Properties study of asphalt containing deicing agent

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Abstract. In order to reduce the pavement wear caused by cracks which made by frost heave or temperature stress, the rubber powder or carbon black had been added to the asphalt roadbed with the as-prepared deicer agent, and the properties of the modified asphalt were evaluated by through penetration, softening point, ductility and Marshall test. The results showed that with the increase of the content of rubber powder (carbon black), the penetration and ductility of the asphalt decreased, and the softening point decreased slightly. When the content of rubber powder and carbon black was 10%, the modified effect of asphalt was the best. When the as-prepared deicer agent and rubber powder (carbon black) are added into the asphalt, the asphalt has some antiseptic and antifreeze properties, and the stability and flow value of the modified asphalt mixture increase, and the wear resistance of the asphalt pavement is increased.

1. Introduction

With the increasing traffic flow, the worn of asphalt pavement is becoming more and more serious. The ice and snow weather will make asphalt pavement skidding, and cause traffic accidents, the other, the pavement will easy to crack and worn in the casuse of frost heave effect [1]. At present, the main method to solve the pavement worn problem is to overlay the anti-skid layer [2], and another method is to improve the temperature sensitivity of asphalt [3].

Now, some research focuses on the anti-spalling, antiskidding, low temperature cracking, temperature -sensitivity, ageing and anti-fatigue performance of asphalt pavement. Many studies have shown that it can improve many properties of asphalt pavement [4] by adding rubber powder into asphalt, such as improving the wear resistance of the pavement and reducing the noise. There are many micropores on the surface of carbon black, which increasing its surface area, and it can be completely dispersed in asphalt to enhance the wear-resistance, durability and temperature- viscosity sensitivity of asphalt.

Adding deicer in asphalt is one of the effective methods [6] to reduce the influence of ice and snow weather on asphalt pavement. In this paper, waste rubber powder (120 mesh) and carbon black (N330) are used as two different additives mixed with the deicer which synthesized in our laboratory to improve the property of asphalt pavement. The optimum ratio of asphalt additive content is obtained according to the analysis results.

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2. Experimental

2.1. Reagents and instruments

The chemical reagents are analytical pure reagents produced by Xilong Chemical Co., Ltd. Asphalt (93 # SBS modified), rubber powder (120 mesh, 1.18g/cm^3) Carbon black (N330, residue of 100 mesh sieve <0.1%; surface area 103m^2/kg) is produced by Foshan Liju Chemical Co., Ltd. Deicer (white particles) is prepared in this laboratory. LJS type Marshall electric compactor, DF-5 type Marshall Stability tester, CXS-2801 type asphalt penetration tester and CXS-2806 type softening point tester were all purchased from Zhejiang Chenxin Machinery Equipment Co., Ltd.

2.2. Modification of asphalt and sample test methods

Asphalt dehydration is carried out according to the reference [7]. The step is as below: heated up to no bubbles in an oven with constant temperature 80°C. Four weighted asphalt samples were added to a metal bowl respectively, heated and melted, then mixed with different weights of rubber powder [8-9] or carbon black under stirring with a constant speed. When the mixture was completely uniform, then poured into a clean and dry can, labeled and tested. The prepared asphalt samples with different content additives were heated in a blast oven at 135°C for 2 hours, then the samples pass over the standard sieve, then filled with mold.

The penetration of modified asphalt [11] was determined by JTJ/T0604-2011 method, the ductility of asphalt was determined by GB/T4508-1999 and JTJ/T0605-2011 methods, and the softening point of asphalt was determined by JTJ/T 0606-2011 method.

2.3. Marshall Stability test

Marshall Stability test is used to design and test the mixture ratio of asphalt mixture [12]. The antistripping ability of asphalt is evaluated by immersion Marshall Stability test [13]. The asphalt-aggregate ratio tested in this paper is 4.8%.

3. Results and analysis

3.1. Penetration analysis

The penetration results of each samples are shown in Figure 1, and the unit is 0.1mm. It can be seen that the penetration of base asphalt is 60, and it belongs to SBS (I-D) class according to the technical requirements of polymer modified asphalt [12]. It will decrease the penetration of asphalt by adding additive in asphalt, and decreased significantly with the increase of additive content. From Figure 1, the penetration of asphalt added with rubber powder is always higher than that of carbon black.

3.2. Ductility analysis

The ductility of each samples at the tensile speed 5cm / min under 25°C are shown in Figure 2. The ductility of asphalt is greater than 100cm. The ductility value of the asphalt decreases with the increase of the additive (rubber powder or carbon black). The ductility of asphalt with rubber powder is lower than that of asphalt with carbon black at the same concentration, which is related to the particle size of rubber powder larger than N330.

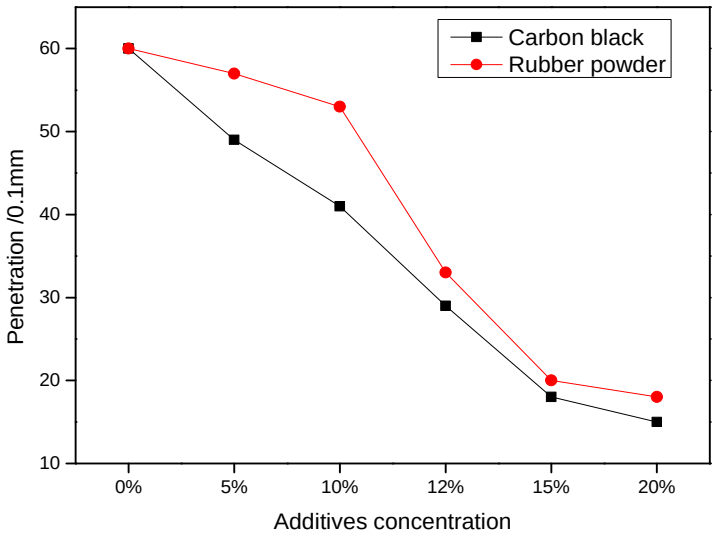


Figure 1. Relationship between Penetration and additive content

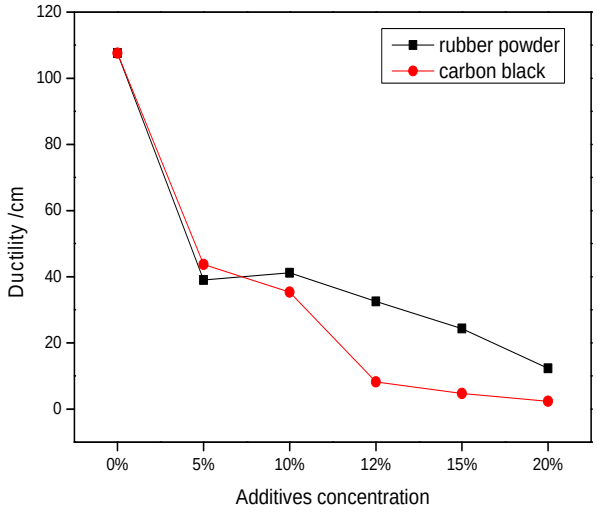


Figure 2. Relationships between ductility and additive content

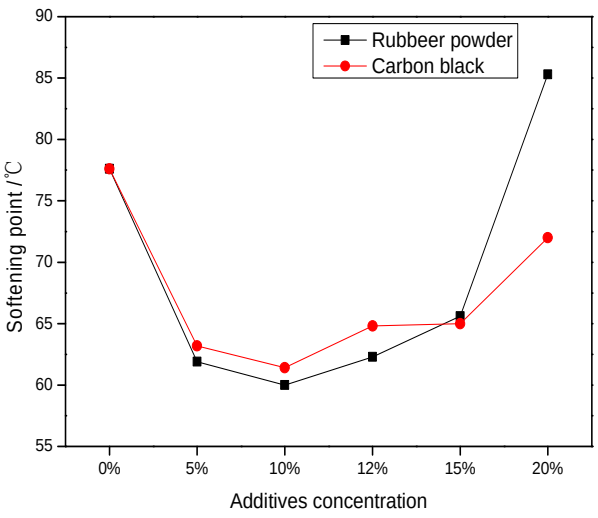


Figure 3. Relationship between softening point and additive content

3.3. Softening point analysis

The softening point of each samples were determined, and the result is shown in Figure 3. The softening point of asphalt is 77.6°C, and the softening point of samples with different content additives are greater than 60°C. The softening point of modified asphalt is lower than that of matrix asphalt, which meets the technical requirements. However, the softening point of asphalt containing 20% rubber powder rises sharply, because too high addition makes the stiffness of asphalt too large, and the viscosity is small, so it is not easy to soften. In the range of 5%~15% addition, the softening point of asphalt with carbon black is higher than that with rubber powder, because the carbon black can increase asphalt rigidity more than rubber powder. When the additive content is 10%, the softening point of asphalt is the lowest, so the best content of additives is 10.0%.

3.4. Marshall Stability test

(1) Screening of aggregates

Divide the aggregate samples according to the standard [14] and collected with divider according to the standard of Table 1. After air drying, reserved the sieve according to the size of the sieve hole. The experimental results of sieving of aggregate and mineral powder are shown in Table 2.

Table 1. The minimum amount of sample required

Nominal maximum particle size /mm	75	63	37.5	31.5	26.5	19	16	9.5	4.75
sample quality not less than/kg	10	8	5	4	2.5	2	1	1	0.5

Table 2. Results of sieving of aggregate and mineral powder

Sieve size	16.0	13.2	9.5	4.75	2.36	1.16	0.6	0.3	0.15	1.175
	Ratio of over square sieve									
1#	100	92.4	14.1	0.8	0.8	0.8	0.8	0.8	0.8	0.4
2#	100	100	97.6	14.7	4.6	0.8	0.8	0.8	0.8	0.4
3#	100	100	100	93.5	73.1	56.2	38.6	27.5	18.6	12.8
4#	100	100	100	100	100	100	100	100	97.8	88.8

The size of the sieve hole is mm. The size of 1# aggregate sample is 10-15mm, the size of 2# aggregate sample is 5-10mm, and the size of 3# aggregate sample is 0-5mm, the 4# aggregate sample is mineral powder.

(2) Aggregate density

Get the aggregate screened according to the standard, and the minimum mass of the sample required for measuring density is shown in Table 3 [15].

Table 3. The minimum amount of aggregate per gear

Nominal maximum particle size /mm	4.75	9.5	16	19	26.5	31.5	37.5	63	75
Minimum mass per quality	0.8	1	1	1	1.5	1.5	2	3	3

Each aggregate was soaked in water which higher 20 mm above the aggregate surface for 24 hours. The mass of each aggregate in different environments was weighed by basket method [31]. According to the measured data, the density of the aggregate is 2.695 g/cm3.

(3) Marshall test piece, test density and water absorption of asphalt mixture

Table 4. Percentage and quality of each aggregate

Aggregate diameter range / mm	16~9.5	9.5~4.75	4.75~2.36	2.36~0	Mineral powder
Proportion	23%	32%	14%	28%	3%
Mass	1656	2304	1008	2016	216

The maximum nominal diameter of aggregate is 16mm in this experiment, so the standard size used in the test. The total 7200g screened and dried aggregates was weighed in proportion, and the proportions and quality of each aggreate are shown in Table 4. The proportionally picked aggregate, the iron bowl for load asphalt and the Marshall specimen were put into an oven at 180°C for 1 h. The asphalt is also heated to 160°C in another oven. The heat preservation aggregate were pour into the barrel from big to small size in turn, and then added 290.304g hot asphalt. After mixing 90s, the mineral powder, 20.736g deicer and 34.56g carbon black (N330) or rubber powder in advance are added, continue to stir for 3min. About 1200g stirred aggregate was put in the iron bowl previously placed in an oven for insulation, and after weighing, put it in the oven for keeping warm at least 10min. start the Marshall electric compactor,

and the compaction times were 75 times [16]. The quality and height of the Marshall Test piece are shown in Table 5. The SA, γf and ρf of the specimens were tested by surface-dry condition method [17] are also shown in Table 5.

Table 5. The quality and height of Marshall Specimen

Sample number	Asphalt + carbon black + deicer					
	1#	2#	3#	4#	5#	6#
Sample quality/g	1169.4	1174.4	1184.0	1178.5	1170.9	1168.5
Sample height /mm	63.9	62.5	63.2	65.3	65.7	63.9
S_a	1.2	1.6	1.6	1.1	0.7	1.2
γ_f	2.308	2.299	2.293	2.320	2.317	2.300
ρ_f	2.255	2.246	2.240	2.267	2.264	2.247
νν	10.3	10.7	10.9	9.9	10.0	10.6
Sample number	Asphalt + rubber powder + deicer					
	1#	2#	3#	4#	5#	6#
Sample quality/g	1175.4	1159.4	1162.1	1163.7	1161.5	1163.8
Sample height /mm	66.8	63.7	63.4	63.8	63.0	63.4
S_a	1.6	0.4	1.8	1.6	1.9	1.3
γ_f	2.346	2.463	2.300	2.294	2.305	2.330
ρ_f	2.292	2.407	2.293	2.241	2.252	2.277
νν	8.8	4.3	10.6	10.9	10.4	9.5

According to the experimental results, the water absorption rate of the specimen is less than 2%, which indicates that the Marshall Test specimen meets the requirements. From the Table, although the quality of some test pieces is small, the height of the test pieces is large. The main reason is that the speed is too slow, causing the temperature of the asphalt mixture to drop when the asphalt mixture is poured into the test mold, so the Marshall Test piece has a lower density.

(4) Standard Marshall Stability test

The test piece which has been measured for density and dried is placed in a water tank at a constant temperature of 60°C for 30 minutes, and its stability and flow values were measured as shown in Table 6. According to the Marshall test mix design standard of stabilized asphalt gravel mixture, the stability of the modified asphalt should be not less than 7.5KN, and the flow value should be in the range of 15~40 (0.1mm). The test measured data is in line with the standard, and the flow value and stability of the asphalt added rubber powder and deicer are not much different from that of asphalt added carbon black and deicer.

Table 6. Standard Marshall Test flow value and stability

Sample number	Asphalt + carbon black + deicer			
	1#	2#	3#	average value
Stability /KN	14.82	12.98	11.42	13.07
flow value /(0.1mm)	23.7	23.6	23.5	23.6
Sample number	Asphalt + rubber powder + deicer			
	1#	2#	3#	average value
Stability/KN	13.18	12.62	12.08	12.63
flow value /(0.1mm)	24.8	24.6	23.73	24.38

(5) Immersion Marshall Stability test

The difference between the immersed Marshall test and the standard Marshall test is that the holding time of specimen of the immersion Marshall Test is 48h in a constant temperature water tank at 60°C.

The experimental results are shown in Table 7, the results showed that the addition of deicer does not affect the usage performance of the asphalt.

Table 7. Stability

Sample number	Asphalt + carbon black + deicer			
	1#	2#	3#	average value
Stability /KN	9.68	9.34	9.13	9.38
Sample number	Asphalt + rubber powder + deicer			
	1#	2#	3#	average value
Stability /KN	9.50	8.88	9.24	9.21

3.5. Ant freezing of deicer and freezing test of core sample

(1) Antifreeze test of deicer

In order to test the antifreeze performance of additives, four beakers were added with 3.0g sodium chloride, synthesized deicer and commercial deicer respectively, and a blank test was carried out with the same amount of deionized water. It is frozen in the freezer area (-20 °C) of the refrigerator for 6h, and the freezing phenomenon is shown in Figure 4. The results show that the water has been completely frozen, the samples containing 3.0g sodium chloride is basically frozen. There has some broken ice in the liquid surface which containing 3.0g synthesized deicer, and there also has a thin layer of ice in the liquid surface which containing 3.0g commercial deicer, it shows that the synthesized deicer can reduce the freezing point of water very well, and the decing property can reach that of commercial product.

The frozen asphalt pavement core sample is frozen in the freezer area of refrigerator, and the icing phenomenon is shown in Figure 5. Figure 5(A) and (B) are the results of icing on the refrigerator for 24h. In Figure 5(A), it can be seen that there has a thin layer of ice on the core sample surface which adding synthesized deicer, similar to the core sample which added commercial deicer in Figure 5(B). Figure 5 (C) take on the results of core sample frozen for 10h, the left is the core of adding synthesized deicer, and the right is the core of adding commercial deicer, all of them have a layer of frost on the surface, but the frost in the right is thinner.



Figure 4. Frozen for 6h

(2) Freezing test of core sample



(a) (b) (c)

Figure 5. Icing of the asphalt pavement core sample

(3) Antiseptic test of deicer

Four jars were added with 5.0g calcium chloride, 5.0g synthesized deicer and 5.0g commercial deicer respectively, and a jar was carried out with the same amount of deionized water as blank test. The solution was accelerated dissolution by ultrasonic dispersion. After being dissolved, the polished rebars were put into the jar and observe the rust result, and the records are shown in Table 8 and Figure 6.

Table 8. Results of corrosion of reinforcing bars by five solutions

Sample	Water	calcium chloride	Synthesized deicer	commercial deicer	time
PH	7	6~7	13~14	13~14	0h
phenomenon	Clear, bright, colorless, rusty.	Clear, bright, colourless and rust free.	Emulsion, rust free.	White suspended layer, emulsion, rust free	
PH	5~6	6~7	13~14	13~14	3h
phenomenon	Yellowish, a little rust.	clear and bright, rust free	clear and bright, rust free	Emulsion, white suspension, rust free	
PH	5~6	6~7	13~14	13~14	10h
phenomenon	Yellow, covered with rust.	Yellowish, a little rust.	clear and bright, rust free	clear and bright, some white suspension, rust free	
PH	5~6	6~7	13~14	13~14	35h
phenomenon	yellow brown, surface of steel full of rust and black	Black; a lot of rust, rebar black.	solution clarified, several rusty spots	clear and bright, some white suspension, rust free	
PH	5~6	6~7	13~14	13~14	15d
phenomenon	Dark brown, rebar becomes dark.	Dark brown, rebar becomes dark.	Solution clarified, a small amount of rust	Solution clarified, a small amount of rust	



(A) (B) (C) (D) (E)

Figure 6. Soaking result of steel bar

In Figure 6, Figure (A) is a steel bar immersed in a commercial deicer, with a few rust spots; Figure (B) is a steel bar immersed in a synthesized deicer, with a few rust spots; Figure (C) is a steel bar immersed in calcium chloride, covered with rust, steel black; Figure (D) is a steel bar immersed in water, covered with rust and turned dark black; Figure (E) is the result of immersion solution.

3.6. Analysis of metal elements in leaching solution

The content of metal elements in leach solution were determined by plasma emission spectroscopy (ICP), and the results are shown in Figure 7. The main composition of the rebar steel is Fe, C, Si, Mn, P, S and other elements. From the Figure, it can be seen that the content of Fe, P, S and other elements in the water immersion solution is higher, corresponding to the most serious corrosion, and there is a dark black FeS on the surface of rebar steel. There are also having many sulfur elements in calcium chloride soaking solution, and the contents of elements in commercial deicer and synthesized deicer soaking

solution are lower than those in water and calcium chloride soaking solution, indicating that synthesized deicer agent and commercial deicer are basically non-corrosive to the rebar steel.

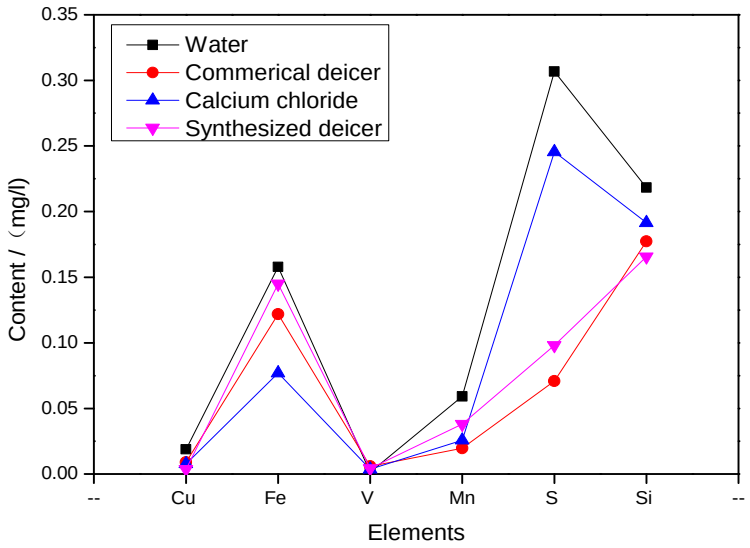


Figure 7. Qualitative analysis results of soaking liquid elements

According to the observation of the corrosion of rebar steel, it can be concluded that the synthesized deicer agent and commercial deicer do not corrode the rebar steel. When paving the asphalt pavement, a certain amount of deicer can be added into the asphalt, and it do not corrosive the steel of the bridge. At the same time, by comparing the two experiments of adding calcium chloride and deicer, it is concluded that the antirust effect of deicer is not due to calcium chloride, but the structure of deicer (surface modified calcium chloride). For commercial deicer and synthesized deicer, the synthesized deicer has the same anticorrosion effect as the commercial deicer, and they all have a very good anticorrosion effect. According to the ice test of deicer, it can be concluded that both commercial deicer and prepared deicer have good freezing resistance.

4. Conclusion

Based on the above analysis, we can draw the following conclusions:

(1) The modification of asphalt is evaluated by the values of penetration, ductility and softening point. The test results of asphalt modified with rubber powder and carbon black can meet the technical requirements of asphalt modification. The modification effect is better at 10% additive, whether it is 120 mesh rubber powder or carbon black N330 as modifier.

(2) The stability and flow value of asphalt in Marshall Test will increase by addition of carbon black N330 and 120 mesh rubber powder, which shows that the addition of additives will increase the stiffness and stability of asphalt mixture, which can increase the worn-resistance of asphalt pavement.

(3) The commercial deicer and synthesized deicer not only have good anti-corrosion ability to rebar steel, but also have good anti-freezing effect. It can prevent the road from freezing at low temperature, and it can play a certain role in maintaining the road surface.

Acknowledgements

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