TESTING OF SPREADERS FOR SNOW AND ICE CONTROL

METHODS AND RESULTS

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ABSTRACT

With a view to revealing the safety and environmental aspects of spreading salt on the public road network in Denmark, work was conducted in 2007 and 2008 on development of testing methods for spreading equipment, and a number of spreading examinations were performed.
The development work was initiated by the Danish Road Directory in close collaboration with municipalities, suppliers of spreaders and the Spreading Technique Laboratory of Århus University.

The purpose is to have requirements established for the distribution of the thawing material, partly in the form of an even distribution across the roadway, and partly in the form of requirements for the maximum amount allowed to be spread outside the roadway.
In addition there are requirements for the dosing of the salt spreader which serve the purpose of demonstrating the average dosing accuracy and any deviation in the dosing per time unit.
In the long term specific requirements are to be established in connection with purchase of salt spreaders.

The results of the tests have revealed a great number of deficiencies in connection with the spreading accuracy of the measuring criteria which were established.
The achieved distribution of the material across the roadway has not been satisfactory as, in general, there has not been an even distribution, and the amount of salt outside the roadway was often too large.

The examinations have demonstrated that there is a need for adjustment of the established requirements for spreading accuracy, and that part of the equipment will need further development.

The examinations conducted have also proved that the method used is very promising in spite of minor deficiencies as it is possible to achieve valid results as no considerations have to be made to weather conditions or other issues which may affect the results. Development of the method is an ongoing process.

The salt spreader examinations were performed. The mobile tests were made at low speed to ensure that the results achieved reflect the distribution from the spreading equipment so that the spreading results are not influenced by factors such as turbulence.
The distribution image across the direction of travel was performed by asymmetrical spreading and was achieved by collected of the material spread in fields where, immediately after passage of the measuring fields, it can be registered and depicted in a distribution image.

KEYWORDS

WINTER MAINTENANCE SERVICES / TESTING OF SALT SPREADERS / METHOD DEVELOPMENT

1. 1. BACKGROUND OF TEST DEVELOPMENT

The Danish Road Directorate keeps a permanent focus on how the use of road salt can be minimised without compromising the safety and practicability of public roads.
This calls for a development-oriented milieu in which new methods are put to the test and cooperation occurs across the boundaries of road authorities and external interested parties.
Increased reductions in salt consumption require that salt spreaders are further developed, so that the distribution image and the amount of salt being spread become known and documented. This is not the case at this time.

The wish for minimising the amount of salt being spread on the roads must be seen from an economic perspective. A reduction in salt consumption would bring about a substantial economic reward. This reduction, nevertheless, must also be considered from the point of view of the environment, since it would represent major benefits for several aspects of the environment, such as plant life and groundwater, and bring down the emission of gases, including CO2, that occurs during salt production and transport.

The expense of road salt amounts to a significant part of Denmark’s winter budget – no less than 8% of the country’s total expenditure in winter maintenance services is allotted to salt purchase.

The continuous development aimed at minimising the use of salt has resulted in a broad use of moistened salt and brine.
One of the latest development initiatives is known as road section forecast, which means that a specific road section is relatively salted according to road temperature and other factors that play a part in the appearance of slippery road conditions. In this way it is not necessary to spread the same amount of salt along the entire road; instead, dosage can be changed according to weather conditions and along the most exposed sections.

If positive developments within winter maintenance services are to continue so that we in the future have a modern winter service that meets requirements in spreading precision and documentation, it is necessary that spreading technology is developed as well.

1.1 The Salt Spreader Development Group

In 2006, the Winter Committee, as it was known then, established a working group with the task of specifying wishes and requirements for spreaders of salts and liquids for snow and ice control.

This working group, which calls itself The Salt Spreader Development Group (in Danish Saltsprederudviklingsgruppen, or SUG) has taken the initiative to find a method capable of numerically showing the distribution image of a salt spreader. The vision is to find a method that can be used to document how appropriate a spreader is in relation to established requirements and standards.
The group members represent the Danish road authorities, The Danish Road Directorate, the Danish municipalities, the Sund og Bælt and the consulting sector.
In the spring of 2009, representatives from the Norwegian and Swedish road authorities visited the test site and found the project very interesting. Consequently, it was agreed to strengthen the cooperation so that this project reaches out from Denmark and embraces all Nordic countries.

There are today methods to show the distribution image, but they are characterised by being slow and laborious. Moreover, they do not allow for test repetition.
The principal objective of developing a test method is finding a way to make a presentation of the capability of a salt spreader to distribute dry materials, moistened salt and brine. Thereby, it will be possible to document the capability of a specific spreader to distribute salt across the road in the desired quantities.

The vision is for the method to be fast, simple and objective, and suited to become widespread among and acknowledged by users, producers and dealers of salt spreaders in the Nordic countries.

Cooperation started in 2006, and has since contributed to important discussions and knowledge sharing.

2. 2. SPREADER TEST

Already in 1997, a series of simple, stationary spreading tests of a selection of spreaders was conducted. These early tests confirmed the perception that the general capability of spreaders to distribute salt evenly over the spreading area did not meet the expectations.

A working group was established to specify general directions for carrying out mobile salt spreading tests.
The tests were carried out as mobile runs on rented grounds in the Aarhus Airport. The following methods were used to measure and asses salt quantities and distribution:

- Vacuum suction

- Sobo-20 measurements
- Photographic registering

The tests were carried out according to plan, and the conclusion was that spreading quality did not live up to the preliminary definition of spreading width or to distribution requirements.

There was great interest in continuing the tests of salt spreaders. However, since the employed method was too expensive, a decision was made to try different ways.

SUG contacted therefore Engineering Centre Bygholm to discuss the possibility of development cooperation.
The centre has Europe's largest spreading technique laboratory in the field of fertiliser spreaders. Since salt and fertilisers are somewhat similar and can be compared, it was worth trying to adapt the method used for fertiliser spreaders so it could be applied to salt spreaders.

3. METHOD

Spreading technique laboratory

At Engineering Centre Bygholm is located Europe's largest spreading technique laboratory, which through the years has conducted research, tests and development of equipment mostly intended to spread solid products such as commercial fertilisers and lime.

Figure 1 – Europe's largest spreading building

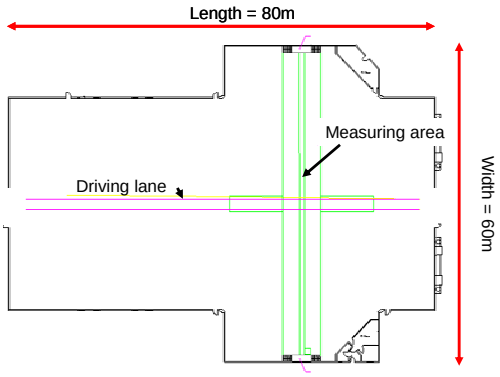


Figure 2 – Spreading building

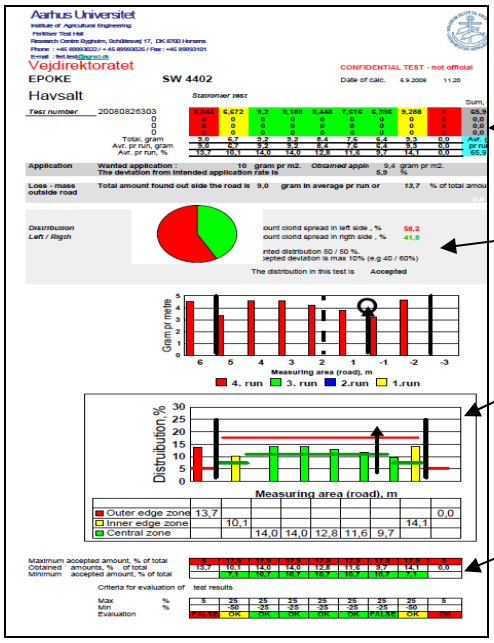
The spreading building is 60 m wide and 80 m long. It is air-conditioned, so that humidity and minimum temperature are kept at constant levels.
A collection area, consisting of depressed funnels, is situated across the site. Below these funnels lies a collecting container on top of a weight cell, which registers online the collected amount of dry material. There are 448 funnels, each measuring 0.25 by 0.50 m. For practical reasons, the tests are calculated for a tray measuring 0.50 by 0.50 m.

Figure 3 – Salt spreader runs over the measuring fieldweight cell

Figure 4 – Collecting container on weight cell

The collected amount of salt is registered online after each dry salt spreading run, as every weight cell is connected to the laboratory's computer. The computer makes the necessary calculations to transform the registered amount into graphic images.

The picture below is a print example of a run made with an Epoke SW 4402 and dry sea salt spreading.



The print contains information on:

Amount spread in the run

Left/right distribution

Distribution across the road surface
Green line = minimum accepted amount
Red line = maximum accepted amount

Results seen in relation to established criteria
Green = accepted
Red = not accepted

3.1 Method development

As far as method development is concerned, focus has been kept on a number of elements that influence to which degree it is feasible to distribute salt evenly. These elements are flow adjustment and dosage control, assessment of the distribution picture in stationary control and control of the distribution picture in mobile tests. Runs are made with different types of salt, i.e. dry and moistened salt as well as salt brine.

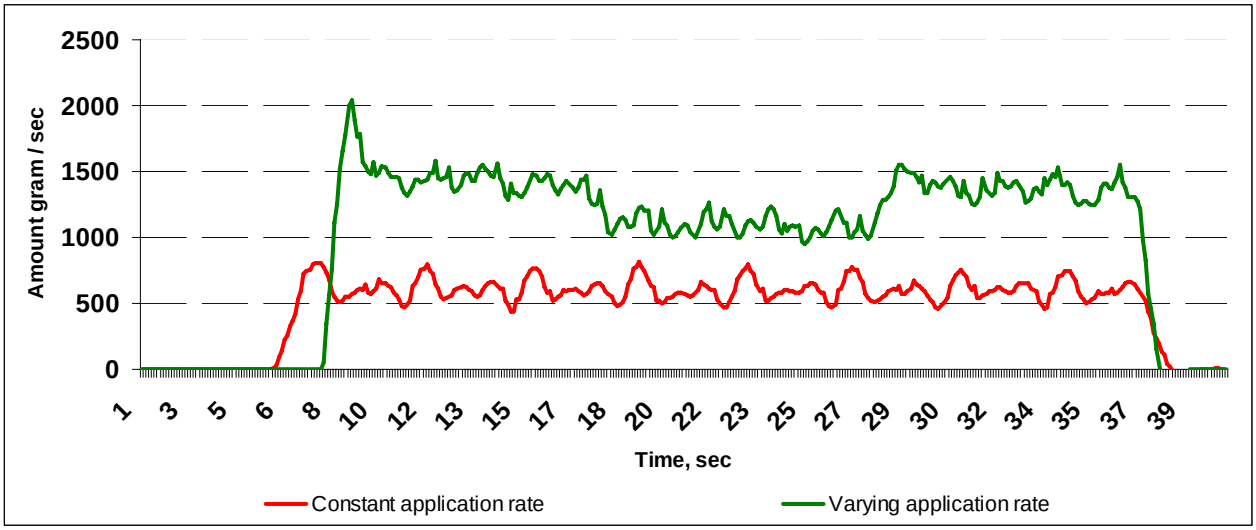
The test method has been developed using spreaders that are common on the Danish market, and with the cooperation of representatives from the producers concerned.

3.1.1 Flow adjustment and dosage control

When adjusting the flow, focus is kept on following the instructions given by the producer. Flow adjustment is made while the spreader is stationary, by collecting the dosed amount over a given time. After weighting the collected material, the necessary adjustments, if any, are made to the machine.

Dosage control is done during the test by collecting salt directly from the dosing device while no material spreading is taking place. The material is collected in a container that is continuously being weighted at a 10Hz frequency. By means of the continuous weighting, information is gathered on both the average dosage precision and fluctuations in the dosing process. Distribution accuracy is of great importance seen from the point of view of the environment, while an even flow of distribution is important to road safety related considerations.

Dosage control is carried out partly by constant dosages in combinations of spreading width, velocity and intended dosage, and partly by simulated changes from one dosage level to another. The second part of the application control is aimed at assessing application precision within each dosage level, at the same time establishing the capability of the spreader to make accurate changes in distribution levels. Additionally, the dosage control makes it possible to measure the time required to change from one dosage level to another.



Example of dosage control at constant (30 km/h and 10 g/m2) and varied dosage (40 km/h and 15, 10 and 15 g/m2 respectively) over 30 seconds

3.1.2 Spreading control by stationary test

Stationary spreading test is used to monitor alterations in the distribution picture when changes are made in salt type or spread width, for instance. This type of spreading test can be done by means of spreading material over a drawn-up measurement field on a plan surface. In the general framework of the project, a minor number of stationary experiments have been carried out in order to compare this type of test to mobile spreading tests. For the test, salt was spread during 30 seconds. Thereafter, it was swept and weighted along

1 m wide lanes. As a supplementary measure, photographies of the distribution picture were taken.

Figure 5: Distribution picture after stationary test

Figure 6: Distribution picture after sweeping the material along 1 m wide lanes

3.1.3 Distribution control by mobile test

Mobile spreading tests over the above-mentioned measurement field are the most important element of the study. In the past, these tests have been conducted on a field-work basis, collecting the spread material by either manual sweeping or mechanical suction. Test results have been inconsistent, as they have been influenced by weather conditions, among other factors.

The new tests, carried out in an in-door environment, have been designed to determine the actual capacity of a piece of spreading equipment without the influence of external factors such as weather conditions, air flow around the truck, etc.

To determine the distribution picture of dry material, the salt is collected and weighted for every meter by means of devices installed in the road system of the spreading building. When working with moistened or liquid materials, the collecting trays in the measurement area are washed. The salt content is then determined by a chemical analysis of the washing water.

The materials employed so far in these tests are common in Denmark: vacuum salt, rock salt and, to some extent, sea salt. Quality requirements for these materials are established in the Road Rules (Vejreglerne, in Danish) of The Danish Road Directorate. Spreading moistened salt or even brine is a common practice in Denmark; these materials are therefore used in these tests as well.

In the preliminary tests, runs across the measurement area were done at speeds of up to 60 km/h. High speed runs are dangerous; moreover, it is difficult for the driver to drive across the measurement area with the necessary precision. In consequence, it was decided that future tests should be done at low speed, that is, 10 km/h. Low speed tests have the additional advantage of eliminating air turbulence around the truck, so the results show the capacity of the spreading equipment more accurately.

The measurement area is originally laid out to measure the spreading of commercial fertilisers according to international standards. The characteristics of the measurement

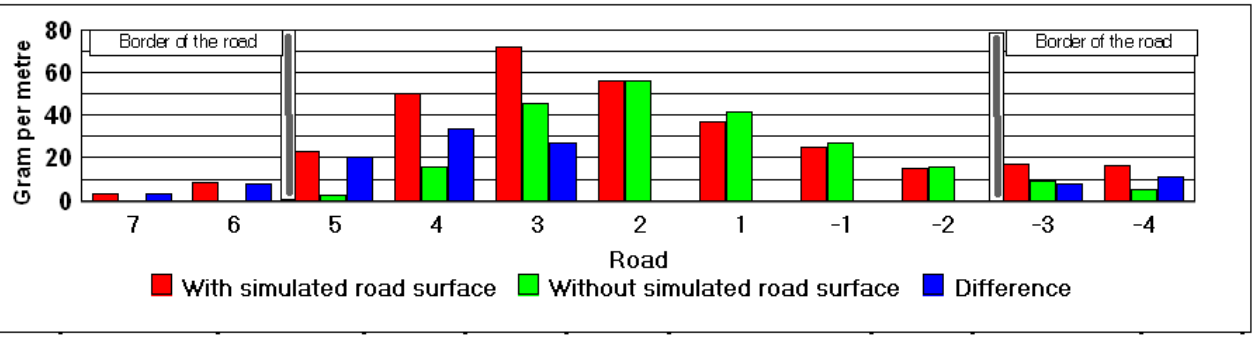
area mean that the spread material is collected and registered at the point where it first hits the road; it is not possible for the material to bounce or slide as it does in practice. This means that the registered distribution picture of some materials is narrower than it would be in practice. To counteract this factor, a plating similar to road surface will be fitted in the future in the front and back of all collecting trays on the measurement area, making it somewhat possible for the material to bounce and slide as in real life conditions.

Figure 7: Measurement area without plates in the front and back of the measurement field

Figure 8: Measurement area with plates in the front and back of the measurement field

Some differences arise when comparing the amounts of material that are collected with and without plates in the front and back of the measurement field. When the test is run with the plating off, the collected amount approximately equals the dosage; when the plates are fitted, however, the collected amount is considerably larger. Since the use of covering plates in the measurement area provides a good picture of how much material is being spread outside the road surface, it has been decided to continue developing the test method with this plating, and to establish dosage capability by stationary tests exclusively.

The figures below show some examples of results obtained by the two methods.



Example of distribution pictures obtained by tests with and without covering plates at the measurement area

3. 4. DEFINITIONS AND MEASUREMENT PARAMETERS

As shown in figure 11, every part of the road and the surrounding area has been defined in order to clarify which of these parts should be given special attention to during the tests.

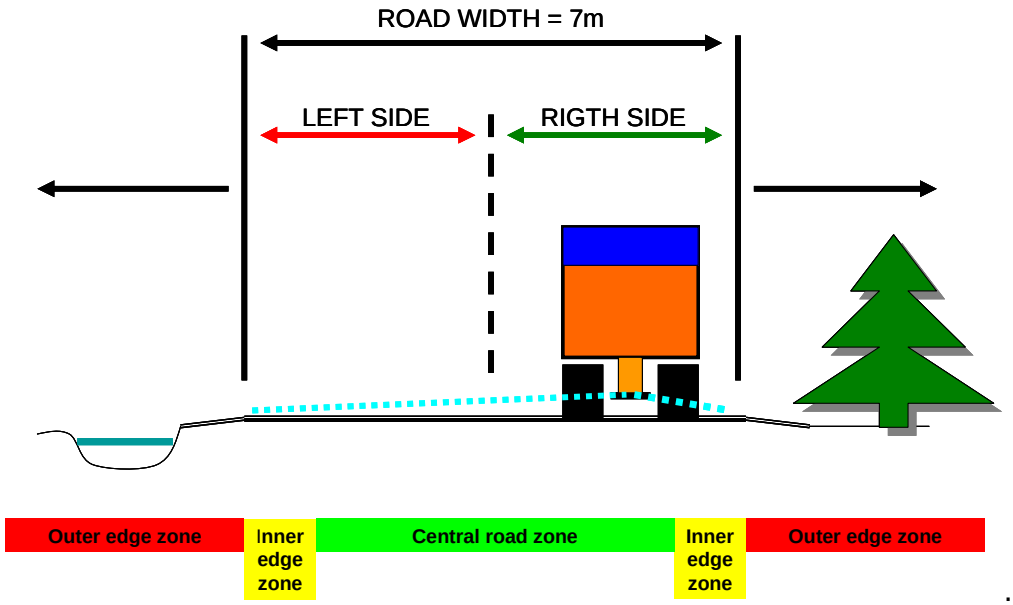


Figure 11 Definitions of road and road surrounding areas

Several measurement parameters have been used in this research to determine the results obtained. Requirements were established for dosage precision, distribution between left and right lanes, allowed amount of material outside the road surface on both sides and desired amount of material in each cross section of the road surface.

4.1 Dosage precision

The requirement in this regard is to keep dosage precision within ± 6% of the intended dosage. This requirement applies both to constant and variable dosages. As for variable dosage, no requirement has yet been established for the time allowed to elapse when changing from one dosage level to another. Similarly, there is no requirement regarding distribution uniformity, which at this time is a problematic issue for some combinations of spreaders and material types.

4.2 Distribution along left and right sides of the road

Test requirements establish an equal distribution of material along left and right sides of the road. This is considered accomplished when fluctuations in the distribution rate are kept within ± 10 percentage points, which means that distribution rates of up to 40/60% are considered satisfactory.

4.3 Amount of material spread in the outer edge zone

From the point of view of the environment, the optimal amount of material in the outer edge zone is 0%. Since this is very difficult to accomplish given the technology available today, it is considered a satisfactory result when no more than 5% of he total amount of material spread is found in the outer edge zones on each side of a 7 m wide road.

4.4 Amount spread across the road

The optimal distribution of material across the road is 100% divided by road width expressed in metres. In the context of these tests, it means that the optimal distribution rate is 14.3% per metre (road width = 7 m)

Since it has proved extremely difficult to obtain such result, tolerance limits had to be set to define what could be considered as acceptable. The table below shows the tolerance limits employed.

	OUTER EDGE ZONE	INNER EDGE ZONE	CENTRAL ROAD ZONE					INNER EDGE ZONE	OUTER EDGE ZONE
Max accepted, %	5	17,9	17,9	17,9	17,9	17,9	17,9	17,9	5
Wanted amount, %	0	14,3	14,3	14,3	14,3	14,3	14,3	14,3	0
Min accepted, %		7,1	10,7	10,7	10,7	10,7	10,7	7,1	

Table 2 Wanted and accepted amounts in different road zones

5. RESULTS

The experience gathered in this piece of research proves that these test facilities provide an appropriate context for testing and determining the distribution picture of equipment for winter maintenance services. The method for determining the distribution of moistened salt and even brine is still in development, but it is expected that it will be possible in the near future to carry out these tests and determine the salt content by means of simple measuring methods that will provide a satisfactory relative picture of the distribution.

This piece of research shows that, given the nature of Danish conditions, and the spreading equipment and thawing material that are commonly used, there lies a big challenge in accomplishing even distribution on the road.
None of the tests produced satisfactory results in all measurement parameters at the same time. Up to 95% of all spreaders in Denmark use one spreading disc only, regardless of whether dry, moistened or liquid materials are to be spread.
The tests were carried out with a 7 m wide road in mind, aiming at an asymmetrical distribution 5 m to the left and 2 m to the right of the truck. The outcome of the tests shows that it is extremely difficult to achieve results which are satisfactory in terms of road safety and acceptable from an environmental perspective at the same time.