THE EFFECT OF SALT SOLUTION ON ASPHALT PAVEMENTS AND ROAD MATERIALS

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ABSTRACT

In this study, the effects of salt on the asphalt pavements were investigated. The Standard tests were applied to the binder, aggregate and the polymer modified bitumen, before and after salt solution conditioning process, to define their properties and to compare the results. The conventional binder was modified by adding %5 SBS to the penetration grade B50/70 bitumen. The Penetration, Softening point, Elastic recovery, Force ductility and Determination of the Fraass breaking point tests were applied to the binder samples. Two different conditioning processes were implemented. The first one was conditioning with 5˚C deg water for 5 days and the second one was conditioning with salt solution containing of %23 salt, for the same temperature and duration. Two types of aggregate were used. The first type was basalt; the second type was lime stone. Stripping, Absorption and Resistance to freezing and thawing tests were applied to the aggregate. The last step was analyzing of the mixes. Determination of the water sensitivity test and Resistance to fuel tests method (salt solution was used instead of fuel) were applied to the three common mix types, which are known as conventional Hot Mix Asphalt (HMA), Polymer Modified Asphalt (PmA) mixture and Stone Mastic Asphalt (SMA).
Comparisons were made between the non-conditioning and conditioning sample system, for all type of mixes and materials. The laboratory tests results carried on the asphalt concrete samples and mix variables are presented in the "Conclusions" section of the study.

Keywords: SMA, Asphalt, Salt solution, Salt, Road materials

1. INTRODUCTION

Keeping roads safe and passable is a key concern for any Municipality or Highway Authority, especially during the winter season when ice and snow accumulation on roads and bridges can create hazardous driving conditions. To accomplish this, Municipality and Highway Authorities are seeking out, and applying winter maintenance strategies that are cost effective and environmentally friendly. One such area where those strategies are being employed is the salt solution used as anti-icing. Deicing is defined as any effort to remove ice from road and bridge surfaces after ice deposition has occurred. This is in contrast to anti-icing, which is defined as a surface treatment applied prior to ice formation that eliminates ice accumulation or facilitates ice removal by lessening the bond between the ice and the riding surface. In general, deicing and anti-icing are accomplished through the use of various chemicals including aqueous solutions of chlorides (e.g. sodium chloride, and calcium chloride) or other chemicals such as calcium magnesium acetate and urea. Although the efficacy of these chemicals for deicing and anti-icing has been clearly demonstrated, possible detrimental effects to asphalt pavements in transportation structures have not been fully examined and documented. Based upon published research, the most problematic chemicals appear to be the chlorides of magnesium, calcium, and sodium and other chemicals containing calcium and magnesium. Use of these chemicals has increased given their relatively low cost, ease of use, and effectiveness for deicing and anti-icing, in certain applications.

The goal of this research was to examine the effects of anti-icing chemicals on asphalt pavements and to recommend changes to Hot-Mix Asphalt (HMA), Stone Mastic Asphalt (SMA) and Polymer Modified Asphalt (PmA) mixture designs, construction practices, and winter maintenance procedures that will make these solutions non-detrimental to pavement durability. The conventional binder was modified by adding %5 SBS to the penetration grade B50/70 bitumen. The Penetration, Softening point, Elastic recovery, Force ductility and Determination of the Fraass breaking point tests were applied to the binder samples. Two different conditioning processes were implemented. The first one was conditioning with 5˚C deg water for 5 days and the second one was conditioning with salt solution containing of %23 salt, for the same temperature and duration. Two types of aggregate were used. The first type was basalt; the second type was lime stone. Stripping, Absorption and Resistance to freezing and thawing tests were applied to the aggregate. The last step was analyzing of the mixes. Determination of the water sensitivity test and Resistance to fuel tests method (salt solution was used instead of fuel) were applied to the three common mix types, which are known as conventional Hot Mix Asphalt (HMA), Polymer Modified Asphalt (PmA) mixture and Stone Mastic Asphalt (SMA).

2. *MATERIALS*

Standard laboratory testing was performed to determine the effect of salt solutions on Hot Mix Asphalt (HMA) and Stone Mastic Asphalt (SMA) produced using conventional and modified bitumen with the same mix designs. HMA and SMA specimen samples were prepared with basalt, limestone and calcite as aggregate, B50/70 bitumen as binder, and Stiren-Bütadien-Stiren (SBS) as additives to modify the mix.

2.1. *Aggregate*

The objective of the tests which were carried on the aggregates was to determine the properties of both limestone and basalt (both coarse and fine materials) aggregate and to decide their availability of the mix.

Hot Mix Asphalt (HMA) and Stone Mastic Asphalt (SMA) specimen samples were prepared with limestone aggregate from Gebze/Kocaeli and basalt aggregate from Çorlu/Tekirdağ region quarries. The gradation chosen for this project is the wearing course Type1 gradation of Turkish Road Authority specification. Table 1 and Table 2 summarize the properties for such kind of aggregate distribution and specification. The graph for the SMA gradation and the specification limits are shown in Figure 1.

Table 1: Aggregate Size Distribution and Specification for SMA Type2

Sieve Size		**Specification SMA Type2 (%)**	**Passing Percent (%)**
No	**mm**		
1/2″	12,7	100	100,0
3/8″	9,52	90-100	91,1
No. 4	4,76	25-45	38,0
No. 10	2,0	20-30	24,0
No. 40	0,42	12-22	13,3
No. 80	0,177	9-17	10,6
No. 200	0,074	8-14	8,8

To determine the physical properties of the aggregates some standard tests were applied. These tests include Density, Absorption, Stripping resistance for both binders; conventional bitumen and modified bitumen, Resistance to Freezing and Thawing, Flakiness and Los Angeles Abrasion tests.

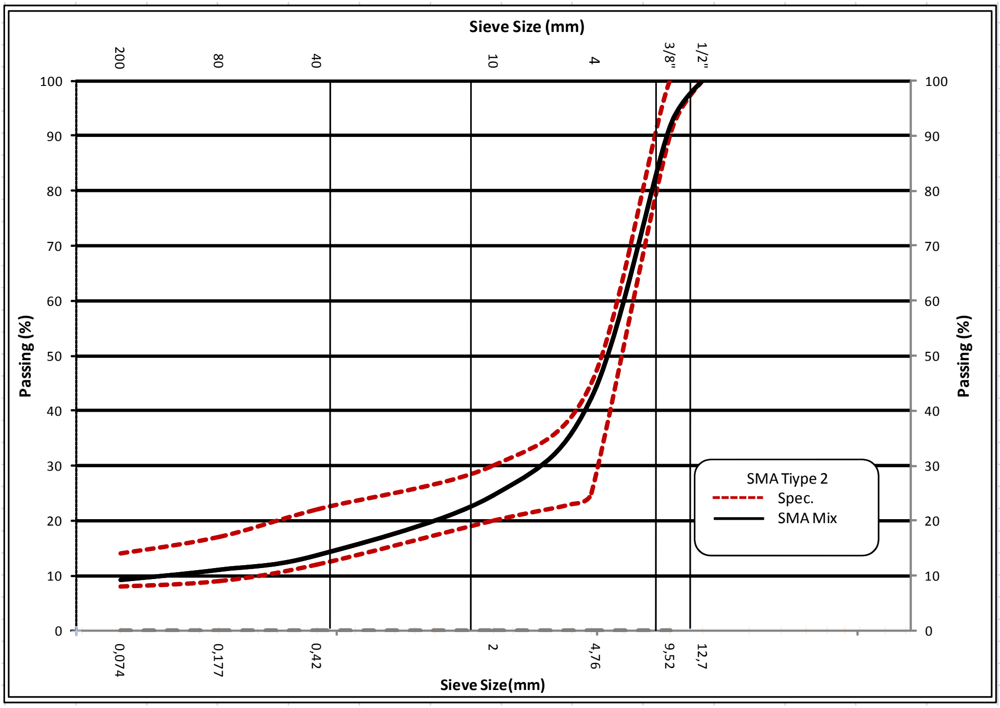

Figure 1: Aggregate Gradation for SMA Type2

Table 2: Size Distribution and Specification of HMA Type1

Sieve Size No	Sieve Size mm	Specification HMA Type1 (%)	Passing Percent (%)
3/4″	19,0	100	100
1/2″	12,7	83-100	89,6
3/8″	9,52	70-90	78,6
No. 4	4,76	40-55	52,7
No. 10	2,0	25-38	31,0
No. 40	0,42	10-20	12,5
No. 80	0,177	6-15	8,2
No. 200	0,074	4-10	5,9

The properties and test results for both limestone and basalt aggregates are shown in Table 3 and Table 4.

Table 3: Properties of Limestone Aggregates

Properties	**Method**	**Spec.**	**Test Results**
Density (g/cm^3)	TS EN 1097-6	-	2,80
Absorption (%)		Max. 2	0,49
Flakiness (%)	TS EN 933-3	-	16
Los Angeles coefficient (%)	TS EN 1097-2	Max. 25	12
Stripping resistance (%)	-	Min. 50	65-75
Resistance to freeze-thaw (%)	TS EN 1367-1	Max. 10	0,35

Table 4: Properties of Basalt Aggregates

Properties	**Method**	**Spec.**	**Test Results**
Density (g/cm^3)	TS EN 1097-6	-	2,84
Absorption (%)		Max. 2	1,26
Flakiness (%)	TS 9582 EN933-3	Max. 25	18,5
Los Angeles coefficient (%)	TS EN 1097-2	Max. 25	11,9
Stripping resistance (B 50/70) (%)	Nicholson	Min. 60	30-40
Stripping resistance (Modified B 50/70) (%)	Nicholson	Min. 60	75-85
Freeze-Thaw	TS EN 1367-1	-	0,69

It can be clearly seen from the tables above that, the limestone and basalt aggregates are available to be used for the mix and the test result values are stated inside the range of the specification.

2.2. Bitumen (B 50/70)

The binder (B 50/70 Bitumen) was taken from Turkish Petroleum Refineries Co. (TÜPRAŞ). In the binder testing system, samples of the binders qualified as 50–70 pen (B 50/70). Samples of binders were split and each binder was subjected to the oven of RTFOT using aging times of 5 days at a temperature of 5 ºC.

2.3. SBS (Stiren-Bütadien-Stiren) Agent

KRATON's Stiren-Bütadien-Stiren (SBS) were used as a bitumen modified polymer agent. KRATON SBS block copolymers have a molecular structure that is characterized by a rubbery core midblock, which for bitumen applications is usually made up of polybutadiene. However, for some applications out of polyisoprene, it is tipped at all ends with polystyrene end-blocks. The mixture conditions were; a temperature of 180ºC, a mix velocity of 3000 rpm and duration of 150 minutes.

3. EXPERIMENTAL PROGRAM

The laboratory study was conducted in four phases. Phase I involved the testing of conventional bitumen specimens (B 50/70), Phase II involved performing the same experiments used in Phase I, but with modified bitumen specimens (PmB of B50/70), Phase III involved the testing of aggregate specimens (Basalt and Lime), Phase IV involved the testing of pavement specimens (Wearing Course with conventional bitumen and modified bitumen, and the SMA Mix). All the specimens for the three types of mixes were left in salt solution for 5 days.

Phase I

In Phase I the binder (B 50/70) were exposed to the deicing salt solution under 5ºC temperature regimes to examine how deicing salt solutions interact with traditional bitumen. Also, the results of these tests were used to compare both the traditional and modified binder parameters for Phase II in which modified bitumen was tested.

The deicer salt solution used is sodium chloride (NaCl) a colorless or white crystalline compound. The salt concentration has a %23 percent of salt, and corresponding specific gravity of 1.18 (measured by a hydrometer) at 15°C. The standard bitumen tests were carried out on the conventional and modified bitumen samples after 5 days conditioning system. In the first group, B 50/70 bitumen samples prepared were immersed in the salt solutions at 5 ºC. Specimens from each test were tested as a thin film for the system. In the second set of tests, modified bitumen samples prepared with SBS were immersed to the salt solution concentration at a constant 5 ºC for 5 days and then standard modified bitumen tests were performed including Penetration, Softening point, Elastic recovery, Force ductility, and Fraass breaking point test. Test results of the both traditional and modified bitumen samples are shown in Table 5 and Table 6 below.

Table 5: Properties of Traditional Binder

Properties ***B 50/70 (Bitumen)***	***Specification*** ***B 50/70***	***Normal Values***	***Water Conditioning (5 days, 5°C)***	***Salt Solution Conditioning (5 days, 5°C)***
Penetration 0.1mm (TS EN 1426)	50-70	57,8	55,8	53
Softening point °C (TS EN 1427)	46-54	48,6	48,8	48,5
Loss on heating, % (TS EN 12607-2)	Max. 0,5	0,06	0,06	0,10
• Permanent Penetration grade °C	Min. 50	69,3	78,3	76,0
• Softening point °C	Min. 48	52,4	52,1	53,3
• Increase in Softening p. °C	Max. 9	3,8	3,3	4,8
Fraass Breaking point (TS EN 12593)	Max. -8	-8	-8	-8

Phase II

In Phase II the modified binder (B 50/70) were exposed to the salt solution under the same temperature (5°C) to examine how deicing salt solutions interact with the modified bitumen.

Table 6: Properties of Modified Binder

Properties ***B 50/70 (Bitumen)***	***Specification*** ***B 50/70***	***Normal Values***	***Water Conditioning (5 days, 5°C)***	***Salt Solution Conditioning (5 days, 5°C)***
Penetration grade, 0.1mm (TS EN 1426)	50-70	38,9	38,9	37,6
Softening point °C (TS EN 1427)	46-54	85,2	85,2	82,2
Elastic Recovery (TS EN 13398)	Min.	97,5	97,5	95,0
Force Ductility °C (TS EN 13587)	Min.	10,25	12,28	9,59
Fraass Breaking point °C (TS EN 12593)	Max.	-12	-12	-11

Phase III

In Phase III the basalt and limestone aggregates were exposed to the salt solution under the same temperature 5ºC to examine how deicing salt solutions interact with the both aggregate types. The properties and test results for both limestone and basalt aggregates are shown in Table 7 and Table 8.

Table 7: Limestone Aggregate Properties

Properties	***Specification***	***Water Conditioning***	***Salt solution Conditioning***
Absorption (TS EN 1097-6)	%2,0	0,49	0,45
Freeze-Thaw (TS EN 1367-1)	No Spec.	0,35	0,03
Stripping (B 50/70)	Min. %50	65-75	65-75
Stripping (Modified Bitumen)	Min. %50	70-80	70-80

Table 8: Basalt Aggregate Properties

Properties	***Specification***	***Water Conditioning***	***Salt solution Conditioning***
Absorption (TS EN 1097-6)	%2,0	1,26	-
Freeze-Thaw (TS EN 1367-1)	No Spec.	0,69	0,03
Stripping (B 50/70)	Min. %50	30-40	30-40
Stripping Modified Bitumen	Min. %50	75-85	75-85

To increase the stripping resistance of the basalt aggregate and to get it inside the specification limits, SBS has been added to the mix, and the binder has been used as modified bitumen in the mix. The samples repeated by the modified bitumen were available in accordance of the specification limits.

Phase IV

In Phase IV the HMA Wearing coarse Type1 with conventional bitumen and modified bitumen mixes, and SMA Type2 mix specimen samples were exposed to the salt solution under the same temperature, 5ºC to examine how deicing salt solutions interact with the pavements.

Comparisons were made between the non-conditioning and conditioning samples, for all types of mixes and materials. The laboratory tests results carried on the asphalt concrete samples and mix variables are presented in the "Conclusions" section of the study.

Water Sensitivity Test

In the current phase of work, three different asphalt mixes approved by related Standard (TS EN 12697-12 Bituminous mixtures - Test methods for hot mix asphalt - Part 12: Determination of the water sensitivity of bituminous specimens) were conditioned and the related tests were carried on. The indirect tensile strength of cylindrical specimens of bituminous mixtures test was applied to the samples. Test results of the three types of mixes are shown in Table 9 below.

Table 9: Indirect Tensile Strength Values for Mixes

Specimen Type	***Water Conditioning***	***Salt Solution Conditioning***
Wearing Coarse Type 1 0/20 (50/70 Bitumen)	68,6	73,6
Wearing Coarse Type 1 0/20 (Modified Bitumen)	74,2	87,6
SMA Type 2 Modified Bitumen)	81,0	86,6

Salt Solutions Sensitivity Test

In the current phase of work, three different asphalt mixes approved by related Standard (TS EN 12697-43 Bituminous mixtures - Test methods for hot mix asphalt - Part 43: Resistance to fuel) were conditioned and the related tests were carried on. This Standard specifies a test method to determine the resistance of a bituminous mixture or pavement to fuels. The procedure involves initial soaking of a test specimen made in the laboratory or cored from a pavement in a fuel, followed by a brushing period with a steel brush mounted in a mixer. The material loss of the specimen is a measure of the resistance to that fuel for that bituminous mixture. The test is normally carried out with jet fuel. But for this project, water and salt solutions were used instead of fuel.The conditioned samples of cylindrical specimens of bituminous mixtures were tested according to the mentioned test standard. Test results of three types of mixes are shown in Table 10 below.

Table 10: The Fuel Resistance Test Results for Mixes

Specimen Type	***Water Conditioning***	***Salt Solution Conditioning***
Wearing Coarse Type1- 0/20 (50/70 Bitumen)	Good resistance	Good resistance
Wearing Coarse Type1- 0/20 (Modified Bitumen)	Good resistance	Good resistance
SMA Type2 (Modified Bitumen)	Good resistance	Good resistance

The results in Table 10 above suggested that both water conditioning and salt solution conditioning results are in good resistance. Again, the results stated that good resistance similarly is the same for all type of mixes; Conventional Wearing coarse Type1, Modified Wearing coarse Type1 and SMA. The study showed that salt solution does not affect the mix in negative way.

4. CONCLUSIONS

Based on the data presented in this paper, the following conclusions can be drawn;

- The bitumen samples are affected by the salt solutions. The penetration grade decreases approximately as four units. That means the bitumen become hardener as a result of conditioning with salt solutions.
- The concentrations of NaCl represent an approximately 5% reduction in the modified bitumen as compared to that used in the water conditioning pavements, that were tested using the same method.
- The salt solutions were affecting the modified bitumen sample very little. This effecting can be neglected.
- There was no any effect of the salt solutions on both basalt and limestone aggregates.
- The HMA and SMA specimen samples were affected very few that can be neglected, but in positive manner by the concentration.
- The result of Resistance to fuel experiment represents that a negative effect of salt solution do not appear on the pavement samples.

In the end, salt solutions (NaCl) appear to be at a neglectible level of effectiveness for the HMA and SMA applications opposite to the common view about damaging the pavements.

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