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Anti-icing Capacity and Service Life Research on the Controlled Released Anti-icing Asphalt Modifier

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Abstract. The release rate of chloride ions could be controlled by adding additives into the anti-icing modifier, for the purpose of extending the modifier's usage life. The anti-icing capacity of the modifier with controlled released additives was researched in this paper by the "Chloride ion concentration change monitoring test" and "Dynamic water simulation test", and the service life of the modifier has been analyzed.

1 Introduction

Road icing is regarded as one of the most dangerous factors of causing traffic accidents in winter. Therefore, to discover an efficient, economic and environmentally friendly anti-icing way to guarantee safety driving on roads has become a hot-button issue to the road managers[1]. Nowadays, commonly used methods are spreading snow melting additives, manpower ice removal, etc., which seems to be inefficiency, and harmful to the environment once the excess salt permeates the surrounding soil[2]. Adding anti-icing modifiers into the asphalt mixture has been known as an effective approach. However, as the salt based components would be rapidly separated out when it meets water, the durability of the modifier is sometimes unsatisfied and the usage life is often shorter than what it has been originally designed[6].

To prevent the modifier's excessive dissolution in water condition in rainy summer seasons, and ensure its working performance in winter, a new kind of anti-icing modifier with controlled released additives has been independently researched and developed in this paper. Its validity has been firstly evaluated based on capacity tests, and the service life has also been predicted at last.

2 Determination of the modifier's optimum adding amount

The anti-icing modifier plays a key role to the freeze-thaw splitting strength of the asphalt mixture. The freeze-thaw splitting strength of asphalt mixture was verified by the addition of different anticoagulant ice modifiers, for determining of the modifier's optimum adding amount.

It is can be seen from figure 1, with the addition of the anti-icing modifier, the strength of the AC-13 has gradually increased after the freeze-thaw cycles. The possible reason is that at the temperature of -18℃, the anti-icing modifier has a reaction with asphalt and then its strength increased and become a permanent strength. When freezing and thawing finished, the anti-icing modifier has played a role during both the splitting process and insulation at the water of 25℃, which led to a result that the strength of the mixture after adding the modifier was higher than those without the modifier. The more amount of the anti-icing modifier was added, the trend was more obviously to see.

With addition of the anti-icing modifier, freeze-thaw splitting strength ratio increased first and then decreased. When the adding amount of the modifier was 5% of the asphalt mixture, the freeze-thaw splitting strength has reached the peak value. Freeze-thaw splitting strength ratio was mainly affected by the strength of after and before the freeze-thaw procedure. The modifier gave a significant influence to the splitting strength after freezing and thawing, thus the ratio was changing along with the adding amount of the modifier. According to the research, it can be seen that the optimum adding amount of the modifier in the asphalt mixture was suitable for 5%

3 Anti-icing Capacity Research

Apply the "Rapid Determination of Chloride Ion Content Instrument" to assess the release rate of the chloride ion. Via the tests of "Chloride ion concentration change monitoring" and "Dynamic water simulation", the capacity of the anti-icing asphalt modifier with the controlled released additives has been analyzed.

3.1 Chloride ion concentration change monitoring test

3.1.1 Test method

Marshall Specimens named A and B were prepared and totally soaked in water at the room temperature for 24h/d, continuously lasted for 20 days. Test the chloride ion concentration daily. The durability of the modifier could be evaluated by determining the change of chloride ion in solution. The tests results are shown in table 5 and figure 2.

3.1.2 Test results analysis

The ratio of the modifier was 5% of the asphalt mixture. Each Marshall Specimen was regarded as 1200g; the mass of the modifier was 60g/specimen. The molar mass of salt based chemical composition in the modifier was considered to be 33.8g/mol/specimen. After soaked for 20 days, the total amount of chloride ion separated out was 0.286mol/L, the loss mass was 10.15g/L, and the residual amount of the modifier was 49.98g. Therefore, in case of the worse immersion conditions on pavements, there was still enough residual modifier in the mixture, which can keep the capacity of anti-icing. The effect of controlling release has been achieved.

It is can be seen from the figure 2, with the separating out and dissolution of the chloride ion, the final concentration in water has reached a peak then become stable lines. It seems that the chloride ion which can be soaked and dissolved by water has totally been separated out. Considering the realities on roads, after continuous immersion, traffic loads was supposed to be the main reason that caused the residual chloride ion precipitation, to against the road icing year by year.

Thus, the chloride ion can be controllably released and the modifier's working performance can be trusted in winter. The durability of the modifier was satisfied.

3.2 Dynamic water simulation test

3.2.1 Test method

Make three anti-icing asphalt mixture specimens, soaked them into the water at temperature of -10℃，0℃，5℃，15℃，25℃，35℃, respectively. According to the average annual rainfall of 72L in the test area, spray water to the specimens in 10 times until it has reached the total amount of the average annual rainfall. Under the condition of simulated hot and rainy summer season, test the chloride content of the collecting water after every time shower to determine the loss amount of the chloride ion in each specimen. The test results are shown in Table 6 and Table 7.

3.2.2 Test results analysis

The adding amount of the modifier with the controlled release additives was 5% of the mixture. As the weight of the every rutting specimen was 10500g, the mass of the modifier was 525g for each. After shower for 10 times, the residual amount of the modifier can be calculated by the loss amount of the chloride ion tested in the collecting water shown in Table 6. The molar mass was considered to be 33.8g/mol of the modifier for each specimen.

It is can be seen form Table 6, after 10 times shower onto the three rutting specimens at each temperature above, the test result showed that the amount of the chloride ion in the collecting solution was gradually increased after each time shower. It impacted that in the situation of wet pavement, there was partial loss of the chloride ion of the modifier. However, it also can be seen from the calculation in table 7 that, after a year of concentrated rainfall, there was still anti-icing modifier existed in the rutting test specimen. It indicated that under the function of the controlled release addictive, the average annual rainfall would neither wash away the whole efficient part of the modifier, nor cause a decisive influence to decrease its anti-icing working capacity in winter.

Figure 3 has shown that, there was no obvious difference of the chloride ion precipitation when it was tested at a high or low temperature. As the modifier was wrapped by asphalt, with the combination effect of the controlled release additives, great loss of the chloride ion in the modifier has been successfully prevented. Thus, in hot rainy summer, it will not cause a large amount of dissolution of the modifier, and the anti-icing function could be guaranteed.

4 Service life prediction

According to table 7, after raining for a year, there was still a satisfied amount of modifier stayed in the specimen. According to the calculation of annual loss, the modifier was predicted to be used for approximately 14~20 years. With the function of the controlled released additives, the durability of the modifier was approved, and the target of road safety driving in winter could be achieved.

5 Conclusions

(1) Deposition rate of the chloride ion could be decreased by adding the controlled released additives into the anti-icing modifier, and the excess loss could be reduced.

(2) According to the whole day immersion and the average annual rainfall water spray tests, the ice removal working performance has been analyzed. Moreover, the loss ratio of the modifier has been calculated and the usage years was predicted. The test results showed that the modifier has satisfied anti-icing capacity, and the release rate of the modifier can be controlled.

(3) With the function of the addictives, the chloride ion would not sharply deposit, therefore the modifier would sustained release for the design years. The effective service life of the modifier has been extended.

Table 1. AC-13 with 0% modifier freeze-thaw splitting strength test.

Adding amount (%)	Height (mm)	Air weight (g)	Water weight (g)	Dry weight (g)	Bulk density (g/cm^3)	Splitting load (kN)	Flow value (mm)	Strength before freeze-thaw (MPa)	Strength after freeze-thaw (MPa)	Strength ratio (%)
0	64.1	1296.9	796	1299.4	2.576	11.01	2.23	/	1.08	83.07
	64	1291.2	790.1	1293.2	2.566	12.69	2.63	1.247	/	
	63.4	1292.3	791.1	1293.3	2.573	11.89	2.61	/	1.168	
	63.4	1291.2	788.2	1292.6	2.56	13.82	2.91	1.37	/	
	64.4	1295	791.5	1297.1	2.561	10.43	2.36	/	1.018	
	64.5	1291	789.8	1293.9	2.561	13.00	1.81	1.267	/	
	64.2	1288.9	789.4	1290.6	2.572	12.56	2.05	/	1.23	
	63.8	1288.5	788.2	1290.3	2.566	15.51	2.53	1.528	/	
Average	64	1291.9	790.5	1293.8	2.567	/	/	1.353	1.124	

Table 2. AC-13 with 2% modifier freeze-thaw splitting strength test.

Adding amount (%)	Height (mm)	Air weight (g)	Water weight (g)	Dry weight (g)	Bulk density (g/cm^3)	Splitting load (kN)	Flow value (mm)	Strength before freeze-thaw (MPa)	Strength after freeze-thaw (MPa)	Strength ratio (%)
2	63.3	1289.6	791.4	1290.9	2.582	12.21	2.23	1.213	/	89.16
	62.8	1286.1	791.1	1286.9	2.594	11.81	1.69	/	1.182	
	62.9	1285.3	789.4	1286.4	2.586	13.77	2.24	1.376	/	
	63.1	1286	792.2	1287.2	2.598	11.96	2.28	/	1.192	
	63.6	1287.3	788.9	1288.9	2.575	13.30	1.96	1.315	/	
	62.9	1283.3	787.6	1284.2	2.584	11.22	1.69	/	1.121	
	62.8	1283.6	789.3	1284.8	2.591	13.96	1.76	1.398	/	
	62.6	1283	787.6	1284.2	2.584	12.26	2.34	/	1.231	
Average	63	1285.5	789.7	1286.7	2.587	/	/	1.325	1.182	

Table 3. AC-13 with 4% modifier freeze-thaw splitting strength test.

Adding amount (%)	Height (mm)	Air weight (g)	Water weight (g)	Dry weight (g)	Bulk density (g/cm^3)	Splitting load (kN)	Flow value (mm)	Strength before freeze-thaw (MPa)	Strength after freeze-thaw (MPa)	Strength ratio (%)
4	63.1	1292.9	795	1293.9	2.592	11.93	1.8	1.189	/	98.02%
	63	1288.8	795.1	1289.8	2.605	12.2	2.38	/	1.217	
	63	1291.3	793.6	1292.4	2.589	14.17	2.85	1.414	/	
	62.5	1289.7	793.2	1290.5	2.593	13.31	2.25	/	1.339	
	63.5	1292.5	792	1293.5	2.577	12.06	2.3	1.194	/	
	63.5	1291.7	795.2	1293	2.595	12.44	2.09	/	1.232	
	63.2	1290.6	793.7	1292.2	2.589	13.33	1.96	1.326	/	
	63.4	1291.8	788	1293.4	2.556	12.44	2.1	/	1.234	
Average	63.2	1291.2	793.2	1292.3	2.587	/	/	1.281	1.255	

Table 4. AC-13 with 6% modifier freeze-thaw splitting strength test.

Adding amount (%)	Height (mm)	Air weight (g)	Water weight (g)	Dry weight (g)	Bulk density (g/cm^3)	Splitting load (kN)	Flow value (mm)	Strength before freeze-thaw (MPa)	Strength after freeze-thaw (MPa)	Strength ratio (%)
6	64.2	1295.6	796.3	1297.8	2.583	12.49	2.21	0	1.283	96.30%
	63.2	1291.9	795.4	1292.9	2.597	15.95	2.23	1.487	0	
	63.3	1292.6	796	1293.7	2.597	14.91	2.34	0	1.481	
	63.1	1293.4	795.3	1294.2	2.593	17.00	1.96	1.494	0	
	64.5	1295.3	792.6	1297.3	2.566	14.58	1.71	0	1.421	
	62.7	1290.3	791.8	1291.5	2.582	16.91	1.72	1.496	0	
	62.8	1294	794.2	1295.3	2.582	15.69	2.05	0	1.571	
	63.5	1289.3	792.4	1290.7	2.587	19.19	1.81	1.5	0	
Average	63.4	1292.8	794.3	1294.2	2.586	/	/	1.494	1.439	

Table 5. Immersion test result of the anti-icing asphalt mixture specimen.

Sample	Cl^- concentration（10^{-2}mol/L）									
	1	2	3	4	5	6	7	8	9	10
A	0.05	0.15	0.27	0.28	0.28	0.29	0.29	0.29	0.29	0.29
B	0.04	0.13	0.25	0.26	0.27	0.27	0.28	0.28	0.28	0.28

A continuation of the above table

Sample	Cl^- concentration（10^{-2}mol/L）									
	11	12	13	14	15	16	17	18	19	20
A	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
B	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29

Table 6. Shower test on the anti-icing asphalt mixture rutting specimen.

Cl^- concentration (mol/L) / Shower times	Test temperature					
	-10℃	0℃	5℃	15℃	25℃	35℃
1	0.00099	0.00076	0.00109	0.00085	0.00075	0.00086
2	0.00107	0.00083	0.00088	0.00085	0.00084	0.00082
3	0.00118	0.00086	0.00092	0.00087	0.00088	0.00084
4	0.00130	0.00085	0.00097	0.00104	0.00093	0.00090
5	0.00130	0.00087	0.00097	0.00108	0.00097	0.00092
6	0.00139	0.00090	0.00095	0.00106	0.00093	0.00092
7	0.00138	0.00094	0.00098	0.00106	0.00098	0.00098
8	0.00139	0.00098	0.00099	0.00112	0.00099	0.00096
9	0.00144	0.00096	0.00100	0.00121	0.00099	0.00101
10	0.00149	0.00097	0.00102	0.00116	0.00098	0.00097
Total	0.01294	0.00895	0.00982	0.01027	0.00930	0.00922

Table 7. Residual analysis of the anti-icing modifier.

Temperature	-10℃	0℃	5℃	15℃	25℃	35℃
Cl^- loss amount (mol/L)	0.01294	0.00895	0.00982	0.01027	0.00930	0.00922
Modifier loss amount (g/L)	0.45951	0.31784	0.34875	0.36474	0.33002	0.32738
Modifier loss mass after shower of 72L water (g)	33.08438	22.88472	25.10966	26.26108	23.76107	23.57119
Modifier residual mass (g)	491.9156	502.1152	499.8904	498.739	501.239	501.4289
Ratio of the modifier residual mass vs specimen total mass (%)	4.69%	4.78%	4.76%	4.75%	4.77%	4.77%
Ratio of the modifier loss mass vs specimen total mass (%)	0.31%	0.22%	0.24%	0.25%	0.23%	0.23%
Prediction of the modifier's working years	14.2	20.8	19.1	18.3	19.9	19.9

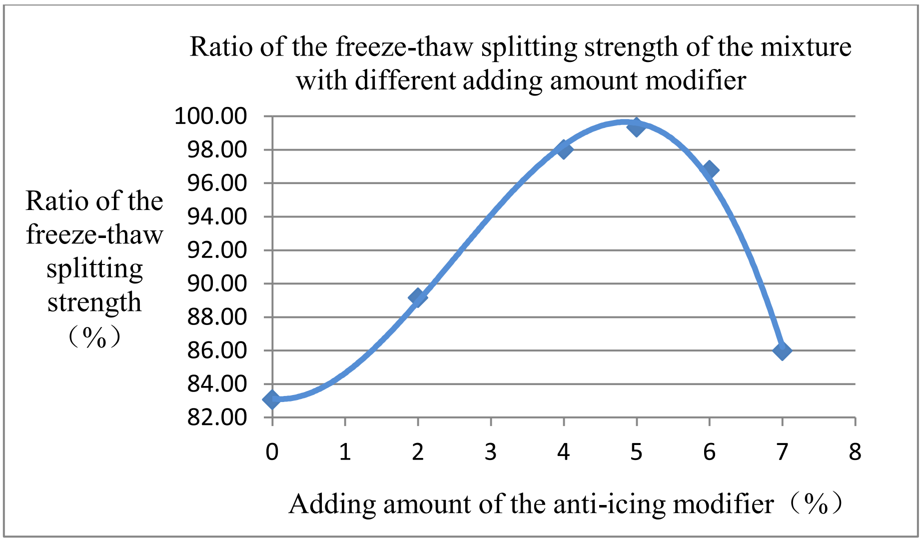

Figure 1. Ratio of the freeze-thaw splitting strength of the asphalt mixture with different adding amount modifier.

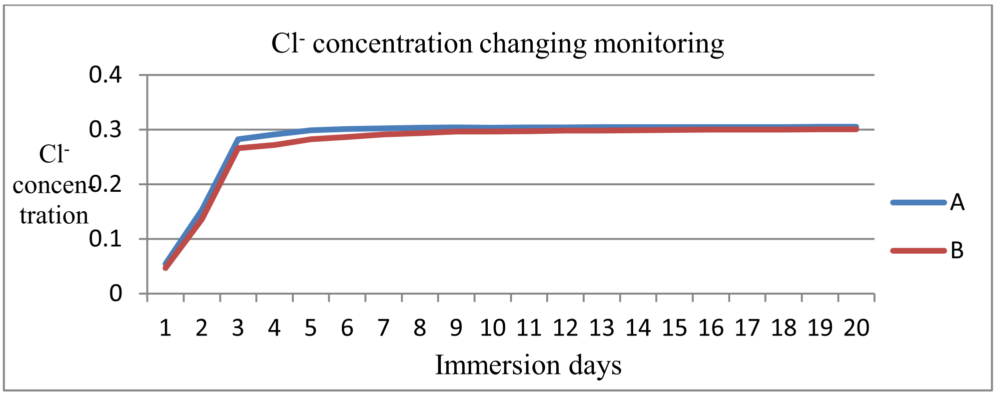

Figure 2. Precipitation of the chloride ion.

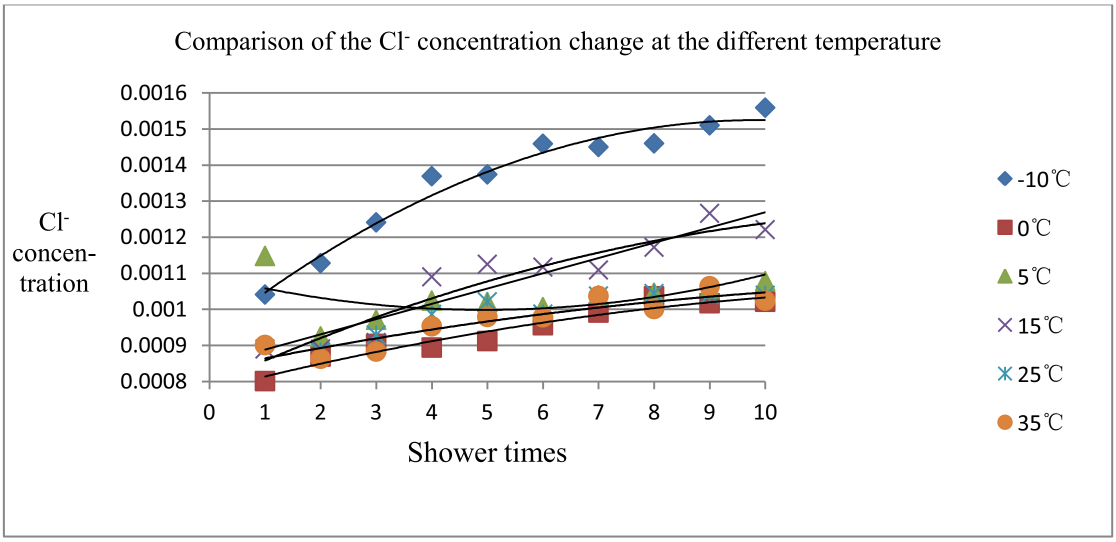

Figure 3. Shower test on the specimens at the different temperature.

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