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Abstract: The fatigue failure form of asphalt pavement is not reflected in the design index of asphalt mixture proportion when determining the optimum asphalt content in the existing asphalt mixture proportion design. In order to solve the problem, the effect of different asphalt content on the fatigue life of three types of asphalt mixtures was studied by indirect tensile fatigue test.The results show that: (1) the splitting strength of asphalt mixture decreases with the increase of asphalt content; (2) the fatigue life of asphalt mixture increases first and then decreases with the increase of asphalt content; (3) the order of sensitivity of fatigue life of three types of asphalt mixture to asphalt content is: AC-5 > STRATA > ATB-25.Some useful suggestions are put forward for the design of asphalt mixture with good fatigue resistance.

1. Introduction

In the process of highway construction in China, due to the good stability, fast construction speed, simple maintenance, excellent performance and many other advantagesof asphalt pavement, it has been favored by the majority of road builders, so it is widely used in the construction of high-grade pavement [1]. However, as a large number of asphalt pavements are usedfor construction, the problem of pavement damage is becoming more and more obvious, especially the problem of fatigue damage and cracking has become one of the main problems of highway damage [2]. Fatigue cracking has seriously affected the service level of the road.Therefore, we should pay attention to this problem.

The design criteria used in the Marshall design method to determine the optimum amount of asphalt include: void fraction (VV), voids in mineral stone (VMA), voids filled with asphalt (VFA), gross bulk density, stability, and flow value. The use of these indicators in the mix design cannot establish the relationship with the pavement performance, nor can it reflect the damage form of the pavement, such as fatigue, rutting, etc., so the designed mix and road performance are poorly combined [3][4]. Although in the Marshall design process, after the design of the mixture, various combinations of performance test (including performance tests such as high, low temperature and water damage) will be carried out, but there is no corresponding fatigue performance verification technologystandard in the currentspecification.So, the mixture designed according to this method does not necessarily have good fatigue performance [5] [6]. Therefore, studying the effect of asphalt dosage on the fatigue life of asphalt mixture is beneficial to improve the existing asphalt mixture proportion

design method and improve the fatigue resistance of the road surface.

2. Raw materials and experimental protocols

2.1Raw materials

The asphalt used in this paper is CNOOC SBS modified asphalt. The stone used is from Andesite from Heilongjiang Province. The basic properties of asphalt and stone are tested according to the requirements and methods in the specification. The test results are shown in the table. It is found that the performance indexes of asphalt and stone meet the requirements of the specification [7][8].

Table 1 Summary of asphalt performance indicators

Asphalt	Test		Company	Result
SBS modified asphalt	Penetration	100g，5s，25°C	0.1mm	67.2
	Ductility	5cm/min，10°C	cm	>100
		5cm/min，15°C	cm	>100
	Softening point	$T_{R\&B}$	°C	63.7

Table 2 Summary of stone property indicators

Test	Result		
	10～30mm	10～20mm	5～10mm
RushingValue %	10.5	11.2	——
Los Angeles abrasion %	18	16.3	——
Water absorption rate %	0.35	0.48	0.51
Apparent density (g/cm3)	2.887	2.896	2.885
Adhesion		5	
Content of the flat particles %	9.2	8.5	8.6

In this paper, the asphalt mixture with better fatigue performance is used for research. The asphalt mixture commonly used for anti-fatigue mainly includes stress absorption layer asphalt mixture and asphalt stabilized macadam mixture. Therefore, this paper selects sand type AC-5 asphalt mixture. STRATA stress absorbing layer asphalt mixture and asphalt stabilized macadam mixture ATB25 were studied. The grading of AC5 type asphalt mixture adopts the upper limit of AC-5 recommended in the specification, and the grading of STRATA stress absorbing layer asphalt mixture is adopted. For the STRATA median value, the ATB25 asphalt stabilized macadam mixture uses the grading upper limit recommended in the specification. The specific grading is shown in Table 3 [9]. In order to study the effect of different oil consumption on the fatigue performance of asphalt mixture, the choice of asphalt dosage in this study is to select the corresponding oil quantity range according to engineering experience, and select 4~5 different asphaltamounts were selected at intervals of 0.3% to 0.5%, the range of AC5 is 8.0~9.5, the range of STRATA is 7.5~9.0, the range of ATB25 is 3.5~4.6, the specific oil quantity is shown in Table 4. In this paper, the test piece is compacted by a rotary compactor.

Table 3 Mineral material design grading

Gradation type	Passing rate（%）												
	31.5	26.5	19.0	16.0	13.2	9.50	4.75	2.36	1.18	0.60	0.30	0.15	0.075
AC	100	100	100	100	100	100	100	75	55	40	28	18	10
STRATA	100	100	100	100	100	100	90	72.5	55	40	25	14	10
ATB25	100	100	80	68	62	52	40	32	25	18	14	10	6

Table 4 Various types of asphalt content

Gradation type	Asphalt content(（%）				
AC	8.0	8.5	9.0	9.5	
STRATA	7.5	8.0	8.5	9.0	
ATB25	3.5	3.8	4.0	4.3	4.6

2.2Asphalt mixture fatigue test plan

2.2.1Splitting experiment

In this paper, the indirect tensile fatigue test method is used for the study. Before the indirect tensile fatigue test, the indirect tensile test is needed to determine the splitting strength, so as to determine the stress level of the fatigue test under the stress control mode. The indirect tensile test is also called the splitting test. By loading the axial direction of the test piece, a certain loading rate is set, then the horizontal and vertical deformation of the test piece can be obtained, so that the corresponding mechanical parameters can be calculated. In the indirect tensile test, the splitting strength can be measured by equipment, and the strain and stiffness modulus need to be obtained by theoretical solution. At this time, only the vertical displacement needs to be measured. In this study, the splitting test was carried out according to the "Asphalt Mixture Splitting Test" in the "Testing Procedures for Asphalt and Asphalt Mixtures for Highway Engineering" (JTGE-20 2011) [7].

2.2.2Indirect tensile fatigue test

This study intends to use the indirect tensile (cracking) fatigue test method for research. The indirect tensile (cracking) test method is a two-point loading mode, which is simple in force and easy to operate. To a certain extent, it is consistent with the road surface stress state and can be used for fatigue test research. The fatigue test in this research work uses a non-intermittent half-sine wave load, the loading frequency is 10Hz, the test temperature is 15°C, the loading instrument is MTS multi-functional mechanical test system (as shown in Figure 1), and digital speckle monitoring technology is adopted. Look at the strain field during the fatigue test of the test piece. This study was conducted using a stress control mode with a fracture stress test using a 0.3 stress ratio level.

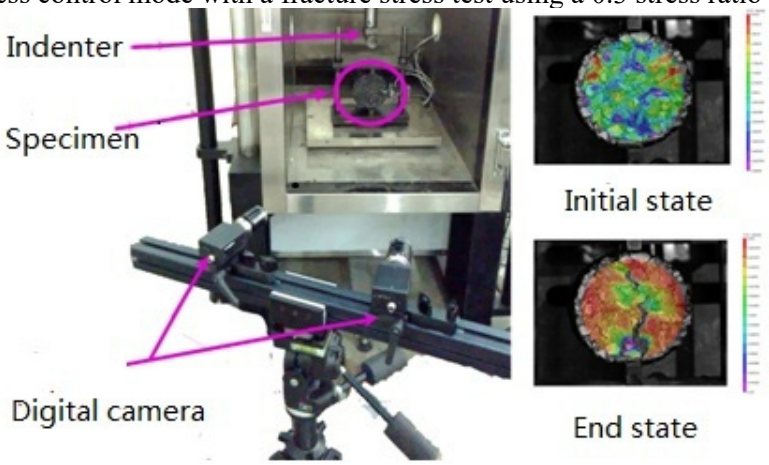


Figure 1 MTS and CCD camera images

2.2.3Fatigue life judgment method

There are many indicators for the life evaluation of asphalt mixture. This paper uses the method N_{fNM}

recommended by ASTM D 7460 to judge the fatigue life of asphalt mixture. In the method N_{fNM}, the asphalt mixture fatigue failure point is defined as the peak value of the mixture normalized stiffness times product NM in the NM - load number map. Asphalt mixture normalized stiffness times product NM is [10]:

$$\mathrm{NM}=\frac{S_N \times N}{S_0 \times N_0} \quad (1)$$

Where N = number of loadings; S_N = stiffness modulus of the asphalt mixture at the Nth loading; S_0 = initial stiffness modulus of the asphalt mixture, taking the stiffness modulus of the asphalt mixture at the 50th loading; N_0 = initial loading times, set as 50. When the maximum NM is reached, the corresponding number of loads is the fatigue life of the asphalt mixture.

3. Analysis of results

3.1Analysis of splitting test results

Before the splitting fatigue test, a splitting test is required to determine the splitting strength, which provides a basis for the stress level of the subsequent splitting fatigue test. The splitting test results of the different graded asphalt mixtures are shown in Table 5.

Table 5 Results of splitting test under different grades（MPa）

Gradation type	Asphalt mixture oil %									
	3.5	3.8	4.0	4.3	4.6	7.5	8.0	8.5	9.0	9.5
AC5	—	—	—	—	—	—	1.97	1.83	1.77	1.58
STRATA	—	—	—	—	—	2.71	2.16	1.75	1.64	—
ATB25	3.45	2.97	2.36	2.78	2.57	—	—	—	—	—

It can be seen from the data in Table 5 that for the same grade of asphalt mixture, as the amount of asphalt increases, the splitting strength of the asphalt mixture decreases, mainly because the oil film of the asphalt mixture increases with the increase of the asphalt content. The thickness becomes large, which in turn causes the splitting strength to decrease.

3.2Analysis of fatigue life of asphalt mixture

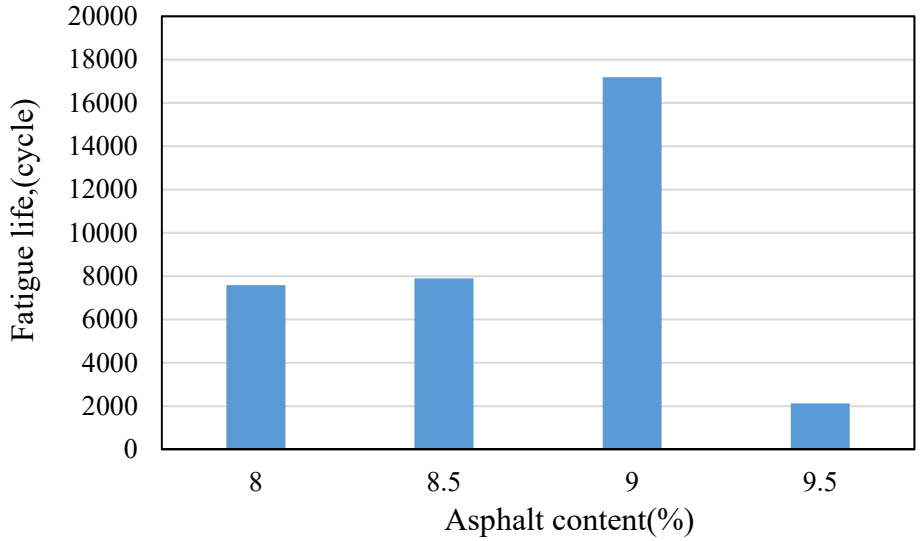
Based on the results of the splitting test, the splitting fatigue test can be carried out at a test temperature of 15 ° C and a loading frequency of 10 Hz. The digital speckle monitoring technique is used to observe the strain field during the fatigue test of the test piece. Table 6 lists the fatigue life of asphalt mixtures with different oil contents.

Table 6 Summary of test data under different grading conditions

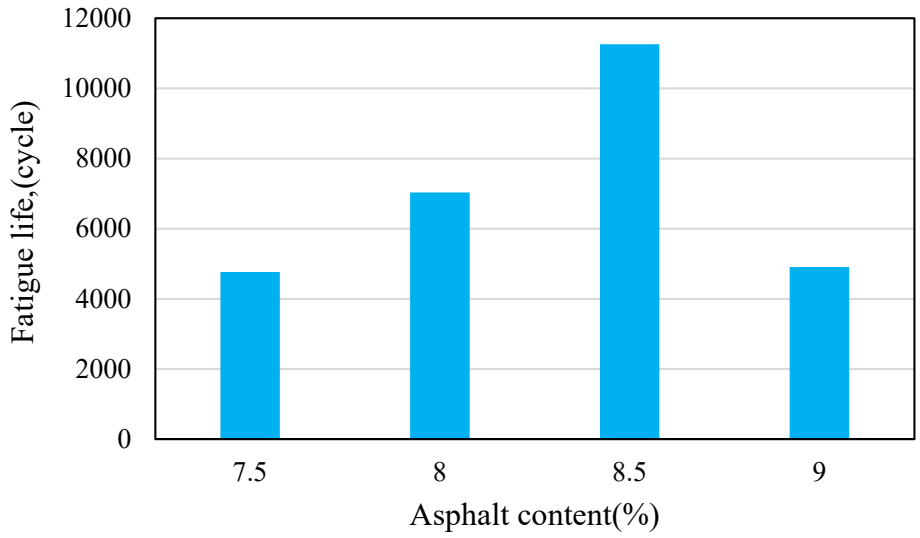
Gradation type	Asphalt mixture oil %	Fatigue life/time		
		1	2	Mean value/cycles
AC-5	8.00	6941	8235	7588
	8.50	7235	8559	7897
	9.00	20679	13687	17183
	9.50	2446	1801	2124
STRATA	7.50	4333	5193	4763
	8.00	6942	7123	7033
	8.50	10390	12126	11258
	9.00	5553	4261	4907
ATB-25	3.50	1851	2151	2001

Gradation type	Asphalt mixture oil %	Fatigue life/time		
		1	2	Mean value/cycles
	3.80	3472	3093	3283
	4.00	3834	4015	3925
	4.30	5768	6768	6268
	4.60	6559	3846	5203

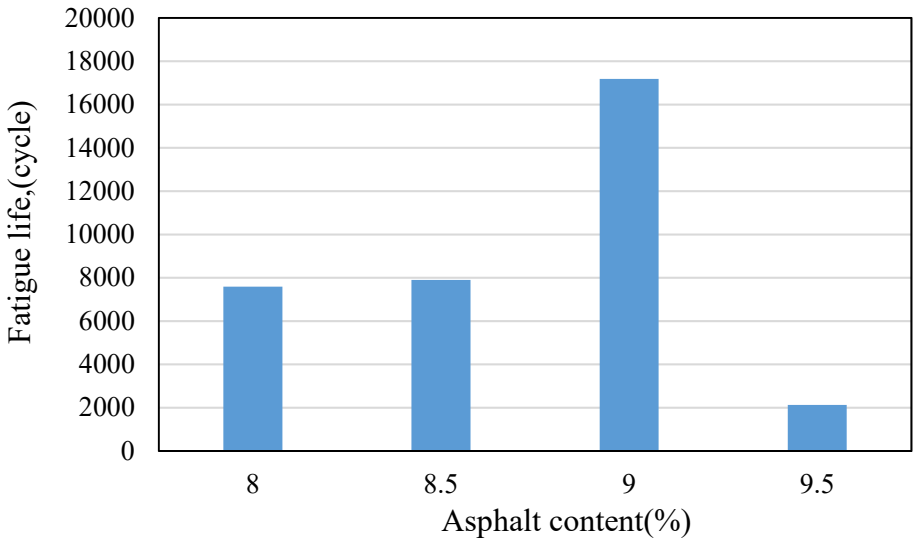
In order to more intuitively characterize the fatigue life of asphalt mixture with the amount of asphalt, the data in Table 6 can be plotted as a histogram as shown.



(a) AC-5 asphalt mixture fatigue life



(b) STRATA asphalt mixture fatigue life



(c) ATB-25 asphalt mixture fatigue life

Figure 2 Fatigue life histogram of various types of asphalt mixture

It can be seen from Figure 2 that for the same asphalt mixture, the amount of asphalt has a significant influence on the fatigue life of the asphalt mixture. When the amount of oil used is low, the increase in the amount of asphalt can improve the fatigue resistance of the asphalt mixture. However, this improvement effect is limited. When the amount of asphalt reaches a certain value, the fatigue life of the asphalt mixture is maximized. When the amount of asphalt exceeds this value, the increase in the amount of asphalt causes the fatigue resistance of the asphalt mixture to decrease. That is, there is an optimum amount of asphalt, and the asphalt mixture corresponding to the asphalt mixture has the best fatigue resistance.

Comparing the effect of the same asphalt mixture on the fatigue life, it is found that the fatigue life of AC-5 asphalt mixture is 9% when the oil consumption is 9%; the fatigue life of STRATA asphalt mixture is 8.5%. Maximum; the ATB-25 asphalt mixture with a fuel content of 4.3% is superior to other oil-based asphalt mixtures in terms of fatigue resistance. By comparing the effect of oil consumption on the fatigue life of three types of asphalt mixture, it can be found that the fatigue life of AC-5 asphalt mixture and STRATA asphalt mixture is more sensitive to oil consumption, while ATB-25 asphalt mixing The fatigue life of the material is less sensitive to the amount of oil used. By comparing the fatigue life of the asphalt mixture under the optimal oil quantity, it is found that the gradation type has a significant influence on the fatigue life of the asphalt mixture, and the anti-fatigue performance of AC-5 asphalt mixture and STRATA asphalt mixture is better., ATB-25 asphalt mixture has poor fatigue resistance.

4. Conclusion

In this paper, the stress control mode is adopted. Under the condition of test temperature 15 °C and loading frequency 10 Hz, three different types of asphalt mixture are used as test objects. Indirect tensile fatigue test method is used to load with MTS, and digital speckle is utilized. The monitoring technology measures the deformation of the test piece, and studies the influence of different asphalt dosage on the fatigue resistance of the asphalt mixture. The following main conclusions are obtained through research:

(1) The splitting strength of the asphalt mixture is affected by the amount of asphalt, and the higher the amount of asphalt, the lower the splitting strength of the asphalt mixture.

(2) The amount of asphalt has a significant effect on the fatigue resistance of asphalt mixture. When the oil quantity is low, the fatigue resistance increases with the increase of oil consumption; when the oil quantity is high, the fatigue resistance The amount of oil decreases and decreases.

(3) The amount of asphalt has different effects on the fatigue resistance of different grades of asphalt mixture. The fatigue lives of AC-5 asphalt mixture and STRATA asphalt mixture are more sensitive to oil consumption, while the fatigue life of ATB-25 asphalt mixture is less sensitive to the amount of oil used.

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