Investigation of the effect of deicers on viscoelastic properties of asphalt mastics

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ABSTRACT

Achieving perpetual pavements requires many factors, among which winter road maintenance is of great importance. In the past decades, the use of chemical deicers has been very common, but their use caused damage to many transportation infrastructures. In the present study, to investigate the effect of deicers on asphalt pavement, asphalt mastic samples were used due to their great influence on the viscoelastic characteristics of asphalt mixtures. The samples were conditioned for 96 hours at 60°C in solutions of distilled water, salt, Calcium magnesium acetate, and Potassium acetate, and one sample was considered as a control, without conditioning. Then, all the samples were tested by frequency sweep test and the 2S2P1D viscoelastic model was fitted on the data. Analyzing the test results and model parameters showed that conditioning in brine solution softens the asphalt mastic samples. Calcium magnesium acetate increases the G* parameter at low loading frequencies (high temperatures). The effect of this deicer on the fatigue parameter is highly dependent on the loading frequency. The lower the loading frequency, the lower the mastic's resistance to fatigue failure. Potassium acetate increases the G* of mastic samples at medium and high temperatures. Also, all the deicers reduce the resistance of samples against rutting damage, and among them, Calcium magnesium acetate has the most damaging effect.

KEYWORDS

Viscoelasticity, 2S2P1D model, Asphalt mastic, Deicer, Winter road maintenance

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1. Introduction

Deicers, such as Sodium chloride, are widely used to prevent the formation of ice and snow on roads, but they can also have harmful effects on asphalt pavements. Studies have shown that deicers can cause softening of the bitumen, reduced pavement strength against moisture-related damages and increased cracking[1]. They can also cause metal corrosion and groundwater pollution. In recent years, researchers have been looking for alternatives to sodium chloride. Some of these alternatives include Magnesium chloride, Urea and organic acid salts. These materials are all less harmful than Sodium chloride, but they are more expensive[2]. Further study of the effects of deicers on asphalt pavements is essential in order to develop safer and more sustainable methods of de-icing roads. In a general conclusion, it can be stated that based on the past studies and the contradictory results reported on the effect of deicers on the performance of asphalt mastics and mixtures, one of the main reasons for the difference in the reported results, is the difference in the moisture conditioning methods and ignoring the impact of high temperatures on the effectiveness of deicers on asphalt mixtures[3-5]. Using more effective and modified methods that can accurately simulate the actual environmental conditions of the presence of moisture and deicers, seems necessary. Also, in the previous studies, just a few studies have been done on asphalt mastic characteristics, although this phase has the most impact on the rheological properties of the asphalt mixture, on the other hand, testing on it is much faster and less expensive than making the asphalt mixture and testing on it. Paying more attention to this phase and testing to determine its properties in a wide range of temperatures and loading frequencies, will help researchers to better understand the behavior of asphalt pavements that are exposed to moisture and deicers. On the other hand, due to the limitations of the devices to test at very low temperatures or very high frequencies, many of the results reported in previous studies, do not provide a correct understanding of the rheological properties of asphalt pavements, and researchers are forced to use models that can predict the behavior of asphalt pavements in a wide range of temperatures and loading frequencies.

2. Methodology

The main objective of this research study is to investigate the effect of the presence of distilled water, Sodium chloride, Calcium magnesium acetate and Potassium acetate as deicers on the rheological properties of asphalt mastic using a frequency sweep test at different temperatures. For this purpose, a Dynamic Shear Rheometer (DSR) was used to determine the rheological properties of asphalt mastic including complex shear modulus (G*) and phase angle (δ). The loading frequency was in the range of 0.01 to 10 Hz and the applied stress was determined in such a way that the strain is less than 1%, in which range it is assumed that bitumen and asphalt mastic are in the linear viscoelastic behavior range. Also, 5 temperatures including 15, 21.1, 37.8, 54.4, and 64 °C (based on the recommended temperatures of AASHTO T342 [7] for determining the dynamic modulus of asphalt mixture) were selected for testing.

3. Discussion and Results

Analysis of the results of the complex shear modulus master curve shows that at high loading frequencies (low temperatures), the mastic samples conditioned in the vicinity of Potassium acetate show higher complex shear modulus values. On the other hand, Sodium chloride and distilled water have made asphalt mastic samples softer at high loading frequencies (low temperatures). In the same way, it can be seen that at low loading frequencies (high temperatures) the samples conditioned in Sodium chloride and Potassium acetate show more hardness. Besides, the lower phase angle values of the mastic samples that were moisture conditioned in distilled water and Sodium chloride indicate that the behavior of the sample has become more elastic. This issue probably occurred due to the washing of bitumen from the surface of the mastic, and as a result, the proportion of bitumen and filler in the sample has changed. The leaching of bitumen from the surface of asphalt composites may occur with different mechanisms, which have been mentioned in previous studies [8], [9]. Investigating the rutting parameter of asphalt mastic samples at high temperatures shows that conditioning in the vicinity of distilled water and all the deicers at loading frequencies of 0.1 and 1 Hz has reduced the rutting resistance. Also, at the loading frequency of 0.01 Hz and at both temperatures of 54.4 and 64 °C, there is no significant difference between the rutting resistance for different samples. This issue is probably due to the fact that at high temperatures and very low loading frequencies, bitumen practically has no load-bearing capacity and it is the filler particles that react against the applied stresses. For this reason, the behavior of different samples is almost similar. The changes in the values of rutting and fatigue indices can be seen in Table 1.

Table 1. The changes in the values of rutting and fatigue indices

Index	Temperature	Frequency	Distilled water	NaCl	CMA	KAc
Rutting (G*/sinδ)	54.4	0.01	7	-8	-9	45
		0.1	39	21	45	35
		1	23	19	24	15
	64	0.01	-10	-9	13	20
		0.1	30	28	35	34
		1	9	13	23	27
Fatigue (G*.sinδ)	15	0.1	0	4	-16	-36
		1	6	26	-6	-10
		10	6	29	-2	-6
	21.1	0.1	0	-4	-27	-63
		1	13	8	-17	-49
		10	18	19	-7	-8

In a general summary, based on the results obtained from the investigation of the fatigue parameter at intermediate temperatures, it can be concluded that moisture conditioning in the vicinity of distilled water and Sodium chloride causes the softening of asphalt mastic and, as a result, the reduction of the G*×sinδ parameter, which can represent a decrease in the sensitivity of mastic to fatigue failure. Also, for all loading frequencies, moisture conditioning in the vicinity of Calcium magnesium acetate and Potassium acetate increases the G*×sinδ parameter, and the probability of failure due to repeated loading and fatigue failure will increase.

4. Conclusions

- Moisture conditioning in the vicinity of distilled water, and/or Sodium chloride causes softening of asphalt mastic at low loading frequencies (high temperatures) and, as a result, decreases the value of G*.

- Calcium magnesium acetate increases the G* parameter at low loading frequencies (high temperatures). The effect of this deicer on the fatigue parameter is highly dependent on the loading frequency, in such a way that the lower the loading frequency, the lower the resistance of the mastic against fatigue failure.

- All the deicers reduce the resistance of asphalt mastic against rutting damage, and among all, Calcium magnesium acetate has the most damaging effect.

- Potassium acetate increases the amount of G* of asphaltic mastic at intermediate and high temperatures.

- The effect of Calcium magnesium acetate and Potassium acetate on the fatigue resistance of mastic samples is highly dependent on the loading frequency. The lower the loading frequency, the less resistant the samples are to fatigue failure.

- The results of the goodness of fit of the 2S2P1D model show that this model can fit the asphalt mastic data with excellent accuracy.

- Investigating the h and k parameters in the 2S2P1D model shows that moisture conditioning in the vicinity of distilled water and the deicers does not change the elasticity of the mastic samples. Also, the G0 parameter did not change with moisture conditioning in the distilled water or the deicers.

- Moisture conditioning in the distilled water and the deicers had the most effect on the τ0 and Gg parameters and can change the viscoelastic characteristics of asphalt mastics.

5. References

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