Title page

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Title:
The Amount of Salt on Road Surfaces after Salt Application
– a Discussion of Mechanisms and Parameters

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ABSTRACT

Field observations have been made to study the development of salt amount on road surfaces after salt application. The objective of the study has been to understand the mechanisms that remove salt from road surfaces after spreading and identify important parameters behind the mechanisms. After salt application salt is transported from the road surface by the three mechanisms; denoted as blow-off, spray-off and run-off. The mechanisms are affected by several parameters grouped in weather parameters, traffic parameters and road characteristics. Four case studies are presented where the amount of salt was measured with Sobo 20. Weather, traffic and winter maintenance activities were recorded. The amount of water on road surface was measured by using absorbent textiles. The results show that the amount of water on the road surface controls the development of salt amount on road surface. Both the mechanisms of salt loss and how much salt becomes dissolved are governed by the amount of water on the road surface. On a wet road surface more salt will be dissolved compare to a moist road surface. This lead to a higher peak value in the amount of dissolved salt (which is detected with the used instrument). Further, on wet road surface there will be a more rapid loss of salt, due to a higher effect of spray-off.

1 INTRODUCTION

Important aims for winter maintenance of roads are to achieve a high level of accessibility, regularity and traffic safety during the wintertime. Securing a sufficient level of is essential to achieve these aims. Snow and ice removal and friction control are therefore the most important activities in winter maintenance of roads. Mechanical and chemical methods are used both for snow and ice removal and for friction control.

Independent of the purpose of a salting action, whether it is to prevent freezing (anti-icing), to melt ice or snow (de-icing), or to prevent the build-up of compacted snow on road surfaces (anti-compaction and anti-adhesion), there are several critical factors that determine the effectiveness of the application. The most critical factors are timing and spreading rate of the application. The amount of salt on the road surface is critical for the road surface conditions and whether or not ice formation or snow compaction occurs. How long the salt remains on the road surface after application is therefore vital for the road surface conditions. Knowledge of the development of the amount of salt after a salt application is relevant for:

- Decision-makers
- Establishing guidelines
- Research and development activities

The person making the decision when to salt and how much to spread benefits from having insight in how much and how long salt remains on the road surface. At higher organisational levels it can be useful knowledge in the work on optimizing the use of salt using guidelines for salt application. The knowledge can, for example, be used further to assess spreading methods under different surface conditions.

There have been several studies on the development of salt amount on road surfaces. Blomqvist and Gustafsson *(1)* studied the distribution of salt in the cross-section of the road and developed a model for development of the salt amount as a function off traffic. Hunt, Mitchell and Richardson *(2)* studied the development of salt amount after brine application. Glue *(3)* investigated also the development after brine application. These studies, however did not consider the amount of water that is present on the road surface.

This work describes a field study on how the amount of salt on road surfaces develops after a salting application. The objective is to understand the mechanisms that remove the salt from road surfaces and identify the important parameters behind these mechanisms. Issues concerning the actual spreading of salt are not addressed in this work. Questions like the efficiency of different spreading methods are not concerned.

2 MECHANISMS THAT CONTROL THE AMOUNT OF SALT ON ROAD SURFACES

There are several parameters that influence the amount of salt on road surfaces. To understand further how the amount of salt develops after salting actions, it is useful to identify the mechanisms that remove salt from the road surface. Considering the road surface as a system, movements of salt out of the system can be observed. Assuming that salt is evenly distributed in a longitudinal direction, the flow of salt in and out of the system can be seen in 2D, a cross-section profile of the road.

Three removal mechanisms can be identified; denoted as 1) blow-off, 2) spray-off and 3) run-off. These mechanisms are illustrated in FIGURE 1.

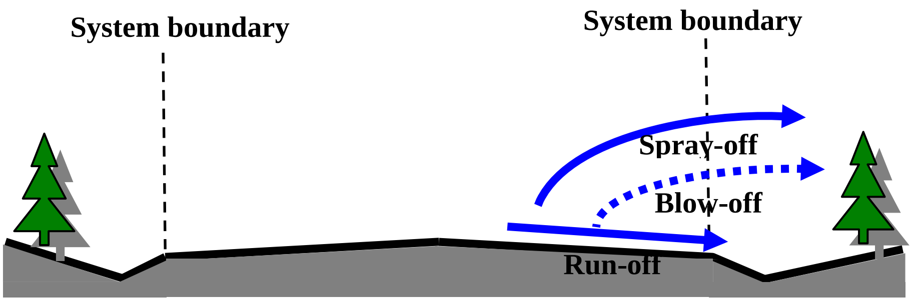


FIGURE 1Cross profile of a road with the salt loss mechanisms illustrated.

Blow-off

The mechanism of blow-off is the removal of solid salt grains from the road. Blow-off is caused by traffic and thus depends on the number of vehicles, type of vehicles and traffic speed. In addition wind will probably increase blow-off. Blow-off will also be affected by the road surface conditions such as how wet the road is, if snow, ice or slush is present. Pavement texture will probably also influence. A coarse texture may "hold" onto the grains to a greater extent than a fine texture.

Spray-off

Spray-off is dissolved salt that is sprayed off the road surface. Spray-off is directly controlled caused by traffic and thus depends on number of vehicles, type and speed. Similarly for spray-off, other parameters may also affect the mechanism. A wet road surface will give more spray-off than a dry or moist one. Wind will increase the spray-off effect. A coarse texture on pavement was found to give less spray-off. *(4)*

Run-off

Run-off is gravity driven drainage of liquid from the road. Run-off will probably onset when there is a critical amount of water that has been collected on the road surface. The system of pores in the pavement will have to be "saturated" before run-off occurs. When the amount of water on the road surface has reached this critical value, run-off will take place. This can be seen as a threshold-value. Both the threshold-value and the flux will depend on the road surface texture, cross-fall and rutting.

Redistribution in the cross-section profile

Salt is redistributed within the system. Redistribution is not a removal mechanism but it can change the salt distribution within the bounderies. A normal part of redistribution is that salt is transported from the wheel tracks to the area between wheel tracks and the shoulder and thereby results in less salt in wheel tracks *(1).*

TABLE 1: Mechanisms that Removes Salt from a Road Surface and the Parameters Affecting the Mechanisms

Mechanism	Weather	Traffic	Road characteristics
Blow-off	Wind Amount of water on road surface - precipitation	Amount Speed Vehicle type	Texture
Spray-off	Wind Amount of water on road surface - precipitation	Amount Speed Vehicle type	Texture Rutting
Run-off	Amount of water on road surface - precipitation		Texture Rutting Cross-fall

The table above summarizes the loss mechanisms and the important parameters that control each loss mechanism. As stated earlier, for blow-off and spray-off, traffic is the “driving force” for the mechanisms. Blow-off and spray-off are in that respect a function of traffic. The “driving force” of run-off is gravity rather than time. Since run-off becomes only significant after a critical amount of water, it seems natural in most cases to plot salt amount as a function of traffic.

3 FIELD STUDIES

Field observations were carried out on ploughing/salting route on the E6 south of Trondheim, Norway. The strategy for the maintenance standard requires that the road surface shall be free of snow and ice, except during snowfall. After snowfall the road shall be free of snow and ice within 4 hours after the snowfall ended. The selected strategy for winter maintenance requires that chemical methods are used for friction control and chemical methods along with ploughing are used after snow removal. On this route salt is spread mostly as prewetted salt (prewetted with 30 % water) or as dry salt.

The road is a typical two-lane road with an AADT (Average Annual Daily Traffic) of approximately 5000. A certain point on the road was chosen for data collection. FIGURE 2 shows the road and the location for field observation. Regular observations were conducted during the winter seasons of 05/06 and 06/07. Each observation period is considered as an individual case.

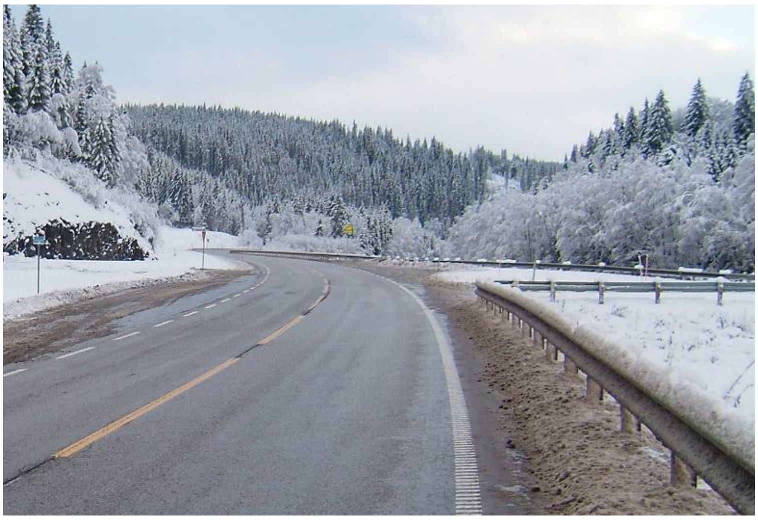


FIGURE 2 The site and the road chosen for field studies.

The basic method for the field studies was to document the road surface conditions and collect data in connection with ordinary maintenance measures and salting action on this section of the road.

3.1 Data collection

The collection of data included both automatic and manual data collection. The parameters relevant for this analysis are:

- Automatic data:
    - Data from maintenance trucks
    - Traffic data
- Manual data:
    - Weather parameters
    - Water on road surface

- Salt amount

The maintenance trucks had a system based on GPS (Global Positioning System) and GSM (Global System for Mobile communications) for logging maintenance measures. This system logs when and what type of maintenance measures that are being conducted. This includes the spreading rate and snow removal. The traffic data includes number of cars and number of heavy vehicles every hour.

Air and road temperature, dew point, precipitation as well as salt amount and amount of water on road surface were measured. The measuring techniques are presented in chapter 3.2 and 3.3. Road surface conditions were documented by taking photographs and qualitative descriptions.

3.2 Measuring salt amount with Sobo 20

Salt amount were measured by using the instrument Sobo 20, see FIGURE 3.

FIGURE 3 Measuring salt amount with Sobo 20 and water amount with Wetex textile.

The instrument has a mouthpiece that is placed on the road surface. This mouthpiece has a rubber gasket which encloses a known area. When pressing the instrument against the surface, a known amount of measuring fluid is sprayed on to the road surface. The measuring fluid is a mixture of acetone and water. The instrument measures the electric conductivity in the measuring fluid. By having a defined area of measurement, a known amount of measuring fluid and the electric conductivity, the instrument calculates the amount of salt on the road surface in g/m^2. A more thorough description of Sobo 20 is found in *(5)*.

During the field observations salt amount were measured in the right-wheel track and between wheel tracks. Each time three repetitions in the longitudinal direction were made and the average from these three readings was calculated.

3.3 Measuring road surface water with Wetex

The amount of liquid was measured by using a absorbent textile called Wetex, see FIGURE 3. By placing a textile piece of known dimensions (0.265 × 0.410 m) on the road surface it will absorb the present liquid. The amount of liquid per unit area was determined by weighing the textile before and after the absorption. It was recognized that this was not a very precise and flawless method because it is never possible to absorb all the water. However, it is simple, rapid and provides relative data on how wet a road surface is. Measurements were taken in right-wheel tracks and between wheel tracks.

For data presentation and analyses, the following classification of wetness for road surfaces has been used:

TABLE 2: Definition of Moist and Wet Road Surface

Road surface wetness	Amount of water [gr/m^2]	Equivalent water film thickness [mm]
Dry	0	0
Moist	0-100	0-0.1
Wet	>100	>0.1

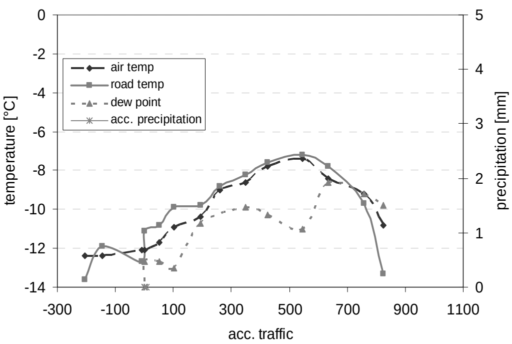
4 RESULTS FROM FIELD STUDY

4.1 Case 1: 2007.01.24

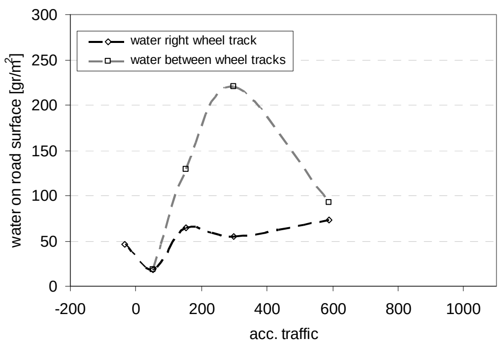
Observation period: 24 January 2007, from 04:00 to 18:00.

The weather was lightly clouded and with air temperature at 04:00 on -12.4º C and road surface temperature of -13.6º C. During the observation period they increased to -7.7º C and -7.2º C, respectively. In the wheel tracks the surface had scattered ice crystals, but not to the extent where the road surface became slippery. The roads were salted at 06:30 with 30 g/m^2 of prewetted salt. After salting and rising temperatures the road surface in wheel tracks became moist. Between wheel tracks there was some loose snow that became slush during observation time.

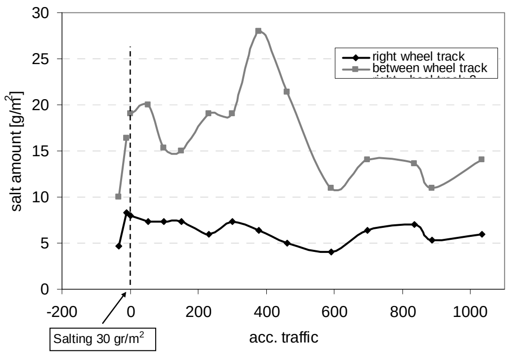
FIGURE 4 The observation point at 07:56 and 09:20.



a) Weather parameters



b) Amount of water on road surface



c) Salt amount on road surface

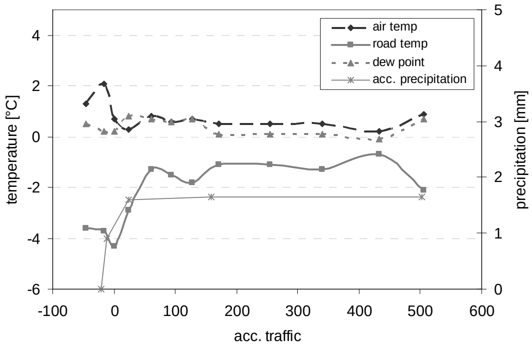
FIGURE 5 The data recorded in case 1.

4.2 Case 2a: 2007.01.31 – south bound lane

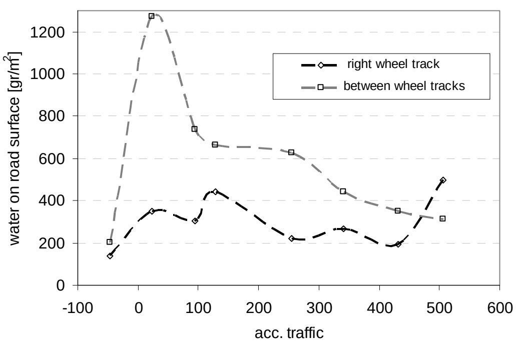
Observation period: 31 January 2007, from 04:00 to 14:00.

There was a light cloud cover with some precipitation in the form of sleet and snow around the time of the salting action. Maximum and minimum air temperatures were +2.1º C and +0.2º C, respectively. Road temperature was a maximum of +0.8º C and a minimum of -0.1º C. The road surface was wet, and there was some slush between the wheel tracks. Salt application in the south bound lane took place at 06:38 with 30 g/m^2 of prewetted salt.

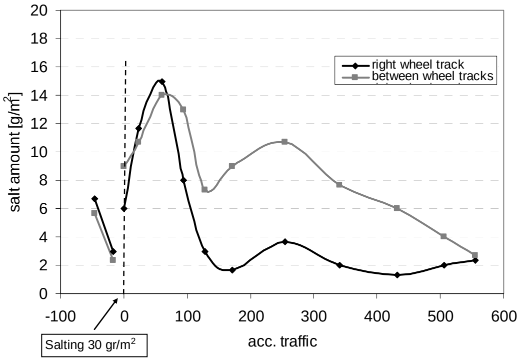
FIGURE 6 The observation place at 07:50 and at 12:43



a) Weather parameters



b) Amount of water on road surface

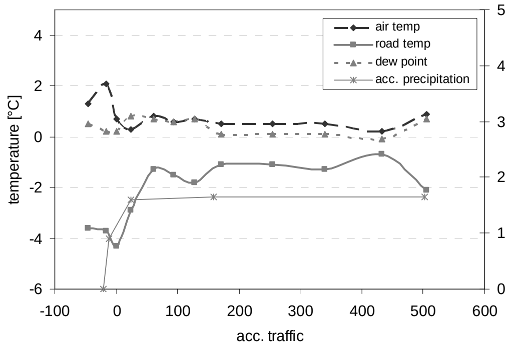


c) Salt amount on road surface

FIGURE 7 Data collected in case 2a.

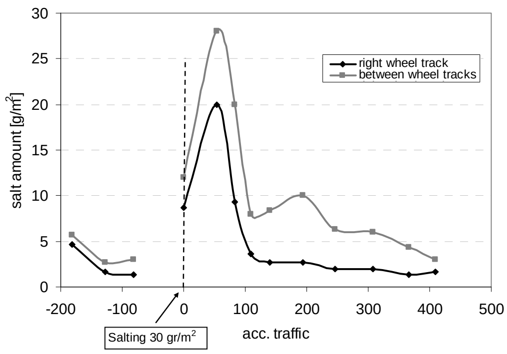
4.3 Case 2b: 2007.01.31 – north bound lane

This shows the same time and condition as case 2b, except that the data is collected in the north bound lane. Here, the salting took place at 07:13. The application rate was 30 g/m^2 of prewetted salt.



a) Weather parameters

b) Water on road surface



c) Salt amount

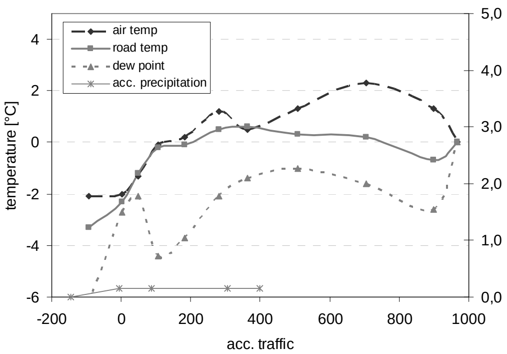
FIGURE 8 Data collected at case 2b.

4.4 Case 3: 2007.02.27

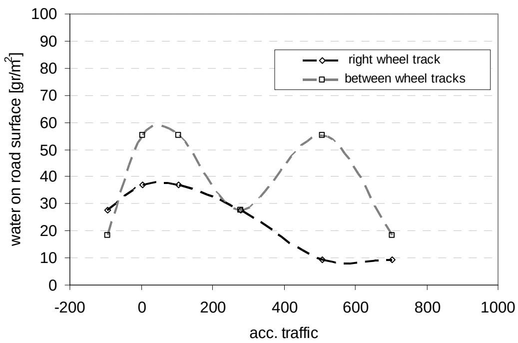
Observation period: 27 February 2007, from 09:00 to 17:30.

The weather was cloudy with rising temperatures. The air temperature was a minimum of -2.1º C and of a maximum +2.3 ºC. The minimum and maximum road temperatures were -0.6º C and -3.3º C, respectively. The road surface could be characterised as moist. There was some light snow on the road surface at the beginning of the observation. Salting took place at 10:14 with an application rate of 30 g/m^2 with prewetted salt.

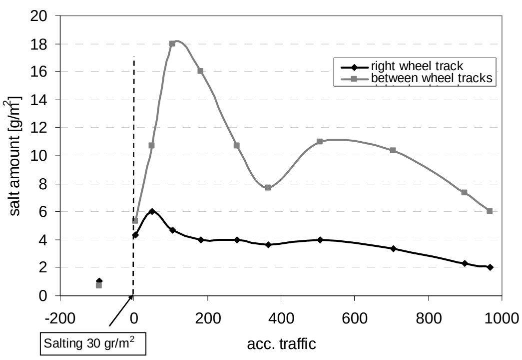
FIGURE 9 The observation point at 09:21 and 16:15.



a) Weather parameters



b) Water on road surface



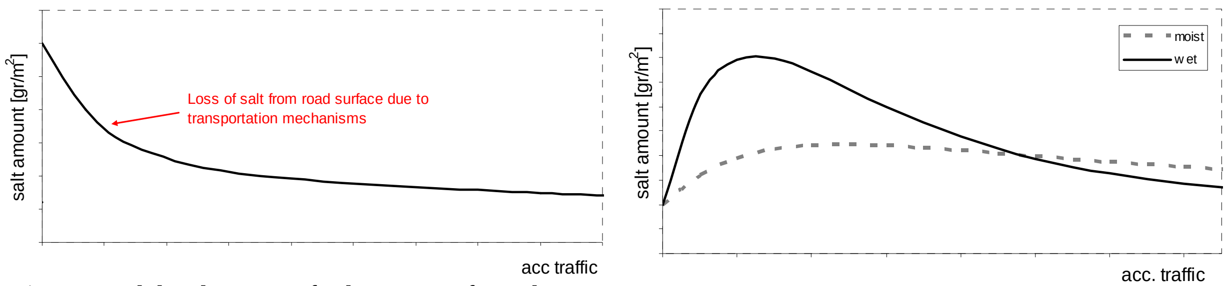
c) Salt amount

FIGURE 10 Data collected for case 3.

5 DISCUSSION

The dissolving of salt

The first important fact one should have in mind when analysing the results from measurements of salt amount is the limitation of the instrument Sobo. Sobo measures the electric conductivity in the measuring fluid. This means that Sobo measures the salt dissolved in the measuring fluid. Tests have shown that the measuring fluid dissolves solid salt that lies inside the measuring area only to a limited extent. If there is a lot of undissolved salt on the road surface, Sobo will only measure a certain ratio of the salt that is present. The fact that Sobo measures little of the undissolved salt on the road surface explains the shape of the curves that plot salt amount versus time or traffic. If Sobo has measured the total amount of salt on the road surface, one would expect a curve like FIGURE 11a. The highest amount of salt should be measured immediately after salt application. Instead measurements with Sobo show a development as in FIGURE 11b. These are idealized curves. The general trend is: Immediately after application the measured salt amount is low, then the amount of salt increases before there is a decline in the salt amount when the mechanisms of salt loss become dominant. The first part of the curve before the peak occurs can be explained by the fact that there is a time- and traffic-dependent process where salt is being dissolved. The salt is present, but is not detected with a measuring instrument like Sobo. As more of the salt dissolves, more salt is measured by Sobo.



a) Expected development of salt amount after salting actions.

b) Salt amount measured with Sobo 20.

FIGURE 11Idealized curves for the development of salt amount after salting actions.

One can also see that the shape of the curve is different when observing salting on wet road surfaces versus moist road surfaces. On a wet road surface there is a clear gradual rise in measured salt amounts and relativity high peaks followed by a rapid loss. In cases where only the road surface is moist, there is neither a rapid rise in measured salt amount nor a high peak value. The cause for these differences is that on a road surface with small amount of moisture there is insufficient water present to dissolve the salt to the same extent as on a wet road surface. The solubility curve for salt shows that at 0 º C 1 gram of salt needs approximately 2.8 grams of water to be fully dissolved (a salt brine is saturated at 26.3 weight percent of salt at 0 º C). Theoretically that means that if dry salt is spread with a rate of 30 g/m^2 there has to be 84 g/m^2 of water present to fully dissolve the salt. This aspect, combined with the notion that dissolving is time depended, explains the differences between a moist and a wet road surface. On moist road surfaces, when most of the salt is finally dissolved and thereby is detected by the Sobo instrument, much of the salt is blown and sprayed off the road. These differences between moist and wet road surfaces can clearly be seen when comparing results from field observations. The fact that the amount of water is important for the process of dissolving salt, and thereby salt that is detected by Sobo, can also clearly be seen in cases 1 and 3, FIGURE 5 and FIGURE 10. In these cases there is a substantial difference in the amount of water inside the wheel tracks compared to between wheel tracks. For this reason there is a more rapid rise and larger amount in measured salt between wheel tracks compared to inside wheel tracks. The amount of salt is also higher between wheel tracks due to the redistribution within road surface.

The loss of salt

The transport mechanisms of salt depend on the amount of water present on road surfaces as indicated in Section 2. FIGURE 12 shows the salt amount in wheel tracks plotted as a function of traffic for all four cases. The data points are grouped into wet or moist road surface according to the definition presented in

TABLE 2.

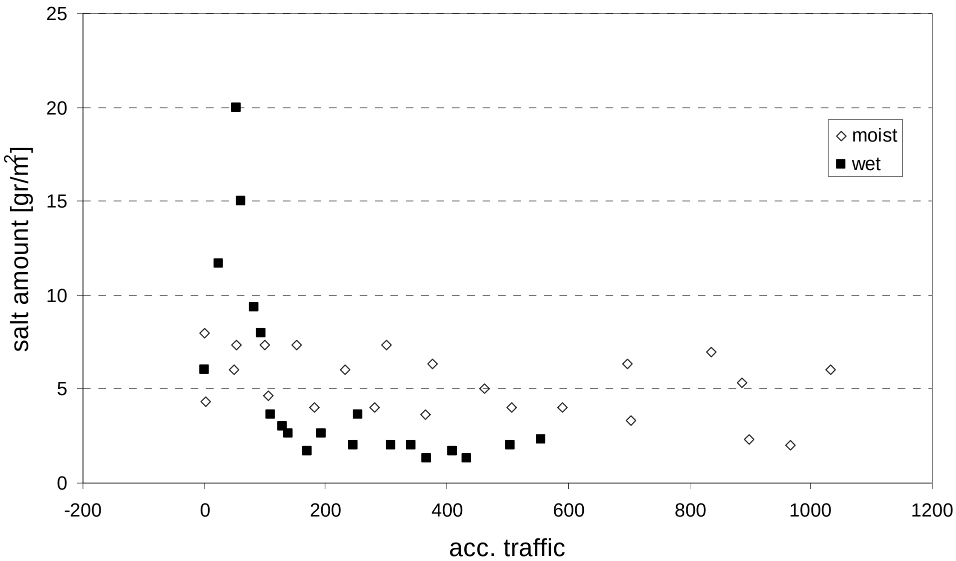


FIGURE 12: Salt amount inside wheel tracks. Data from all four case studies grouped according to wet and dry road surface.

Immediately after spreading one should be careful to compare the data for moist and wet road due to the fact that Sobo does not measure dry salt, and to limited degree, dissolves dry salt. Exactly where the data is comparable (all salt dissolved) is not known. Considering FIGURE 12 the data shows the clear tendency that there is a more rapid loss of salt on wet road surfaces. The magnitude of the loss is also greater on wet compared to moist road surfaces. After about 150 cars the amount of salt is clearly higher on moist road surfaces compared to wet road surfaces. The mechanism of spray-off on wet road surfaces seems to be more important compared to the blow-off effect on moist road surfaces. The salt seems to be present longer on the road surfaces on moist compared to wet road surfaces. This is because on a moist road surface when finally the salt is dissolved there is no or very little spray-off.

The results from the field observations clearly show that the amount of water on road surface is controlling the development of salt on road surface after salting actions. How wet the road surface is will decide what type of loss mechanisms that governs the development and the magnitude of the loss mechanisms. A dry or little moist road surface will give a large blow-off effect, but no or little spray-off and no run-off. More amount of water will give more spray-off and at a wet road surface one will also have run-off.

6 CONCLUSION

The removal of salt from road surfaces is described by the three mechanisms blow-off, spray-off and run-off. The controlling parameters are discussed and can be grouped in weather, traffic and road characteristics.

Field observations including salt amount measurements have shown interesting results with respect to the discussion of the transport mechanisms. The results have shown that the amount of water controls the development of salt on the road surface. Road surface wetness determines which removal mechanism that is dominant and the magnitude of the loss. The dissolving of salt is highly depended on amount of water on road surface. It is shown that the development of salt amount on road surfaces are substantial different on moist road surfaces compared to wet road surfaces. On wet road surfaces there is a more rapid rise and fall of salt amount compared to moist road surfaces. There is a higher maximum value on the amount of salt on wet road surfaces that can be detected with the used instrument. However, on moist road surfaces the salt remains longer on the road surface because of less or no spray-off. This means that there are higher amount of salt on moist road surface compared to wet after the same amount of traffic has passed.

The instrument Sobo can be used examine the questions addressed in this work, but the results should be interpret in considerations of the known the limitations of Sobo. A further exploration of the mechanisms of blow-off and spray-off requires the development of an instrument than can measure the total amount of salt, not only the dissolved salt.

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