type of sub-grade soil. Considering that the tensile strain of the thick asphalt layers is small, it makes it difficult for the pavement to produce fatigue cracking. Therefore, the American CTL strain sensor is selected to be embedded in the asphalt structure layer 3 at the position of 7 m, as is shown in figure 1.

![Figure 1. Pavement structure and sensor layout.](image1)

2.2. 1/3 Proportional Scale Accelerated Loading Test

The 1/3 plotting scale road surface accelerated loading test loads the road surface by means of a one-way revolving cycle of three tires. The accelerated loading device is shown in figure 2. The wheel load of this test is 6 kN, the tire pressure is 0.8 MPa, the tire outer diameter is 380 mm, the rolling speed is 13.3 km/h and the rolling length is 800 mm. The test path is subjected to 3,600 single wheel loads per hour and the test temperature is 15℃.

![Figure 2. Schematic diagram of 1/3 plotting scale road accelerated loading equipment.](image2)
2.3. Data Collection

The strain data is collected half an hour after the first operation of the 1/3 scale accelerated loading device. The load is 14~16 hours per day and the daily load is about 40 ~ 60 thousand times. In order to ensure the accuracy and stability of the data during the loading process, the data were collected twice a day for 3 minutes each time. The acquisition frequency of each channel is 2000 Hz, that is, 0.0005 s at a time. The strain value data under real wheel load is obtained by noise filtering with DATAQ Dynamic Response processing software.

3. The Bottom Strain of Asphalt under the Action of Driving Wheel

The data collected for 3 minutes at a time were first processed, and then the strain response after rolling once was intercepted in a representative area. The data collected and treated at the asphalt layer bottom are shown in figure 3.

![Figure 3. Bottom strain of asphalt layer.](image)

It can be seen from figure 3 that the bottom of the asphalt surface layer under the action of driving wheel is both under tension and compression, presenting an alternating tension and compression state. When the tire is not rolled on the ground, the asphalt is under pressure. When the tire is rolled on the ground, the asphalt layers show obvious tensile state. The tensile strain is larger than the compression strain before the wheel arrives, and the maximum pulling strain is about 3.45 times of the maximum compression stress. When the tire is gradually off the ground and under pressure, the strain decreases slowly and finally tends to be stable, which is similar to the compression deformation before wheel load. In the process of pavement loading, the basal strain of asphalt layer at the center of wheel bottom is measured by the G5 strain sensor embedded in pavement paving. Because of the silty sub-grade of structure layer 3 and the thinner asphalt layer thickness, the bottom strain of asphalt layer is larger than other structures [9]. The actual measured range of asphalt bottom strain is 296.8 με~1025.8 με. According to figure 4, in the whole process of loading, asphalt layers are subjected to considerable tensile strain. Before loading for 724,800 times, the curve of strain with loading times is consistent with the law of temperature change, that is, there is no loose or crack damage at the bottom of asphalt layers, and the strain gauge and asphalt mixture are in coordination to deform. After loading for 724,800 times, the bottom strain of asphalt layer increases suddenly, and the change curve of strain and temperature varies with the number of axial loads, indicating that the asphalt strain gauge and asphalt mixture cannot work together. Therefore, it can be deduced that the asphalt layer of this structure is damaged, and cracks may occur from the bottom of asphalt layer. The longitudinal crack of the road surface initially appeared at 506,071 times. When it was loaded to 679,300 times, three short longitudinal cracks at the wheel bottom were connected and connected to two cracks in the adjacent road structure, forming a longitudinal crack about 3.8 m long and 2 mm crack width. When it was loaded 905,246 times, the pavement cracks developed into blocks. Through coring the structure, it
was found that the asphalt layer had fatigue cracking and the cracks were connected from bottom to top [10].

![Figure 4. The bottom tensile strain of asphalt layer with different loading times.](image)

**4. Conclusion**

Using 1/3 proportional scale accelerated loading equipment, more than 900,000 times of loading tests were carried out on graded gravel base asphalt pavement, and the main conclusions are as follows:

1. The fatigue performance evaluation method of asphalt layer based on accelerated loading test is proposed by embedding strain sensors in asphalt layer bottom and establishing pavement temperature field.

2. Under the action of heavy axial load, the asphalt layer undergoes great tensile strain. The asphalt strain sensor was used to measure the asphalt layer bottom strain of graded gravel flexible asphalt pavement, and the maximum strain of asphalt layer bottom is 1025.8, and the minimum strain is 296.8.

3. The response of the bottom strain of asphalt layer and the pavement temperature change at the middle depth of asphalt layer under different times of wheel loading are obtained, and the discriminant index of whether the asphalt layer is cracked or not is put forward, which lays a foundation for the study of long-term observation test road or accelerated loading test road in the future.

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