Analysis of fracture morphology of asphalt concrete under different temperatures

Chunyu Zhang*

Yunnan Science & Technology Research Institute of Highway, Kunming, China

*Corresponding Author Email: chunyuzhang@163.com

Abstract. By studying the fracture morphology of splitting failure and bending failure of asphalt mixture under different temperatures, it is confirmed that temperature has an impact on the micro mechanism of asphalt mixture fracture. The fracture at low temperature is relatively flat, the fracture of aggregate and asphalt aggregate interface account for a certain proportion, and the failure of asphalt mixture is mainly brittle fracture; With the increase of temperature, the fracture surface becomes rough, and the fracture of asphalt mortar layer is mainly; The addition of rubber powder improves the viscosity of asphalt and the bonding strength of asphalt mortar, greatly improves the fracture ratio of aggregate and interface area, and improves the crack resistance of asphalt mixture; The fracture morphology of asphalt mixture specimen better reflects its mechanical characteristics.

Keywords: Asphalt concrete; Splitting failure; Bending failure; Fracture morphology.

1. Introduction

The fracture of materials is affected by internal composition and structure, micro defects, external load, temperature and other factors, and is related to the loading history. The fracture of material records the irreversible deformation during material fracture, as well as the information of crack initiation, propagation and fracture. Using the relevant knowledge of fracture morphology, the micro mechanism of material fracture can be qualitatively studied through the analysis of fracture, so as to reveal the nature and failure law of material fracture[1-3] .The research on the fracture of metal materials is relatively mature and widely used in the analysis of material failure mechanism and the reasonable improvement of material production technology [4-5], but the research on the fracture of civil engineering materials is only about 40 years. Many scholars use scanning electron microscope to observe the fracture morphology of rock under different loading conditions, analyze the fracture mechanism of rock, and reveal the nature and failure law of rock fracture [6-10]. Shen Xinpu and others recorded the whole failure process of single-sided precast notch and double-sided precast notch concrete beams under four-point shear loading with cameras. Through the analysis of continuous speckle patterns, they revealed different crack propagation processes and final failure forms of concrete specimens, and obtained the horizontal displacement field, vertical displacement field, horizontal strain field Vertical strain field and shear strain field [11].Khosravani MR and others observed the fracture morphology of concrete four point shear specimen through scanning electron microscope, and systematically analyzed the relationship between fracture energy and fracture fractal dimension [12-13].

Asphalt concrete is a typical viscoelastic temperature sensitive material. Under different temperature conditions, asphalt mortar and its interfacial bonding strength with aggregate have an important impact on the bifurcation and deflection effect of asphalt concrete in the process of crack generation and propagation under tension and compression load, which determines the overall fracture performance of asphalt concrete [14,15]. Due to the viscoelastic properties of asphalt, it is difficult to observe the fracture morphology of asphalt concrete by scanning electron microscope. In this paper, the splitting test and three-point bending test of asphalt mixture mixed with matrix asphalt and rubber modified asphalt under different temperatures are carried out to test its tensile strength, and the fracture image of asphalt mixture sample is recorded by high-resolution digital camera to compare and analyze the meso mechanism of sample fracture under different temperatures and bonding materials.

2. Experiment presentation

AH-90# road petroleum asphalt and rubber powder modified asphalt of Liaohe Oilfield are used in the experiment, and their properties meet the requirements of technical standards. The coarse aggregate adopts limestone gravel, the fine aggregate is limestone debris, and the mineral powder is ground limestone powder. The aggregate is sieved into a single particle size and cleaned for standby. The apparent relative density of aggregates of each particle size is shown in Table 1.

Table 1. Apparent relative density of aggregate

Particle size/mm	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	Mineral powder
Apparent relative density (g·cm-3)	2.808	2.806	2.795	2.772	2.702	2.703	2.703	2.695	2.732	2.693	2.725

AC-16 mineral aggregate gradation is adopted in this experiment. Considering avoiding the grading limit area proposed by Superpave, the mineral aggregate gradation for the test is determined, as shown in Table 2. Marshall method is used to determine the optimum asphalt aggregate ratio of asphalt mixture. The asphalt content of ordinary mixture AC-16 is 5.1%, and that of rubber modified asphalt mixture is 5.3%.

Table 2. Aggregate grading of AC-16

Gradation types	Mass percentage passing the following sieve holes (mm) %									
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Upper grading limit	100	92	80	62	48	36	26	18	14	8
Lower grading limit	90	76	60	34	20	13	9	7	5	4
Composite gradation	95	82	68	48	34	20	15	11	8	4

In this paper, the fracture morphology of Asphalt Mixture Specimens at different temperatures is studied, and the splitting experiment and trabecular bending experiment at 20 ℃ and - 10 ℃ are designed. Firstly, Marshall specimens and trabecular specimens of asphalt mixtures with different types of asphalt are prepared indoors. The size of Marshall specimens is a cylindrical specimen with a diameter of 101.6mm and a height of 63.6mm. The trabecular bending test specimens are cuboids cut from rutting plate specimens formed by wheel mill (250mm×40 mm×40 mm); Splitting test and trabecular bending test are carried out on the pavement material strength testing machine, and the loading rate is 50 +/- 5mm / min; Four parallel specimens are used for each group of tests. Before loading, the specimens are placed in curing boxes with different temperatures for more than 10 hours to ensure the consistency of internal and external temperatures. The strength test results are shown in Table 3.

Table 3. Indoor tensile stress test of asphalt mixture

Type of specimen	Asphalt type	Number of specimen type	Test condition	Test results(MPa)
Standard Marshall specimen	Matrix asphalt	JP-10	Splitting test (-10°C)	3.64
	Rubber modified asphalt	XP-10		4.83
	Matrix asphalt	JP20	Splitting test (20°C)	1.35
	Rubber modified asphalt	XP20		1.80
Trabecular specimen	Matrix asphalt	JP-10	Trabecular bending test (-10°C)	2.50
	Rubber modified asphalt	XP-10		3.94
	Matrix asphalt	JP20	Trabecular bending test (20°C)	1.09
	Rubber modified asphalt	XP20		1.75

The test results show that the tensile strength of asphalt mixture is quite different under different temperature conditions, and the splitting tensile strength and bending strength at - 10 ℃ are greater than those at 20 ℃, which proves that asphalt mixture is more temperature sensitive, and the addition of rubber modified asphalt has a positive impact on the tensile strength of asphalt mixture. In order to further understand the failure mechanism of asphalt mixture under different temperature conditions, the fracture of asphalt mixture sample is photographed by high-resolution digital camera, the morphological characteristics of fracture of sample are analyzed in detail, and the failure mechanism of asphalt mixture is discussed.

3. Analysis of fracture morphology of asphalt mixture

Asphalt mixture is a suspension dense structure, and its mesostructure consists of three basic parts, namely aggregate, aggregate asphalt interface area and asphalt layer [16]. The damage of asphalt mixture first occurs at the weakest position, and there are two possible paths for crack propagation, that is, the crack extends in the original direction through the aggregate or the crack deflects and extends around the aggregate along the cementation zone. There are three possibilities for the damage of the cementation zone: aggregate fracture, aggregate asphalt interface degumming failure and asphalt binder layer failure. The fracture morphology of asphalt mixture at different positions is quite different, and the fracture of coarse aggregate is gray white; The fracture of the interface area is gray black, and the fracture is mostly smooth; The fracture of the asphalt layer is black and bright. The fracture morphology at three positions is shown in Figure 1.

A. limestone fracture B. Interface fracture C. Asphalt layer fracture

Figure 1. Fracture morphology of asphalt mixture at different positions

It is reported that the failure of cementation zone is closely related to the thickness of asphalt layer, test temperature, loading rate and material combination. Generally, the strength of free asphalt layer is the smallest, the strength of asphalt mortar is 2-4 times that of free asphalt, and the asphalt strength of interface layer is 2-7 times that of free asphalt layer [15-16].

3.1 Analysis of fracture morphology in Splitting test

In this paper, four groups of splitting tests were carried out, with three parallel specimens in each group and a total of 24 fracture sections. A high-precision digital camera was used to take photos. The paper listed a typical section of each group of specimens for analysis, and the section is shown in Figure 2.

JP-10 XP-10 JP20 XP20

Figure 2. Typical fracture morphology of Marshall specimen in splitting test

As can be seen from Figure 2:

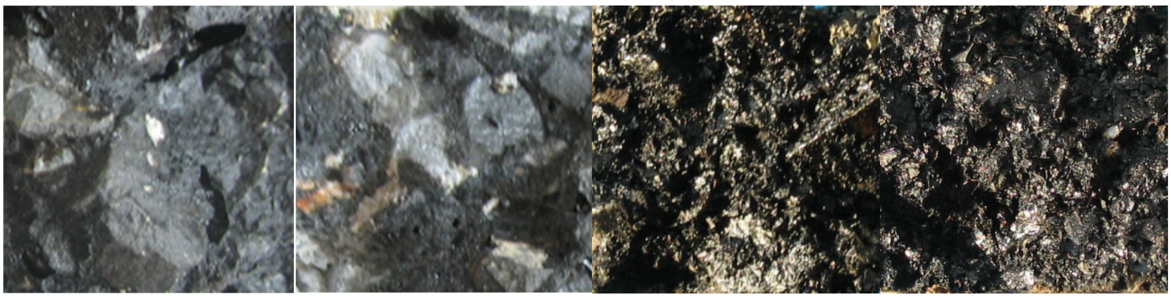
The section of Marshall specimen at -10 °C is neat, and the fracture includes several forms, such as aggregate fracture, debonding failure of stone asphalt interface, failure of asphalt bonding layer and so on; The section of matrix asphalt mixture contains a small amount of aggregate fracture and a large number of small cavities, indicating that there are a large number of closed pores in the mixture; The section of rubber modified asphalt mixture is more flat, and bright asphalt closed pore fracture is rare in the section, and the fracture of aggregate and interface area account for a large proportion. It is proved that rubber modified asphalt improves the tensile strength of asphalt mixture, which is the result of rubber powder improving the viscosity of asphalt and the interfacial bonding strength between asphalt and aggregate.

The section of 20℃Marshall specimen is uneven, the fracture is mainly the damage of asphalt mortar layer, the fracture of aggregate is very few, and the number of degumming damage of stone asphalt interface is also very few, indicating that the bonding strength of asphalt decreases after the temperature increases; The upper and lower ends of the specimen section are quite flat and the middle is rough, indicating that the crack first occurs at the upper and lower pressing strip position of the section and gradually extends to the middle of the specimen. A large number of honeycomb cavities are still distributed in the section of matrix asphalt mixture, and the rubber modified asphalt mixture is relatively dense.

To sum up, when the temperature is low, the splitting of asphalt mixture is mainly brittle fracture and the section is flat. Rubber modified asphalt improves the strength of asphalt mortar and the bonding strength of stone asphalt interface, which plays a positive role in the crack resistance of asphalt mixture; With the increase of temperature, the section surface becomes rougher and the asphalt mortar layer is mainly broken, which is due to the decrease of the bonding strength of asphalt in the asphalt mixture due to the increase of temperature. The fracture morphology of Marshall specimen of asphalt mixture better reflects its mechanical characteristics.

3.2 Analysis of fracture morphology in Trabecular bending test

In this paper, four groups of trabecular bending tests were carried out, with three parallel specimens in each group and a total of 24 fracture sections. The paper listed a typical section of each group of specimens for analysis, and the section is shown in Figure 3.



JP-10 XP-10 JP20 XP20

Figure 3. Typical fracture morphology of trabecular bending test

As can be seen from Figure 3:

The cross section of the -10°C small beam bending test specimen is relatively flat, and the fracture includes several forms, such as aggregate fracture, stone asphalt interface degumming failure, asphalt bonding layer failure and so on; There are still many voids in the section of matrix asphalt mixture, and the fracture proportion of aggregate is not high; The rubber modified asphalt mixture is relatively dense, the fracture is more flat, the crack extends along the original direction through the aggregate, there is little deflection, the aggregate fracture is more, and the specimen belongs to brittle fracture.

The cross-section of 20°Ctrabecular bending test specimen is uneven, and the fracture includes the debonding failure of stone asphalt interface and the failure of asphalt mortar layer; The fracture is bright, the asphalt layer has many fractures, and the section has ductile deformation. When testing the bending strength, the crack will completely lose its strength when it grows from the beam bottom to 1 / 4 position, and the fracture is formed by tearing along the crack propagation direction with external force. The section of matrix asphalt mixture is rougher, mainly damaged by asphalt mortar; Rubber modified asphalt mixture is relatively dense, with a large proportion of interface degumming fracture, and its crack resistance is better.

To sum up, the bending failure of asphalt mixture at low temperature is brittle fracture and the section is flat. With the increase of temperature, the surface of the bending section of the trabecular is rough, and the damage is mainly the damage of asphalt layer and asphalt aggregate bonding layer. The addition of rubber powder improves the bonding strength of asphalt mortar and the crack resistance of asphalt mixture. The fracture morphology of asphalt mixture trabecular bending specimen also better reflects its mechanical characteristics.

4. Conclusions

Based on the study of splitting fracture and bending fracture of asphalt mixture under different temperatures, the following conclusions are drawn:

The fracture morphology of asphalt mixture at different temperatures is quite different. At low temperature, the fracture is relatively flat. The fracture includes aggregate fracture and asphalt aggregate bonding layer fracture. The failure of asphalt mixture is mainly brittle fracture; With the increase of temperature, the fracture surface becomes rough, and the fracture morphology is mainly damaged by asphalt mortar layer. The addition of rubber powder improves the viscosity of asphalt and the bonding strength of asphalt slurry, greatly improves the fracture ratio of aggregate and interface area, and improves the crack resistance of asphalt mixture. The fracture morphology of asphalt mixture specimen better reflects its mechanical characteristics.

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