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Fatigue Damage Analysis of Aspahlt Mixture Specimen During Cyclic Bending Test

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Abstract: Based on the fact that damage index is calculated using stiffness or modulus directly in fatigue damage experiment for asphalt mixture and it is unable to reveal the reality of asphalt mixture's micro-damage characteristic, theback-analysis method was suggested to determine the fatigue damage characteristic of asphalt mixture. At first,the classic fatigue damage theorical solution of beam specimen during three points bending testwas deduced usingfatigue damage model suggested for asphalt mixture, and the characteristic parametres in the model were determinedbased on the results of fatigue test. The variations of bending stress, deflection, damage index, crack expanding velocity,etc. in the specimen during fatigue damage were simulated by using nonlinear finite element method, and the fatigue lifeand the crack length while breaking were predicted. The results show that the numercal fatigue life is well identical withexperimental results, which proves the reasonableness and effectiveness of the fatigue damage model suggested forasphalt mixture.

Keywords: Asphalt mixture; Cyclic bending test; Nonlinear fatigue damage; Simulation

1. Introduction

The fatigue performance of asphalt pavement is one of the important properties of durability and characterization of asphalt road. In view of asphalt mixture and pavement structure fatigue damage is essentially local material degradation and gradually expand and develop into cracks until fracture process, therefore, need to test further on the basis of applying the theory and method of fatigue damage mechanics reveals evolution process of damage of the material and structural fatigue, understanding the mechanism of fatigue failure.

For example, experimental study on bending fatigue experiment with beam test section equivalent calculated deflection and bending moment bending stiffness is defined to calculate the damage value, obviously, it said in the beam section average damage value, ignore the difference of the same section in different stress state of regional damage, resulting in fatigue the relationship between damage evolution and its related parameters can not reflect the characteristics of the micro damage and damage evolution process. The main reason is that the local strain and microstructure change of the specimen are not directly related to the definition of classical damage in these tests. Therefore, the author combined bending fatigue test of asphalt concrete beam test, using the back analysis approach is proposed to reflect the damage evolution model of asphalt mixture. The steps are: firstly, nonlinear fatigue damage evolution model of asphalt mixture; then, analysis method and numerical simulation analysis of fatigue test interpretation process, and compares the result with the fatigue test results, finally proves the rationality and validity of the model.

2. Bending Fatigue Test and Fatigue Damage Parameters of Asphalt Mixture

This study uses three point bending fatigue test method. In this study we selected 3 No. 70 asphalt production grain type gradation asphalt concrete specimens, and the rolling forming method of making cut into the specified dimensions. The fatigue test, this study uses 10 Hz sine wave as the load waveform, the loading time is 16 Ms. The flexural tensile strength and flexural modulus of resilience of the 3 asphalt concrete used in the test are shown in Table 1.

Table 1. Bending Strenghth and Modulus of Asphalt Mixtures

Asphalt varieties	Temperature/%	Flexural tensile strength/Mpa		Springback model of bending and tension	
		average value	Deviation coefficient/%	average value	Deviation coefficient/%
A	15	4.12	3.88	1919	6.95

B	15	3.51	6.2	1515	5.43
C	15	2.56	5.7	645	4.97

According to the bending fatigue test results, the regression values of the fatigue parameters C and P in the fatigue equation NCO-P are shown in table 2.

Table 2. Results of Fatigue Tests

Asphalt varieties	Asphalt content/%	Penetration (0.1mm)	temperature/	p
A	4.5	55.6	15	3.48
B	4.25	57.4	15	3.51
C	4.35	59.8	15	3.47

3. Finite Element Analysis of Fatigue Damage of Three Point Bending Specimen

The curve of the distribution of the bending tensile stress of the bottom surface of the specimen before fatigue cracking is shown in figure 1.

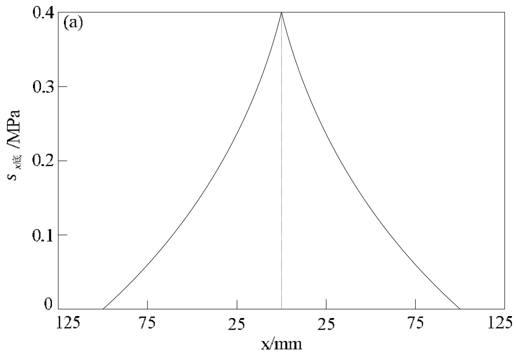

Figure 1. Distribution of bending stress at specimen bottombefore cracking when x=0.4 MPa

The maximum bending stress at the bottom of the beam specimen is also reduced from 0.40 MPa to 0.25MPa; meanwhile, the bending stress of the M point decreases gradually from the maximum to 0 MPa when it is DM=1.0, as shown in figure 2.

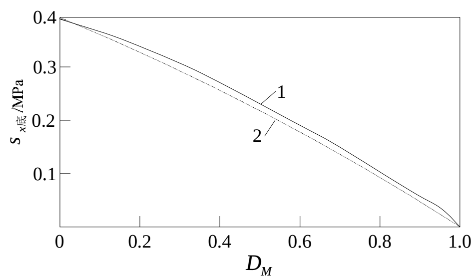

Figure 2. Variation of Mpoint's bending stress with damage inspecimen middle when x= 0.4 MPa

It can be seen from Figure 2 that the decay rate increases with the increase of the damage variable DM; moreover, the bending stress of the midspan M point is close to that of the classical theory.

When after cracking, as the crack length increases, the beam bottom tensile stress position on both sides to continue to transfer, as shown in figure 3. And the zero value of the bending tensile stress near the crack is slightly enlarged.

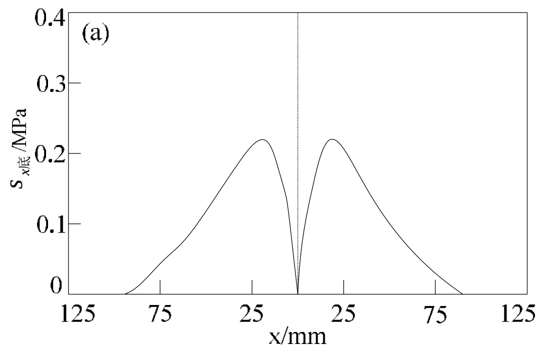

Figure 3. Distribution of bending stress at specimen bottom after cracking

Before the damage occurs, most of the section is interrupted and the bending tensile stress is almost linear, but there is an abnormal phenomenon near the top of the beam specimen and the concentrated load area, that is, the compressive stress increases sharply (as shown in Figure 4).

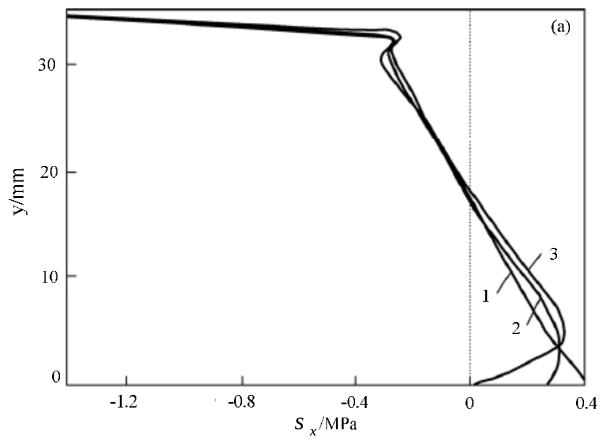

Figure 4. Distribution of bending stress along cross section of specimen middle

This is due to the beam damage began to appear, the damage zone mainly in the cross, it has great influence on the bending stiffness; with the further damage and damage zone expanded, damaged area to reduce the impact on bending stiffness of beam deflection tends to be gentle.

There is a large area of damage and slight damage between the upper part of the beam and the fulcrum, which is due to the tension and shear damage considered in the fatigue damage, and we usually think that the compression does not cause damage.

4. Fatigue Damage Life

The fatigue curve is drawn according to the result of finite element method before the crack of the bottom surface of the beam specimen. The fatigue life curve obtained by the finite element method and the test regression can be drawn from the curve that the maximum error of the two is less than 17.7%, and the prediction error of fatigue life is within 30%, which is acceptable.

When the specimen is cracked at the bottom of the beam, the fatigue life is short when the stress is large and the fatigue life is stable when the crack length is about 20 mm, and the fatigue life will be in the stage of unstable expansion. If the crack length is 25 mm, the fatigue life of the beam is about 0.74 times longer than that of the crack.

With the increase of the crack length, the crack propagation rate also increases gradually, and the crack exhibits a sharp change trend when the crack expands to 20 mm. The results are consistent with the previous results according to the beam deflection, the fatigue life and the crack length.

5. Conclusion

According to the fatigue damage mechanics theory, deduced the fatigue process of two point bending beam internal stress field and damage evolution equation with the number of loading cycles, and the fatigue crack formation stage and expansion stage fatigue life formula. According to the fatigue test data, the characteristic parameters in the fatigue damage model of asphalt concrete materials are obtained.

This paper applied fatigue damage mechanics finite element method, and analyzed the change law of fatigue damage process of tensile stress, midspan displacement and damage variable, the crack growth rate of the final prediction of asphalt mixture specimen at the unstable fracture crack length. The numerical simulation results of fatigue life are in good agreement with the experimental results, which proves the rationality and effectiveness of the proposed asphalt mixture fatigue damage model under the two point bending fatigue test of the beam specimen.

For the two point bending beam specimen, the fatigue life of the fatigue crack propagation stage is shorter than that of the forming stage. The fatigue crack growth is mainly characterized by stable extension, so the Paris formula can be used to describe the fatigue crack growth stage.

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