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Study on Properties of SBS Modified Asphalt Mortar Blended with Nickel Iron Slag Fiber

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Abstract. The properties of asphalt mortar with fiber added directly affect the road performance of SMA. Based on the raw material performance test, the paper carried out the dynamic shear rheological test (DSR) and the bending beam rheological test (BBR) on the SBS modified asphalt mortar with nickel iron slag fiber. From the macroscopic point of view, the high temperature and low temperature performance of the asphalt mortar with fiber were analyzed and compared; Scanning electron microscopy (SEM) was used to analyze the distribution of nickel iron slag fiber in SBS modified asphalt and the interface structure between fiber and modified asphalt from a microscopic point of view. The results of the study show that the best high and low temperature performance is the addition of mineral No. 3 nickel iron slag fiber, and its compatibility with asphalt is also best.

Introduction

Fiber stabilizer is an indispensable part of SMA. Its main function is oil absorption and reinforcement, which can significantly improve the road performance of the mixture. Nickel iron slag fiber is a new environmentally friendly inorganic material with high strength and good heat resistance, corrosion resistance and aging resistance. In this paper, three kinds of nickel iron slag fibers with different chemical compositions were selected to study the properties and microscopic properties of the nickel iron slag fiber asphalt mortar. The high-low temperature performance of asphalt mortar with nickel iron slag fiber and its fusion with asphalt were analyzed[1-4].

At present, the three most commonly used fibers in SMA are lignin fiber, polymer fiber, and mineral fiber[5,6]. In this paper, the rheology method is used to compare the high-temperature and low-temperature performance of asphalt mortar with three types of nickel iron slag fibers from a macro perspective. The distribution of three nickel iron slag fibers in SBS modified asphalt and the interface structure between fiber and modified asphalt were analyzed by SEM from a microscopic perspective.

Raw Materials

Asphalt Binder，Mineral Powder and Wood Fiber. The SBS modified asphalt，mineral powder and wood fiber used in this article were tested according to the specified test methods. All the indicators were in compliance with the specifications.

Nickel Iron Slag Fiber.

(1) Nickel Iron Slag Fiber Properties

The three kinds of nickel iron slag fibers with different chemical compositions were named No.2, No.3 and No.4 respectively. Table 1 shows the properties of the three kinds of nickel iron slag fibers.

Table 1 Nickel Iron Slag Fiber Properties

Test Project	Exterior	Fiber length（mm）	Oil absorption rate (times)	Impurity content（%）	Density（g/cm^3）
No.2	Soft, white	＜6（Manual cutting）	4.97	0	1.33
No.3	Hard, dark		5.92	5~10	
No.4	Hard, green		4.82	10~15	

The three nickel iron slag fibers were examined for their chemical composition. The results are shown in Table 2.

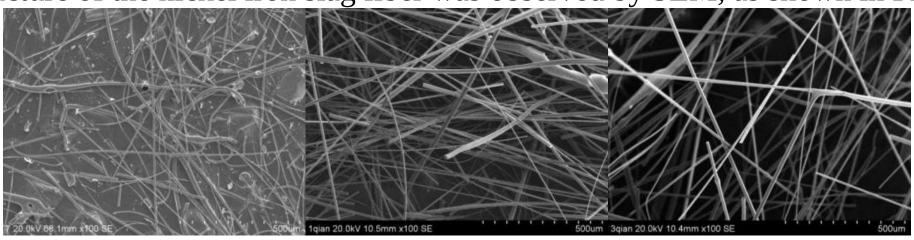
Table 2 Fiber Chemical Composition Test Results

Sample Name	Fe（%）	SiO_2（%）	Al_2O_3(%）	CaO（%）	MgO(%）	Cu（%）	Ni（%）
No.2	0.53	48.88	12.32	17.45	16.48	<0.01	＜0.005
No.3	1.91	56.97	14.13	6.07	16.39	<0.01	＜0.005
No.4	2.76	35.40	11.52	9.85	14.19	<0.01	＜0.005

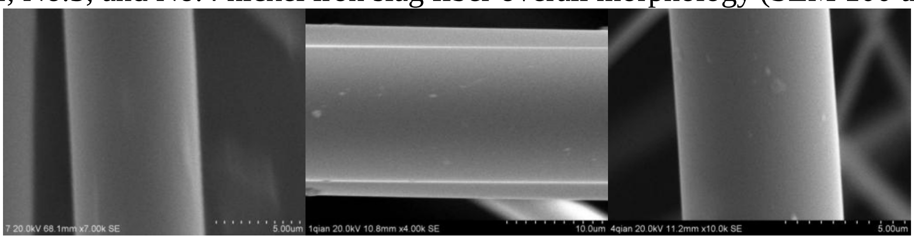
From Table 2, it can be found that the contents of the chemical composition of the three kinds of nickel iron slag fibers are different. Among them, the contents of Fe, SiO_2, and CaO are quite different, while the contents of other chemical components are not much different. The difference in chemical composition results in the difference in chemical properties.

(2) Micro-morphology of Nickel Iron Slag Fiber

The microstructure of the nickel iron slag fiber was observed by SEM, as shown in Fig. 1.



No.2, No.3, and No.4 nickel iron slag fiber overall morphology (SEM 100 times)



No.2, No.3, and No.4 nickel iron slag fiber surface microstructure (SEM 10000 times)

Fig.1 Surface microstructure of nickel iron slag fiber under SEM

As can be seen from Fig.1 , when the three kinds of nickel iron slag fibers were all magnified by 100 times, the appearance of the three kinds of nickel iron slag fibers was observed to be slender strips and the diameters were of different sizes, and there was no significant difference in shape. From the analysis of the overall morphology of the fibers, the fibers were densely distributed and cross-cross, showing an upright and regular pattern. Observing the surface structure of individual fibers, it can be found that the three kinds of nickel iron slag fibers all have a relatively smooth cylindrical morphology, and the cross-sectional shape is also a complete circle. There are a small number of surface defects such as irregular shapes and distributed point protrusions on the surface of the fiber, and the size is about several hundred nanometers. These surface defects are formed during the preparation of high temperature flame drawing of fibers.

Research on Performance of Asphalt Mortar

In this paper, DSR and BBR were used to study the high-temperature and low-temperature properties of wood fiber and nickel-iron fiber asphalt binders from a macro perspective.

DSR Test. The anti-rutting factor G*/sin δ is an index of the DSR for assessing the deformation resistance of the fiber asphalt mortar under high temperature conditions. Test selected SBS modified asphalt mortar. The ratio of powder to glue is 1.2, and the mass ratios of wood fiber, 3 kinds of nickel iron slag fiber and asphalt are 4:100 and 6:100 respectively (equivalent to 0.3% of wood fiber in asphalt mixture and 0.4% of three kinds of nickel iron slag fiber, 6.5% the amount of asphalt).The test temperature is 60°C and 70°C. On the basis of certain experimental experience, by consulting a large amount of literature, the content of wood fiber is 0.3%, and the content of nickel-iron-slag slag fiber is 0.4% as the best fiber content. The results of the DSR test are shown in Table 3.

Table 3 Comparison of DSR Test of Asphalt Mortar with Fibers Added at 60°C and 70°C

Temperature（°C）	Fiber type	|G*|（KPa）	δ（°）	G*/sinδ（KPa）
60	Undoped fiber	2.87	74.6	2.98
	Wood fiber	4.74	64.4	5.26
	Mineral 2	4.84	65.3	5.33
	Mineral 3	5.06	67.2	5.49
	Mineral 4	4.41	62.2	4.98
70	Undoped fiber	1.88	75.2	1.94
	Wood fiber	4.07	62.5	4.59
	Mineral 2	4.20	64.8	4.64
	Mineral 3	4.79	65.8	5.25
	Mineral 4	3.72	60.4	4.28

From the experimental data in Table 3, it can be seen that the δ decreases and the G* increases after adding the fiber to the asphalt mortar, so the G*/sin δ increases a lot, indicating that the added fiber can improve the high temperature performance of the asphalt mortar. The δ and G* of each asphalt mortar decrease to a certain extent, and the G*/sinδ also decreases when the test temperature increases. The main reason is that the temperature rise leads to the decrease of viscous plasticity of the asphalt mortar, so the rutting resistance is reduced. At the same temperature, the mineral No.3 fiber has the best high temperature performance, and the mineral No.2 fiber has better high temperature performance than the wood fiber. The mineral No. 4 fiber has the worst high temperature performance. When the temperature increases, the high temperature resistance of the asphalt binder blended with mineral No.3 fiber is the best, and its performance is the least affected by the temperature, and the anti-aging performance is the best. Therefore, the extent of G*/sinδ reduction of the asphalt mortar blended with mineral fiber No.3 is also the smallest.

BBR Test. Creep stiffness S and creep rate m are two parameter indexes of the BBR to evaluate the low-temperature performance of asphalt mortar. Both reflect the ability of asphalt to resist permanent deformation and the rate of change of asphalt stiffness under load[7].

Test selected SBS modified asphalt mortar. The ratio of powder to glue is 1.2, and the mass ratios of wood fiber, 3 kinds of nickel iron slag fiber and asphalt are 4:100 and 6:100 respectively (equivalent to 0.3% of wood fiber in asphalt mixture and 0.4% of three kinds of nickel iron slag fiber, 6.5% the amount of asphalt). On the basis of certain experimental experience, by consulting a large amount of literature, the content of wood fiber is 0.3%, and the content of nickel iron slag fiber is 0.4% as the best fiber content. Tests were conducted to determine the low temperature performance of asphalt mortar at -12°C and -18°C. See Table 4 for BBR test data.

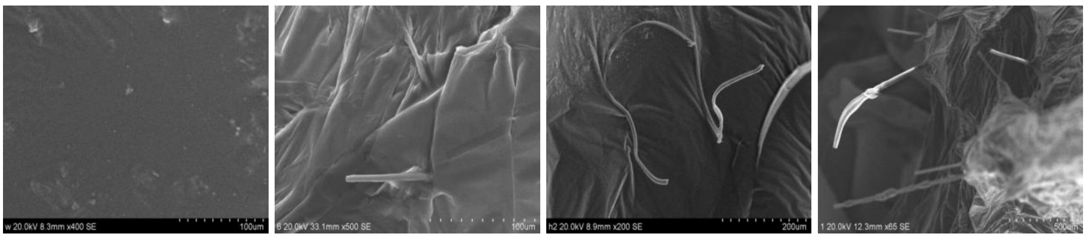
Table 4 Comparison results of asphalt mortar BBR test at -12°C and -18°C with fiber

Temperature（°C）	Fiber type	S（MPa）	m
-12°C	Undoped fiber	226	0.368
	Wood fiber	202	0.379
	Mineral 2	194	0.385
	Mineral 3	172	0.412
	Mineral 4	269	0.343
-18°C	Undoped fiber	584	0.323
	Wood fiber	531	0.335
	Mineral 2	522	0.344
	Mineral 3	494	0.379
	Mineral 4	612	0.293

From the test data in Table 4, it can be seen that asphalt mortar with various fibers have different effects at the same temperature and optimum fiber content. The added mineral No.3 fiber had the lowest creep stiffness and the best low temperature ductility, followed by the addition of mineral No.2 and wood fiber, and the mineral No.4 fiber had the worst low temperature performance.

Study on Microscopic Properties of Fiber Asphalt

Analysis of Fiber's Overall Morphology in Asphalt. SEM was used to observe the micro-morphology of SBS modified asphalt and three kinds of nickel iron slag fiber asphalt. Combined with the road performance of SBS modified asphalt, three kinds of modified asphalt containing nickel iron slag fibers were microscopically examined. The results are shown in Fig.2.

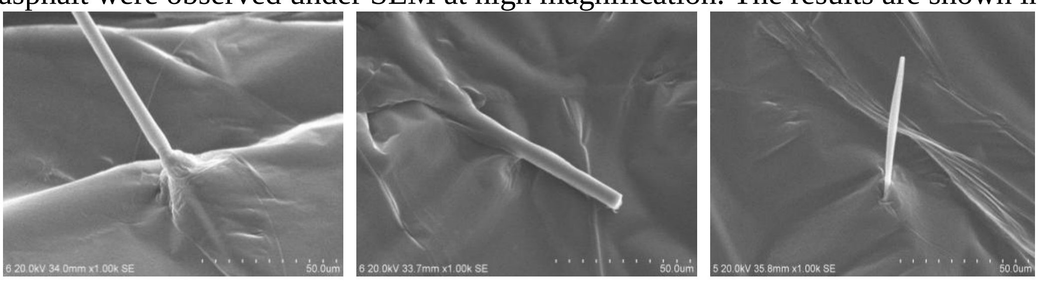


SBS modified asphalt and No.2, No.3, and No.4 nickel iron slag fiber modified asphalt

Fig. 2 Scan image

As can be seen from Fig.2 , the asphalt is grayish black under SEM, and wrinkles appear on the surface due to the fluidity and homogeneity exhibited by the asphalt in the viscous state. The three kinds of nickel iron slag fibers blended into the asphalt show a state of irregular dispersion, intertwined with each other, and can be well combined with the asphalt. Fiber and asphalt tightly combined to form an interfacial layer, and the fiber swelled, showing an increase in size compared to the appearance size under scanning electron microscopy, showing as a full cylinder.

Microscopic Analysis of the Interface between Asphalt and Fiber. In order to study the interfacial fusion of asphalt and fiber, the interface layer distributions of three kinds of nickel iron slag fibers and asphalt were observed under SEM at high magnification. The results are shown in Fig.3.



No.2, No.3 and No.4 nickel iron slag fiber modified asphalt

Fig. 3 Microscopic scanning images of fiber and modified interface in modified asphalt

As can be seen from Fig.3, after the three kinds of nickel iron slag fibers are added to the asphalt, the asphalt forms a uniform thickness coating on the surface of the fibers. Some of the asphalt will be irregular after being incorporated into the asphalt although the surface of the fiber is relatively smooth. From the standpoint of the uniformity of asphalt coating on the fiber surface, No.3 nickel iron slag fiber is best. The figure clearly shows that the nickel iron slag fiber can absorb some light oil components in the asphalt, swelling occurs, making the fiber more full, indicating that the fiber and the asphalt form a physical adsorption.

From the perspective of the asphalt-fiber interfacial layer, the interface between the three kinds of nickel iron slag fibers and asphalt produced a distinct interface zone, which showed continuous and partial wrinkling, indicating that the nickel iron slag fiber and the SBS modified asphalt has good compatibility. By comparing the fusion of the three kinds of nickel iron slag fibers with the asphalt interface, it was found that the compatibility of the No.3 nickel iron slag fibers with asphalt was better due to the difference in their surface. The compatibility and continuity of No.4 nickel iron slag fibers at the interface with asphalt are relatively poor, probably because the surface of No.4 nickel iron slag fiber is smoother than that of No.2 and No.3 nickel iron slag fibers, resulting in slightly poorer adhesion to asphalt.

Conclusions

(1) By the DSR of the nickel iron slag fiber asphalt mortar, it can be obtained that the high temperature performance of the asphalt mortar with the added fiber is better than that of the unmixed fiber, and the best high temperature performance is the mineral No.3 fiber asphalt mortar, mineral No.2 fiber is better than wood fiber, and the worst is mineral No.4 fiber.

(2) By the BBR of the nickel iron slag fiber asphalt mortar, it can be obtained that, with the same temperature and optimum fiber content, the effect of adding different fibers to the asphalt mortar is not the same. The No.3 fiber had the best low temperature performance, followed by the mineral No.2 fiber and wood fiber, and the No.4 fiber had the worst low temperature performance.

(3) The distribution of the three kinds of nickel iron slag fibers in the modified asphalt and the interfacial structure of the fibers and the modified asphalt were compared by SEM. The three kinds of nickel iron slag fibers mixed into asphalt showed a state of irregular dispersion, and can be better combined with the asphalt. Uniformity of No. 3nickel iron slag fiber coated with asphalt and continuity of the asphalt junction are both better than No.2 and No.4 nickel iron slag fibers. Through the comparison of the interface fusion between fiber and asphalt, it can be seen that the compatibility of No.3 nickel iron slag fibers with asphalt is better, and that of No.4 nickel iron slag fibers is poor.

Acknowledgements

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