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DE-ICING EXPERIENCE IN LITHUANIA

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Abstract. With respect to traffic safety Lithuania is a country of increased risk. Thus, in order to ensure traffic safety, it is necessary to maximally reduce the number of accidents, probability of accident risk. The climate in Lithuania is much warmer than the climate of continental regions of the same latitudes. It could be characterised as of average cold, with much snow in winter. In winter traffic conditions are more complicated. When the road pavement is slippery or covered with snow, the accident risk increases. These tasks are solved by winter road maintenance. One of the main objectives of winter maintenance – by removing snow and ice from road pavement and increasing the coefficient of grip between road pavement and tyres – is to reduce accident risk on roads. On slippery road, as soon as unfavourable air and driving conditions appear, the number of accidents increases. At present to prevent road from climatic factors or to eliminate the ice layer from the road surface in a short time is using "Wet salt" technology. An effective acting of the "Wet salt" reveals itself even at –15 °C and the effect could continue up to 12 h after it is spread. However, this is very dependant on weather conditions, change in temperatures, intensity of precipitation and its duration, also traffic volume.

On Lithuanian highway Vilnius–Panevėžys the analysis of the change in seasonal traffic volume was carried out. To improve winter maintenance of this highway the change in the number of accidents was analysed, depending on the season of the year; also the increase in the number of accidents in winter season was analysed. Investigations of salt, used to minimise road slipperiness, were carried out too. Moisture content %, chlorides content, calculated as natrium chloride % and amount of sulphates % of sodium chloride were investigated. Results of quality investigations of sodium chloride salt, used to reduce road slipperiness, showed that by its chemical composition sodium chloride salt meets very well requirements for the quality of salts used to spread Lithuanian roads, while deviations in the grading of samples taken are not significant.

Keywords: winter road maintenance, road snow cleaning, road traffic flow, salt, traffic safety, traffic accident.

After Lithuania's accession to the European Union the increase in number of vehicles and the change of the need for transportation cause the growth of traffic volume on Lithuanian roads. With respect to traffic safety Lithuania is the country of an increased risk. Thus, in order to ensure traffic safety, it is necessary to take various measures, the whole complex of which would allow to maximally reduce the number of accidents, probability of accident risk, traffic congestions, users' costs and environmental pollution.

Part of these tasks is solved by road maintenance, one component of which – winter maintenance - takes more than 40 % of all funds allocated to road maintenance [1]. In winter more and more materials are spread on Lithuanian roads to decrease slipperiness. When using salts for winter maintenance, traffic safety is improved. The application of salts means high costs, since the cost of chemical materials and their transport has been increasing every year. Therefore a very important task for road builders is to look for the ways to reduce the use of salts for winter maintenance.

1. Specific features of climatic conditions in Lithuania and their effect on road traffic

The climate in Lithuania is much warmer than the climate of continental regions of the same latitudes. The largest effect on air temperature and its distribution within the territory of Lithuania is made by the Atlantic Ocean and the distance from the Baltic Sea. Lithuanian climate is not typically coastal and it could be characterised as on average cold, with much snow in winter. Nearly in the whole Lithuania, except for the sea-coast, the coldest winter month is January (the temperature in the second decade of Janu-

ary is –5,6 °C). Average monthly air temperature is +5,1 °C and it changes from +2,8 °C on the sea-coast (in Klaipėda) to –6,8 °C in the North East (in Dūkštas). The absolute maximum air temperature in January is +10,5 °C (in Nida) and absolute minimum air temperature was – 40,5 °C (in Varėna in 1940). The permanent snow cover reaches 5 cm (western part of Lithuania) and 20–25 cm (northern part of Lithuania). The average number of days with fog and precipitation is 40–100 days per year (in different years up to 150 days) and 50–70 % of these days can be observed in the cold period of the year. The average number of days with glazed frost is 10–15 days per year (in different years up to 50 days) (December–April period). The average duration of glazed frost is 12 hours (in some cases – up to 48 h). 10–25 days per year with snowstorms and the average duration of one snowstorm reaches 5–7 hours, and the maximum – 30–40 h. There are 60–80 of the temperatures changes from negative to positive and vice versa every year.

By the amount of precipitation the territory of Lithuania is situated in the zone of excess moisture, since not the whole amount of precipitation can evaporate. A characteristic dangerous meteorological phenomenon for winter period is freezing rain. In October–April the average number of days with freezing rain is 9–19 days. The average duration usually does not exceed 12 h.

In winter traffic conditions are more complicated, since road pavement is covered with ice film; snow causes troubles with traffic conditions, snowdrifts reduce visibility, dark period of the day becomes longer. Snow makes a serious obstacle to traffic. A negative impact of snow on traffic conditions depends on its amount, on the intensity of snow or snowstorm and its repeated frequency, air temperature, speed and direction of wind and traffic volume. All these factors are closely related and could be repeated in different variants. A layer of plane and soft snow on road pavement is formed when it is snowing without wind. After this type of precipitation the grip between the tyres and snow-covered pavement is reduced up to 0,2 mm, at the same time the length of braking distance is increased [2].

Condition of snow-covered road is not stable – it gradually changes under the influence of the above-mentioned factors. A fresh snow is very soft. Under the effect of temperature and vehicle tyres the snow is getting dense, especially when the air temperature comes close to 0 °C. Fig 1 shows the dates of snow cover appearance, which are close to the average dates of the drop of temperature below 0 °C.

When getting dense the snow changes road maintenance conditions: the grip coefficient between road pavement and vehicle tyres is significantly decreased, resistance to vehicle rolling is highly increased.

Soft and moist snow trouble traffic conditions very much. When driving on such a road, the energy used by the vehicle to cover a certain road section can increase up to 15 times. At the same time fuel consumption is very much increased, which can exceed the average fuel consumption limit by 30 % [2]. Due to non-cleaned snow the vehicle operating costs and travel time delay costs considerably increase. The drivers are forced to reduce speed that, due to a low coefficient of grip, could stop the vehicle at a time.

Various factors make effect on road slipperiness: temperature, type and condition of the carriageway; temperature, type and amount of precipitation; cloudiness; wind speed and direction; difference in the temperatures on carriageway surface and in the air very close to pavement surface. When the road pavement is slippery or covered with snow, the accident risk increases [3] (Table 1).

Table 1 shows that the risk to get involved into a road accident, when road pavement is slippery or covered with snow, is 1,5–4,5 times higher than with pavement being dry.

Driving conditions are highly dependent on pavement condition and coefficient of grip between tyres and pave-

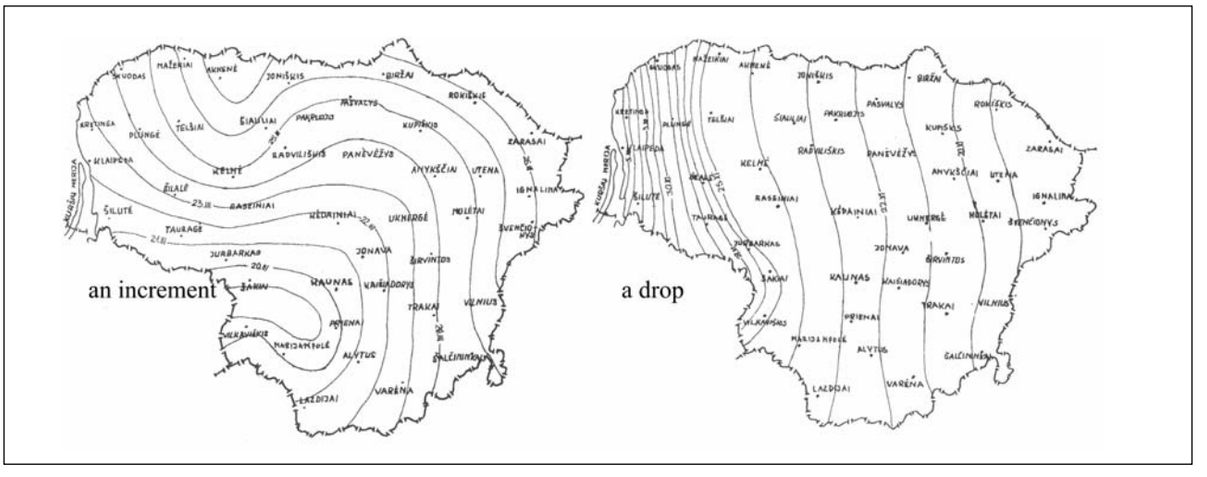

Fig 1. The first date of increment and a drop of the average day air temperature below 0 °C in Lithuania

ment. The coefficient of grip depends on pavement condition (dry, moist, covered with snow or ice), design and condition of tyres and the driving speed. When the speed increases from 10 to 60 km/h, the coefficient of grip decreases for more than twice. Some values of the coefficient of grip are given in Table 2.

One of the main objectives of winter maintenance – by removing snow and ice from road pavement and increasing the coefficient of grip between road pavement and tyres – is to reduce the accident risk on roads.

The most dangerous for road traffic is freezing ice, covering road pavement with a thin, up to 1 mm thick, layer of ice. During freezing ice the grid of pavement and tyres decreases up to 0,08–0,15. The film of ice on road pavement is usually 1–3 mm thick, a white mat coat of compressed ice and snow uses to be up to 10 mm thick. There are three types of icing: glazed frost, ice and frozen snow. All these types can act individually or at the same time, thus it is complicated to determine their effect. Characteristics of glazed pavement are given in Table 3.

A layer of ice in winter period in 55 % of cases is formed the temperature being from +4 up to –200 °C, in 80 % of cases – from + 2 up to – 6 °C and in 90 % of cases from + 20 °C up to –15 °C. Relative air humidity (W) is very important for the formation of ice on pavement. In 95 % of cases the glazed frost is formed, when W = 70–100 % and in 90 % of cases – when W = 80–100 % [4].

Table 1. Dependence of accident risk level on pavement condition

Pavement condition	Relative risk level
Dry, clear	1,0
Moist, clear	1,3
Coat of compressed snow on pavement	1,5
Sheet of ice on pavement	4,4

Table 2. Dependence of driving conditions on pavement condition and grip of tyres

Pavement condition	Driving conditions	Grip of tyres when driving speed is 60 km/h
Dry, clear	Very good	0,7
Moist, clear	Normal	0,5
Wet, dirty	Favourable	0,3
Glazed	Unfavourable	0,1–0,2

Table 3. Characteristics of glazed pavement

Indicator	Type of ice covering		
	Glazed frost	Ice	Frozen snow
Thickness of layer, cm	0,5–0,1	2,0–0,8	2,0
Density of ice, g/cm^3	0,5–0,9	0,8–0,9	0,3–0,8
Grip of tyres	0,05–0,15	0,1–0,2	0,2–0,3
Speed of formation	high	normal	slow

2. Special winter traffic conditions

Road traffic safety depends on road type, category, relief, number of intersections and their level etc and is related to outside factors, depending on dark time of the day, weather and pavement condition. When it is snowing or the pavement being icy, the number of accidents increases, especially when rapid icing takes place or during freezing rain.

Investigations in various countries show, that the number of accidents during winter period decreases when the road users get used to winter traffic conditions. First slipperiness or a slipperiness after a long-time period of good weather makes a rather large influence on the number of accidents. On a slippery road, as soon as an unfavourable air and driving conditions appear, the number of accidents increases. Later, when the users get used to winter conditions, this phenomenon practically disappears.

Norwegian investigations showed that in both cases when chemical materials are used or are not used for spreading roads, a braking distance does not get shorter. This is because after the road is spread with salt the drivers increase speed [3]. Swedish and German scientists investigated, how the degree of accident risk changes in the course of a day where salt is spread on roads and not. Possibilities to get into an accident 12 hours before starting winter maintenance works were investigated and after 12 hours period when the works were implemented. The risk to get into an accident before winter maintenance works are implemented is significantly increasing with the worsening of traffic conditions. After the necessary works of snow cleaning and spreading are implemented, the accident risk slightly decreases up to the level before the worsening of traffic conditions. Therefore, in order to ensure normal traffic conditions, it is necessary to carry out winter maintenance works as soon as possible [3].

It has been proved by the investigations of Nordic scientists, that salt spreading on roads reduces the number of traffic accidents. If salt is not used, the number of accidents increases. Timeliness and quality of winter maintenance operations have a large influence on road capacity. In many countries investigations have been carried out to find out which winter maintenance works influence the driving speed [3]. The results are given in Table 4.

These investigations proved that winter maintenance works increase an average speed up to 7 km/h. The increase in speed depends on the quality of winter maintenance works: the coefficient of grip between road pavement and vehicle tyres increases. Weather and traffic conditions being bad, the road users have a choice – to postpone a planned trip or to travel under bad weather and traffic conditions. Conclusions of the Norwegian scientists say that on average one or two trips are postponed every year due to unfa-

Table 4. Influence of winter maintenance works on driving speed

Investigator	Type of winter maintenance work	Limit speed, km/h	Change in average speed, km/h
Oberg, 1978	Sand spreading	No data	+2,4
Runing, 1981	Salt spreading	80	+5,1
Oberg, 1981	Snow cleaning	90	+2,0 – +7,0
Oberg and others, 1985	Salt spreading	No data	No data
Oberg and others, 1991	Salt spreading	90	+0,0 – +2,0
Sakshaug and Vaa, 1995	Salt spreading	80	+4,0

vourable weather and traffic conditions [3]). No investigations of this kind have been carried out in Lithuania.

3. Analysis of 10-year experience in using "Wet salt" technology in Lithuania

Road condition in winter should ensure safe driving at a normal speed throughout the whole winter. The actual width of a carriageway, based on which the driver chooses speed and anticipates possibility to overtake another vehicle, depends on the thickness of snow cover, length of icy road sections, their distribution and duration of icing.

At present to prevent road from climatic factors or to eliminate the ice layer from the road surface in a short time is nearly impossible; however, there are many real possibilities by using "Wet salt" technology to implement the main requirements for road operation in winter and to create conditions for vehicles to drive safe and comfortably at a necessary speed. This technology is widely used in the whole world and at present there is nothing to replace it. The main advantage of the use of "Wet salt" – an immediately starting process of thawing a snow-ice cover.

To moisten salt one can use sodium chloride solution, but a more effective spreading is when the „Wet salt" is produced by moistening sodium chloride with calcium chloride solution or magnum chloride solution. Using $CaCl_2$ as a solution a double effect could be achieved: dry salt is moistened and starts to act immediately after it is spread on the road and a mixture of salts is prepared ($NaCl + CaCl_2$), which acts at a lower air temperature and ice thawing speed is higher.

An effectively acting mixture is $NaCl : CaCl_2$ – 88 : 12. It is produced when 0,35 tonne of 30 % concentration of $CaCl_2$ solution is sprayed into 1 tonne of dry NaCl. If a relative air humidity is low, the salt starts to act only in a longer time period. It was determined that dry salt is active effectively up to –10 °C, while an effective acting of "Wet salt" reveals itself even at –15 °C. The practice showed that the effect of "Wet salt" could continue up to 12 h after it is spread. However, this is very dependant on weather conditions, change in temperatures, intensity of precipitation and their duration, also on traffic volume.

Ten-year experience in using "Wet salt" technology in Lithuania showed the following advantages and disadvantages.

Advantages:

1. The use of "Wet salt" technology speeded up the process of snow-ice thawing and at the same time allowed to more rapidly assure traffic safety.

2. This technology could be successfully used to treat road pavement with a small amount of salt beforehand when freezing rain or glazed frost is approaching.

3. The trucks for spreading and cleaning in winter period, could be used for other transport works in other months.

4. When winter season is over, there is no need to sweep sand from the shoulders and to take it away. Thus the vehicle operating costs are reduced, environment is less polluted.

Disadvantages:

1. It would be necessary to refuse salt spreaders with a support wheel, ensuring operation of a water pump. Very often the wheel stops rotating and the driver does not notice it. Certain road sections remain not spread and are very dangerous from the traffic safety point of view.

2. Repair and maintenance of „Wet salt" spreaders, supply of spare parts (especially of electronic part) have not been solved yet.

3. After each spreading the salt spreaders must be emptied, since the spread material could freeze to the tank and the transporter will not be able to send it to the spreading equipment. Removal of salt remainders from the tank in salt storehouse is rather complicated and long process; therefore the drivers try to spread salt remainders on the road. Unnecessary salt spreading causes large losses.

4. It is necessary to erect sensors in the „Wet salt" spreaders to record the remainders of salt in the tank and the amount of the spread salt in tonnes.

4. Seasonal traffic volume analysis on highway Vilnius–Panevėžys

On Lithuanian highway Vilnius–Panevėžys the analysis of the change in seasonal traffic volume was carried out. At present there are 6 traffic measuring posts. In 2002 the traffic volume on this road, if compared to 1997, has increased by 9,5 %, in 2003 – by 15,7 %. The growth of annual average daily traffic (AADT) from 1997 to 2003 is 2,6 %. In 2003–04 the traffic volume has increased for more than 6 % annually. Fig 2 shows the highest growth of AADT in 2002 and 2003. In the year 2003 the AADT on this road was 6115 vpd (vehicle per day).

Analysis of traffic volume showed that the lowest traffic volume is in December, January, February and March, and a special attention should be paid to Monday and Friday. The decreased traffic volume in winter season meets a general tendency of traffic volume on Lithuanian highways.

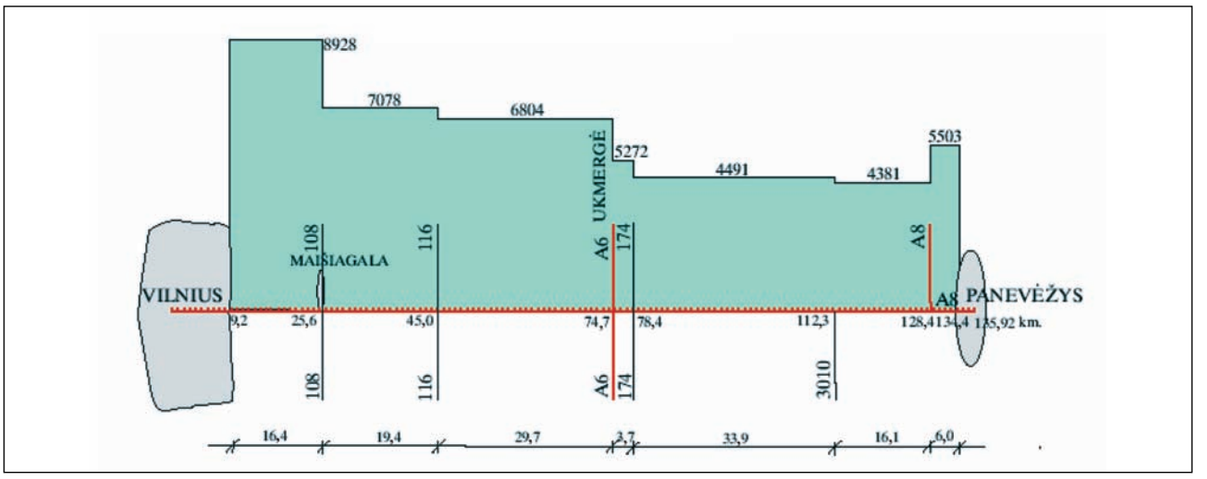

Fig 2. Traffic volume on highway Vilnius–Panevėžys in 2003

5. Analysis of seasonal accidents on road Vilnius–Panevėžys

For improving the winter maintenance of highway Vilnius-Panevėžys the change in the number of accidents was analysed, depending on the season of the year. Also the increase in the number of accidents in winter season was analysed. The highest average number of accidents is in winter and comes to 11,2 of accident per month (in summer this number is 8,8). Most collisions with pedestrians took place in winter – 24 accidents.

Fig 3 shows the change in the number of accidents in a 5-year period (2000–04) on the highway Vilnius–Panevėžys by month. The largest number of accidents took place in October. The most safe month in this period was March. The largest number of injured persons is in November. Since the months at the beginning of winter – October and November are very dangerous from the point of view of traffic safety. When implementing winter maintenance operations on the highway Vilnius–Panevėžys, a special attention should be drawn to these months.

6. Investigations of sodium chloride salt

Investigations of salt, used to minimise road slipperiness, were carried out. Table 5 gives the amount of salt applied during 7 years (in 1997–2004) and its average need by month.

Also the analysis of quantitative indices of the used salt (sodium chloride) was carried out. The samples of sodium chloride were taken from the salt storehouses, based on the requirements for taking samples from storages (Table 6).

Investigation of sodium chloride salt particle size distribution was carried out by a certified laboratory of State Enterprise "Problematika". Particle size distribution was determined by dry mechanical and manual screening. Error of testing 0,16 %. Investigation of chemical indices of

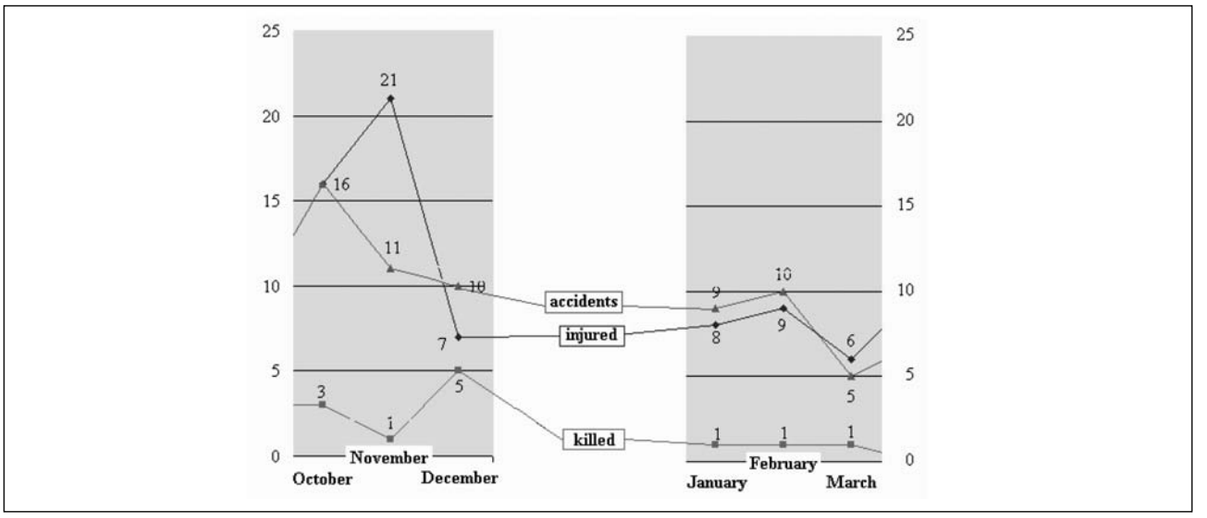

Fig 3. Road accidents on highway Vilnius–Panevėžys in 5 winter seasons

sodium chloride was carried out by a certified laboratory of Joint-Stock Company "Alzida", building materials and articles testing company. The following indices of sodium chloride were investigated: moisture content %; chlorides content, calculated as NaCl % and amount of sulphates %.

Based on sodium chloride salt investigations and the results obtained, it could be stated that the taken samples by their chemical composition meet very well requirements for the limit values; by the particle size distribution there are slight deviations from the permissible limit values [5]. It could be stated that salt used on highway Vilnius–Panevėžys satisfies the qualitative requirements. Test results are in Table 7.

Table 5. Amount of salt used on the highway Vilnius–Panevėžys during 7 years

Year	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	Total	Average salt need per month
October	32	0	0	0	0	23	671	726	104
November	386	390	1095	603	1553	603	421	5051	722
December	1242	886	1183	1655	1416	1578	1655	9615	1374
January	1104	952	721	533	942	732	850	5834	833
February	679	1308	598	412	856	505	931	5289	756
March	526	417	238	131	220	265	224	2021	289
April	37	0	0	10	0	127	0	174	25
Total	4006	3953	3835	3344	4987	3833	4752	28 710	4101

Table 6. Samples to determine the particle size distribution of sodium chloride

Sampling location	Name of material	Manufacturer	Sample No
Salt storehouse of Kaunas Maintenance Service	Technical white salt	G/S "Belaruskalij "	2-2109
Salt storehouse of Vievis Maintenance Service	Technical white salt	G/S "Belaruskalij"	2-2110
Salt storehouse of Ukmergė Maintenance Service	Technical white salt	G/S "Belaruskalij"	2-2111
Salt storehouse of Širvintos Maintenance Service	Technical white salt	G/S "Belaruskalij"	2-2112

Table 7. Results of NaCl composition

No	Requirements			Results							
	Indicator	Index	Amount	Sample No	Result	Sample No	Result s	Sample No	Result	Sample No	Result
				2-2109		2-2110		2-2111		2-2112	
1	Particle size distribution										
	>5 mm	%	0–5	0	+	0	+	0,0	+	0	+
	4–5 mm	%	5–10	3,5	–1,5	3,7	–1,3	3,5	–1,5	3,3	–1,7
	2–4 mm	%	20–30	28,8	+	28,4	+	27,2	+	22,5	+
	0,71–2 mm	%	30–40	39,9	+	44,0	+4,0	37,5	+	35,8	+
	0,16–0,71 mm	%	20–30	25,9	+	19,1	–0,9	27,5	+	29,0	+
	< 0,16 mm	%	0–5	5,3	+0,3	4,50	+	4,2	+	9,2	+4,2
	< 0,063 mm	%	≤ 1	0,0	+	0,045	+	0,1	+	0,2	+
	Extra condition: particle > 5 mm and < 0,16 mm, put together should be	%	≤ 5	5,3	+0,3		+	0,1	+	0,2	+
2.	Moisture content	%	≤ 3	no research		no research		0,20	+	0,20	+
3.	Amount of insoluble material in water	%	≤ 3	no research		no research		0,87	+	0,85	+
4.	Amount of chloride calculated like NaCl	%	≥ 93	no research		no research		96,50	+	97,75	+
5.	Amount of sulphate	%	≤ 2,5	no research		no research		0,21	+	0,18	+

7. Conclusions

1. Ten-years experience in using "Wet salt" technology in Lithuania showed that this method of reducing road slipperiness is effective and at present there is nothing to replace it. In future it is necessary to improve "Wet salt" technology, seeking for a more efficiency and economy.

2. It was determined by the analysis of the AADT during 5 years on highway Vilnius–Panevėžys that the lowest traffic level is in December, January, February and March. A decreased traffic volume in winter season meets a general tendency of AADT on Lithuanian highways.

3. Analysis of accidents on highway Vilnius–Panevėžys in the 5-year period showed that from the point of view of traffic safety the most dangerous are winter beginning months – October and November. The largest traffic volume on this road is on Mondays and Fridays. When implementing winter maintenance operations, a special attention should be paid to these months and these days of the week.

4. Results of quality investigations of sodium chloride salt, used to reduce road slipperiness, showed that by its chemical composition sodium chloride salt meets very well the requirements for the quality of salts used to spread Lithuanian roads, while deviations in the grading of samples taken are not significant.

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