Jens Kristian Fonnesbech

SAVE MILLIONS
IN WINTER SERVICES!

MANUAL APPLICABLE HARD ROAD SURFACES

HISTORÍA

Correction in

Save millions

in winter service.

Page 18, 4.1 Salting, add:
"If it is rain, changing with clearing and temperature that give rise to slippery roads, salting continues (9 grams of salt per m^2) until the situation is under control.

Page 30, 4.2. Call for salting
"Call have to be done, at least 4 hours before a snowstorm or slippery roads are expected."
Change to
"Call for salting, have to be done in time, so all roads are salted before the risk of slippery roads occur. If the call is when it is raining, you have to salt again on the part of the route where it was heavy rain."

Page 28
" 2 -20 30 29" -> "24 -20 30 29"

Page 35, 6. Traffic accidents with slippery roads
"Based on this database is calculated, that we have to expect accidents with slippery roads [9]:
1 accident on a route with brine spread with nozzles.
2 accidents on a route with salt spread as pre wetted (or dry) salt.
3 accidents on a route with salt spread of a combi spreader (brine, pre wetted or dry salt).
The numbers are annually on 100 km preventive salted road in a normal Danish winter."
Change to
"Based on this database is in january 2018 counted, how many slippery roads accidents have been on big 2 lane roads on Funen in the winters 2014 to 2017.
The results are for every winter for every 100 km 2 lane road :

1 slippery road accident when spreading salt as brine with nozzles
2½ slippery road accident when spreading salt as dry or prewettet salt on highway
4 slippery road accident when spreading salt with kombispreader on motorway. On the motorway 8% of all accidents in winter, were with slippery roads. On other highways only 5% of all accidents in winter, were with slippery roads"

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HISTORIA

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”I call it intelligent winter service!” say team leader Lars Frandsen, Middelfart Municipality.

”It requires, that people who work with winter service think first, but then it will benefit both the environment and all of us”

Table of contents

Annex 1. Risk management spreading salt in winter service

Annex 2. Example of procurement of salt spreader

Annex 3. Example, Sobo20 measurement of salt on the road

Annex 4. Example of spreading width

Preface

Thank you to all of you who help me, in the battle to sure that winter service have to be founded in science.

Without your courage to use resources on measurements on effectiveness of salt spreaders under practical circumstances, we do not have the basis for this book.

Thanks to former Head of Contractors Jørgen Lie, Middelfart Municipality, his Team Leader Lars Holmberg Frandsen and Driver Jørgen Hansen, Vestfyns Kørsel. Without you, I do not have the practical experiences. It is the same with Head of Park and Roads Henrik Sommerlund, Kerteminde Municipality, who has used the ideas fully in the municipality.

Thanks to Professor Lars Bolet, AUC, for sparring and assistance in the more theoretical statistical treatment of measurement data.

Thanks to road authorities in Southern Denmark, who has willingly provided data from Vinterman available for statistical processing, together with extracts from the police records of traffic accidents with slippery roads.

Finally, but not least, a huge thank you to my wife Kirsten Marie, because you patiently accepted that I spent so much time on the subject.

1. Introduction

Impressive pack ice in Ringkøbing Fjord. Copyright © TV2

Do you know someone, playing or crawling on pack ice by the sea? If you do, you know that sea ice is not slippery!

The rule shall apply on ice or snow with 3% Sodium Chloride (NaCl) on roads, too. The measurements, which confirm this "old truth" took place in Finland[1] with temperatures down to –20°C.

1. "Relation of Road Surface Friction and Salt Concentration", Taisto Haavasoja, Juhani Nylander and Pauli Nylander, SIRWEC 2012, Helsinki, 23-25 May 2012, Finland.

The explanation is, that ice with Sodium Chloride is soft, and it means, that Sodium Chloride on a road before a snowstorm reduces the chance that ice will form and bond to the surface.

Norwegian University of Science and Technology, Trondheim, confirm in laboratory that Sodium Chloride soften Ice, and presented the result on a seminar in Horsens 2015. The laboratory testing show that ice with Sodium Chloride change the structure and is much weaker than ice without salt.

This new/old wisdom can be used to minimize salt consumption and make winter service more effective

This manual give both a theoretical and practical view, which you can use to make economical savings and at the same time raise service level.

My hope is that this manual will be used. Only practical use can give innovation and remove the misunderstandings, which are in this manual, too.

2. Definitions

Nozzle spreader:

Salt spreader using jets to spread brine on the roads. 15 ml brine/ m^2 is 4 gram salt/m^2.

Nozzle spreader. The nozzles incline backward. Precision salt spreading.
Private photo from Fyns Amt, January 25. 2006

Pre wetted salt spreader:

Salt spreader using rotating disc to spread salt on the road. The spreader can use dry salt or pre wetted salt. Pre wetted salt is 70% dry salt and 30% brine. 10 gram pre wetted salt is 7 gram dry salt and 3 gram brine, total 7,6 gram salt.

Pre wetted salt spreader. Source: Epoke A/S

Combi spreader:

Salt spreader, where the driver can use pure brine, dry salt or pre wetted salt in the wanted combination. The combi spreader have a spreading disc and some spreaders have nozzles, too.

Combi spreader. Here with both disc and nozzles. Source: Epoke A/S

3. Theory

3.1. Objectives

Slippery roads

The target is not to have slippery roads from snow or ice. The target can be written:

Surface friction coefficient has to be more than 0,4.

Friction requirement is from Danish requirement to new wet asphalt.

Snow

Snow in amounts essential affecting traffic, have to be removed.

3.2. Ice

Ice or snow, with 3% Sodium Chloride (NaCl), is not slippery!

Measurements[2] on traffic roads in Finland show, that ice or snow with 3% Sodium Chloride, do have a friction coefficient >= 0,5. It is not slippery! The measurements took place with temperatures down to –20°C.

2 "Relation of Road Surface Friction and Salt Concentration", Taisto Haavasoja, Juhani Nylander and Pauli Nylander, SIRWEC 2012, Helsinki, 23-25 May 2012, Finland.

Many people know this phenomenon from ice on the sea. Ice on the sea (3% Sodium Chloride) is not slippery.

The target is then to be sure to have 3% Sodium Chloride in the water/ice or snow on the road.

3.3. Snow

Sodium Chloride on the road surface before a snowstorm, reduce the risk that snow bound to the surface.

An important observation in the Finnish study [1] and [2] is, that soft salty ice tends to break into small icy particles, which do not form packed ice any more, but become collected by the side of the wheel track looking like loose dirty snow. This kind of ice reduces friction marginally.

The observation is old, for example from 2009 "Fact Sheet, ANTI-ICING" from "The North Dakota Department of Transportation":

"It forms a bond-breaker between the pavement surface and the snow and ice layer which melts snow more quickly and reduces the chance that ice will form and bond to the surface. It is similar to how cooking oil prevents food from sticking to the frying pan."

The target is then to be sure to have Sodium Chloride on the road before a snowstorm. Later can the snow easily be removed with snowplough.

4. Praxis

4.1. Salting

On a moist road surface is around 0,1 mm water or 0,1 litre water/ m^2.

On a wet road surface is around 0,2 mm water or 0,2 litre water/m^2.

If the water contain respectively 3 gram and 6 gram Sodium Chloride/m^2 is it 3%.

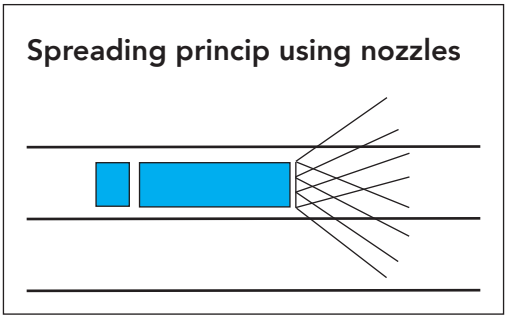
It means in situation with moist road surface, we have to be sure there is around 4,5 gram salt on every square meter (safety factor 1,5).

Equivalent with freezing rain, we have to be sure there is around 9 gram salt on every square meter (safety factor 1,5).

When snowstorm and snow ploughing go on, salting go on, too, every 6 hours (9 gram salt/m^2).

Precision salt spreading

Only brine spread with jet nozzles can meet the requirement of exact the correct amount of salt on every square meter and sure the salt remain on the surface.



All known experiments and measurement show that disc spreaders can not fulfil the requirement of the correct amount of salt on every square meter[3] and[4].

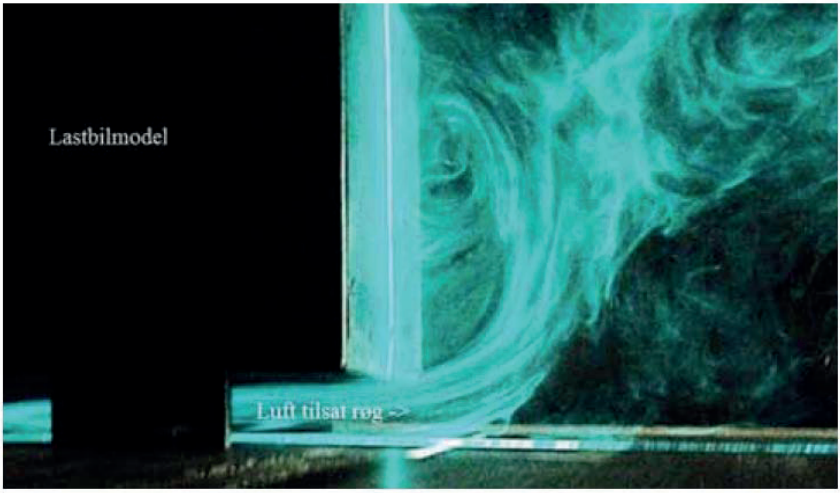
When buying new equipment you have to make requirements to sure spreader every time place the salt correct. You can for example put out a tender as shown in annex 2.

Wind and turbulence

Wind across the road can affect long jets. It is a reason that the jets have to be short when it is possible, for example behind the truck.

But the turbulence behind the truck means that the jets have to hit the asphalt 2,5 meter behind the truck. It is necessary that the jets do not atomize in the turbulence zone.

3 "Quality in Spreading – Reducing Impact on Environment" by Addressing Precision in "Distribution of Ice Control Agent Spreading Technologies". Lars. Bolet og J.K. Fonnesbech, Paper presented at TRB's 89th Annual Meeting, January 2010, Washington DC.
4 "Saltsprederes præcision". Lars Bolet and J. Kr. Fonnesbech, Trafik & Veje, oktober 2010

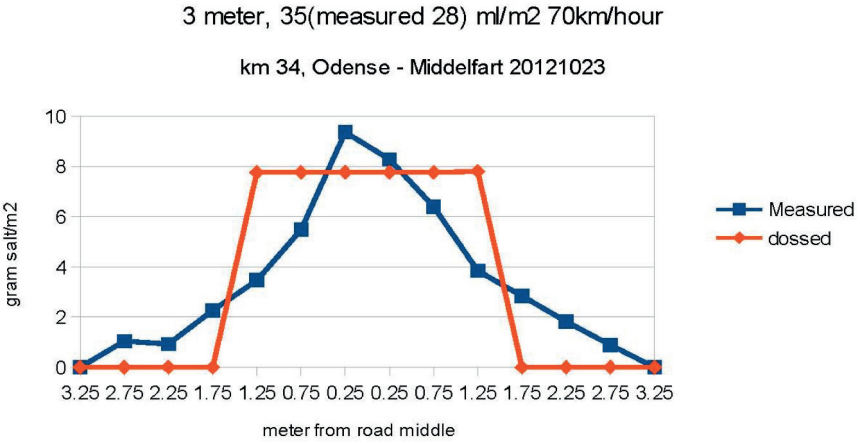


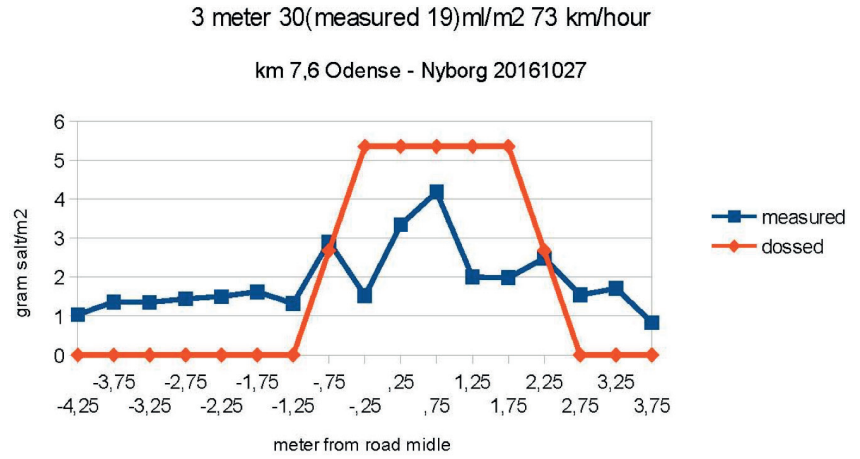
Example of vertical turbulence behind a truck. "Trafik og Veje", 2013, October, page 43

If the brine atomize in the turbulence zone behind the truck, the brine may be spread far away. In measurements in Kerteminde Municipality 2016, the turbulence lift 40% of the brine away. It means that you have to dose 60% more brine.

Brine can be atomized in the turbulence zone from 2 reasons:

1. Spray nozzles, a nozzle which atomize the brine.
2. The jets hits the asphalt nearer than 2,5 meter behind the truck, from this point the brine is atomized.





In the first measurement from 2012 the jets hit the asphalt 2,5 to 3 meter behind the truck, around 80% of the salt was measured in the 3 meter spreading zone. In the next measurement from 2016 the jets hit the asphalt 1,2 to 1,4 meter behind the truck, only 50% of the salt was measured in the 3 meter spreading zone.

Brine

In Denmark you can buy saturated brine. The requirements to saturated brine is salinity >26% NaCl.

Brine can be produced local, but then you can normally not get salinity >24% NaCl. Local produced brine often content grain of sand that over time can spoil valves and nozzles.

Salinity is typical measured with a densitometer, but can be measured by a refractometer, too.

If the sample used, is from top of the brine, it is the lowest salinity which is measured

Private photo

Stratification in brine, extreme stable and danger!

Slippery roads, because of spreading freshwater or nearly freshwater on the road is dangerous but very general! The problem is stratification.

When mixing brine or when a saturated brine is diluted, it makes stratification. It means that fresh water with low density always will be placed over brine with high density. The same occur when rain is falling on an open brine container. This stratification is extremely stable! The density difference between freshwater and 24% brine is 1:1,15 (or 15%). In comparison is the stratification in a lake, because of temperature, 1:1,001 (or 0,1%).

In order to avoid stratification you have to use forced mixing. For example you can pump brine from the bottom of the container and spray it on the surface of the brine "freshwater". The brine will then settle down trough the "freshwater" and mix a little freshwater to brine. Over time there is no more stratification.

Stratification may not arise in a container without adding water or salt.

It is a common misunderstanding that stirring or another movement in the brine can eliminate stratification.

If you have slippery roads on the last of your brine spreading route, it is surely from stratification.

New equipment shall carry on an alarm, to tell if the salinity is under 20% NaCl.

Salt on the road

Only salt spread as brine can be used for preventive salting on dry road. The brine will fast dry on the dry road and then it will not move, but stay as a tiny layer of chalk.

In the opposite dry or pre wetted salt will fast blow of the road. It is because the hard turbulence from fast driving trucks. Even if the road is wet, the dry or pre wetted salt will remove quickly.

In measurements from 2009[5] we measured the following on a 2 lane highway:

- Dosing 10 gram brine/m² and 0 gram salt/m²: We found: 99% (90%)
- Dosing 10 gram brine/m² and 5 gram salt/m²: We found: 52% (45%)
- Dosing 10 gram brine/m² and 13 gram salt/m²: We found: 23% (29%)

Figures within brackets is from similar measurements done by Swedish Vegverket.

Measuring salt on the road

To build up experience in how quickly salt is removed from the surface you have to do measurements. For example, after you have spread brine, you can do measurements before ending the regularly workday.

5 Measuring salt spreading with SOBO20, http://aiban.dk/artikler/Vejdirektoratets%20Falkoping%20hojhastighedsspreder.pdf

The experience is important when you later on have to decide when the next salting have to occur. In time the experience can help to get better dosing.

The measurements have to be at least on two different roads placed with more than 10 km between. The roads directions have to be nearly perpendicular to each other. In the measuring point you may do average of 6 measurements in both lanes. The 6 measurements have to be placed 0,25, 0,5, 0,75, 1,0, 1,25 and 1,5 meter from the middle of the road. Look at annex 3.

SOBO20. Private photo

The salt stick SOBO20 works well for those measurements. The SOBO20 have to be modified, in a way so you may use pure de-mineralized water with conductivity <10 mikroSiemens/cm[6]. Remember that SOBO20 which use pure water may freeze if you do not be careful.

6 SOBO20, paper about SOBO20, Vinterudvalget revised edition 1.1 june 2005, http://vejdirektoratet.dk/DA/vejsektor/vinter/organisation/Projekter%20og%20fors%C3%B8g/Documents/SOBO.pdf

I have to be point out, that no known stationary monitoring station can measure the amount of salt on the road.

In "Fugtsalt kontra saltlage på motorvej 2003" a quotation is made:

"The Group considers that it is doubtful that continue to work with data from Vaisala sensors – even under the most favourable conditions (high water film thickness) – can provide some indications of degradation model for NaCl spread as brine or pre wetted salt on a road."[7]

Spreading width of salting

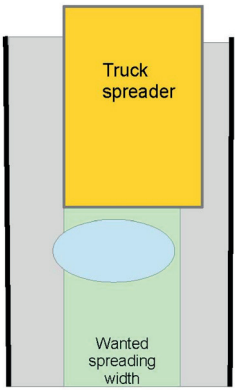
On an ordinary traffic road with roof-shaped profile, you have not to salt on the outer 1,25 meter of the road.

In annex 4, is examples of spreading width on roads with roof-shaped profile.

If the road has one-sided slope it has to be salted to the outer side with the highest level. The reason is that salt does not break down, but move away (downwards) on the road.

If a road have places for bicycles you can choose to dose a little more on these places.

Road 4 meter, spreading width 2 meter.
Drive ½ meter from right roadside.
Spreading 1,25 meter from right roadside,
and 0,75 meter from left roadside.



7 "Fugtsalt kontra saltlage på motorvej 2003", Vejdirektoratet, Fyns Amt, Miljøministeriet and Epoke.

Measuring the spreading precession

When buying a new spreader, you have to do examination. Do the spreader dose and place the salt correct on the road.

It would be good to do the examination on a wet road. Spreading have to be done with normal velocity and settings of the spreader. Length of spreading is 500 meter or more with every setting. The spreading have to be done before morning traffic. Later, when morning traffic is ended, the measuring have to be done. You can for example use 5 Sobo20, placed with 2 meter between each on the road. The measuring points are then placed 0,25 meter, 0,75 meter, 1,25 meter and so on from the middle of the road.

Measuring of 10 different settings will give you a good indication of the quality of the spreader, and the basis to check the spreader, as mentioned in annex 2. It will be good to record a motion picture of the spreading and make data collecting that help you later on can examine faults. Later you have to check whether the consumption of brine is equal with the setting.

Example from Kerteminde Municipality October 2016

SOBO20 measurement		***From data collection***	
Found on the road	*Difference from settings*	*Setting doses*	*Calculated from consumption*
ml/m²	%	ml/m²	ml/m²
11	-27	15	14
19	-37	30	25
2	-20	30	29
17	-43	30	21
20	33	15	17
19	27	15	17
22	47	15	15
28	87	15	15
26	-13	30	25
26	-13	30	30

Total we found 104% of the dose from the setting and the standard deviation was 42%. The result is so bad, that the spreader factory must help in finding a reason.

If you do manual setting when spreading, you have to check how fast the spreader respond on dosing and width setting. You can drive back the spreader and use a Mobil to check the respond time.

Another way to check consumption is by weighing spreader before spreading and again after spreading. The difference have to be compared with consumption from data collection.

Route optimization

In interest of the economy you have to minimize the trucks route length. In praxis we call out for spreading 4 hours before expected snow or slippery roads in Denmark. Normal is ½ hour response and then there is 3½ hour to do the salting. Experience tell us that a truck can drive nearly 160 km in 3½ hour spreading salt on small and bigger roads. If optimization is good nearly 120 km is salted.

I do not know IT programs who effectively can do route optimization, but when using the super computer on University of Southern Denmark I can get the result easier.

As a general rule you save 50.000 Euro every year, when you can save a spreader. The saving are from preparedness, less wasted time when a truck works effectively in 3½ hour, compared to 2 trucks works effectively in 2*1¾ hour and depreciations of truck and spreader.

Further in a 5 years plan you save 1000 Euro every km the optimization can reduce the length with.

The calculation is simple:

5 year * 100 operations/year * 1 km/operation * 2 Euro/km = 1000 Euro

At any change of the roads you have to evaluate the need of a new route optimization.

Spreader/truck, how big?

In Denmark a 4 axle truck with a 12,5 m^3 spreader will be fine for the most roads.

You have always to take in considerations if other sizes will be better. For example on motorway, spreaders on trailers could be better, combined with small spreaders for ramps and service areas.

4.2. Call for salting

Call have to be done, at least 4 hours before a snowstorm or slippery roads are expected. In Denmark there are very good weather forecasting, which can help to do it precisely.

Dosing of salt have to be decided before call. For now we do not know better, than salting the same dose the whole route. For example 15 ml 24% brine/m^2 before hoarfrost and 30 ml 24% brine/m^2 before snowstorm or freezing rain.

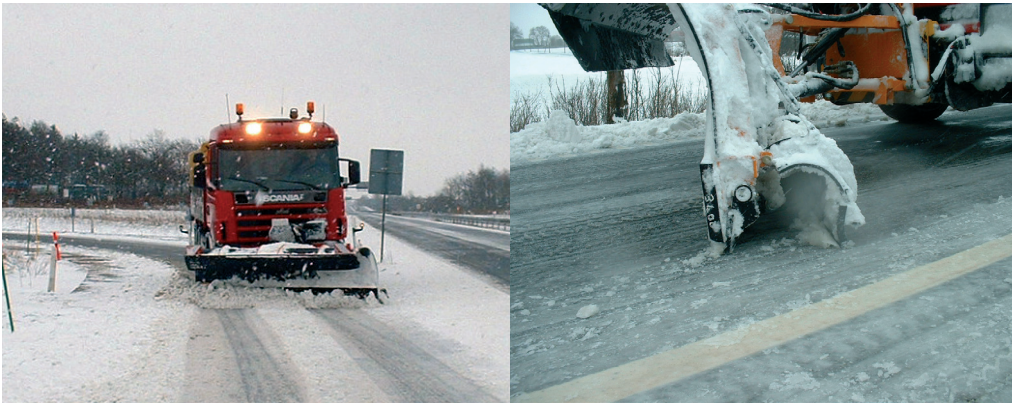
Economically in Denmark is it better to call 10 times to much, than to miss 1 call.

In annex 1 the cost to the community of 1 missing call is estimated to 30.000 Euro per 100 km. The 4.000 Euro is the cost of the municipality.

To be sure you get enough calls,you can consequently in the forecast use the road temperature 1°C lower than expected.

4.3. Snow clearing

With the powerful trucks we are using today, side ploughs are good for snow clearing. On bigger roads the snow ploughs must have flap for removal of slush.



Source: Epoke A/S

Optimal snow ploughing velocity <40 km/hour[8].

If using salting preventively, as described, it is unnecessary to use steel flaps.

Snow ploughing, under Danish conditions, has not been studied or researched well. I hope some one will make good this failure in the future.

4.4. Sand/gravel

Sand and gravel unfit the fight against slippery roads in Denmark. The traffic remove quickly sand and gravel from the road, and later on we have to remove it from drains and road shoulders. Often are gravel placed on the outer place of the road, where it disturb bicycles.

Sand on the road shoulder will in time make a higher level of the shoulder. This problem can be solved with a special machine.

8 "Mekanisk fjerning af sne og is, Testing av ulike typer ryddeudstyr, rapport nr. 2558", june 2009, Torgeir Vaa, Anders Svanekil.

In very cold sectors, for example in Norway, can gravel and boiling water be sprayed over the hard snow, where it will freeze and give friction for a long time.

Figur 21.11 in Lærebok, Drift og vedlikehold av veger, Statens Vegvesen rapport 365 (Norway). Photo: Torgeir Vaa

5. Economic/budget

For planning and optimizing winter service you have to use risk management. With risk management you soon get a view where you economical have the best opportunities to do it better.

The risk management annex 1 show for example, that cost to the community, for local bad spreading of salt from the combi spreader, is 1 million Euro per 100 km road every normal winter in Denmark, mainly because of traffic accidents cause slippery roads!

The next is build on own experiences with yearly costs of road authorities, including winters 2011-2017 in Middelfart Municipality, where they have used preventive salting with brine spread with nozzles.

5.1. 2 lane highways

For budget in Denmark you can use:

Preventive salting 2 lane highways cost 1.000 Euro per km road per year, when you use brine spread with nozzles and the active salting length of the spreader is more than 100 km road. Of cause the cost will vary from year to year.

Snow ploughing 2 lane highways cost 750 Euro per km road per year, when using preventive salting with brine, but it will vary more than salting.

5.1. Small roads

Most municipalities is only salting small roads after slippery roads occur.

If a municipality chose preventive salting on the small roads, too, the routes can be further optimized. It will reduce the yearly cost with further 10%.

6. Traffic accidents with slippery roads

In Denmark police record traffic accidents. One of the data parameters is slippery roads snow or ice. Based on this database is calculated, that we have to expect accidents with slippery roads[9]:

1. *accident on a route with brine spread with nozzles.*
2. *accidents on a route with salt spread as pre wetted (or dry) salt.*
3. *accidents on a route with salt spread of a combi spreader (brine, pre wetted or dry salt).*

9 "Valg af saltspredningsmetode har store konsekvenser", J. Kr. Fonnesbech, Trafik & Veje oktober 2014

7. Prejudice/Urban myth

Many prejudices and urban myths exist about salt and brine. Here I will tell you about the worst and most stubborn urban myths, **which are not backed up by reality!**

7.1. "Saturated brine is slippery when it freeze" False!

Most people know the situation: Snow and ice have been removed by snowplough and traffic, while salt has been used to melt the snow/ice. Then the weather change, it is freezing hard and the road is drying, and the road become white from salt. But the road was not slippery between wet salt (saturated brine) and the dry road, with dry salt!

The prejudice/urban myth "Saturated brine is slippery when it freeze" are not backed up by reality!

7.2. "Brine is not enough in snowstorm" False!

In the four winters 2011-2015 is collected "Vinterman" data from 9 road authorities in South Denmark[10]. Data is only from 2 lane highways, which all are preventive salted.

Total it is:
110 km is salted with pure brine. Nozzle spreader
900 km is salted with pre wetted or dry salt. Pre wetted spreader
450 km is salted with brine, pre wetted or dry salt. Combi spreader

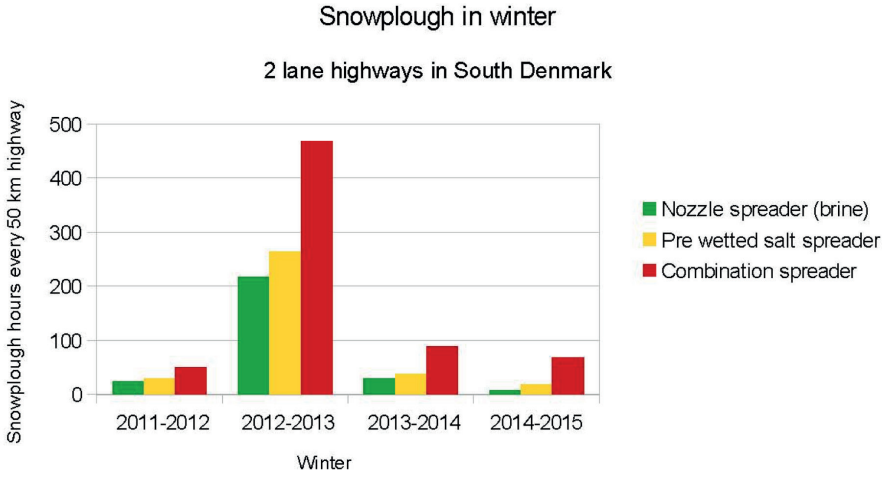
10 "Red liv, Spar penge og gavn miljøet", J. Kr. Fonnesbech, Trafik & Veje, oktober 2015

In "snow winter 2012-2013" you use 220 hours snowplough per 50 km road, when only using brine spread with nozzles.

In the same winter you use respectively 260 and 470 hours snow-plough per 50 km road, when salting with pre wetted spreader and combi spreader.

The data show, that brine spread with nozzles is the most effective salting method in snowstorm.

The prejudice/urban myth "Brine is not enough in snowstorm" are not backed up by reality!



In the four winters with data collected, the route using combi spreader, use 2½ times more hours at snow ploughing than the route using brine spread with nozzles.

8. Conclusion

We can save a lot of money and a lot of salt in Denmark by preventively salting all roads, which already in some cases are salted now[11]!

To receive the economical and environmentally profit, you have to use only pure brine spread with nozzle, and the salting routes have to be optimized. In praxis no route has to be shorter than 100 km road which is salted.

It is realistic to make following goals in Denmark:

"Winter service have to be developed so we do not have accidents with slippery roads on roads which are salted."

To catch the goals, it is essential with new research and a generally accept that the responsibility of slippery roads is the road authority.

11 "Spar 1 million på Vintertjeneste". Henrik Sommerlund and Jens Kristian Fonnesbech. Trafik og Veje, oktober 2016.

9. Postscript

If engineers have to help in research and development, they must accept there prime qualification. It is to calculate and make constructive criticism of the benefits and their disadvantage to society as a whole.

A basis to this calculations is to accept, what is known about the technology, including own measurements of potentials and limits of the technology.

Annex 1. Risk Management spreading salt in winter

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Asperup, Marts 18. 2017

NOTE

Risk management spreading salt (NaCl) in winter service

Estimated annually extra costs to the road authority every 100 km 2 lane road. All points can be changed, but the road authority has to do the choice. (Number in brackets show cost to the community).

1. Combi spreaders failure in distribution of salt	0.2 (1) million Euro
2. Pre wetted spreaders failure in distribution of salt	0.1 (0.6) million Euro
3. Nozzle spreaders failure in distribution of salt	0.06 (0.3) million Euro
4. Only short winter routes	0.04 (0.04) million Euro
5. Missing call for spreading salt	0.005 (0.03) million Euro

The next points are just directed against brine spread with nozzles.

6. Turbulence from a fast driving truck (salt waste)	12.000 (12.000) Euro
7. Stratification in brine ("fresh water" over brine)	6.000 (30.000) Euro
8. 12.5% standard deviation in dosing	6.000 (6.000) Euro
9. Fixed 3 meter spreading behind the truck (salt waste)	4.500 (4.500) Euro
10. Spreading width minimum 3 meter (salt waste)	1.800 (1.800) Euro

Basic preconditions

200 km potential slippery road lanes, without salt lead to 1 police reported traffic accident with slippery road.

1 police reported traffic accident cost the community 0.3 million Euro (2016) cf. "Transport-økonomiske Enhedspriser!"

http://www.modelcenter.transport.dtu.dk/Noegletal/Transportoekonomiske-Enhedspriser

In the price is welfare losses.

Direct cost for the community of 1 police reported personal injury is 100.000 Euro.

The analyses is based on traffic accidents with slippery roads in Danish normal winters (mild winters).

1 snowplough hour cost 130 Euro based on contracts in Middelfart municipality.

1 ton salt cost 60 Euro delivered and handled on place, based on information from Middelfart municipality.

The annual costs for a 4 axle truck to a salt spreading route is 65.000 Euro, based on experience from Middelfart municipality. (Perhaps the cost can be reduced to 50.000 Euro on short routes). It is worth nothing that road authorities in their tender, make different requirements, which make it difficult to compare, but the end result is as indicated.

Foundation

Bad distribution of salt from a spreader with spreading dish, will in the following be used as a reference, to assess the risk.

Bad distribution:

As inspiration is used the article "Saltsprederes præcision" Trafik og Veje nr. 10, 2010 page 43-45, Lars Bolet and Jens Kristian Fonnesbech.

The dish spreader is chosen as reference, because it is the most common in Denmark and there have been most accepted measurement series with this spreader.

The article is very theoretical, but we can use inspiration from an example, from which I shall quote: "It means, that we have to work with an distribution waste factor of 4.2, if only 2% of the road had to be missing salt."

The quote can be translated to: "If we call for spreading salt with a dose 4.2 times the necessary, 2% of the road get not enough salt."

Standard reference for risk analyse:

Following preconditions is used:

100 call in the winter, on a 100 km 2 lane road.
Dosing is always 4,2 time the necessary:

With these preconditions you get:

100 call/year x 100 km road/call x 2 km lane/km road x 2% too little salt = 400 km lane too little salt/year

Counting of police reported traffic accidents on 2 lane roads on Funen and in Southern Jutland in mild winters say 2 accidents per 100 km with slippery roads when using pre wetted salt spreader. It means 1 accident every 200 km lane with too little salt.

As written in basis precondition:

200 km potential slippery road lanes, without salt lead to 1 police reported traffic accident with slippery road.

See also.:
http://aiban.dk/artikler/Reducering%20af%20trafikuheld%20engelsk%20udgave%20til%20hjemmeside.pdf

1) Combi spreaders failure in distribution of salt

Combi spreaders failure in distribution of salt on the road lead annually to 3 police reported traffic accidents with slippery roads every 100 km roads. The cost for the community is 1 million Euro and for the road authority 0,2 million Euro.

Articles written in "Trafik og Veje":

- 2015/10, page 24-25 "Red liv, spar penge og gavn miljøet" (Save human lives, save money and benefit the environment).
- 2014/10, page 26-27 "Valg af saltspredningsmetode har store konsekvenser" (choosing salt spreading method has great consequences)
- 2013/4, page 36-38 "Halvering af glatføre uheld" (Half the traffic accidents with slippery roads)

In the first article is statistic for salt consumption and snowplough consumption.

The combi spreader use more salt than the nozzle spreader. Annually extra price 3.7 tons/km *100 km * 60 Euro/ton = 22.000 Euro

The combi spreader use more snow plough than the nozzle spreader.

Annually price 200 hours extra snowplough per 100 km road * 130 Euro/hour = 16.000 Euro

2) Pre wetted salt spreaders failure in distribution of salt

The pre wetted salt spreaders failure in distribution of salt on the road lead annually to 2 police reported traffic accidents with slippery roads every 100 km roads. The cost for the community is 0.6 million Euro and for the road authority 0,1 million Euro.

Pre wetted salt spreader use more salt than the nozzle spreader.

Annually extra price 2.6 tons/km * 100 km * 60 Euro/ton = 16.000 Euro

3) Nozzles salt spreaders failure in distribution of salt

The nozzles spreaders failure in distribution of salt on the road lead annually to 1 police reported traffic accidents with slippery roads every 100 km roads. The cost for the community is 0.3 million Euro and for the road authority 0,06 million Euro.

With the Epoke spreader, which is in use now, can periodical failure of a nozzle be the cause. The failure take place more times on a route.

4) Only short winter routes

A route on 110 km road which is active salted cost annually 600 Euro/km salted road.

A route on 50 km road which is active salted cost annually 1000 Euro/km salted road. The difference for 100 km road is 40.000 Euro.

5) Missing call for spreading salt

The cost is based on the fact that a missing call occur when there only is risk of slippery roads on some places on the road. Objective all 200 km road lane have too little salt, but in the estimate we use only 20 km. The cost for the community is 0.1 accident * 300.000 Euro/accident = 30.000 Euro.

Missing call have always to be investigated. It is better to call 10 times to often (cost 7.000 Euro) than miss one call.

6) Turbulence from a fast driving truck (salt waste)

In Sobo20 measurements of salt spread from Epoke Virtus Ast in October 2016, the influence from turbulence was measured with the velocity 70 km/hour. Around 40% of the salt, which should have been placed behind the truck, was placed besides the truck. It means you have to dose 66% more. When annually normal use is 3

ton salt/km, losses become 200 ton salt per 100 km per year. Cost 200 ton * 60 Euro/ton = 12.000 Euro.

7) Stratification in brine ("fresh water" over brine)

Brine with low salt concentration (in extreme situations pure fresh water) has low density and will be placed over brine with high density. If this situation, by a fault, occur, the last part of the route will be slippery, because the low concentration brine will be spread at last. The problem occur only when you use pure brine.

In Middelfart municipality are 2 known situations in 4 years. It is estimated that 10 km annually get too little salt, which is 0.1 accident. The cost for the community is 30.000 Euro and for the road authority 6.000 Euro.

Experience tell us, that knowledge of the problem, is not enough to eliminate the risk. Only an effectively alarm based on the measured salt concentration between the pump and the nozzles on the spreader can eliminate the risk.

8) 12.5% standard deviation in dosing

From data, in the data collection from an Epoke Virtus Ast brine spreader, can be calculated that spread quantity in 100 meter sections have 12,5% standard deviation. To be sure that less than 5% of the road get too little salt, you have to dose 33% more. When annually normal use is 3 ton salt/km, losses become 100 ton salt per 100 km per year. Cost 100 ton * 60 Euro/ton =6.000 Euro.

9) Fixed 3 meter spreading behind of the truck

If all roads in a municipality are salted preventive, near 25% of the salt consumption is wast, when 3 meter spreading width is fixed behind the spreader. When annually normal use is 3 ton salt/km, losses become 75 ton salt per 100 km per year. Cost 75 ton * 60 Euro/ton = 4.500 Euro.

10) Spreading width minimum 3 meter

If all roads in a municipality are salted preventive, near 10% of the salt consumption is wast, when 3 meter spreading width is minimum. When annually normal use is 3 ton salt/km, losses become 30 ton salt per 100 km per year. Cost 30 ton * 60 Euro/ton =1.800 Euro.

Annex 2. Example of procurement of salt spreader

Requirements for salt spreader

Spreading precision, salt distribution on the road

Salt must after spreading be evenly distributed in the desired area of the road. Spreading precision are taken into account in the evaluation of the most economically advantageous tender.

As a minimum spreading width have to be adjusted with intervals of maximum 1 meter.

The spreader have to spread minimum 6½ meter to the left and minimum 4½ meter to the right, measured from the centre line of the truck.

If minimum spreading width is 2 meter, the 2 meter have to be placed ½ meter to the right and 1½ meter to the left, measured from the centre line of the truck.

Dosage

In the chosen spreading width, brine must be able to be dosed between 5 ml/m2 and 40 ml/m2, with intervals of maximum 5 ml/m2 or equivalent if dosage are in gram.

Dosage have to be stable and uniform in the longitudinal plane. Dosing uniformity and stability are taken into account in the evaluation of the most economically advantageous tender.

GPS control and driver navigation

The spreader must be equipped with a GPS controlled system, which control and adjust the spreader settings when spreading salt. The system have to navigate the driver, too.

The supplier have to ensure that GPS control system on the chosen route are recorded and works by delivery.

The supplier have to:
either learn 2 of the clients employees how to record and make changes in the GPS system
or, without costs for the client, record all the clients wishes to route changes the next 5 years in the GPS system.

GPS control and driver navigation are taken into account in the evaluation of the most economically advantageous tender.

Data collection

Data collection should show:

- Spread amount of salt is registered with an accuracy of +-3% and have a maximum standard deviation on 6% from the chosen dosing in 100 meter interval.
- That all changes in spreading width and symmetry are registered together with the location.
- That all changes in dosing are registered together with the location.

- That data transmission to "Vinterman" or another winter service system works.

Data collection are taken into account in the evaluation of the most economically advantageous tender.

Camera and monitor

The spreader shall use a camera/monitor device, so the driver can clearly see the individual jets of brine. The monitoring are taken into account in the evaluation of the most economically advantageous tender.

Alarm, security system against spreading fresh water

The spreader must be equipped with a warning system, which is activated if brine < 20% salt and which stop the spreading if brine < 15% salt.

The warning system are taken into account in the evaluation of the most economically advantageous tender.

Velocity

The spreading will have to be implementable at normal legal truck speed. When spreading must be more than 5.5 meter from the truck centre line is accepted lower velocity.

Alternatively thaw agent

The spreader must be equipped with an additional tank for alternatively thaw agent in liquid form. The use of thaw agent to be automatically controlled by the GPS control.

Tank capacity

The spreader must be equipped with a tank to ensure an efficient use of 12 m3 brine per filling and minimum 250 litre alternatively thaw agent.

Evaluation of the most economically advantageous tender

From the risk management is known , that price of a salt spreader is very small compared to the direct costs of winter service for the road authority and negligible compared to the community costs. It means the quality requirements for salt spreader should be weighted very high.

In the following attempt requirements set in the order of economical importance for the work the spreader have to make.

The supplier must set yourself in % how much spreader can meet the requirements.

Spreading precision

Spreading precision will be measured after delivery on a busy traffic road with annual daily traffic > 2000.

10 various spreading options are selected, which differ in both dosing and spreading width.

The spreading take place early in the morning with high but legal speed on a wet road with smooth and fine graduated asphalt. The individual spreading section is at least 500 meter. In order to determine faults or special results the spreading should be videotaped.

The measurement of salt on the road take place 3-6 hours later, in the middle of the individual section. Measurements shall be conducted after the principles, which have been used in spreading measurements in the County of Funen 2004. The results can be seen on www.aiban.dk (consulting). For example http://aiban.dk/Sobo20%20spredningmaalinger/EpokeSpratronicSpreder.pdf

The supplier have to take into account in tender, that spreading measurements is subject to some uncertainty.

Spreading precision. The salt distribution across the road

Ideal distribution, which gives full reduction in evaluation of the most economically advantageous tender:

The worst of the 10 measurements is chosen and for this one is the rules (total measured salt is here total dosed salt):

At least 85% of measured salt have to be inside the spreading width. Salt have to be uniformly distributed, within each meter

have to be measured +-30% of the dosed amount and within each road lane have to be measured +-15% of the dosed amount.

Example:
You have chosen spreading width 6 meter and dosing 30 ml/m2, it is 180 ml/m. It has to be documented in data collection.

At least 153 ml has to be inside the 6 m spreading width. Minimum 76 ml have to be in the 3 m to the left and minimum 76 ml have to be in the 3 m to the right. At the same time there has to be minimum 21 ml and maximum 39 ml per m2 on the spreading area.

There is no reduction in evaluation of the most economically advantageous tender if measurements show:

Less then 60% of measured salt is within the spreading zone, or with 2 lane road there is less than 30% in the 1 lane or with 6 meter spreading width there is less than 3% in the outer meter.

In the calculations are used relatively values. It means that total measured amount of salt is the same as salt dose. In the calculation you are allowed to move spreader ½ meter if it help to meet the requirements.

Accurate dosing

For each of the 10 salt spreading are calculated how many % salt there are measured total From these calculations is standard deviation calculated.

Example from an earlier measurement:
The following % salt was measured:

72%, 65%, 81%, 58%, 133%, 129%, 145%, 184%, 86% and 86%. Standard deviation 41%

If standard deviation is < 20% it will give full reduction in evaluation of the most economically advantageous tender.

There is no reduction in evaluation of the most economically advantageous tender if standard deviation > 40%

Operation control

To get full reduction in evaluation of the most economically advantageous tender, documentation must show that the spreader is equipped with GPS controlled spreading of salt on the winter route and guiding of the driver. It must show, too, that change in the recorded data to the GPS control, can be done in an easily manner.

Documentation must be supported by references from use of the system.

Documentation must include simple manual procedure when some thing get wrong in the automated system.

There is no reduction in evaluation of the most economically advantageous tender if spreading width not can be done precisely +-10 meter lengthwise, or if the GPS controlled system in praxis do not works without stop on a 4 hours route.

Data collection

To get full reduction in evaluation of the most economically advantageous tender:

Registration of spread brine must be with an accuracy of +-3%, together with information about the spreader setting (spreading width, symmetry and dose), time, velocity and position from GPS.

Data transfer must function real time to "Vinterman" or another winter service system.

Documentation must be supported by references from use of the system.

There is no reduction in evaluation of the most economically advantageous ten-der if the above items can not be fulfilled or spread brine can not be with an accuracy better than +-10%

Camera and monitor

To get full reduction in evaluation of the most economically advantageous tender, spreader shall use a camera/monitor device, so the driver all time clearly can see the individual jets of brine.

There is no reduction in evaluation of the most economically advantageous tender if the driver not all time can see the individual jets clearly.

Alarm, security system against spreading fresh water

To get full reduction in evaluation of the most economically advantageous tender, the spreader must be equipped with a warning system, which is activated if brine < 20% salt and which stop the spreading if brine < 15% salt.

There is no reduction in evaluation of the most economically advantageous tender if the alarm do not work in praxis.

Example evaluation of the most economically advantageous tender
(all prices are fictional)

The supplier "BRINE A/S" make a tender of 2 spreaders:
Tender price each spreader. 100.000 Euro

"BRINE A/S" set yourself in % how much spreader can meet the requirements on annex to tender:

1. Spreading precision:	
Salt distribution on the road	50 %
2. Accurate dosing:	
Salt dose with standard deviation <20%	100 %
3. Operation control:	
GPS controlled spreading	100 %
3. Data collection	
Data collection	100 %
4. Camera and monitor	
Clearly individual jets	100 %
5. Alarm	100 %

Documentation is fine and the client is convinced and accept the % set as realistic.

Tender price in Euro			200000
	Weight	requirements	
	In %	are met ..%	
Spreading precision	30	50	-30000
Accurat dosing	10	100	-20000
Operation control	10	100	-20000
Data collection	5	100	-10000
Camera and monitor	5	100	-10000
Alarm	5	100	-10000
	Price used for comparing and evaluation of the most economical advantageous tender		100000

Table show with green how much the supplier "Brine A/S" can met the requirements.

The last column show the calculated values in the assessment of the tender.

In rows 4, 5, 6, 7, 8 and 9 is calculated how much there may be deducted in the tender price.

The blue price, is the price which is used to compare with other tender prices.

When the spreaders are delivered, the client pay 50% of the tender price. Then start control of the requirements. If all requirements are met (in this example Spreading precision met requirements 50% or more), is paid the rest of the tender price.

If one ore more points do not met the requirements, the points is calculated again to see how much there should have been deduct-

ed in the tender price. The difference multiplied by 2 is subtracted the tender price, before rest of the price is paid.

Example:
”Camera and monitor” do not work in praxis. In the table was deducted 10.000 Euro. The client has paid 100.000 Euro. Rest 100.000 Euro minus 2 x 10.000 Euro = 80.000 Euro. The Client pay the rest 80.000 Euro.

As the clients only interest is that requirements are met, the supplier can get rest of the tender price paid if the supplier within the next half year show that requirements are met.

Annex 3. Example, Sobo20 measurement of salt on the road

Middelfart KOMMUNE

Winter service

Residual salt

Scope: **Construction Department**

Annex:
Table set out residual salt SOBO20

Objective

To have a satisfactory knowledge of how much residual salt you have on the road, before it is decided when the next salting have to occur.

Activity

Residual salt have to be measured on to places, which have been preventively salted:

Nørregade in Ejby between km 5.3 and 5.4 (north – south).
Bogensevej in Middelfart, between the roundabouts with Vandværksvej and KorsholmAllé (east - west)

Measuring time

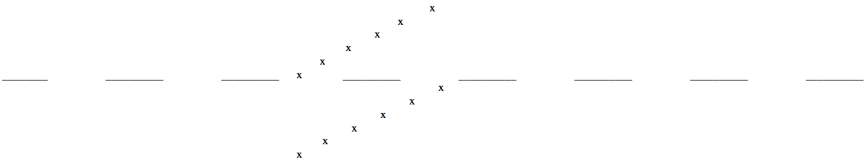
Usually just before ending the regularly workday.

Generally measurements stop, when a measurement is lower than 2 gram salt/m², or when it has been raining in the area, which means that measurements are not representative for the whole area.

The watchman can always choose to do more measurements.

Measurement residual salt

One measurement is the average of 6 SOBO20 measurements in one lane. The 6 measurements have to be placed 0,25, 0,5, 0,75, 1,0, 1,25 and 1,5 meter from the middle of the road and with 1 meter between longitudinal, look at the scheme plan.



The measurements have to be moved in a way which ensure no influence from earlier measurements.

Security

The measurements take place on traffic roads often when the weather is bad. Its why it is essential that the worker use protective clothing with reflectors. The car parking have to protect the worker and the yellow warning lights must be on.

Data entry

Data from the measurements of residual salt have to be in a spread-sheet with data from salt spread, for statistical reasons.

New preventive salting can be prevented when:

All 4 measurements show more than 2 gram salt per m^2 (hoarfrost and freezing moist road)

or

all 4 measurements show more than 5 gram salt per m^2 (snowstorm or freezing rain)

and

- No precipitation has occur after last spread of salt.
- No precipitation has occur after measuring residual salt
- With dry road it is less than 18 hours after last measuring and with moist road less than 8 hours.

Middelfart KOMMUNE

Measurement SOBO20
Ordinary

Residual salt g/m² average.

	Left	Right
Nørregade in Ejby km 5.35.		
Bogensevej in Middelfart km 5.3		

Remarks

---------- ----------

Date Name

Middelfart KOMMUNE

Measurement SOBO20
Ordinary

Residual salt g/m² average.

	Left	Right
Nørregade in Ejby km 5.35.		
Bogensevej in Middelfart km5.3		

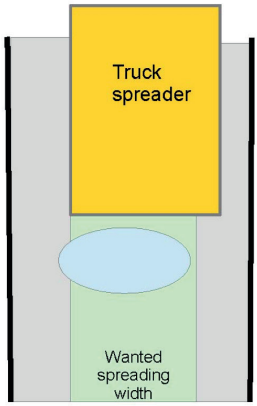
Remarks

---------- ----------

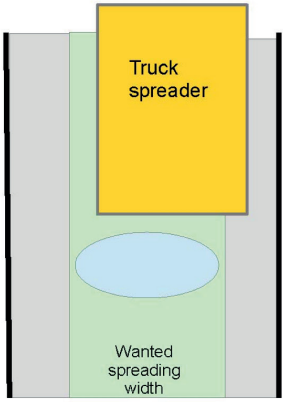
Date Name

Annex 4. Example of spreading width

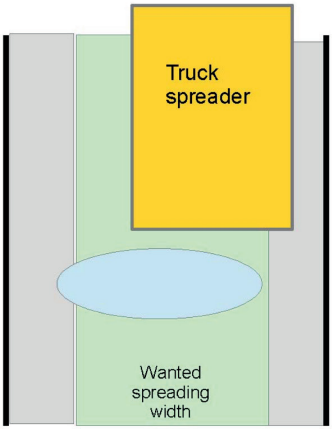
Road 4 meter, spreading width 2 meter.
Drive ½ meter from right roadside.
Spreading 1,25 meter from right roadside,
and 0,75 meter from left roadside.



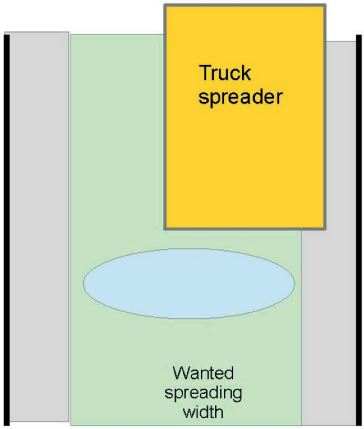
Road 4,5 meter, spreading width 2 meter.
Drive ½ meter from right roadside.
Spreading 1,25 meter from right roadside,
and 1,25 meter from left roadside.



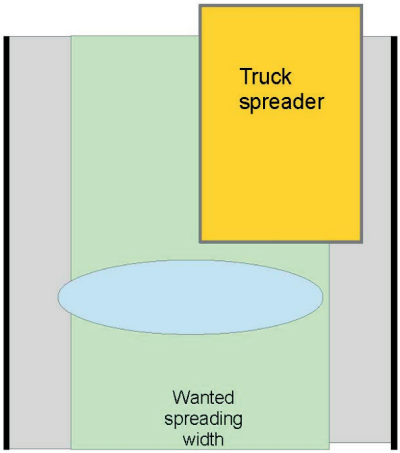
Road 5 meter, spreading width 3 meter.
Drive ½ meter from right roadside.
Spreading 1,25 meter from right roadside,
and 0,75 meter from left roadside.



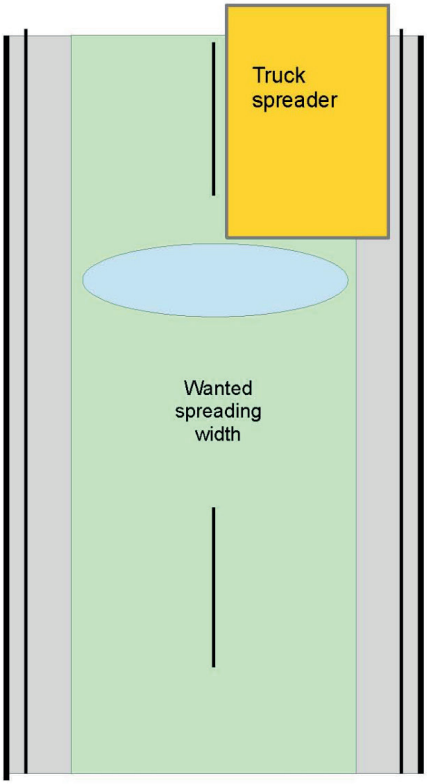
Road 5,5 meter, spreading width 3 meter.
Drive ½ meter from right roadside.
Spreading 1,25 meter from right roadside,
and 1,25 meter from left roadside.



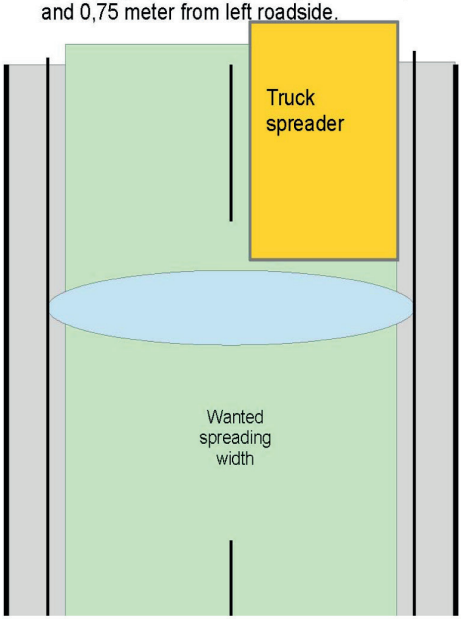
Road 6 meter, spreading width 4 meter.
Drive ½ meter from right roadside.
Spreading 1,25 meter from right roadside,
and 0,75 meter from left roadside.



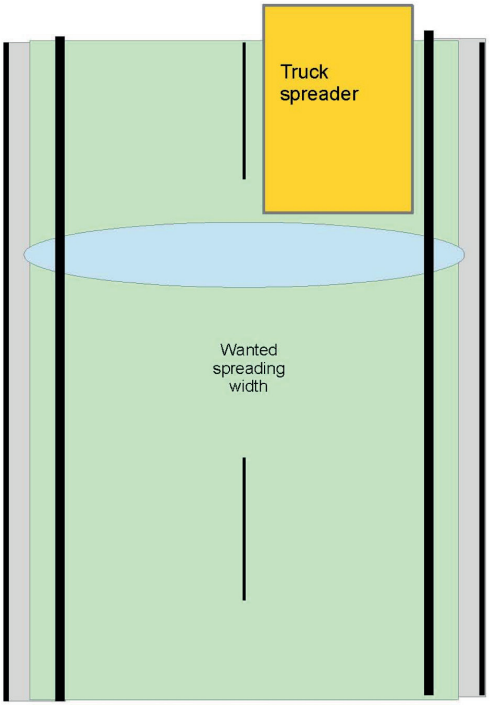
Road 6,5 meter with road markings
spreading width 4 meter.
Drive 0,25 meter from right roadmarking.
Spreading 1,25 meter from right roadside,
and 1,25 meter from left roadside.



Road 7,5 (7) meter with road markings,
spreading width 6 meter.
Drive 0,25 meter from right road marking.
Spreading 0,75 meter from right roadside,
and 0,75 meter from left roadside.



Road 8 (>8) meter with road markings for bicycles,
spreading width 8 meter.
Drive 0,25 meter from right road marking.
Spreading 0,4 meter from both right and left roadside.



Road with both right and left turn lanes.
spreading width 11 meter.
Spreading 1 meter from right roadside
and 0,75 meter from left roadside.