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Research Article

Road Performance Comprehensive Evaluation of Polymer Modified Emulsified Asphalt Fiber Microsurfacing

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To further improve the road performance of microsurfacing, two kinds of polymer modified emulsified asphalt and three kinds of fibers were selected to prepare a variety of microsurfacing mixtures. The composition of the microsurfacing was optimized and verified. The effects of polymer modified emulsified asphalt and fiber types on the road performance of the microsurfacing were analyzed. Based on TOPSIS method of entropy weight, the road performance of the microsurfacing was comprehensively evaluated, and the microsurfacing with the best comprehensive road performance was optimized. The results show that the addition of waterborne polyurethane can further improve the water stability and low-temperature crack resistance of the waterborne epoxy resin modified emulsified asphalt fiber microsurfacing. Adding fiber can effectively improve the road performance of the microsurfacing. After adding polypropylene fiber, the bonding performance and water damage resistance of polymer modified emulsified asphalt microsurfacing were improved to the maximum. After adding basalt fiber, the deformation resistance, the 60°C dynamic stability, and the −10°C splitting strength of polymer modified emulsified asphalt microsurfacing reached the maximum. Among the three fibers, polypropylene fiber microsurfacing has the best comprehensive road performance, followed by basalt fiber microsurfacing.

1. Introduction

Microsurfacing is to use special mechanical equipment to mix polymer modified emulsified asphalt, coarse and fine aggregates, fillers, water, and additives into slurry mixture according to the design ratio and pave them on the old pavement to form a thin layer. Microsurfacing is a pavement maintenance overlay technology. It has the advantages of low cost, short construction period, and rapid opening of traffic. To meet the higher requirements of pavement maintenance technology under large traffic volume, heavy load, and complex climate conditions, researchers have carried out more research on how to further improve the road performance of microsurfacing, such as water damage resistance, crack resistance, and wear resistance.

At present, many researchers improve the road performance of microsurfacing by optimizing the performance of modified emulsified asphalt binder or adding fiber. Ji et al. [1] determined the optimum asphalt aggregate ratio, emulsifier content, and waterborne epoxy resin (waterborne epoxy resin is a thermosetting material formed by the reaction of epoxy resin emulsion with waterborne epoxy resin curing agent) content at the waterborne epoxy resin modified emulsified asphalt (WEREA, which refers to the thermosetting asphalt composite produced by adding epoxy resin emulsion and waterborne epoxy resin curing agent to emulsified asphalt) microsurfacing by orthogonal test. Li et al. [2] prepared different types of WEREA microsurfacing and studied the shear resistance between the microsurfacing and asphalt pavement under water immersion conditions. Zheng et al. [3, 4] prepared waterborne epoxy resin and SBR composite modified emulsified asphalt microsurfacing and explored the durability of the microsurfacing. Liu et al. [5, 6] pointed out that adding waterborne epoxy resin can improve the bonding performance, rutting resistance, and water damage resistance of microsurfacing. Chen et al. [7–11] optimized the construction method and open traffic time based on the change of performance of WEREA microsurfacing. Yao et al. [12] prepared discontinuous graded fiber microsurfacing and studied the effects of fiber type and grading type on rutting resistance and crack resistance of the microsurfacing. MS-3 polypropylene fiber microsurfacing has the best crack resistance effect. Sun et al. [13] studied the effects of aggregate gradation, filler type and content, and polypropylene fiber content on the antisliding and wear resistance of the microsurfacing through indoor accelerated loading test. Wang et al. [14] analyzed the effects of different gradation, different aggregate, and fiber type on the water stability and rutting resistance of microsurfacing mixture. Luo et al. [15] analyzed the effects of fiber type and fiber content on microsurfacing crack resistance and rutting resistance and recommended that the optimal fiber content is 0.10–0.20% of the weight of asphalt mixture.

In conclusion, the road performance of microsurfacing such as water damage resistance, crack resistance, and wear resistance can be effectively improved by optimizing the performance of modified emulsified asphalt binder and adding fiber [16, 17]. However, there is a lack of systematic and in-depth research on the polymer modified emulsified asphalt fiber microsurfacing. The influence of polymer modifier and fiber type on the road performance of the microsurfacing needs to be further clarified. The road performance of polymer modified emulsified asphalt fiber microsurfacing can be further improved. At the same time, there are many evaluation indexes for the road performance of microsurfacing, so it is necessary to carry out comprehensive evaluation on its road performance. The purpose of this study is to clarify the influence of polymer modifier and fiber type on the road performance of the microsurfacing and provide a comprehensive evaluation method of microsurfacing, and the polymer modified emulsified asphalt fiber microsurfacing with better comprehensive performance was optimized.

2. Experimental Plan

To further improve the road performance of microsurfacing, two kinds of polymer modified emulsified asphalt and three kinds of fibers were selected to prepare a variety of microsurfacing mixtures. The composition of the microsurfacing was optimized and verified. The effects of polymer modified emulsified asphalt and fiber type on the bonding performance and deformation resistance of the microsurfacing were analyzed. The water damage resistance, high temperature stability, and low temperature crack resistance of each microsurfacing were tested. The antisliding and wear resistance of polymer modified emulsified asphalt fiber microsurfacing were studied. Based on TOPSIS method of entropy weight, the road performance of the microsurfacing was comprehensively evaluated, and the microsurfacing with the best comprehensive performance was optimized. This study is of great significance in improving the service quality of microsurfacing, ensuring road driving safety, and prolonging road service life. It provides a certain reference for the scientific evaluation of microsurfacing road performance.

3. Test Materials and Methods

3.1. Raw Materials. Two kinds of polymer modified emulsified asphalt and three kinds of fibers were selected to prepare a variety of microsurfacing mixtures. The raw materials for preparing polymer modified emulsified asphalt include asphalt, emulsifier, and modifier. The 90# asphalt and mixed cationic slow-cracking medium-setting emulsifier were adopted. According to the previous research [9, 10], waterborne epoxy resin (it includes epoxy resin emulsion and waterborne epoxy curing agent; their mass ratio is 1 : 1) and waterborne polyurethane were used to prepare polymer modified emulsified asphalt. Polyester fiber (PETF), polypropylene fiber (PPF), basalt fiber (BF), and portland cement (P.O. 32.5) were selected. The microsurfacing was prepared by using polymer modified emulsified asphalt, limestone mineral filler, basalt aggregate, fiber, cement, etc. Referring to the MS-3 grading in Technical Guide for Micro-Surfacing and Slurry Seal, China [18], and in combination with the grading of microsurfacing which was widely studied and applied in China [3–7], the grading of microsurfacing in this study was determined. The lower layer of the composite specimen for microsurfacing performance test adopted the AC-13 grading median specified in Technical Specifications for Construction of Highway Asphalt Pavements (JTG F40-2004), China [19], SBS modified asphalt was selected, and its asphalt aggregate ratio was 5%. The main technical indexes of each material are shown in Tables 1–3. The gradation of microsurfacing and AC-13 asphalt mixture is shown in Table 4.

3.2. Preparation Scheme

3.2.1. Preparation of Polymer Modified Emulsified Asphalt. According to the existing research results [3–7], WEREA with 8% (mass percentage of modifier in modified emulsified asphalt) by mass of waterborne epoxy resin was prepared. To further improve the low-temperature toughness of WEREA, composite modified emulsified asphalt (WERPUEA) with 4% by mass of waterborne epoxy resin and 4% by mass of waterborne polyurethane was prepared. The polymer modified emulsified asphalt was prepared by emulsifying first and then modifying. Emulsified asphalt was prepared by colloidal mill, and the processing fineness can reach 2–4 μm. The content of emulsifier is 0.9% of the mass of emulsified asphalt. During the preparation process, the temperature of asphalt was controlled at 130–135°C and the soap solution was controlled at 50–55°C. A certain mass of emulsified asphalt and modifier were weighed; the modifier was added to emulsified asphalt and mixed evenly. The mixture was mixed by high speed mixing shear apparatus at a low speed (100–300 r/min) for 3 min, and then it was mixed by high speed (500–800 r/min) shear for 2 min. Finally, it was manually stirred slowly for 1 min to defoaming.

Table 1: The main technical indexes of asphalt and mineral materials.

Materials	Technical indexes
Asphalt	Penetration (25°C, 100 g and 5 s), 94 (0.1 mm); softening point, 46.9°C; ductility (5 mm/min, 10°C), 39.2 cm; dynamic viscosity (60°C), 224 Pa·s
SBS modified asphalt	Penetration (25°C, 100 g and 5 s), 53 (0.1 mm); softening point, 72.5°C; ductility (5 mm/min, 5°C), 33 cm; Mass loss after TFOT, −0.368%; penetration ratio after TFOT, 67.9%
Limestone mineral filler	No agglomerates and lumps; plasticity index, 2.60%; moisture content, 0.3%; hydrophilic coefficient, 0.5; plasticity index, 2.5%
Basalt aggregate	Crushing value, 11%; polished stone value, 52 BPN; acicular content, 4.8%; weared stone value, 12%; sturdiness, 3%
Cement	Normal consistency, 25.5%; The 80 μm sieve residue, 7.6%; initial setting time, 85 min; final setting time, 181 min; soundness (boiling process), qualified; flexural strength (28 days), 6.4 MPa; compressive strength (28 days), 38.8 MPa

Table 2: The main technical indexes of polymer modifier.

Materials	Appearance	Solid content/%	Epoxy equivalent	Active hydrogen equivalent	Viscosity (25°C)/ mPa·s	pH value	Specific gravity
Epoxy resin emulsion	White emulsion	50 ± 2	220–360 (solids)	—	400–1200	2–7	1.02–1.09
Waterborne epoxy resin curing agent	Yellowish transparent liquid	50 ± 2	—	291 (solids)	8000–10000	11–13	1.05–1.10
Waterborne polyurethane	Translucent liquid	30 ± 1	—	—	50–200	6–8	1.04–1.06

Table 3: The main technical indexes of fiber.

Fiber type	Diameter/ μm	Length/ mm	Tensile strength/MPa	Elongation at breaking/%	Elastic modulus/MPa	Hygroscopicity/ %	Oil absorption rate/(g·g^{-1})
Polyester fiber	20	4–6	650	33.8	12.2×10^3	10.87	3.25
Polypropylene fiber	20	4–6	365	29	5.2×10^3	0	3.81
Basalt fiber	16	4–6	1554	2.4	100.1×10^3	0.176	3.63

Table 4: The gradation of microsurfacing and AC-13 asphalt mixture.

Standard test sieves size/mm		16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
The microsurfacing	Mass passing percentage/%	—	—	100	75	51	32	21	16	12	9
AC-13 asphalt mixture		100	95	77	53	37	27	19	14	10	6

3.2.2. Preparation of Microsurfacing Mixture. Referring to Technical Guide for Micro-Surfacing and Slurry Seal, China [18], and combined with the existing research and application results [3–7], the composition of microsurfacing has been preliminarily determined. The asphalt aggregate ratio of the microsurfacing mixture is 7.0–8.0%. The water consumption is 6–10% of the mass of mineral materials. The cement content is 1.5% of the mass of mineral materials. The fiber content is 0.2% of the mass of the microsurfacing mixture. The microsurfacing preparation scheme is shown in Table 5.

3.3. Test Methods. Based on the performance indexes such as mixing time, cohesion torque, wet track abrasion loss value, and sticky sand value, the composition of the microsurfacing was optimized and verified. The effects of polymer modified emulsified asphalt and fiber types on the bonding performance and deformation resistance of the microsurfacing were analyzed. The water damage resistance, high temperature stability, and low temperature crack resistance of the microsurfacing were tested. The antisliding and wear resistance of the microsurfacing were studied. The test process is shown in Figure 1.

3.3.1. Basic Performance Test Method

(1) Mixing Time. About 100 g of mineral aggregate, mineral filler, fiber, etc. was added to the mixing cup. They were mixed. Water and modified emulsified asphalt were poured in turn. Mix and start to record the time. When the microsurfacing mixture begins to thicken and the hand feels strong, it indicates that the mixture begins to show signs of demulsification. Record the time at this moment, that is, the mixing time.

(2) Cohesion Torque Test. The cohesion torque tester was used to simulate the influence of the horizontal force generated by the vehicle on the microsurfacing mixture. The

Table 5: Preparation scheme of the microsurfacing.

Scheme	Type of modified emulsified asphalt	Fiber type
1	WEREA	—
2		Polyester fiber (PETF)
3		Polypropylene fiber (PPF)
4		Basalt fiber (BF)
5	WERPUEA	Polyester fiber (PETF)
6		Polypropylene fiber (PPF)
7		Basalt fiber (BF)

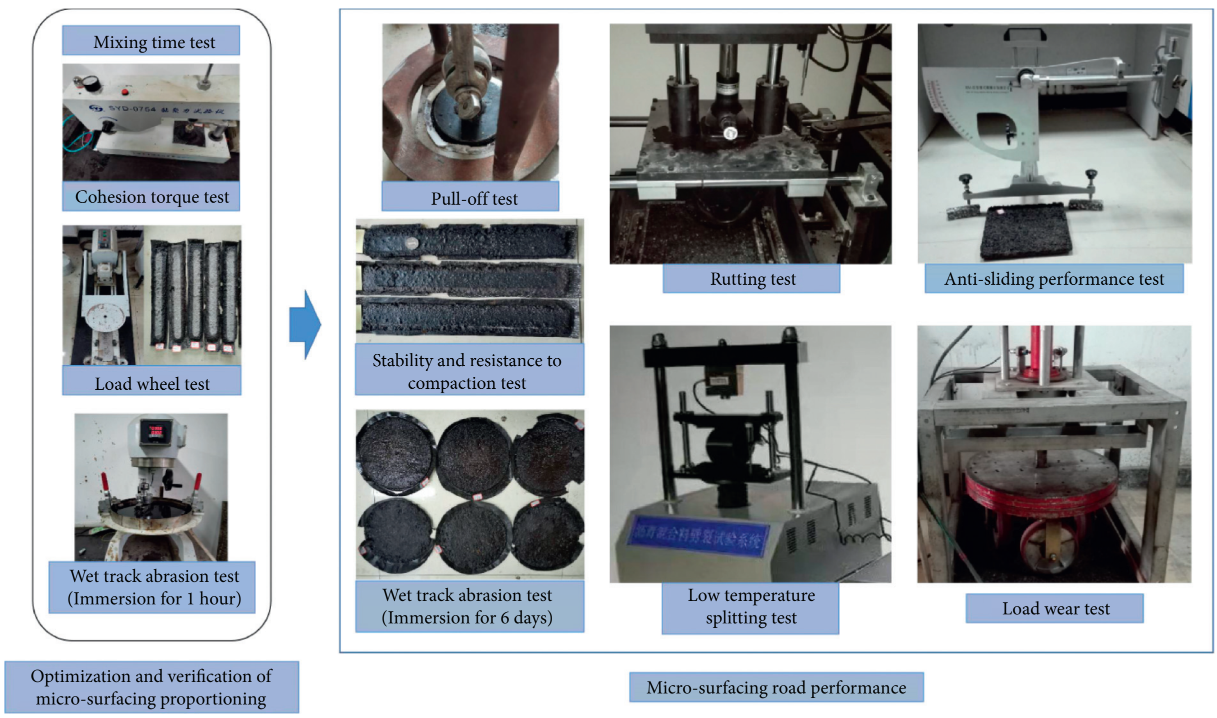

Figure 1: Microsurfacing performance test.

reading of the torque meter after the test on the force application handle is used to determine the initial setting time and open traffic time of the microsurfacing mixture.

(3) Wet Track Abrasion Test (Immersion for 1 hour). According to the relevant requirements in Technical Guide for Micro-Surfacing and Slurry Seal, China [18], the wet track abrasion test and load wheel test were used to optimize and verify the asphalt aggregate ratio of the microsurfacing. Before the abrasion test, the test piece was placed in a $25 \pm 1^{\circ}$C water bath for 1 hour. The abrasion time was 300 ± 2 s. The wet track abrasion loss value was calculated according to

$$WTAT = \frac{m_a - m_b}{A_s}, \quad (1)$$

where WTAT is wet track abrasion loss value of the microsurfacing; m_a is mass of test piece before abrasion, g; m_b is mass of test piece after abrasion, g; A_s is abrasion area, m^2.

(4) Load Wheel Test. The test piece with length, width, and height of 380 mm × 50 mm × 12.7 mm was formed. The test piece was rolled 1000 times with the load wheel tester at $25 \pm 2^{\circ}$C. After rolling, the specimen was taken out, washed, and dried at 60°C to constant weight. The weight G_a of the test piece was weighed. The 300 g hot sand with a temperature of 82°C was poured into the sand frame and flattened. Then the load wheel tester was started and rolled for 100 times. The weight G_b of the test piece after adhering the sand was weighed. The sticky sand value LWT is calculated according to

$$LWT = \frac{G_b - G_a}{A_f}, \quad (2)$$

where LWT is sticky sand value, g/m^2; A_f is the rolling area, m^2.

3.3.2. The Bonding Performance and Deformation Resistance Test

(1) Pull-Off Test. According to the relevant requirements in Water Quality Asphalt Waterproof Coating for Highway (JT/T 535–2015), China [20], the pull-off strength was used to evaluate the bonding performance of the microsurfacing. The AC-13 asphalt mixture board with the size of

30 cm × 30 cm × 3 cm was selected for the lower layer of the microsurface bonding performance test specimen, and the microsurfacing mixture with the thickness of 1.0–1.2 cm was paved on the upper layer. The quick drying AB adhesive was used to bond the puller to the surface of the cured specimen. Under the condition of 25°C, the pull-off strength was tested with a pull-out tester, and the loading rate was 10 mm/min. The pull-off strength is calculated according to

$$\sigma = \frac{F}{A}, \tag{3}$$

where σ is the pull-off strength, MPa; F is the failure load, N; A is the bonding area of the test specimen, mm^2.

(2) Stability and Resistance to Compaction Test. The test piece was formed according to the load wheel test. The width L_a of the specimen was measured. The test piece was put into the load wheel tester, and it was rolled 1000 times at 22 ± 2°C. After rolling, the specimen was taken out, and the width L_b of the specimen after rolling was measured again. The width change rate PLD of the specimen were calculated according to

$$PL\ D = \frac{\left(L_b - L_a\right) \times 100}{L_a}. \tag{4}$$

3.3.3. Water Damage Resistance, High Temperature Stability, and Low Temperature Crack Resistance Test. (1) Wet Track Abrasion Test (Immersion for 6 Days). The test piece was formed according to the wet track abrasion test method. Before the abrasion test, the test piece was placed in a 25 ± 1°C water bath for 6 days, and then the abrasion test was carried out and wet track abrasion loss value was calculated.

(2) Rutting Test. According to the relevant requirements in Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering (JTG E20-2011), China [21], the rutting test was carried out. The composite test piece was prepared according to the pull-off strength test method. The test temperature of rutting test is 60°C and the wheel pressure is 0.7 MPa. The dynamic stability (DS) of the test results was used to evaluate the high temperature stability of the microsurfacing.

(3) Low Temperature Splitting Test. According to the relevant requirements in Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering (JTG E20-2011), China [21], low temperature splitting test was used to evaluate the crack resistance of the microsurfacing. Firstly, the cylinder specimen with diameter and height of 101.6 mm × 63.5 mm was formed. The specimen was placed in a −10°C constant temperature oven for more than 6 hours, and then the splitting test was carried out at a loading rate of 1 mm/min. The low temperature performance of the microsurfacing was evaluated by splitting strength and tensile strain.

3.3.4. Antisliding and Wear Resistance Test

(1) Antisliding Performance Test. According to Field Test Methods of Highway Subgrade and Pavement (JTG 3450–2019), China [22], the antisliding performance of the microsurfacing was evaluated by British Pendulum Number. The British Pendulum Number was tested at three different test points of the specimen. At the same time, considering the temperature correction, the test results were converted into the British Pendulum Number at the standard temperature of 20°C.

(2) Load Wear Test. Through the load wear test of the four-wheel wear tester, the wear mass loss rate was used to evaluate the wear resistance of the microsurfacing. The composite test piece was prepared according to the pull-off strength test method. After paving the microsurfacing, the composite test piece was put into the 60°C oven for curing to constant weight for standby. The load wear test was carried out with the four-wheel wear tester at room temperature. Polyurethane tire (20 cm in diameter and 5 cm in width) with good wear resistance and shore hardness of 70–75 A was selected as the test wheel. The test wheel pressure was 0.7 MPa. The load wear times were 20000 times.

4. Results and Discussion

4.1. Optimization and Verification of Microsurfacing Mixture Composition. Taking the microsurfacing prepared by WEREA and PETF as an example, the microsurfacing mixture was prepared by setting three levels of asphalt aggregate ratio of 7%, 7.5%, and 8% and three external water contents of 6%, 8%, and 10%. Based on the performance indexes such as mixing time, cohesion torque, WTAT, and LWT, the composition of the microsurfacing was optimized. Furthermore, the rationality of the composition of other polymer modified emulsified asphalt fiber microsurfacing was verified.

4.1.1. Optimization of Microsurfacing Mixture Composition. Based on the performance indexes such as mixing time, cohesion torque, WTAT, and LWT, the asphalt aggregate ratio and external water content of WEREA-PETF microsurfacing were optimized. The test results are shown in Figures 2–4.

It can be seen from Figures 2–4 that when the asphalt aggregate ratio is 7–7.5% and the external water content is 6%, the mixing time of the microsurfacing mixture is less than 120 s, which is difficult to meet the mixing requirements of the mixture. Under other conditions, the mixing time meets the relevant requirements in Technical Guide for Micro-Surfacing and Slurry Seal, China [18]. Under the condition of the same asphalt aggregate ratio, the mixing time of the microsurfacing mixture gradually increased with the increase of external water content. Considering that excessive water addition will affect the strength formation of the microsurfacing, the external water content of the microsurfacing was set as 8%, and this external water content was used for subsequent research.

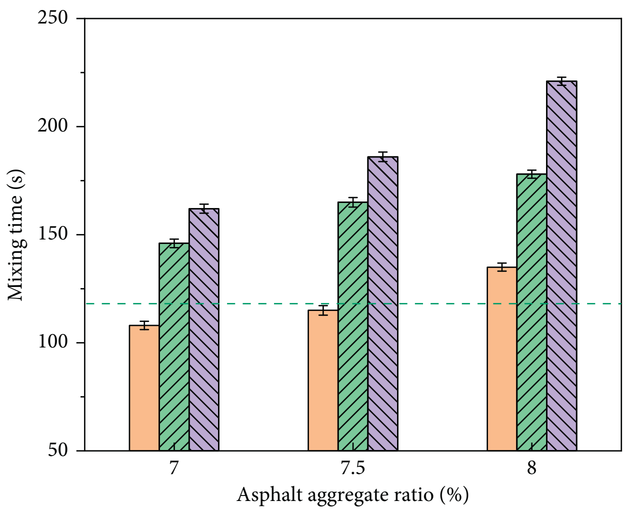

Figure 2: Mixing time under different external water content.

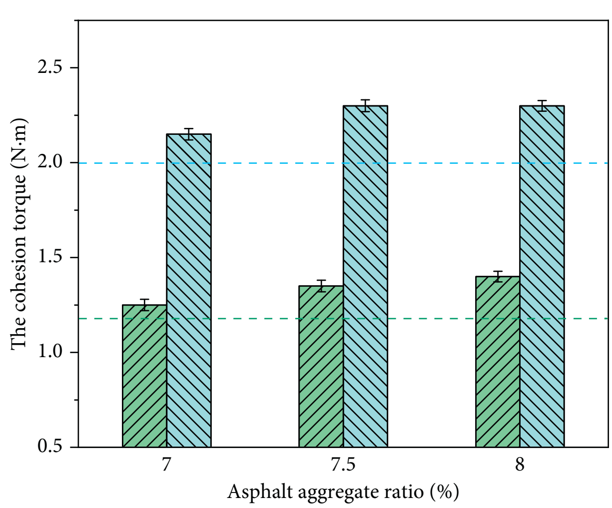

Figure 3: The cohesion torque under different asphalt aggregate ratio.

With the increase of asphalt aggregate ratio, the WTAT (immersion for 1 hour) of the microsurfacing gradually decreased, and the LWT and cohesion torque of the microsurfacing gradually increased. When the asphalt aggregate ratio increased from 7% to 7.5%, the WTAT decreased significantly by about 9%. When the asphalt aggregate ratio increased from 7.5% to 8.0%, the WTAT decreased by about 3%, but the LWT increased by 18%. When the asphalt aggregate ratio is 8.0%, slight oil flashing occurred during the rolling process of the load wheel test. Therefore, considering the cohesion torque, WTAT, and LWT of the microsurfacing, it is suggested that the asphalt aggregate ratio of the polymer modified emulsified asphalt fiber microsurfacing is 7.5%.

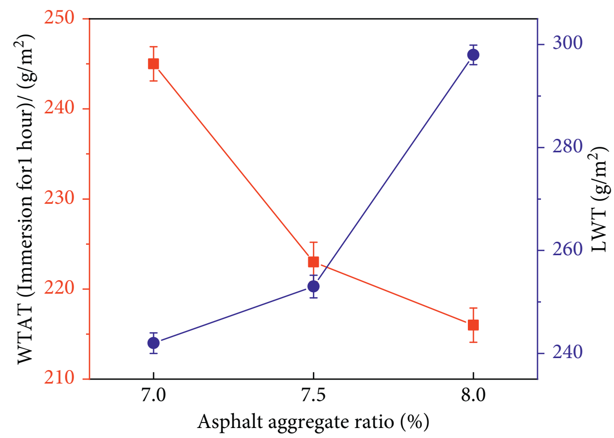

Figure 4: WTAT and LWT under different asphalt aggregate ratio.

4.1.2. Verification of Microsurfacing Mixture Composition. Based on the performance indexes such as mixing time, cohesion torque, WTAT, and LWT, the composition of the polymer modified emulsified asphalt fiber microsurfacing was verified. The test results are shown in Figures 5–7.

It can be seen from Figures 5–7 that the mixing time of each polymer modified emulsified asphalt fiber microsurfacing is greater than 120 s and the 30 min cohesion torque and 60 min cohesion torque are greater than 1.2 N·m and 2.0 N·m, respectively, which meets the relevant requirements in Technical Guide for Micro-Surfacing and Slurry Seal, China [18]. At the same time, the WTAT (immersion for 1 hour) and LWT are significantly lower than 540 g/m^2 and 450 g/m^2 specified in Technical Guide for Micro-Surfacing and Slurry Seal, China [18]. The above properties verified the rationality of the external water content and asphalt aggregate ratio of the microsurfacing.

Compared with the microsurfacing without fiber, the mixing time of polymer modified emulsified asphalt fiber microsurfacing was slightly reduced, the cohesion torque was increased 7–16%, the WTAT was reduced by 11–15%, and the LWT was reduced by 10–12%. It shows improved bonding properties and wear resistance.

4.2. Road Performance of the Microsurfacing. The road performance of polymer modified emulsified asphalt fiber microsurfacing, such as deformation resistance, water damage resistance, high temperature stability, low temperature crack resistance, antisliding, and wear resistance, was evaluated. The effects of polymer modifier and fiber type on the road performance of microsurfacing were clarified.

4.2.1. The Bonding Performance and Deformation Resistance. The bonding performance and deformation resistance of polymer modified emulsified asphalt fiber microsurfacing

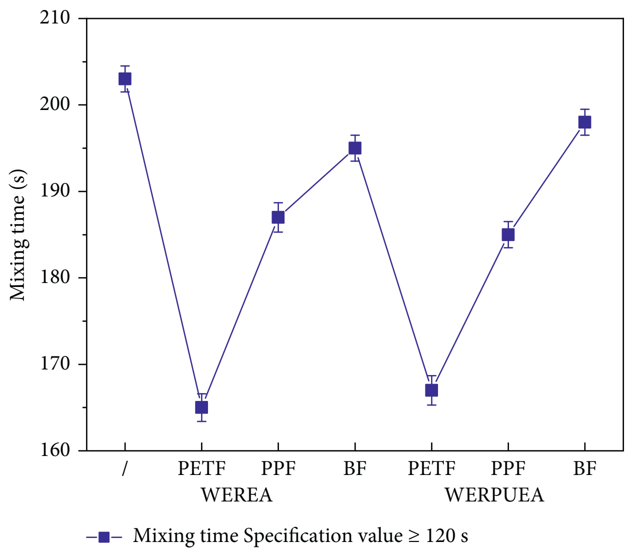

Figure 5: Mixing time of different types of microsurfacing.

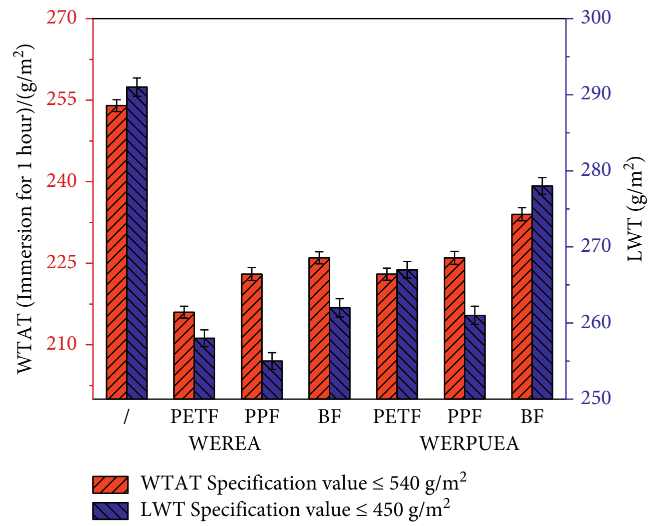

Figure 7: WTAT and LWT of different types of microsurfacing.

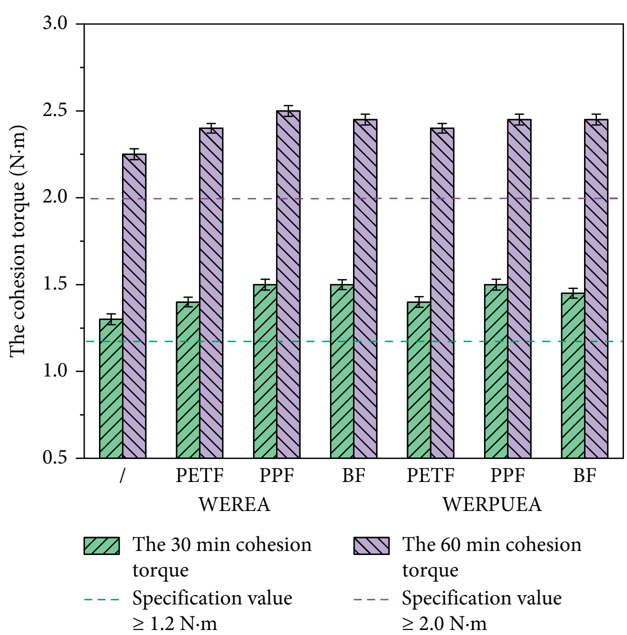

Figure 6: The cohesion torque of different types of microsurfacing.

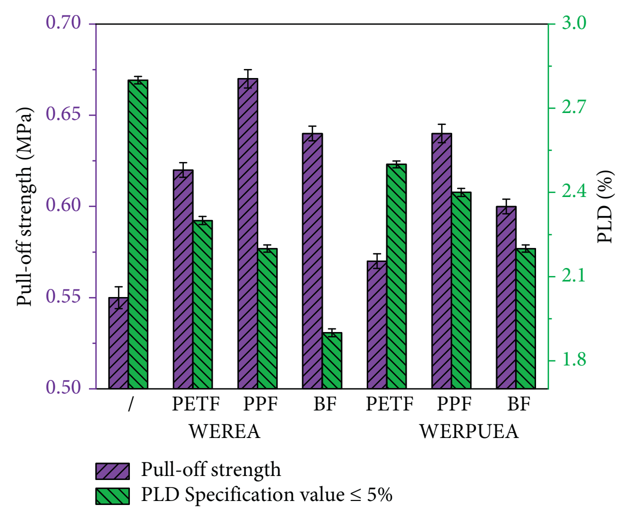

Figure 8: The pull-off strength and PLD of the microsurfacing.

were evaluated by pull-off strength and PLD. The results are shown in Figure 8.

Figure 8 shows that, compared with the WEREA microsurfacing without fiber, the pull-off strength of the fiber microsurfacing increased by 13–22% and the PLD decreased by 18–32%. The bonding performance and deformation resistance of the microsurfacing are effectively improved. Under the condition of adding the same type of fiber, the bonding performance and deformation resistance of the microsurfacing prepared by WEREA are better than those prepared by WERPUEA. Adding PPF has the greatest improvement on the bonding performance of polymer modified emulsified asphalt microsurfacing. The analysis shows that PPF has the largest oil absorption rate and can play an effective role in reinforcement and bonding in the microsurfacing. The addition of BF can greatly improve the deformation resistance of the microsurfacing. The oil absorption rate of BF is relatively large. At the same time, BF has higher tensile strength and elastic modulus, so that the microsurfacing prepared by BF has improved deformation resistance.

4.2.2. Water Damage Resistance, High Temperature Stability, and Low Temperature Crack Resistance. The water damage resistance, high temperature stability, and low temperature crack resistance of polymer modified emulsified asphalt fiber microsurfacing were evaluated by the WTAT (immersion for 6 days), DS, the −10°C splitting strength, and tensile strain. The results are shown in Figures 9 and 10.

It can be seen from Figures 9 and 10 that, after adding PETF to the WEREA microsurfacing, the WTAT (immersion for 6 days) increased and the water damage resistance

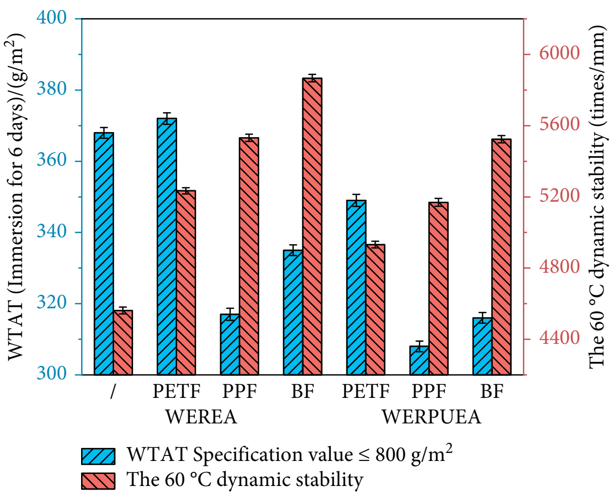

FIGURE 9: WTAT (immersion for 6 days) and DS.

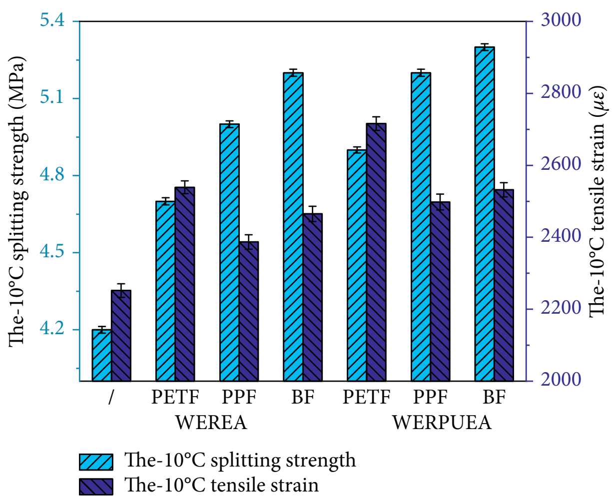

FIGURE 10: The −10°C splitting strength and tensile strain.

decreased slightly. In addition, compared with the WEREA microsurfacing without fiber, after adding other types of fiber, the WTAT (immersion for 6 days) of the microsurfacing reduced by 9–14%, the 60°C dynamic stability increased by 15–29%, the -10°C splitting strength increased by 12–24%, and the -10°C tensile strain increased by 6–13%. The water damage resistance, high temperature stability, and low temperature crack resistance of the microsurfacing have been effectively improved.

Under the condition of adding the same type of fiber, compared with the WEREA fiber microsurfacing, the WTAT (immersion for 6 days) of the WERPUEA fiber microsurfacing reduced by 6–8%, the −10°C splitting strength increased by 4-5%, and the −10°C tensile strain increased by 4–6%. The results show that the addition of waterborne polyurethane can improve the water stability and low-temperature crack resistance of the WEREA microsurfacing.

The addition of PPF has the greatest improvement on the water damage resistance of polymer modified emulsified asphalt microsurfacing, and the addition of BF has the greatest improvement on the 60°C dynamic stability and −10°C splitting strength of the microsurfacing. The −10°C tensile strain of the WERPUEA-PETF microsurfacing reached the maximum. The analysis shows that the high water absorption of PETF leads to the poor water damage resistance of its microsurfacing, but the high elongation at break of PETF increases the low-temperature tensile strain of its microsurfacing.

4.2.3. Antisliding and Wear Resistance. The antisliding and wear resistance of polymer modified emulsified asphalt fiber microsurfacing were evaluated by British Pendulum Number and wear mass loss rate. The results are shown in Figure 11.

It can be seen from Figure 11 that, after adding fiber, the antisliding performance of polymer modified emulsified asphalt microsurfacing increased slightly, and the British Pendulum Number of each microsurfacing is greater than 70 BPN, which can effectively improve the antisliding performance of the old pavement. After adding fiber to the microsurfacing, the wear mass loss rate after 20000 times of load wear reduced by 8–20%. The wear resistance of the polymer modified emulsified asphalt microsurfacing is effectively improved. The addition of BF has the most obvious effect on the wear resistance of microsurfacing. Under the condition of adding the same type of fiber, the wear resistance of the WEREA microsurfacing is better than that of the WERPUEA microsurfacing.

4.3. Road Performance Comprehensive Evaluation of the Microsurfacing. There are many road performance evaluation indexes of polymer modified emulsified asphalt fiber microsurfacing, including bonding performance, deformation resistance, water damage resistance, high temperature stability, low temperature crack resistance, antisliding, and wear resistance. Each fiber has different effects on various road performance of the microsurfacing. Therefore, it is necessary to carry out the road performance comprehensive evaluation of the microsurfacing and select the fiber microsurfacing with the best comprehensive road performance. The TOPSIS method of entropy weight introduces entropy weight method when determining the weight of evaluation indexes [23, 24]. The advantage of this method is that its weight can be determined objectively according to the amount of information provided by each evaluation object index, excluding the influence of human subjective factors. Therefore, this method is used to comprehensively evaluate the road performance of polymer modified emulsified asphalt fiber microsurfacing. The sample matrix $A = [a_{ij}]_{m\times n}$ shown in Table 6 was constructed, including 7 schemes and 8 evaluation indexes. The pull-off strength, dynamic stability, splitting strength, tensile strain, and British Pendulum Number are benefit indexes, and the PLD, WTAT (immersion for 6 days), and wear mass loss rate are cost indexes.

Firstly, Table 6 of the decision matrix was standardized and normalized. The decision matrix A was standardized by using (5) (calculation benefit index) and (6) (calculation cost

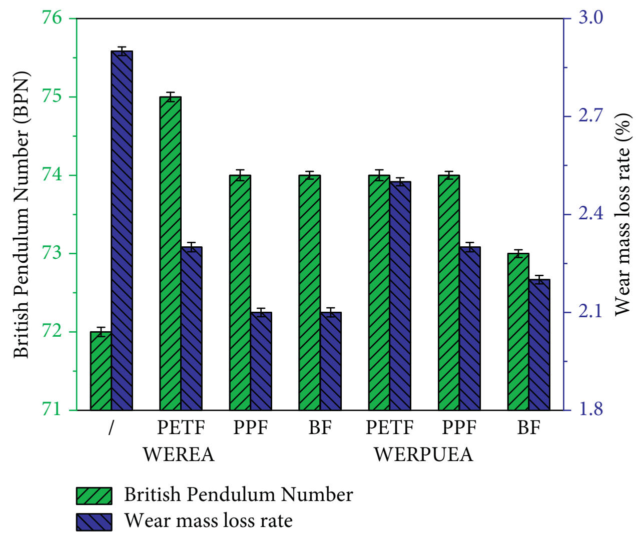

Figure 11: British Pendulum Number and wear mass loss rate of the microsurfacing.

Table 6: Road performance of polymer modified emulsified asphalt fiber microsurfacing.

Scheme	Type of modified emulsified asphalt	Fiber type	Pull-off strength/ MPa	PLD/ %	WTAT (immersion for 6 days)/(g/ m^2)	The 60°C dynamic stability/ (times/mm)	The −10°C splitting strength/ MPa	The −10°C tensile strain/$\mu\varepsilon$	British Pendulum Number (20°C)/BPN	Wear mass loss rate/%
1		—	0.55	2.8	368	4562	4.2	2252	72	2.9
2	WEREA	PETF	0.62	2.3	372	5234	4.7	2539	75	2.3
3		PPF	0.67	2.2	317	5532	5.0	2387	74	2.1
4		BF	0.64	1.9	335	5867	5.2	2465	74	2.1
5		PETF	0.57	2.5	349	4932	4.9	2716	74	2.5
6	WERPUEA	PPF	0.64	2.4	308	5169	5.2	2498	74	2.3
7		BF	0.60	2.2	316	5524	5.3	2532	73	2.2

index), and the standardized decision matrix $B = [b_{ij}]_{m\times n}$ was obtained. According to (7), standardized decision matrix $B = [b_{ij}]_{m\times n}$ was normalized to obtain $P = [p_{ij}]_{m\times n}$.

$$b_{ij} = \frac{a_{ij} - \min_j(a_{ij})}{\max_j(a_{ij}) - \min_j(a_{ij})}, \tag{5}$$

$$b_{ij} = \frac{\max_j(a_{ij}) - a_{ij}}{\max_j(a_{ij}) - \min_j(a_{ij})}, \tag{6}$$

$$p_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}}. \tag{7}$$

Next, according to the calculation steps in [23], the entropy weight of each index was calculated as $W = (0.1447, 0.1169, 0.1834, 0.1241, 0.1022, 0.1213, 0.1091, 0.0983)$.

Then, the weighted standardized decision matrix was further constructed to obtain the positive ideal solution: $v^+ = (0.1447, 0.1169, 0.1834, 0.1241, 0.1022, 0.1213, 0.1091, 0.0983)$ and the negative ideal solution: $v^- = (0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000)$. The Euclidean distance from each scheme to the positive ideal solution was calculated: $d^+ = (0.3554, 0.2224, 0.1127, 0.1141, 0.2178, 0.1233, 0.1341)$, and the Euclidean distance from each scheme to the negative ideal solution was calculated: $d^- = (0.0115, 0.2014, 0.2865, 0.2807, 0.1853, 0.2737, 0.2614)$.

Finally, the relative closeness of each scheme (as shown in Table 7) was calculated: $C_1 = 0.0312$, $C_2 = 0.4752$, $C_3 = 0.7177$, $C_4 = 0.7110$, $C_5 = 0.4597$, $C_6 = 0.6895$, $C_7 = 0.6610$. The relative closeness of each polymer modified emulsified asphalt fiber microsurface treatment scheme is $C_3 > C_4 > C_6 > C_7 > C_2 > C_5 > C_1$. The larger the relative closeness value is, the closer the scheme is to the positive ideal solution; that is, under the comprehensive consideration of the road performance of the microsurfacing, such as bonding performance, deformation resistance, water damage resistance, high temperature stability, low temperature crack resistance, antisliding, and wear resistance, the comprehensive road performance of WEREA-PPF microsurfacing is the best. Among the three fibers, the PPF microsurfacing has the best comprehensive road performance, followed by the BF microsurfacing.

In the actual test process, in general, PPF has the largest comprehensive improvement on the road performance of polymer modified emulsified asphalt microsurfacing, followed by BF. The road performance of PPF microsurfacing is at a high level. The above research results are consistent

Table 7: The relative closeness of each scheme.

Scheme	Type of modified emulsified asphalt	Fiber type	The relative closeness
1	WEREA	—	0.0312
2		PETF	0.4752
3		PPF	0.7177
4		BF	0.7110
5	WERPUEA	PETF	0.4597
6		PPF	0.6895
7		BF	0.6610

with the conclusion drawn by the evaluation system, which shows that the TOPSIS method of entropy weight is applicable to evaluate the comprehensive road performance of the microsurfacing. The addition of fiber can effectively improve the road performance of polymer modified emulsified asphalt microsurfacing. The comprehensive road performance of WEREA-PPF microsurfacing is the best.

5. Conclusion

(1) Waterborne polyurethane can improve the water stability and low-temperature crack resistance of the WEREA microsurfacing. Compared with the WEREA fiber microsurfacing, the *WTAT* (immersion for 6 days) of the WERPUEA fiber microsurfacing reduced by 6–8%, the −10°C splitting strength increased by 4-5%, and the −10°C tensile strain increased by 4–6%.

(2) After adding fiber, the road performance of the microsurfacing increased by 10–30%. The addition of PPF has the greatest improvement on the bonding performance and water damage resistance of the microsurfacing, and the addition of BF has the greatest improvement on the deformation resistance, the 60°C dynamic stability, and −10°C splitting strength of the microsurfacing.

(3) The TOPSIS method of entropy weight is applicable to evaluate the comprehensive road performance of the microsurfacing. The PPF microsurfacing has the best comprehensive road performance, followed by the BF microsurfacing.

(4) This study comprehensively evaluated the road performance of polymer modified emulsified asphalt fiber microsurfacing. It is necessary to further clarify the mechanism of fiber strengthening various road performance of microsurfacing.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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