DISTRIBUTION OF SPREADING AGENTS ON THE ROAD SURFACE

G. Hausmann

KOMMZEPT-Ingenieurbüro Hausmann, Bannewitz, Germany

hausmann@kommzept.com

H. Badelt

Federal Highway Research Institute, Bergisch Gladbach, Germany

Badelt@bast.de

ABSTRACT

Detailed knowledge of the distribution of spreading agents on the road surface and their effective times are prerequisites for the economical use of applying spreading agents.

Knowledge of the temporary course of effect of melting salts on road surfaces allows to repeat spreading only as soon as any necessity arises from the point of view of road safety.

In this respect, some investigative work was carried out in some countries in the past [1]. In this context it was always problematic to be able to measure salt quantities during road blocks only.

The objective of the research project was to register the effective quantities of salt on the road surface over two winter periods across the total cross-section of a dual-lane highway.

For this purpose road sensors were applied that were able to establish salt quantities on the road by measuring the electrical conductivity and the thickness of the water film.

As part of the research project, two extensive laboratory tests were performed on two sensor models in order to establish their measuring precision.

After having selected the sensor make, a total of twelve sensors was installed at Kilometer 29.8 on the Highway A4 in the direction of Goerlitz. The measuring field was operated from December 2006 through April 2008 and supplied approximately 8 million pieces of data regarding road conditions during the winter seasons. Parallel to that, about 210 spreading actions that were performed by the regular spreading service in the range of the measuring field were evaluated.

The following findings were derived from these analyses:

- The spreading agent gets pushed out of the wheel track very quickly. However, in most cases a small quantity of residual salt is sufficient to prevent dangerous slipperiness.
- With preventive spreading of pre-wetted salt on dry or slightly moist road surfaces only a small part of the applied salt becomes effective if there is no precipitation within a short time.
- Preventive spreading must be applied with timely precision; if possible not longer than 60 minutes before an expected icing event occurs.
- In the case of spreading pre-wetted salt onto the moist road surface, only about 25 to 50% of the salt applied is dissolved depending on the spread rate and other factors. The remaining part of the salt is passed to marginal areas without contributing to de-icing.
- After spreading, the quantities of residual salt activated by precipitation range between 0.5 and 1.5 g/m².
- Salt portions from purely spreading brine are pushed from the road much more slowly.

KEYWORDS

WINTER MAINTENANCE / RESIDUAL SALT / PRE-WETTED SALT / BRINE / ROAD SENSOR

1. INTRODUCTION

From 2006 to 2008, detailed investigation was carried out at a highway section regarding the distribution of spreading agents (NaCl) applied to the road and the influence of traffic on the effective times of the spreading agent. The aim of the research was to scientifically determine statements regarding resting periods of spreading agents on road surfaces [5]. Possibilities for applying spreading agents in road winter service more efficiently shall be deduced from that.

2. TEST OF ROAD SURFACE PROBES AND SET-UP OF THE MEASURING FIELD

For performing this research project, 12 road sensors were installed in two lanes of the Motorway A4 in the area of the Dresden-Hellerau Highway Surveillance Center, with the help of which temperatures, liquid film thicknesses and residual quantities of salt on the road surface could be measured during ongoing traffic at 5-minute intervals. By means of a newly developed test procedure, the type of road sensor best suited for the intended investigations had previously been selected in a conditioning chamber of the Federal Highway Research Institute [3]. In the tests, the sensors were charged with brine using a machine-controlled spray valve (Figure 1). The brine was of different concentrations which were applied in steps from 0.01 mm thickness respectively.

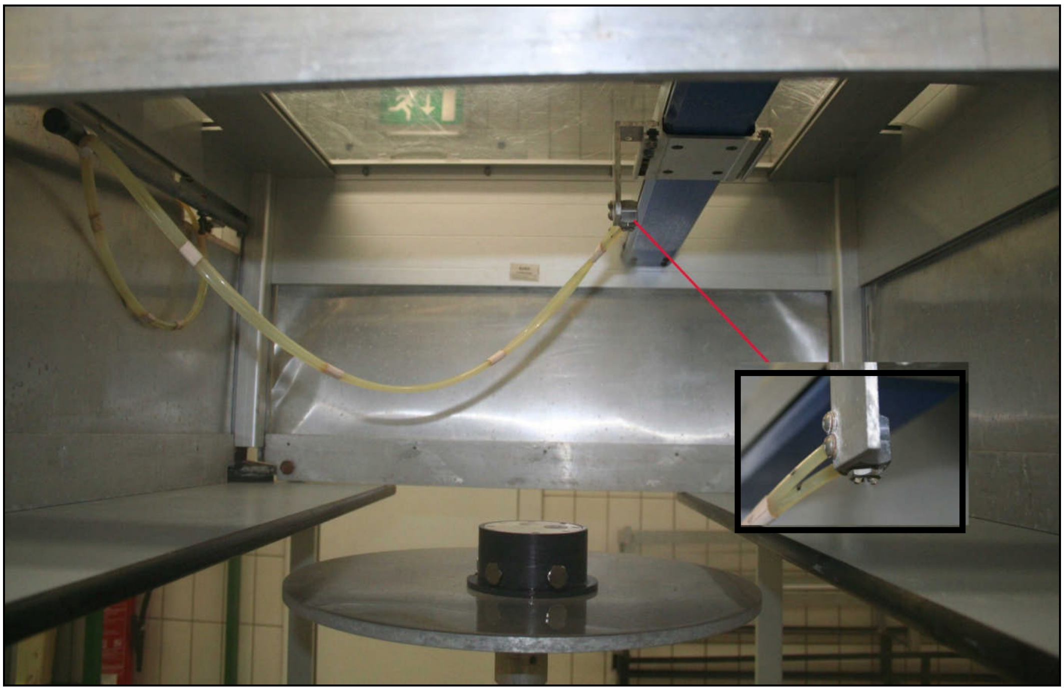

Figure 1: Machine-controlled spraying device for applying melting salt solutions of defined concentration and defined film thickness (the insert shows the jet)

The road sensors were arranged in such a way that measurements could be taken in the four wheel tracks, between the wheel tracks and in the marginal areas of the lanes (Figure 2). A part of the road sensors were arranged in pairs in the same position of the road cross-section in order to be able to asses the measuring accuracy of the road sensors and the longitudinal distribution of the melting salts, respectively.

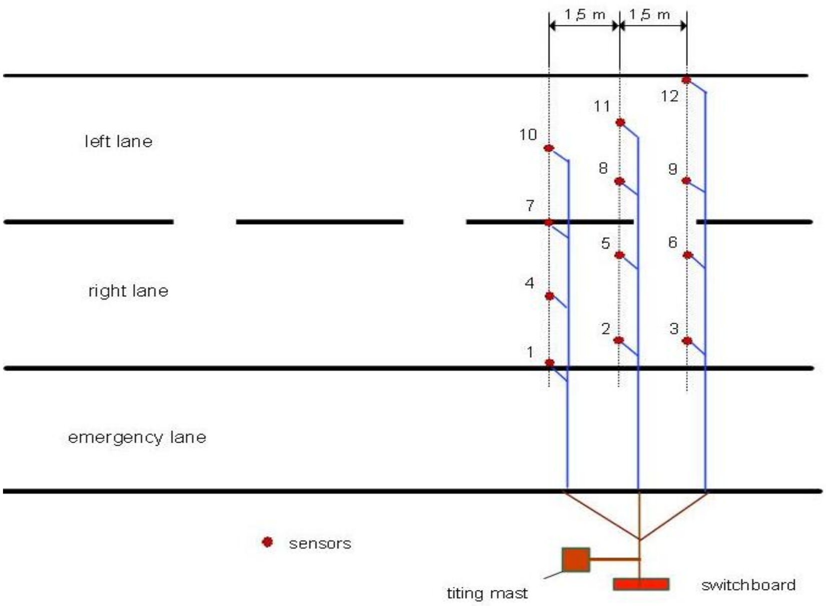

Figure 2: Arrangement of the road sensors in the measuring field

The measuring field consisted of the following components:

- 12 road sensors - Vaisala DRS 511 AB2 (passive sensors) with the features:
- Measuring / calculating the freezing temperatures
- Measuring the road surface temperature
- Recording the residual salt quantity [g/m²]
- Measuring the water film thickness
- Collection of data regarding the road condition
- Sensor combination for measuring the air temperature and relative humidity - Vaisala HMP45D
- Windset for measuring the wind speed and direction – Vaisala WA15 D7A
- Sensor for measuring the ground temperature – Vaisala DTS12G3.

The measuring field was set up immediately next to an existing ice detection system of the company Boschung. The measured values of this ice detection system were available for comparison.

Parallel to this, other meteorological data next to the measuring field, such as air temperature, humidity, precipitation, wind speed and wind direction were determined.

The following data were recorded by the responsible highway surveillance center in the range of the measuring spot for each spreading agent application:

- Number plate of the spreader vehicle
- Date
- Clock-time
- Spreading width
- Spreading density
- Position of the spreading pattern on the road surface
- Application of moistened salt Yes/No
- Application of a snow plough Yes/No

3. Execution and Evaluation of Measurements

In the time of investigation during the winter service periods of 2006/07 and 2007/08, 217 winter service missions were performed and documented. A total of 8 million pieces of data was acquired.

Spreadsheets have been generated from the raw data by means of specifically developed software, in which all recovered data are contained for each measuring point in time. Mean values have been generated from the relevant measuring values of the paired sensors.

This permits to create 3D diagrams for each individual event, from which the salt quantity (SM), freezing temperature (GT), road surface temperature (FT) or water-film thickness (WD) across the entire road cross-section can be learned in the course of time (Figure 3).

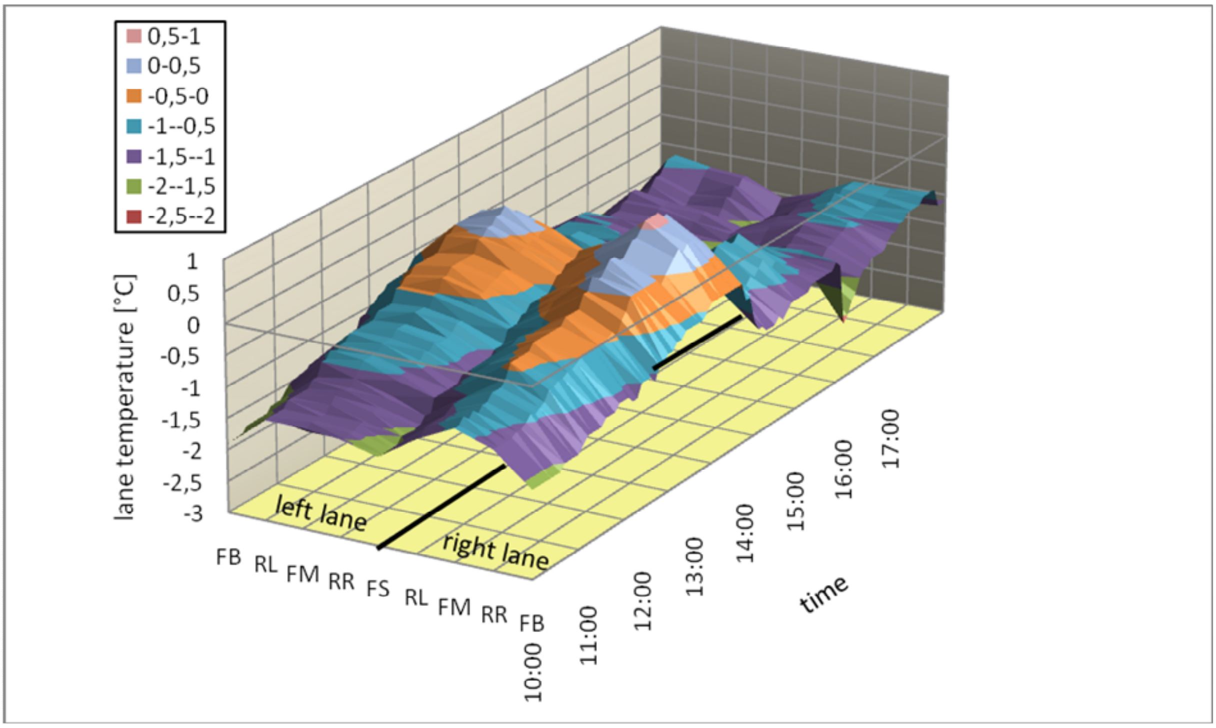

Figure 3: Characteristic temperature distribution across the cross-section of two lanes
FB – road margin, FS – separating line between the lanes, RR – right wheel track, RL left wheel track, FM – center of lane

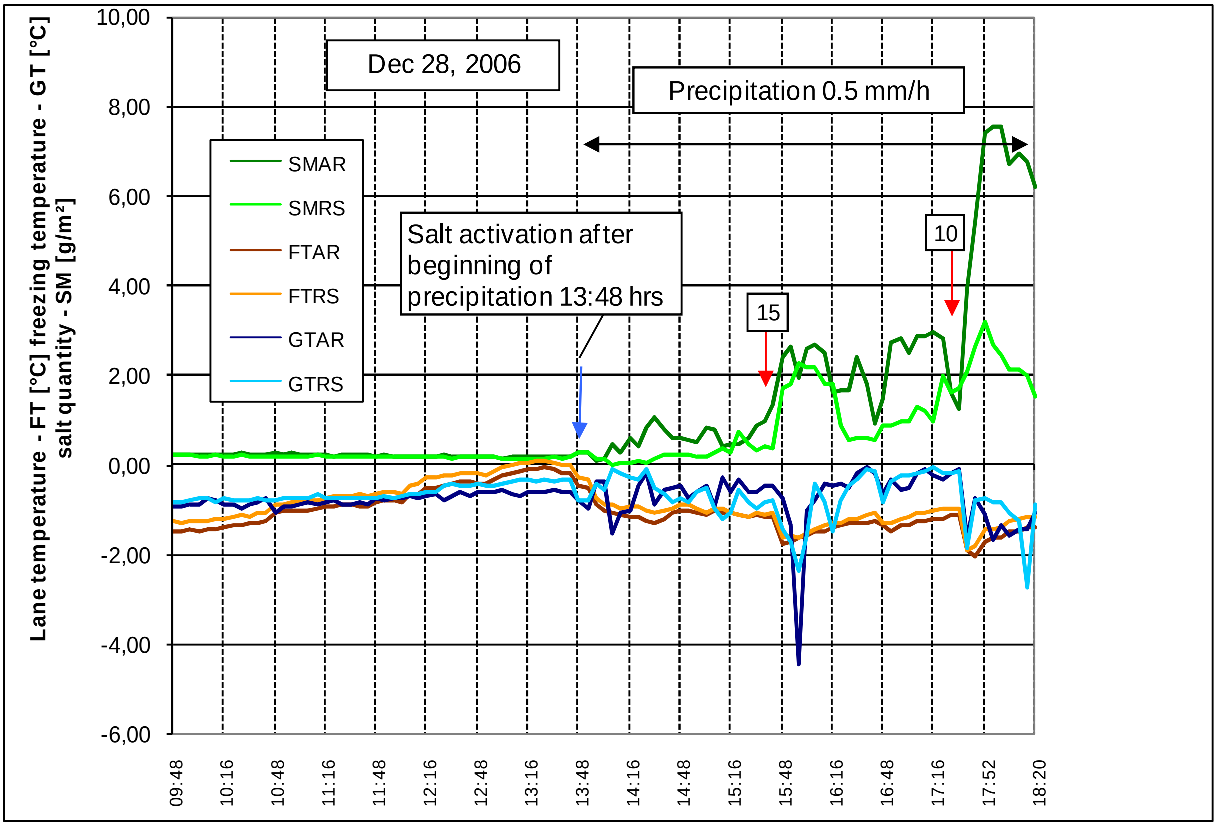

Figure 4: Salt activation after precipitation set in and the effect of subsequent spreading

The data were further summarized by averaging the values, differentiating between “within the wheel track” (RS) and “outside the wheel track” (AR). From the values so gained, meaningful diagrams on the course of spreading agent quantities, the freezing temperature and the surface temperature, differentiating between RS and AR, have been generated for each event. These diagrams are particularly well suited for documenting the effect of individual spreading processes and precipitation events (Figure 4).

From the large number of data from individual events, general conclusions can be drawn only if characteristic individual data are filtered from each individual event to facilitate a summary and the comparison.

For the further analysis, the road situation in which spreading is performed is classified as follows:

A) Road surface dry or slightly moist (max. 0.04 mm of water film)

B) Road surface wet or covered in little snow or slush – snow plough not applied

C) Clearing the road from snow or slush – with the snow plough applied

Regarding the issue of how much salt is required for fighting road slipperiness, it is important to know what quantity of salt gets dissolved on the road surface under real winter conditions. In order to obtain such values, the maximum values were read out from the sets of data after the respective spreading, separately as relating to the wheel track (RS) and outside the wheel track (AR) and comprised in a separate spreadsheet. Also, the time from the spreading until the maximum dissolved quantity was reached was recorded. Thereby, it is of crucial importance whether the road surface was already moist and more moisture is added by precipitation. Hence, the established data were evaluated separately with view of their road surface classification (of types A, B or C). In the evaluation, also the fact had to be taken into account that it is a dynamic process; i.e., while more salt is being dissolved, previously dissolved salt may have disappeared from the road surface in the form of spray. Consequently, it is impossible to establish an overall balance in that 7.6 g/m² of salt (spreading density FS 30, 10 g/m²) had been applied and a mere maximum of 3 g/m² became visible, with 4.6 g/m² remaining absolutely ineffective.

The diagram (Figure) shows that, in spreading events at times of no precipitation at all, clearly less dissolved salt is measured. It is basically the brine added in the case of FS 30, anyway. This is just to confirm metrologically that, in the case of dry road surface or very little moisture, salt gets hardly dissolved, since there is no fluid left for it.

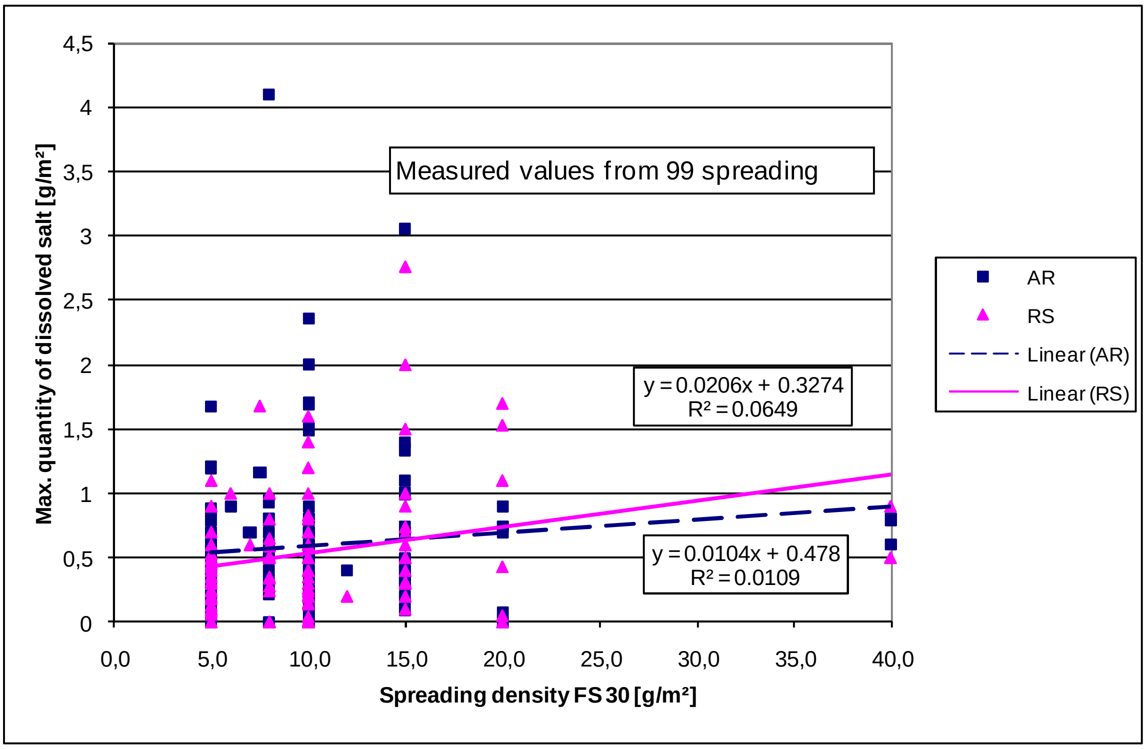

Figure 6: Maximum quantity of dissolved salt, depending on the spreading density (road surface dry or slightly moist)

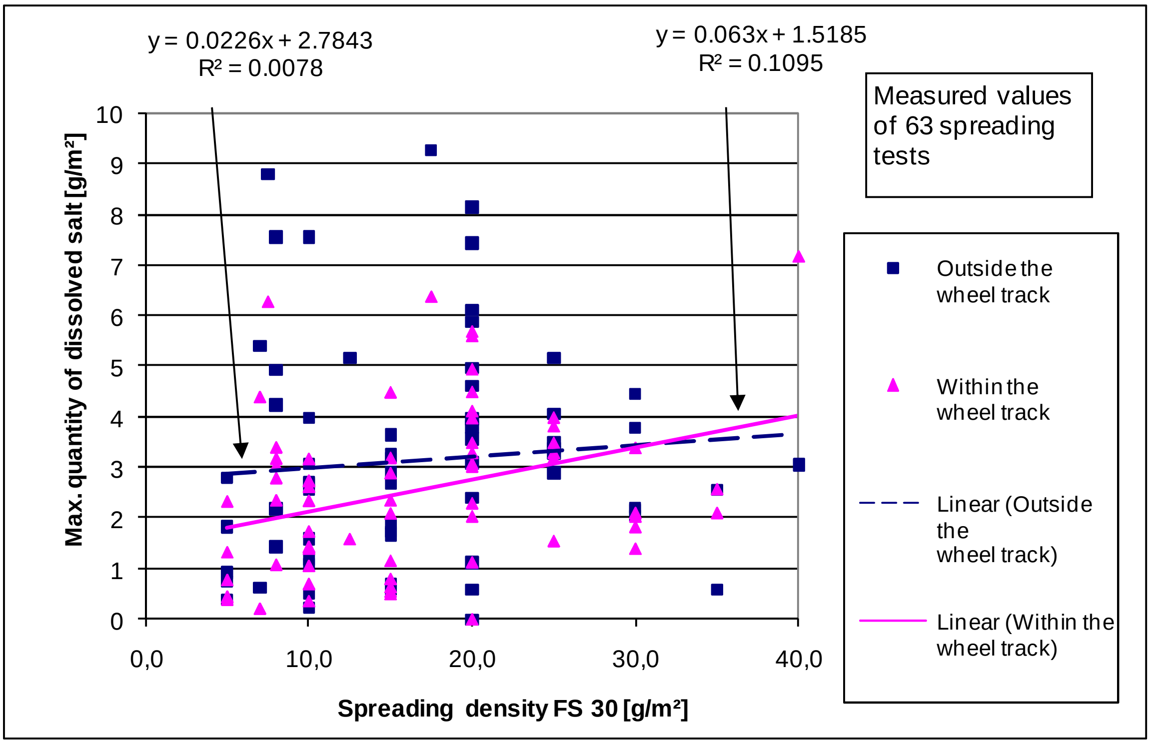

Figure 5: Maximum quantity of dissolved salt depending on the spreading density (road surface wet, with snow plough applied)

On the wet road surface, clearly more salt gets dissolved (Figure 6). However, the values range widely. It can be seen clearly that more salt is dissolved inside the wheel track than outside the wheel track, which may be owing to the mechanical effect of tires supporting the process of dissolution.

A comparative consideration will then demonstrate the impact of the liquid quantity on the road surface if the relative share of the dissolved salt is calculated. Thereby, the portion of the salt that dissolved after the sensor measurements is correlated to the quantity of salt allocated to a spreading density. For demonstrating this, the mean value of the maximum dissolved salt in the measurements outside and inside the wheel track is formed (Figure 7). It can clearly be seen that the share of the dissolved

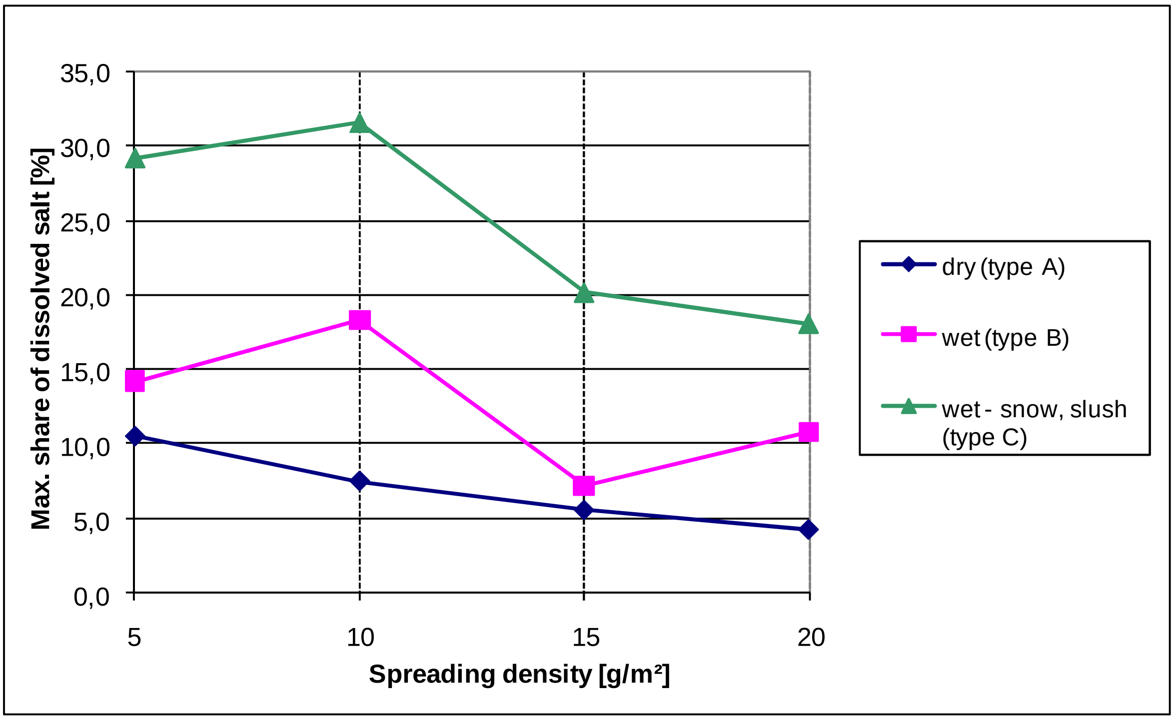

Figure 7: Maximum share of dissolved salt depending on the spreading density and the road surface situation

salt is, as a trend, decreasing with the spreading density rising. This means, the higher the spreading density, the lower the percentage of the salt, with the help of which a melting effect is achieved. In comparison with the spreading density of 5 g/m², there is a slight rise in the dissolution rate at 10 g/m² for types B and C, which contradicts the general tendency. The same is also to be observed with type B at spreading densities of 15 to 20 g/m². There is currently no plausible explanation for this phenomenon. But it must be taken into account that, for these comparative points, relatively few measuring data are available.

The rate of dissolved salt established by the measuring is altogether to be regarded as surprisingly low. The all in all large number of measuring values provides high security regarding the accuracy of the measurements.

4. Referential Measurements Made by a Novel Measuring Procedure

For the verification of the measuring values, a novel measuring procedure was adopted on some measuring days (Figure 8). This procedure allows to record and analyze both dissolved and solid constituent parts of the salt.

This procedure permits the measurement of residual salt at high accuracy on dry, but also moist or wet road surfaces [2]. In that respect, the device is especially suited for verifying the measurements made by road sensors, but also for complementing them. In this procedure, thawing material is collected from an exactly defined road surface area. Immediately prior to such absorption, the road surface is moistened by means of distilled water. The absorbed liquid is analyzed regarding its salt content. This analysis provides very precise values of the residual salt quantity prevailing on the road surface.

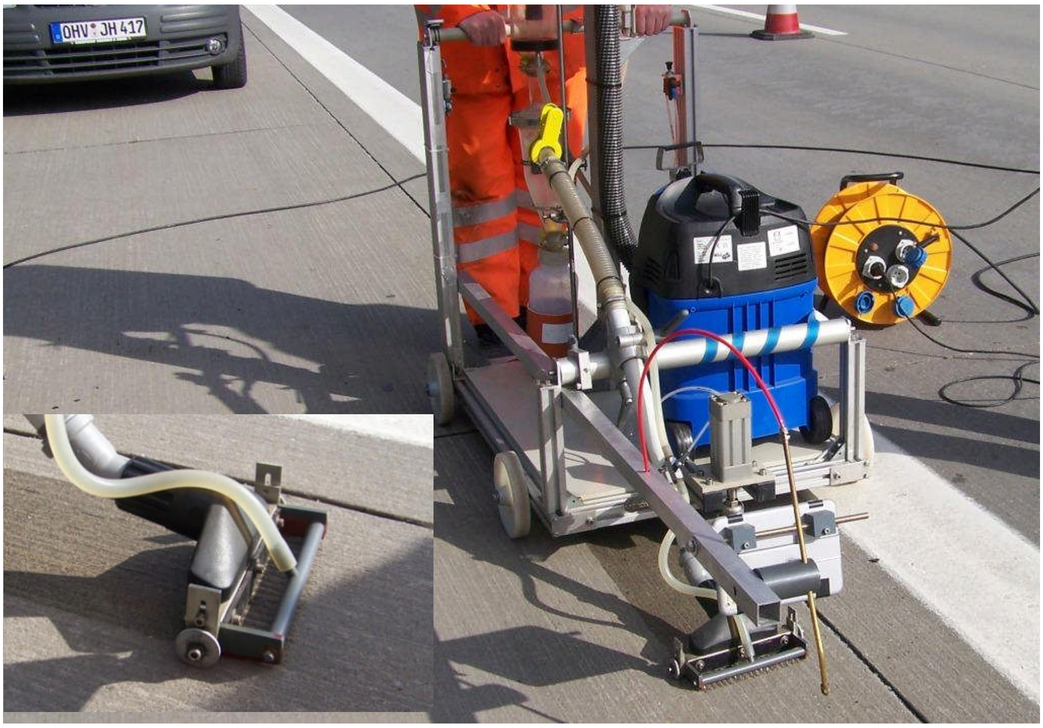

Figure 8: Salt intake by means of the rinsing/suction device, detail: suction port with moistening nozzles

By means of this device, comparative measurements to those values obtained by the road sensors were taken. However, for their different measuring approaches, a direct comparison is impossible. But the findings have been supported that considerably larger quantities of salt than previously assumed are transported to marginal areas within very short time.

Further spreading tests also investigated the remaining time of fine-grain evaporated salt and salt solution on the road surface. Thereby, it was observed that the salt portions from salt solutions remain on the road surface much longer (Figure 9). This is particularly to be expected if, as a precaution, spreading is applied to dry or only slightly moist road surfaces. The effective time of salt solutions on the road surface is currently being investigated in extensive measuring series on the road surface under field conditions.

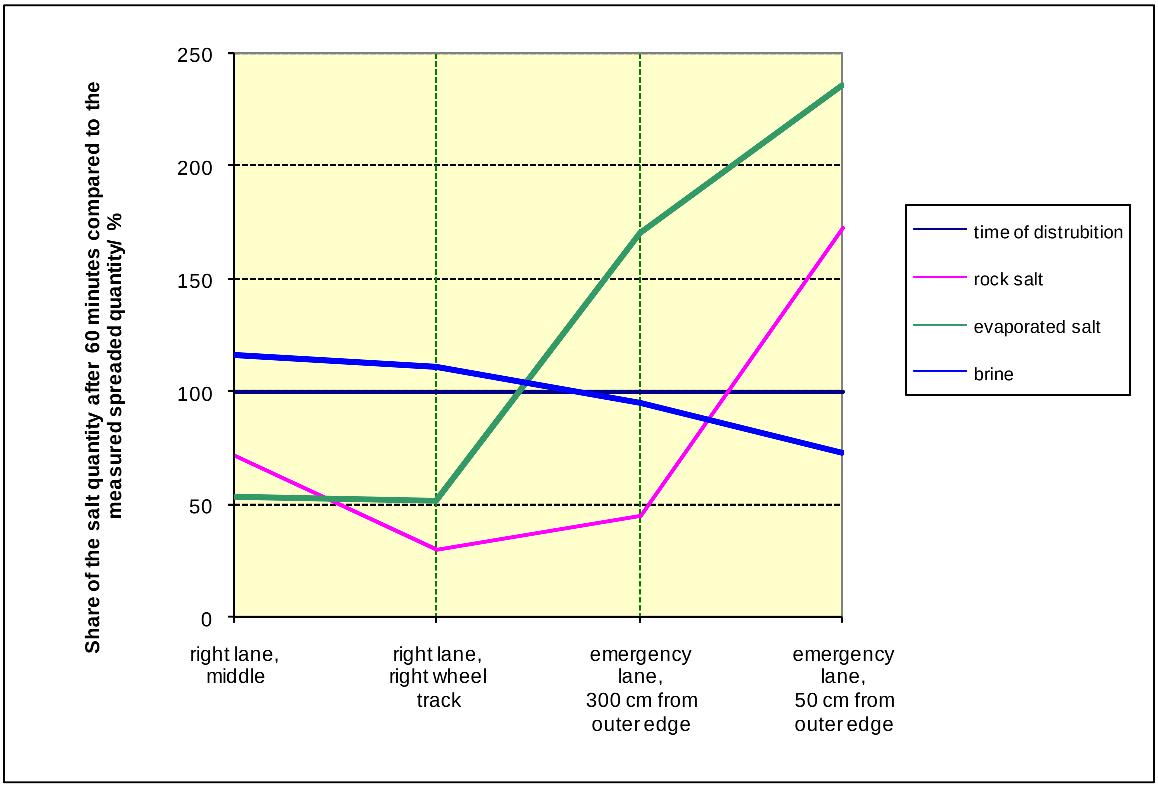

Figure 9: Relative change of salt quantities in the right lane and on the hard shoulder or emergency lane after 60 minutes of road traffic passing over [4]

5. Summary and Outlook

The measuring values obtained with the help of the measuring field within the scope of the research topic provide detailed insight into the processes on the road surface of a section of highway during the winter service season.

For the first time, exploitable measuring values of two complete winter service seasons have been made available for an entire road surface cross-section of a dual-lane highway.

The centerpiece of the measuring in the sense of the objective was to determine the salt quantities dissolved on the road surface.

The following findings can be derived from the measuring:

- Inside the wheel tracks, salt gets dissolved faster than outside the wheel tracks, but will then be pushed aside more quickly.
- The surface temperature in and between the wheel tracks of the right lane is approx. 1 – 1.5 K higher in normal traffic than between the lanes and at the margin of the lanes.
- The surface temperature in and between the wheel tracks of the right lane is approx. 0.5 – 1.0 K higher in normal traffic than at comparable points of the left lane.

- During the process of NaCl dissolving, a decrease in temperature of approx. 1 K occurs on the road surface within a period of 10 to 15 minutes.
- In the event of preventive spreading of pre-wetted salt onto the dry road surface, only that part of brine and that quantity of salt will be effective for which there is water on the road surface to dissolve them, if there is no precipitation within a period of approx. 120 minutes.
- In the frequently applied preventive spreading to prevent glazing or rime ice, only a small portion (12% on average) of the salt becomes effective. The larger part is pushed from the road surface before it can dissolve.
- When exclusively spreading brine to prevent glazing or rime ice, there is high probability that considerably lower salt losses will occur.
- When spreading pre-wetted salt onto the moist road surface, only an average of about 25% of the applied salt, depending on spreading density and other factors, will dissolve at a time. Maximum values of 50% have been observed.
- In the event of snow precipitation from approx. 1cm/h (1mm water/h) and temperatures from –3°C, slipperiness will occur on heavily frequented roads after 60 minutes already if spreading is not repeated.
- Within 24 hours, residual salt quantities reactivated by precipitation are at 0.5 to 1.0 g/m². Correlation with the texture of the road surface is to be assumed.
- Temperatures are measured with the help of available sensor technology at a high level of precision and reliability.
- Under field conditions, measurement of the water film thickness as well as the determination of the freezing temperature and the salt quantity is affected by disturbing factors resulting in imprecision. The issue must be raised as to what extent the conditions on the road surface can be reflected at all by the completely differently structured sensor surfaces.

In evaluating the findings, it must be considered that the investigations have been carried out on a highway where vehicles are driven at a usual average speed (trucks approx. 80-90 km/h, cars approx. 130 km/h).

From the knowledge gained, the following conclusions can be derived for the currently practiced winter service on roads of the mentioned traffic conditions:

- Preventive spreading is only sensible if applied timely, i.e. immediately prior to icing events to be expected.
- The time-frame for preventive spreading on the dry road surface is maximum 60 minutes and on the moist road surface maximum 120 minutes.
- By increasing spreading densities in preventive spreading, this timeframe cannot be extended.
- It is completely sufficient if the spreading width is adjusted in such a way that the outer wheel tracks are also covered by the spreading. Distribution across the entire width of the lane will be caused by the rolling traffic within a few minutes anyway.

Further investigations and research will focus on the following topics:

- Extensive measuring regarding the effective time of brine applied to the road surface.
- Investigations and tests with view of required spreading densities of brine against glazing and rime ice.
- Investigations of technically optimal solutions for spreading brine.
- An economic analysis of partially converting the winter service to the application of brine.
- An investigation regarding the transferability of the available findings onto roads of less or slower traffic.
- Complementing the measuring values of road sensors with non-contact friction value measuring. Selection and testing of suitable approaches.
- Investigation of mechanisms of moisture distribution on road surfaces and their drying and the related crystallization of residual salt.

It must principally be stated that, in preventive spreading and in spreading against thin ice layers in particular, there is potential for saving melting salt, which can be opened up by the target-oriented application of information technology and differentiated spreading technologies.

REFERENCES

[1] BLOMQUVIST, G., GUSTAFSON,M. (2004), Residual Salt on Road Surface – Case Study, Transportation Resarch Circular E-C063, TRB, National Resarch Concil, Washington D.C.

[2] BADELT, H.; MORITZ, K.; HEINZE, P. (2007), Verfahren der Firma ESG f ü r die Beurteilung von Streubildern – Ermittlung erzielbarer Wiederfindungsraten, BASt, Abschlussbericht zum kIAP F 1100.6507008, Bergisch Gladbach

[3] BADELT, H.; BREITENSTEIN, J.;FLEISCH, J., H Ä USLER, G; SCHEUERL, S.; WENDL,A. (2006), Pr ü fung von Sensoren f ü r Gl ä ttemeldeanlagen, Bericht zu den Projekten 96653, 99655, 01670, 99653, 01652, BASt Bericht 146, Bergisch Gladbach

[4] BADELT, H.; HAUSMANN, G.; M Ü LLER, A. (2008), Tausalzverteilungen nach Verkehrseinwirkungen gemessen mit dem Feuchtsalzaufnahmegerä t der Firma ESG. BASt-Forschungsbericht, Bergisch Gladbach, non publié

[5] HAUSMANN, G., (2009), Verteilung von Tausalzen auf der Fahrbahn. Reihe BASt "Verkehrs-technik" Band BASt-V-180, Wirtschaftsverlag Bremerhaven