MATERIALS AND TECHNOLOGIES FOR WINTER ROAD MAINTENANCE IN LITHUANIA

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ABSTRACT

Winter season in Lithuania lasts 5–6 months. Therefore, the problems of road safety assurance are faced. In Lithuania, like in many European and other countries in the world, traditional materials of winter road maintenance are used: NaCl, $CaCl_2$, their mixes or more ecological products manufactured on their basis. On gravel roads or low-volume roads the mixes of NaCl and frictional materials (sand, crushed stone) are used. For maintenance purposes (to reduce slipperiness) a wet salt technology is applied or spreading of chloride- frictional material mixes. In order to investigate an efficiency of different skid-resistant materials, in 2011–2013 the field measurements and laboratory tests were performed. During the first stage, laboratory tests of five different skid-resistant materials were carried out using different testing methods. During the second stage, three skid-resistant materials of different properties were selected and, having constructed experimental road sections, measurements of the change in road slipperiness and snow cover in respect of time were carried out under different environmental conditions and thicknesses of snow and ice cover. Measurements were carried out with the help of an optical friction measuring device RCM 411.

KEYWORDS

Friction, snow melting materials, road condition monitor, slipperiness.

1. INTRODUCTION

The aim of the research paper is to study the efficiency of five different slipperiness reducing materials (here and after referred to as SRM) under different conditions (environment, weather, surface temperature, transport intensity) and with respect to the thickness of snow and ice layer.

Tests were conducted in the laboratory (Cuelho E. *et al.* 2012, Xu H. *et al.* 2012, Борисюк Н.В. 2012) and in the field to study five different SRMs: sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), a mixture of sodium and calcium modified chlorides (here and after referred to as SCMC), and a mixture of sodium acetate and sodium formate (here and after referred to as SASF). Test results were obtained for the ice mass losses and efficiency of SRMs. Then, the results were analysed and three SRMs were selected. Test road sections were constructed to perform measurements of change in road slipperiness using an optical mobile sensor called Road Condition Monitor RCM 411 (road friction measuring device).

2. TESTS

2.1. LABORATORY TESTS ON THE EFFICIENCY OF SRM AND ON THE LOSS OF ICE MASS

Laboratory tests are carried out by two different test methods, in accordance with test methods developed by the testing laboratory of JSC „Problematika“: tests on the ice mass loss and the efficiency of SRM. Tests are conducted with test samples (ice) under different constant temperatures (–3°C, –6°C, –9°C, –15°C, –20°C), and measurements are taken by applying SRM on the sample at different time intervals (2, 4, 6, 8, 10, 15, 20, 25, 30, 40, 50, 60, 90, 120 min.).

Ice samples for the ice mass loss test are prepared of uniform thickness and width. The required amount of water is poured into stainless steel trays in order to form a 3 mm ice layer. Trays with water are cooled in climatic chambers until ice is formed. When ice is formed, trays with ice are weighed and the mass of ice is calculated. The samples are kept in a climatic chamber at a constant specified temperature. Trays with ice samples stay in a climatic chamber until the temperature of ice surface reaches the indicated temperature. When the required temperature is reached, the same amount of SRM of about 10 g., fr. 0,5/1 mm is spread on the surface of ice sample. Ice samples with SRM spread on top of them are kept in the climatic chamber for different, preset intervals of time. The ice samples stay in the climatic chamber for the required time. Then trays are removed and weighed. The dissolved solution is poured off and the remaining ice in the tray is weighed. The percentage of change between the mass of melted ice and the mass of ice is calculated after obtaining the average value of three samples tested under the same conditions.

The study of the efficiency of SRM involves the measurement of activity of SRM in the process of ice melting at different environmental temperatures. The study of SRM using this method requires the formation of analogous ice sample, the same which is used for the ice mass loss test. The ice sample is kept at a constant specified temperature, and is affected by ~10 g. of SRM. The surface temperature of the sample is measured during the entire test period (120 min.).

2.2. MEASUREMENTS OF CHANGE IN ROAD SLIPPERINESS

An optical mobile sensor RCM 411, road friction measuring device, was used during the experiment to measure the coefficient of road surface friction and the water layer thickness. Such devices are currently used in the Netherlands (MNPO), the Czech Republic (Cross) and in Finland (Destia ir Foreca Consulting). At the beginning of December, they are expected to be used in Germany (Ravensburg) and in Switzerland (ASTRA) (Chen S. S. *et al.* 2009, Flintsch G. W. *et al.* 2009, Lee C. *et al.* 2008, Munehiro K. *et al.* 2012, Nakatasuji T. *et al.* 2005).

Road surface friction is the main indicator describing the quality of winter road maintenance on the roads of national significance of Finland, Sweden and Norway. The coefficient of friction is an absolute value, that indicates the adhesion between the road surface and the vehicle tires. A test road section was constructed on the road No. 107 Trakai–Vievis (14,32–15,4) km (AADT 1802 veh./d.) to study the impact of different SRMs on the change in road slipperiness in winter. The test road was divided into three sections. Two (traditionally used in Lithuania and tested) SRMs were spread on those sections under different temperatures, precipitation conditions and with respect to the thickness of road surface (ice, snow, wet snow, etc.). The change in slipperiness was measured and then analysed under the same environmental conditions. Measurements were made and the following data was recorded:

1. Test road section;
2. Date of measurement, start time and finish time;
3. Environment, weather conditions;
4. Air temperature, °C;
5. Road surface temperature (on each test road section, at different time intervals), °C;
6. Test materials (amount, concentration, etc.).

3. TEST RESULTS

3.1. TEST RESULTS ON THE EFFICIENCY OF SRM AND ON THE LOSS OF ICE MASS

All SRMs are tested under the same conditions, as defined in test methods. Measurements of ice mass loss are expressed as a percentage. The initial mass of ice is taken to be 100%. The change in ice mass loss is given in Figures 1–5, which show the impact of different SRMs on the ice under the same environmental conditions. In addition, the graph displays the change in temperature of ice sample surface under the effect of SRMs, which showed extreme ice melting values.

In order to analyse the impact of SRM on the ice, four ice mass loss intervals were selected and were divided into four categories of SRM efficiency. The categories of SRM efficiency are listed in Table 1.

Table 1 – The categories of SRM efficiency

The category of SRM efficiency	Ice mass losses, %
High efficiency	> 40
Average efficiency	20–40
Low efficiency	5–20
Inefficient	< 5

The intensity (%/min.) of melting (the change of ice mass loss) was calculated upon receipt of the results of the application of different SRMs on the ice sample. Four values (%) of ice mass loss change were taken for the analysis of the intensity of ice melting. These values were divided into four categories of ice melting intensity. The categories of ice melting intensity are listed in Table 2.

Table 2 – The categories of ice melting intensity

The category of ice melting intensity	Ice melting intensity, %/min.
High intensity	> 2
Average intensity	1–2
Low intensity	0.5–1
Very low intensity	< 0.5

The results of ice melting intensity are presented in Table 3.

After the performance of SRM efficiency tests, it was observed that independently of environmental temperature and SRM used, ice melting intensity considerably reduces

(<0,5 %/min) in the time interval from 10 to 20 min. (Bianchini A. *et. al*. 2011, Matsuzawa M. *et al.* 2009, Samodurova T. V. *et al.* 2010, Rezaei A. *et al.* 2013).

Table 3 – Results of the ice melting intensity

SRM	**Time, min**	**Ice melting intensity, %/min**				
		Temperature, °C				
		–3	**–6**	**–9**	**–15**	**–20**
NaCl	4	1.0	0.5	0.3	0.1	0.0
	10	1.7	1.0	0.5	0.2	0.0
	20	0.3	0.2	0.0	0.0	0.0
	30	1.7	0.5	0.4	0.2	0.0
	60	0.2	0.2	0.0	0.0	0.0
	120	0.0	0.0	0.0	0.0	0.0
$CaCl_2$	4	2.3	2.0	2,0	1.2	0.9
	10	0.9	0.5	0.3	0.1	0.1
	20	0.1	0.0	–0.1	0.0	0.0
	30	0.6	0.2	0.3	0.0	0.0
	60	0.1	0.0	0.0	0.0	0.0
	120	0.1	0.0	0.0	0.0	0.0
NANF	4	1.4	0.7	0.3	0.1	0.0
	10	1.2	0.8	0.5	0.0	0.0
	20	0.2	–0.1	0.3	0.0	0.0
	30	1.1	0.5	0.1	0.1	0.0
	60	0.3	0.2	0.0	0.0	0.0
	120	0.1	0.0	0.0	0.0	0.0
$MgCl_2$	4	3.1	2.5	2.2	1.7	1.3
	10	0.6	0.4	0.4	–0.1	–0.2
	20	0.1	0.0	–0.1	0.0	0.0
	30	0.4	0.0	0.1	0.0	0.1
	60	0.1	0.1	0.0	0.0	0.0
	120	0.0	0.0	0.0	0.0	0.0
NCMC	4	1.1	0.8	1.0	0.4	0.3
	10	1.1	0.8	0.4	0.2	0.1
	20	0.4	0.4	0.0	0.0	0.0
	30	1.8	0.7	0.3	0.1	0.0
	60	0.3	0.2	0.1	0.0	0.0
	120	0.1	0.0	0.0	0.0	0.0

In order to figure out the cause of such a sharp decrease in intensity, additional measurements of temperature of ice surface were made by applying SRM to its surface. The temperature of ice surface was measured for SRM, when melting intensity at different environmental temperatures and time intervals reached the extreme values (min., max.). The change in temperature of ice sample surface was measured by taking the maximum and minimum intensity of SRM in the time interval from 10 to 20 min. The results obtained from measurements showed that when different SRMs are applied to ice sample, the temperature of ice surface decreases within the first minutes of testing and stabilizes up to the temperature of test environment at different time intervals. It was also noted that the time interval, during which the temperature of ice sample surface stabilizes, depends on the environmental temperature. In order to find out the impact of change in temperature of ice surface on melting process, the time, during which the temperature of sample surface reaches the temperature of test environment ±0,1°C, was measured. The points of temperature stabilization are marked on the graph that shows the change in temperature (Fig. 1–5).

3.1.1. The study of the efficiency of SRM at the environmental temperature (*t*= –3 °C)

The ice mass loss and the change of surface temperature with respect to time at environmental temperature (–3)°C are shown in the graph (see Figure 1).

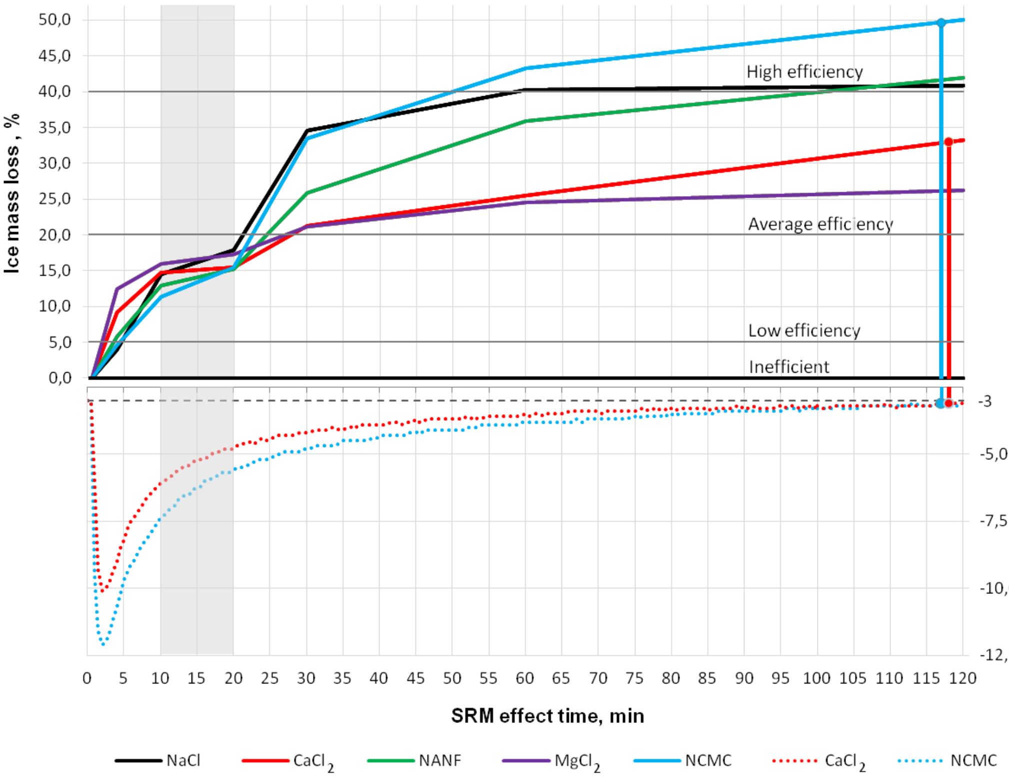

Figure 1 – Ice mass loss and surface temperature change (*t*= –3 C)

Test results showed that at a given environmental temperature (–3)°C and under the effect of SRM, the lowest measured ice mass loss interval 2,7% (NaCl, SASF) is reached after 20 minutes, and the highest measured ice mass loss interval 23,9% ($MgCl_2$, SCMC) is reached after 120 minutes. On the basis of the obtained test results it can be concluded that at a given temperature and under the effect of different SRMs, ice melting properties can be identified after 30 minutes.

According to the categories of SRM efficiency indicated in Table 1, at a given environmental temperature (–3)°C, NaCl, SCMC and SASF can be attributed to the category of very efficient SRMs. SCMC reaches the highest efficiency level after 50 minutes, while NaCl and SASF do it only after 110 minutes. The calculations showed that $CaCl_2$ ir $MgCl_2$ are of average efficiency. The average efficiency of all SRMs is reached after 20–30 minutes, therefore it can be concluded that at a given environmental temperature (–3)°C, SCMC melts the ice most efficiently and the effectiveness of NaCl and SASF is lower by 10%.

When ice samples are affected by SRM in accordance with the categories of ice melting intensity indicated in Table 2, the highest ice melting intensity is observed at the beginning of the test in the time interval of 10 min. When ice sample is affected by $CaCl_2$ and $MgCl_2$, ice melts most efficiently (2,3–3,1) %/min. within the first 4 minutes, and in the time interval from 4 min. to 120 min. the intensity of ice melting decreases to low and very low levels. The ice melting intensity of other samples affected by SRM up to 30 minutes, except for the time period from 10 to 20 min., remains average. After 30 minutes the ice melting intensity of all SRMs decreases to a low level, and after 60 minutes decreases to a very low level. Having analyzed the obtained results, it can be stated that at a given environmental temperature (–3)°C, high ice melting intensity is observed only at the beginning of its operation, in the time interval up to 10 min.

The most efficient melting in the time interval from 10 min. to 20 min. is observed when SCMC is applied, and the lowest melting efficiency is observed when $CaCl_2$ is applied. The change in temperatures is shown in Figure 1.

When SCMC is applied to ice sample within the first 2 minutes, the temperature of ice surface decreases by 9,1°C, and in case of $CaCl_2$ by 7,1°C. Both temperatures stabilize up to the set temperature of (–3)°C at the end of the test. Having analyzed the results of ice surface temperature measurements, it can be stated that at a given temperature (–3)°C, better efficiency is achieved when SRM is applied, the one that reduces the ice surface temperature most effectively, that is SCMC. The stabilization of ice surface temperature after the same time interval under the effect of SRM shows that the time interval of both SRMs is the same.

3.1.2. The study of the efficiency of SRM at the environmental temperature (*t*= –6°C)

The ice mass loss and the change of surface temperature with respect to time at environmental temperature (–6)°C are shown in the graph (see Figure 2).

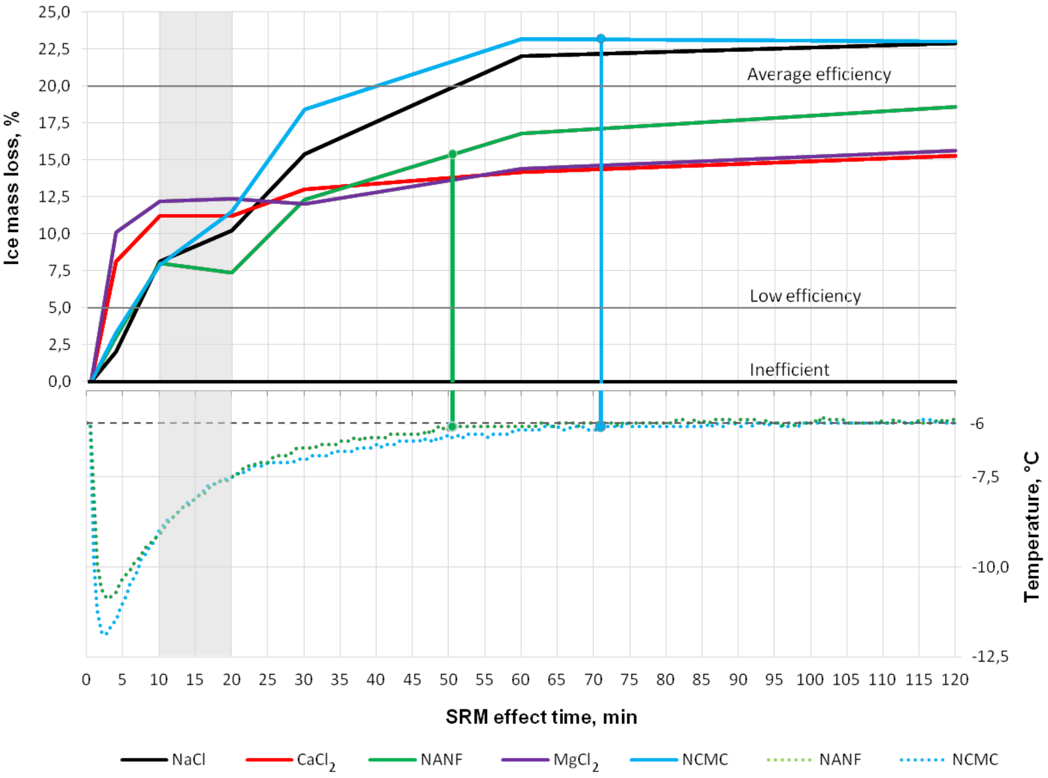

Figure 2 – Ice mass loss and surface temperature change (*t*= –6 °C)

Test results showed that at a given environmental temperature (–6)°C and under the effect of SRM, the lowest measured ice mass loss interval 4,4% ($MgCl_2$, SASF) is reached after 20 minutes, and the highest measured ice mass loss interval 8,9 % (SCMC, $CaCl_2$) is reached after 120 minutes. On the basis of the obtained test results it can be concluded that at a given temperature and under the effect of different SRMs, ice melting properties can be identified after 30 minutes. At a given environmental temperature (–6)°C the ice melting efficiency of SRM increases twice in the time interval from 20 min. to 120 min.

According to the categories of SRM efficiency indicated in Table 1, at a given environmental temperature (–6)°C, NaCl and SCMC can be attributed to the category of average SRM efficiency. SCMC reaches the average efficiency level after 40 minutes, while NaCl does it 10 minutes later. The calculations showed that SASF, $CaCl_2$ and $MgCl_2$ are of low efficiency. Having analyzed the obtained test results of the ice melting efficiency, it can be concluded that at a given environmental temperature (–6)°C, SCMC and NaCl have the same efficiency value at the end of the test and melt the ice most efficiently. SCMC and NaCl melt the ice <4% more efficiently than SASF, that is by 8% more efficiently than $CaCl_2$ and $MgCl_2$, which are of low effectiveness.

When ice samples are affected by SRM in accordance with the categories of ice melting intensity indicated in Table 2, the highest ice melting intensity is observed at the beginning of the test in the time interval of 10 min. When ice sample is affected by $CaCl_2$ and $MgCl_2$, ice melted most efficiently (2,0–2,5) %/min. within the first 4 minutes, and in the time interval from 4 min. to 120 min. the intensity of ice melting decreases to a very low level. The ice melting intensity of other samples affected by SRM up to 30 minutes, except for the time period from 10 to 20 min., remains low. After 30 minutes the ice melting intensity of all SRMs decreases to a very low level. Having analyzed the obtained results, it can be stated that at a given environmental temperature (–6)°C, $CaCl_2$ and $MgCl_2$ melt the ice most efficiently in the time interval up to 10 minutes, however, they do not have long-term ice melting properties.

The most efficient melting in the time interval from 10 min. to 20 min. is observed when SCMC is applied, and the lowest melting efficiency is observed when SASF is applied. The change in temperatures is shown in Figure 2.

When SCMC is applied to ice sample within the first 2 minutes, the temperature of ice surface decreases by 5,9°C, and in case of SASF by 4,9°C. The temperature of ice affected by SCMC stabilizes up to the set temperature of (–6)°C after 70 min., and in case of SASF after 50 minutes. Having analyzed the results of ice surface temperature measurements, it can be stated that at a given temperature (–6)°C, better efficiency is achieved when SRM is applied, the one that reduces the ice surface temperature most effectively, that is SCMC. Also, the measurement results showed that when there is a 1,0°C difference between the temperatures upon their decrease, the value of ice melting efficiency of SRM is affected by 4 percent difference, and the duration of impact is lengthened up to 20 minutes.

3.1.3. The study of the efficiency of SRM at the environmental temperature (*t*= –9 °C)

The ice mass loss and the change of surface temperature with respect to time at environmental temperature (–9)°C are shown in the graph (see Figure 3).

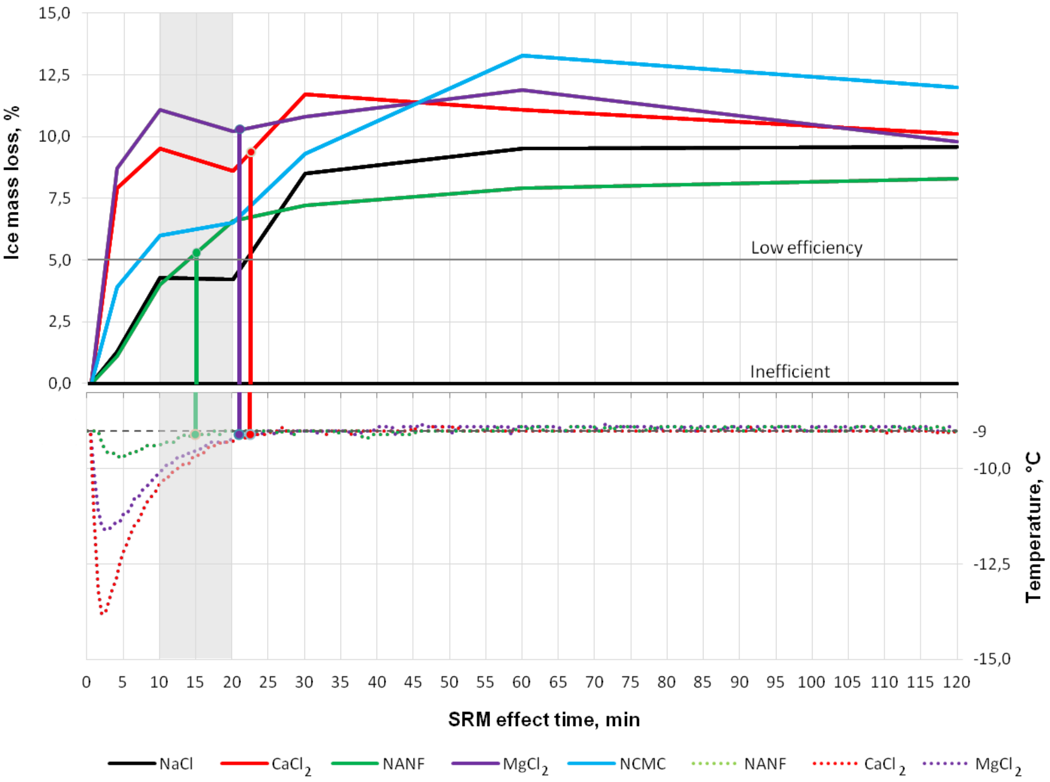

Figure 3 – Ice mass loss and surface temperature change (*t*= –9°C)

Test results showed that at a given environmental temperature (–9)°C and under the effect of SRM, the highest measured ice mass loss interval 7,6% (SASF, $MgCl_2$) is reached after 4 minutes, and the lowest measured ice mass loss interval 3,8% (SCMC, SASF) is reached after 120 minutes. On the basis of the obtained test results it can be concluded that at a given temperature and under the effect of different SRMs, ice melting properties can be identified at the beginning of the test, in the time interval of 4 minutes, and in the course of time the properties of ice melting become similar.

According to the categories of SRM efficiency indicated in Table 1, at a given environmental temperature (–9)°C, all SRMs reach only the category of low efficiency. SCMC reaches the highest efficiency value of 13,3% after 60 minutes. The effect of all SRMs on the ice melting approaches zero after 60 minutes, therefore it can be concluded that at a given environmental temperature (–9)°C, SCMC melts the ice most efficiently. The efficiency of SCMC after 120 minutes is at least 2% higher than of other SRMs.

When ice samples are affected by SRM in accordance with the categories of ice melting intensity indicated in Table 2, the highest ice melting intensity is observed at the beginning of the test in the time interval of 10 min. When ice sample is affected by $CaCl_2$ and $MgCl_2$, ice melts very efficiently (2,0–2,2) %/min. within the first 4 minutes, and in the time interval from 4 min. to 120 min. the intensity of ice melting decreases to a very low level. Ice melting intensity under the effect of NaCl, SCMC and SASF is very low during the entire test period, except for the time period from 4 min. to 10 min., when the melting intensity is average. Having analyzed the obtained results, it can be stated that at a given environmental temperature (–9)°C, high ice melting intensity of $CaCl_2$ and $MgCl_2$ is observed only at the beginning of their operation, in the time interval up to 10 min. The melting intensity of SCMC is average in the time interval up to 10 min., however, it continuously increases up to 60 min.

The most efficient melting in the time interval from 10 min. to 20 min. is observed when SASF is applied, and the lowest melting efficiency is observed when $CaCl_2$ and $MgCl_2$ are applied. The change in temperatures is shown in Figure 3.

When SASF is applied to ice sample within the first 2 minutes, the temperature of ice surface decreases by 0,9°C, in case of $CaCl_2$ by 4,8°C and in case of $MgCl_2$ by 2,6°C. The temperature of ice affected by SASF stabilizes up to the set temperature of (–9)°C after 15 min., and in case of $CaCl_2$ and $MgCl_2$ after 20 minutes. Having analyzed the results of ice surface temperature measurements, it can be stated that at a given temperature (–9)°C, better efficiency is achieved when SRM is applied, the one that reduces the ice surface temperature most effectively, that is $CaCl_2$.

3.1.4. The study of the efficiency of SRM at the environmental temperature (*t*= –15°C)

The ice mass loss and the change of surface temperature with respect to time at environmental temperature (–15)°C are shown in the graph (see Figure 4).

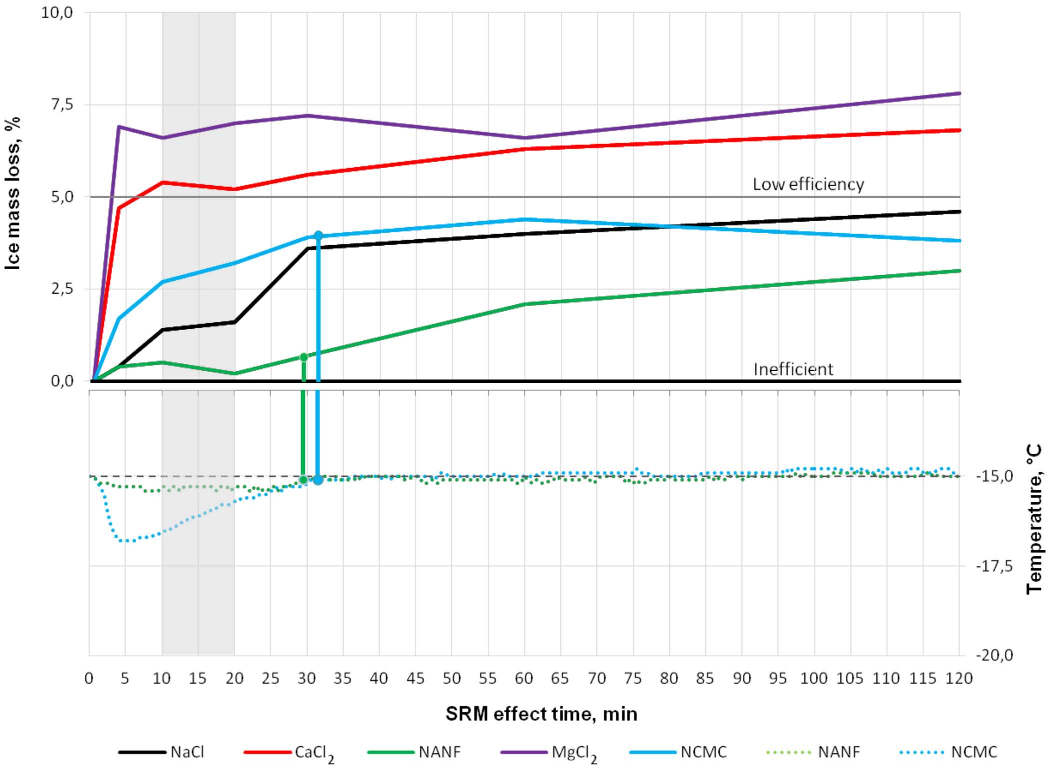

Figure 4 – Ice mass loss and surface temperature change (*t*= –15°C)

Test results showed that at a given environmental temperature (–15)°C and under the effect of SRM, the highest measured ice mass loss interval 6,8% ($MgCl_2$, SASF) is reached after 20 minutes, and the lowest measured ice mass loss interval 4,5% ($MgCl_2$, SASF) is reached after 60 minutes. On the basis of the obtained test results it can be concluded that at a given temperature (–15)°C and under the effect of different SRMs, ice melting properties can be clearly identified at the beginning of the test, in the time interval of 20 minutes, and in the course of time the properties of ice melting become similar.

According to the categories of SRM efficiency indicated in Table 1, at a given environmental temperature (–15)°C, $CaCl_2$ and $MgCl_2$ can be attributed to the low efficient SRM. NaCl, SCMC and SASF melt the ice inefficiently. $MgCl_2$ reaches the highest value (–7,8)% of efficiency after 120 min., and the efficiency of $CaCl_2$ is lower by 1%. There is no need to study the efficiency of other SRMs, as the ice mass losses do not exceed 5%.

When ice samples are affected by SRM in accordance with the categories of ice melting intensity indicated in Table 2, the highest ice melting intensity is observed at the beginning of the test in the time interval of 4 min. When ice sample is affected by $CaCl_2$ and $MgCl_2$, ice melts averagely (1,2–1,7) %/min. within the first 4 minutes, and in the time interval from 4 min. to 120 min. the intensity of ice melting decreases to a very low level. The ice melting intensity of other SRMs remains very low. Having analyzed the obtained results, it can be stated that at a given environmental temperature (–15)°C, high ice melting intensity of $CaCl_2$ and $MgCl_2$ is observed only at the beginning of their operation, in the time interval of 4 min.

The most efficient melting in the time interval from 10 min. to 20 min. is observed when SCMC is applied, and the lowest melting efficiency is observed when SASF is applied. The change in temperatures is shown in Figure 4.

When SCMC is applied to ice sample within the first 5 minutes, the temperature of ice surface decreases up to – 16,8°C, in case of SASF up to –15,3°C. The changes in temperature are very low < 1,8°C, therefore SRM melts the ice inefficiently.

3.1.5. The study of the efficiency of ice melting materials at the environmental temperature (*t*= –20°C)

The ice mass loss and the change of surface temperature with respect to time at environmental temperature (–20)°C are shown in the graph (see Figure 5).

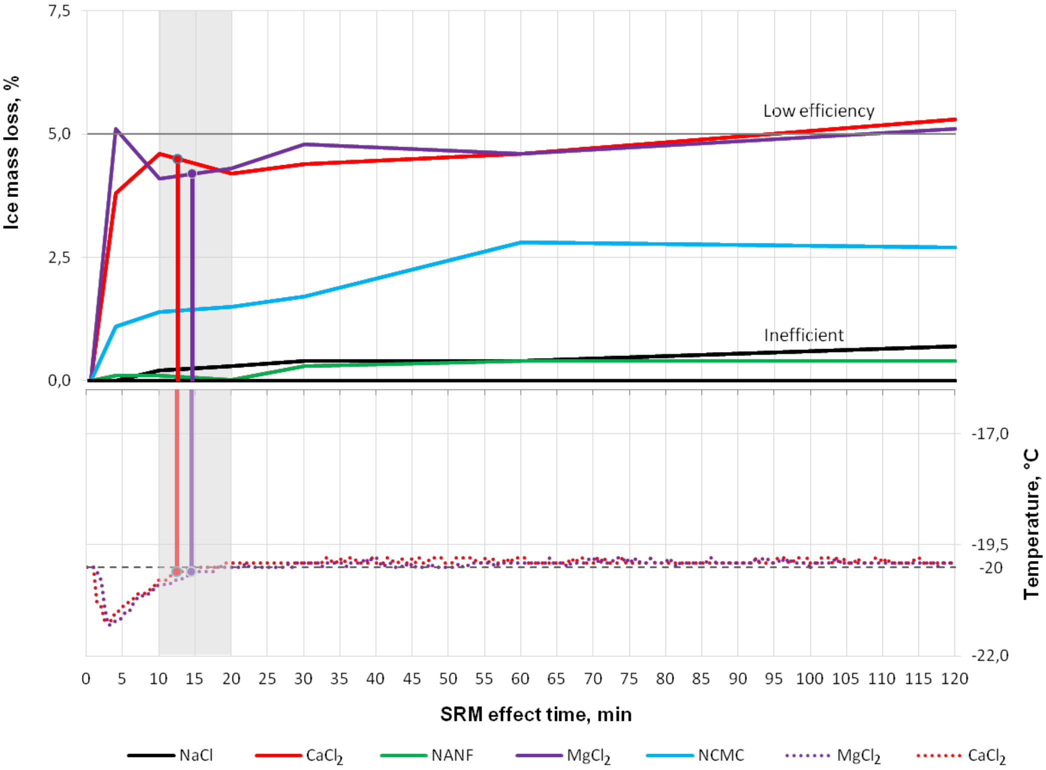

Figure 5 – Ice mass loss and surface temperature change (*t*= –20°C)

Test results showed that at a given environmental temperature (–20)°C and under the effect of SRM, the highest measured ice mass loss interval 5,1% (NaCl, $MgCl_2$) is reached after 4 minutes, and the lowest measured ice mass loss interval 4,1% (SASF, $MgCl_2$) is reached after 20 minutes. On the basis of the obtained test results it can be concluded that at a given temperature (–20)°C and under the effect of different SRMs, ice melting properties remain the same during the entire test period.

According to the categories of SRM efficiency indicated in Table 1, at a given environmental temperature (–20)°C, $CaCl_2$ and $MgCl_2$ can be attributed to the low efficient SRM. This category of efficiency is reached at the very end of the test, that is after 120 minutes. Other SRMs melt the ice under these environmental conditions inefficiently.

When ice samples are affected by SRM in accordance with the categories of ice melting intensity indicated in Table 2, the highest ice melting intensity is observed at the beginning of the test in the time interval of 4 min. When ice sample is affected by $CaCl_2$ and $MgCl_2$, ice melts most efficiently (0,9–1,3) %/min. within the first 4 minutes, and in the time interval from 4 min. to 120 min. the intensity of ice melting decreases to a very low level. There is no need to study the efficiency of other SRMs, as the ice mass losses do not exceed 5%.

The most efficient melting in the time interval from 10 min. to 20 min. is observed when $CaCl_2$ is applied, and the lowest melting efficiency is observed when $MgCl_2$ is applied. The change in temperatures is shown in Figure 5.

When $CaCl_2$ is applied to ice sample within the first 2 minutes, the temperature of ice surface decreases by 1,2°C, in case of $CaCl_2$ by 1,3°C. Both temperatures stabilize up to the set temperature of (–20)°C on the 12-th and 14-th minute of the test. Having analyzed the results of ice surface temperature measurements, it can be stated that at a given temperature (–20) °C, better efficiency is achieved when SRM is applied, the one that reduces the ice surface temperature most effectively, that is SCMC. The stabilization of temperature up to the set temperature of (–20)°C at the beginning of the test after 12-th min. and 14-th min. indicates that the activity duration of the two tested materials is the shortest one.

3.2. TEST RESULTS OF THE MEASUREMENTS OF CHANGE IN ROAD SLIPPERINESS

Measurement of road slipperiness was performed by using a mobile phone and the μTec friction meter. The μTec friction meter provides the possibility not only to see the measurement results on the screen of the phone, to safe the measurement results (and GPS data at the same time) in the internal memory of the phone or in the additional memory, but also to send the results in real time to an indicated server.

Measurement of road slipperiness by using an indirect method – the road surface condition sensor RCM 411. It is an optical measuring device, which determines:

1. Road surface condition: dry, wet, moist, ice, snow, wet snow,
2. Road surface layer thickness,
3. Adhesion coefficient.

The device is installed on a tow-ball of the vehicle (see Figure 6).

Figure 6 – A sensor for measurement of friction (RCM 411) installed on a tow-ball of the vehicle

The color of the line reveals the surface state: red stands for ice, blue stands for water, violet stands for wet snow and white stands for snow. A thin line is water layer thickness in millimeters. The data is communicated to a user interface running on mobile phone (see Fig. 7) and can be sent to the server to be displayed on a color-coded map. The data can be also stored in the internal memory of the device and it can be transferred further in EXCEL file formats.

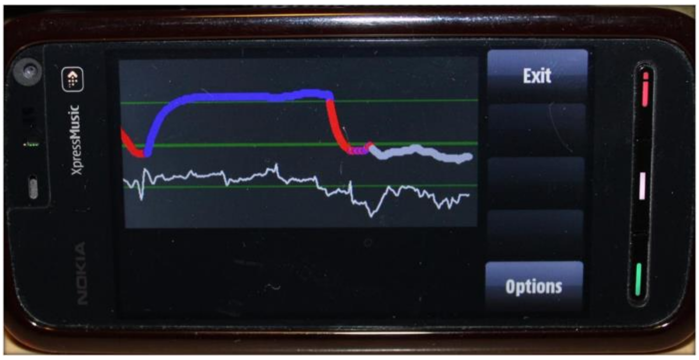

Figure 7 – Friction measurements on the screen of a mobile phone

Typical variants of friction coefficients (informative):

1. Dry road 0,80±0,10 (depends on the tires and the condition of road surface);
2. Solid ice 0,20 or less (for all tires when there is a thin layer of solid ice).

Measurements were carried out on the road No. 107 Trakai–Vievis (14,32–15,4) km (AADT 1802 veh./d.) under different temperatures, precipitation conditions and with respect to different thicknesses of road surface layers (ice, snow, wet snow, etc.). The measurements were conducted on a 600 m long experimental road section and on a 200 m long test road section. The obtained test measurement results showed that materials used to mix with each other under the wheels of moving cars when the material was spread on short road sections. Therefore, it was rather difficult to study the impact of the test materials on the road surface. In order to study the efficiency of ice melting materials, test road sections were lengthened up to 400 m (total length of test road section

– 1200 m). The length of experimental road sections was the same during the entire experiment. A typical scheme of test road sections is shown in Table 4. Traditional winter maintenance materials and test ice melting materials were spread on the road for the performance of measurements in accordance with the valid requirements of Lithuania (amount, method, concentration, etc.). The materials were spread on the road at the same time. Road surface friction measurements were taken prior to spreading the two materials. Measurements of friction coefficient were carried out immediately after spreading the ice melting materials, and measurements were continued in the equal intervals of time until materials were fully activated (friction coefficient ≥ 0,80) or until it became a constant.

Table 4 – Typical scheme of measurements on the road

Test road section length, m	***1200***		
Test road section, m	***400***	***400***	***400***
Spreading material	Traditional spreading material (NaCl)	Test spreading material	Traditional spreading material (NaCl)

During the performance of measurements the increase of road surface friction was observed immediately after spreading SRM.

Measurement results showed a large difference, which depends not only on test SRM, but also on the relief of the road, the surrounding environment, vegetation, structures and other factors. Therefore, according to the results obtained, no accurate conclusions can be drawn about the efficiency of tested in the laboratory SRM and the road surface friction in the natural environment.

4. CONCLUSIONS

In February 2012, the performance of first tests regarding “The Study on the Efficiency of Winter Road Maintenance on the Roads of National Significance of the Republic of Lithuania” were started in order to develop a research program and methods. Test methods included the selection and analysis of test methods of ice melting materials (methods which are used in foreign countries), road surface condition measuring devices and techniques. Research program was designed, test methods were developed and the following tests were carried out:

1. Laboratory tests on the efficiency of SRM;
2. Measurements of friction on the roads.

While conducting a laboratory experiment on the efficiency of SRM, it was observed that independently of environmental temperature and SRM used, ice melting intensity considerably reduced in the time interval from 10 to 20 min. During the performance of road measurements the increase of road surface friction was observed immediately after spreading SRM. Testing methodology of ice melting efficiency was developed in order to find the cause of this phenomenon. The obtained results showed that a sudden decrease in temperature of ice surface, when it is affected by SRM, depends on the environmental temperature and chemical properties of SRM. The developed method allows to study the efficiency of SRM at different environmental temperatures.

In compliance with the results obtained from the experiments, the efficiency and intensity of SRM can be grouped according to the value results, which allows to divide SRM into categories according to their different properties.

In accordance with the ice melting efficiency, SRM were divided into the following categories:
1. At a given environmental temperature (–3)°C, NaCl, SASF and SCMC are of high efficiency, while $CaCl_2$ and $MgCl_2$ are average efficiency SRM;
2. At a given environmental temperature (–6)°C, NaCl and SCMC are of average efficiency, while SASF, $CaCl_2$ and $MgCl_2$ are low efficiency SRM;
3. At a given environmental temperature (–9)°C, all tested SRM are of low efficiency;
4. At a given environmental temperature (–15)°C, $CaCl_2$ and $MgCl_2$ are of low efficiency, while NaCl, SASF and SCMC are ineffective.
5. At a given environmental temperature (–20)°C, $CaCl_2$ and $MgCl_2$ are of low efficiency, however they as well as NaCl, SASF and SCMC can be considered ineffective.

Tested SRM can be divide according to the time intervals, when SRM are effective:
1. At a given environmental temperature (–3)°C, SRM are effective up to 120 min.;
2. At a given environmental temperature (–6)°C, SRM are effective in the time interval from 50 min. to 70 min.;
3. At a given environmental temperature (–9)°C, SRM are effective in the time interval from 15 min. to 22 min.;
4. At a given environmental temperature (–15)°C, SRM are effective in the time interval from 30 min. to 32 min.
5. At a given environmental temperature (–20)°C, SRM are effective in the time interval from 12 min. to 14 min.

In order to study and to compare the impact of different SRMs on the road surface friction, experimental road section should be rather long (>500 m) and should be similar with regard to environment, relief, etc.

In order to find out the efficiency of SRM, the required amount and concentration of the material and in order to achieve safe driving conditions in winter, it is necessary to conduct additional measurements, that would allow to develop a thermal map for a particular road section.

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