Deicing of Roads in Norway with Brine

ROAR STOTTERUD AND KNUT MAGNE REITAN

Norway's Public Roads Administration (PRA) started a test program for deicing roads with brine in 1989. With limited access to earlier experiences with the method, the PRA wanted to evaluate the suitability of use of brine in Norway. The following was to be achieved by applying brine instead of dry or prewetted salt: (a) instant reaction, (b) increased spreading speed, (c) reduced consumption rates of salt, and (d) faster drying of deicing roads. The follow-up has shown that these objectives have been met. The effects have been judged to be very good when brine is applied in conjunction with preventive actions before expected snowfalls or icy conditions and after the formation of frost or thin layers of ice. During precipitation the effects depend on the intensity and duration of the snowfall. Brine can be used when temperatures are warmer than about −10°C (14°F).

The operational requirements of Norway's Public Roads Administration (PRA) do not warrant the deicing of roads with chemicals even when the friction conditions are poor. However, operational requirements allow the use of salt as a preventive action: before a snowfall, or to remove ice or frost when such conditions occur. In Norway the requirements do not allow the use of deicing agents as a means of snow removal.

Approximately 3500 km (2,200 mi) of national roads in Norway are treated with salt. The total salt consumption associated with these roads is 40 000 Mg (44,000 tons) a year.

When dry salt is spread as a preventive action, experience has shown that approximately 80 percent of the salt blows off of the pavement into the ditch. Much of the salt is therefore wasted and contributes to the environmental problems as well as other problems associated with the use of salt. These problems are to some extent reduced if the salt is prewetted. However, experience has shown that roads treated with prewetted salt take a long time to dry. Motorists have reacted negatively to these conditions.

Despite the modest rates of salt spreading, the PRA, both for environmental and economical reasons, wanted to minimize salt consumption without worsening the driving conditions. This desire was the background for the initiative in spring 1989 for a program to test the use of brine instead of dry or prewetted salt. With limited access to earlier experiences with the method, the PRA wanted to initiate a comprehensive project to evaluate the use of brine as an alternative to current methods.

PURPOSE OF TEST

The basis for the whole project was to evaluate the suitability of brine in Norway. The conditions on roads salted with brine were compared with conditions on roads salted with dry or prewetted salt. Other questions were

- Under what conditions is the use of brine a suitable method?
- What quantities are required during varying
  - –Temperatures?
  - –Intensity of precipitation?
  - –Road conditions?

Further objectives were to attain thorough results from mixing equipment and brine spreaders.

DESCRIPTION OF EQUIPMENT

Brine is by definition a fully saturated solution of sodium chloride in water. The solution achieves a 25 percent concentration with a specific gravity of 1.18 kg/L (9.8 lb/gal). To manufacture the brine, a mixing plant is required. There are two ways to produce brine:

- Batch mixing: the required volumes of water and salt are put into a tank, and the mixture is agitated until the salt is dissolved and the solution is saturated.
- Continuous mixing: the mixing plants have separate tanks for mixing and storage. The water is pumped through a layer of salt on the bottom of the mixing tank. This action is sufficient to achieve a saturated solution, which is pumped into a storage tank.

Four mixing plants have been tried. The production capacity of the batch-mixing plants is approximately 20 m^3/hr (26 yd^3/hr). The continuous-mixing plants produces up to 30 m^3/hr (39 yd^3/hr). One of the continuous-mixing plants is equipped with a storage tank that holds 300 m^3 (392 yd^3).

In one location in a dairy industry district, the local dairy industry delivered brine at no cost. Brine is used in the production of cheese, and the alternative for the industry was to dump the brine into the sewer system and be charged for it. Therefore, the manufacturers of cheese were able to deliver the used brine to the local road station for free. Tests have shown that there were no harmful additives to the brine that could reduce the effect of deicing or further damage the environment.

The brine spreaders that have been tried are based on two principles:

- Disc spreaders: brine is thrown out from one or two discs.
- Nozzle spreaders: several nozzles are placed on a spray bar.

R. Stotterud, Norwegian Public Roads Administration, Box 6390, Etterstad 0604, Oslo 6 Norway. K. M. Reitan, Vendelborggt 32, Hokksund N-3300 Norway.

In addition there is a new type of spreader that can spread both brine and dry or prewetted salt at the same time. The spreader is based on two or three discs or discs in combination with nozzles.

All brine spreaders can spread from less than 10 g/m² (0.033 oz/ft²) to 60 g/m² (0.197 oz/ft²), 5 m (16 ft) in width and up to 55 km/hr (34 mph). With a spreading width of 7 m (23 ft), the equipment can spread at least 40 g/m² (0.132 oz/ft²). The adjustment is continuous or in steps of 5 g/m² (0.017 oz/ft²). Some of the equipment can spread over a width up to 12 m (39 ft).

The equipment has been developed continuously during the project. With good cooperation between the users and the manufacturers of the equipment, new ideas and improvements were tested. The results are that there are now very few problems with the equipment and that the equipment satisfies the specifications.

RESULTS

Frequent measurements on five reference points have given much information that shows that the effect of brine on the road surface depends on weather and road conditions. The effect has also proven to be dependent on the traffic volume and the intensity of precipitation.

The results are divided into three groups depending on the measured coefficient of friction in the first hour after the spreading. The friction is measured with "Digi-slope," which gives the coefficient of friction when the test vehicle brakes at 40 km/hr (25 mph) with locked wheels.

Result	*Coefficient of Friction After Spreading*
Good	Better or equal to 0.40
Adequate	Between 0.30 and 0.40
Poor	Less than 0.30

Documented results were attained from 566 spreadings, of which 76 percent gave good results, 10 percent adequate results, and 14 percent poor results (Figure 1). Under normal conditions the results will be better, because in the project we wanted to find the limits for the use of brine. Therefore, brine sometimes was used under conditions that were unsuitable for use of salt, such as low temperatures and heavy snowfall.

In areas in the southwestern part of Norway where conditions are favorable for the use of salt, 96 percent of the spreadings were successful. In the northern part of Norway where the test stretches were located on the outer perimeter of an area considered suitable for salting, because of more snow, 83 percent of the results were good. Areas with a continental climate with low winter temperatures are not considered as suitable for the use of salt. Nevertheless, more than 70 percent of the brine spreadings were successful in these areas.

In areas where brine was used for two seasons, the results were better than in areas where people just had one season with experience, showing that it is necessary to have experience with brine to get the best results.

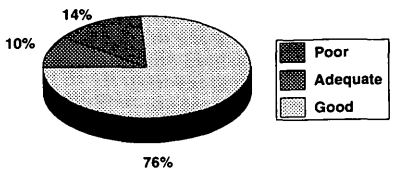

FIGURE 1 Results from all spreadings of brine.

Causes

All conducted spreadings have a reason that is registered. The causes are classified in the following groups:

- Prev. ice (preventive salting against frost and ice),
- Prev. snow (preventive salting against snow),
- Frost (salting on frost and thin layers of ice),
- Snow (salting on snow and during snowfall),
- Freezing rain (salting for freezing rain or rain on frozen surfaces), and
- Miscellaneous (salting for other reasons).

Figure 2 shows results associated with different causes for spreading. The figure shows also the number of spreadings for each cause and includes all test stretches. On average, three out of four spreadings have been successful.

Preventive salting against ice has attained good results from 92 percent of the spreadings. Good results also came from 98 percent of spreadings for frost and thin layers of ice, which shows that brine is ideal under these conditions. Almost every spreading gave the desired effect, and the quantity of salt was reduced to 75 percent that of dry salting. Heavy or long-lasting snowfall after the spreadings is the reason why a few of them gave poor results.

According to the registrations, 74 percent of the preventive spreadings against snow gave good results. In reality, all spreadings gave the desired effect and stopped the snow from adhering to the surface. The measurements showing poor friction were conducted after the snowfall had begun and before the roads were cleared, so friction was measured on a sheet of snow or slush.

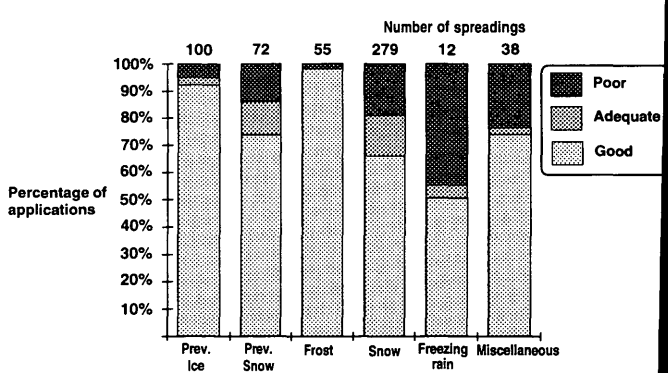

FIGURE 2 Cause for salting, all stretches.

During snowfall, 66 percent of the spreadings gave good results. Considering the fact that 15 percent gave adequate results with coefficients of friction between 0.30 and 0.40, it can be stated that the method also can be used during snowfall.

During freezing rain, 85 percent of the spreadings were successful. The few problems that occurred took place early in the morning with little traffic.

Other causes for spreadings were the occurrence of slush, packed snow, thick packed ice, or any combination thereof. A total of 74 percent of these spreadings were successful, although 24 percent (corresponding to nine spreadings) gave poor results. These spreadings occurred with slush on packed ice.

Weather and Road Conditions

Almost every spreading on dry, moist, and wet roads and on frost gave good results. The results showed reduced effects when slush, snow, or thick ice occurred on the roads. Good results were obtained on thin layers of ice, although the results deteriorated with increasing thickness. Brine must not be used on ice that is so thick that it is impossible to see the surface underneath. Under such conditions, brine will only make the road more slippery.

A total of 77 percent of the spreadings on slush gave good results. The quantity of slush on the surface greatly influences the results: the more slush there is, the more salt is required to keep the friction above 0.40. Even during salting on loose snow on the road, 61 percent of the spreadings gave good results. On hard and packed snow, only 41 percent of the spreadings gave good results. If spreadings classified as adequate with coefficients of friction between 0.30 and 0.40 are included, then an 82 percent success rate was achieved. However, the rate of success depends of the thickness of the packed snow and ice.

From these results it is obvious that application of brine is not suited for melting snow and ice. The results gradually deteriorate with increased quantities of slush, snow, or ice on the road.

The quality of the road condition during spreading is shown in Figure 3. The figure includes all test stretches. Figure 3 shows that problems can occur on days with precipitation and that the application of brine is often insufficient when thick layers of snow and ice occur. The results from salting in conjunction with precipitation will improve considerably with better clearing of snow. Improved clearing combined with salting will also prevent the creation of packed snow or thick ice on the road surface, and thus eliminate most of the troublesome conditions in connection with salting.

Most spreadings occurred on days when precipitation was registered as snow or slush. However, these conditions prevailed only a few winter days, and on only a few of those days the coefficient of friction registered below 0.40. The spreadings that gave good results thus cover most of the winter period as indicated by registration of slippery roads. Under conditions suitable for salting, only 5 percent of the time was for slippery roads (i.e., coefficients of friction below 0.40).

Even on days with snowfall, most spreadings gave good or adequate results. Problems arise during long-lasting snowfalls or intense snowfalls. Spreadings during snowfalls with temperatures below $-6°C$ (21°F) have mainly given poor results. Intense snowfall has also given problems with temperatures as high as $-1°C$ (30°F). Figure 4 gives an indication of when brine is suitable in conjunction with snowfall.

During a snowfall, the better the clearing efforts, the better the results. With frequent clearing and frequent salting, the results are also good during intense snowfalls. Heavy snowfall has an intensity of 3 mm (0.1 in.) water per hour—equivalent to approximately 3 cm (1.2 in.) of dry snow per hour. Accurate snow quantities have not been registered during these investigations, but we have experienced that brine has had a good effect during heavy snowfalls. Problems have occurred when the snowfall lasted for 5 to 10 hr with the same high intensity. The results are a function of

- Intensity of precipitation,
- Temperature of air and road surfaces,
- Traffic volume, and
- Clearing equipment and clearing arrangement.

Since brine is not suitable for melting any quantity of snow, it is important to clear away most of the snow and slush before salting. Frequent clearing with good equipment that can remove snow and slush in the tracks are required. By salting and clearing on the same spot at least every 60 or 70 min, the results from the spreadings have been good even during heavy

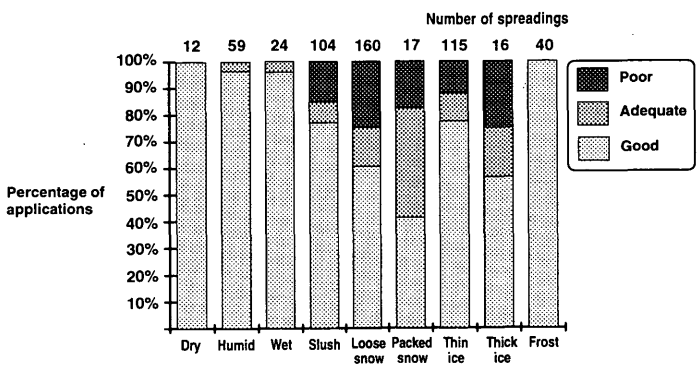

FIGURE 3 Road condition and salting results, all stretches.

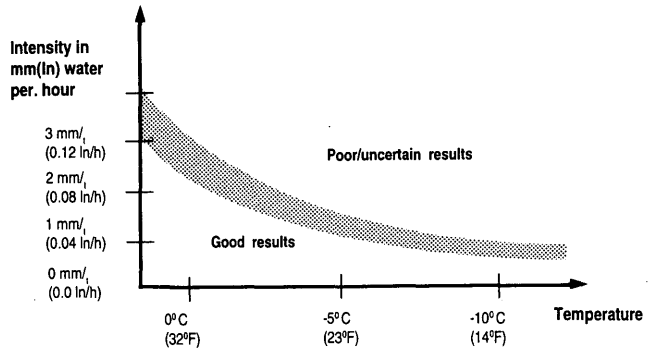

FIGURE 4 Brine during snowfall (1 mm water equivalent to 1 cm dry snow).

snowfalls. Clearing with slush plows that follow the unevenness in the surface has improved the results from using brine.

DURATION OF EFFECTS OF SPREADINGS

The duration of the effects attributed to spreadings depends on traffic volume, temperature, type of precipitation (fog, mist, rain, etc.), salt quantity, and type of surface.

Immediate Effect

The effect of brine is independent of traffic volume. Dry salt must be crushed before it is effective, but brine is already diluted and effective the moment it is spread on the road.

Preventive Spreading

Preventive salting against frost and icing normally lasts for at least 10 hr or until precipitation occurs. Salting in the evenings normally lasts till after the morning rush hour. The effect of salting when the humidity is high can be shorter since the moisture condenses on the road surface and dilutes the brine. Traffic causes the water to evaporate, hence the road will gradually dry up and the salt remains on the surface. The heavier the traffic, the quicker the salt dries up and disappears. Salting during evening hours with decreasing temperatures and reduced traffic volumes might require new spreading before the morning traffic.

The effect of the spreadings are known to last for 2 or 3 days when temperatures are down to −6°C (21°F). When the humidity has reached a low level whereby the moisture does not condense on the road, the brine will not be diluted and consequently have full effect. This occurs even though the traffic volume is not large enough to dry up the moisture on the road surface.

In the autumn and spring, when night frost with hoar frost or ice forming on the road surface is likely to occur, a spreading will last at least until the forthcoming night. Under such conditions the traffic volume is less important than it is in winter. On roads with traffic of 200 to 300 annual average daily traffic, salt can be used as a preventive action during these periods. This makes the method suitable on most roads in periods when slippery roads are least expected by the road users.

Rime and Thin Layers of Ice

Good results are achieved on rime and thin layers of ice with an average winter day traffic (AWDT) of 1,000 or more, of 3 days duration, if no more moisture is added.

Brine will normally melt frost and thin ice on the road surface. However, too little traffic might cause the road to freeze, because friction heat created by the interaction between the surface and tires will evaporate the water on the road—the more heat, the more water evaporates and the quicker the road dries up. The evaporation will remain low with little traffic, and the brine will be diluted and the freezing point will increase, so the likelihood of a good effect increases with the traffic.

Low Temperatures

At temperatures below −6°C (21°F), the effect of the spreading can last for long periods, normally until the precipitation starts or the temperature and the level of humidity rise. The humidity will increase with the temperature, and moisture on the road surface will condense. The brine will be diluted and the freezing point will increase.

The air is normally dry at low temperatures, which causes the roads to dry quicker under these circumstances. This is clearly shown by this winter's measurements. Preventive salting or salting on frost or thin layers of ice have given good results at temperatures down to −12°C (10°F). The AWDT should be more than 1,000, and at decreasing temperatures the hourly traffic volume should be at least 30 when the humidity is high.

Good results can also be achieved with little traffic, provided the amount of brine is small. Twenty grams of brine per square meter (0.066 oz/ft^2) have given good results at −10°C (14°F). By spreading more brine, more water must be evaporated, which in turn requires heavier traffic.

Some measurements have been conducted with sensors that register the freezing point of the liquid covering the road surface. When the brine-spreading vehicle has passed, the freezing point drops immediately to about −12°C (10°F), whereas with dry salt the process is slower and the freezing point rarely goes below −8°C (18°F). These measurements show that the spread brine has a better ability to last than dry salt.

Precipitation

Periods with precipitation require frequent spreadings; thus, frequency is a function of the intensity of the precipitation. With an intensity of 3 cm (1.2 in.) snow per hour, deicing with brine must be conducted with 40 g/m^2 (0.132 oz/ft^2) at least every 60 or 70 min. Clearing of snow and slush is also required before each spreading, keeping the coefficient of friction near 0.40. During light snowfall when the snow re-

mains on the pavement, spreadings should be conducted at intervals of 4 hr or less.

Type of Surface

The effect of brine normally varies little with the type of surfacing. However, experience indicates that the effect is best with certain surface dressings, giving good friction and little splash from the road surface. The effect of both dry salt and brine is poor on porous asphalt. Since diluted salt is collected in cavities and percolates through the surface, leaving the top surface without salt, it will freeze quicker.

RECOMMENDED BRINE QUANTITIES

Humidity is important for the quantities used in connection with preventive salting. The combination of humidity and temperature gives the dewpoint as an expression of when the air is saturated by moisture. When the road-surface temperature is lower than the dewpoint, moisture from the air condenses on the road surface. Greater brine quantities are required when this occurs. This is simplified in Table 1 to distinguish only between humidity above or below 85 percent. Dewpoint apparatus in combination with road-surface temperature will give a reliable indication of the danger of having condensation on the road.

SPEED OF SPREADING

The speed during spreading of brine should not exceed 55 km/hr (34 mph). Trials have been carried out at greater speeds with adequate results, but it is more difficult to achieve full width of the spreading at higher speeds. Another possible problem is brine whirling up behind the spreading vehicle when the speed is too high, covering the windshields of the following cars with brine.

Compared with other methods, the brine method is superior with respect to spreading speed:

Method	*Maximum speed [km/hr (mph)]*
Brine	55 (34)
Prewetted salt	40 (25)
Dry salt	30 (19)

TABLE 1 Recommended Brine Quantities

Climate and Road Conditions	Brine Quantity [g/m^2 (oz/ft^2)]
Preventive action against ice	
Dry road, humidity below 85%	10–15 (0.033–0.050)
Dry road, humidity above 85%	15–20 (0.050–0.066)
Wet road	15–20 (0.050–0.066)
Preventive action against snow	40 (0.132)
On hoar frost and thin ice	15–20 (0.050–0.066)
On snow and during snowfall	40–60 (0.132–0.197)

The spreading vehicles cause less hindrance to the traffic at high spreading speeds, and the range per spreading unit is larger. Thus, it is possible to spread the same length of road in a shorter period of time than when spreading of dry or prewetted salt.

EFFECT AND PRINCIPLE OF SPREADING

The effect of brine on the road is independent of the type of spreading equipment. Both disc and nozzle spreaders spread the brine evenly on the road surface. The disc spreader spreads the brine in a sickle manner. This has sometimes created "washboards" during spreading in snowfall. The nozzles spread the brine in jets and have good coverage in the preadjusted area.

Sidewinds will affect the width of the spread. With a spreading width of 7 m (23 ft), sidewinds can vary the actual width up to 1 m (3.3 ft). One factor in favor of nozzle spreaders in areas with rough weather is the ability of nozzles on a boom to spread brine on the pavement even in strong winds. Spreadings from side nozzles and discs can be blown away before they actually hit the pavement. Dry salt spreaders are no alternative under such conditions.

Splash from brine can be a problem for oncoming vehicles. Disc spreaders have created the largest problem in this respect, particularly spreaders with one disc that spread in lanes with opposite traffic.

CONSUMPTION OF SALT

The consumption of salt depends on climate conditions, quantity of precipitation, and the length of the winter period. On the test stretch in northern Norway the consumption was 16.4 Mg/centerline-km (29.1 tons per mile). The reason for the high consumption was mainly much snow and a long winter period (5 to 6 months). In southwestern Norway, where most of the spreadings were preventive against ice forming during the night, the consumption was 2.7 Mg/centerline-km (4.8 tons per mile). This type of salting consumes one quarter of the salt required by the use of dry salt. This test stretch is comparable with two routes that were salted with dry salt. The consumption on these dry salt routes were 7.5 Mg/centerline-km (13.3 tons per mile) and 14.5 Mg/km (25.7 tons per mile).

The use of brine reduces overall salt consumption on the test stretches by approximately 35 percent when compared with dry or prewetted salt. Table 2 shows salt consumption

TABLE 2 Salt Consumption with Brine and Prewetted Salt as a Percentage of Dry Salt Consumption

	Consumption (%)		
Cause for Salting	Brine	Prewetted Salt	Dry Salt
Prev. ice/Frost	25	70	100
Prev. snow	33	75	100
Ice/Frost	30	75	100
Snow	100	100	100

with brine and prewetted salt as a percentage of consumption with dry salt. Consumption is shown for the most important causes for salting. The numbers are only approximates; nevertheless, they show that considerable quantities of salt can be saved by changing from dry or prewetted salt to brine.

SUMMARY OF EXPERIENCES

Preventive Action Against Ice

Brine is well suited for preventive action against ice. It is effective immediately, lasting for at least 12 hr, and all the salt remains on the road. It can be used in temperatures down to −10°C (14°F) and in quantities of 10 to 20 g/m² (0.033 to 0.066 oz/ft²). In this capacity, brine is better than dry or prewetted salt.

Frost

Brine is also well suited for use on frost; it too is better than dry or prewetted salt. It has an immediate effect and remains effective for 12 hr; all the salt remains on the road. Brine can be used down to −10°C (14°F), but when the humidity is above 85 percent, it should not be used below −6°C (21°F). Quantities are to be 10 to 20 g/m² (0.033 to 0.066 oz/ft²). There is a danger of freezing when traffic is less than 30 vehicles per hour.

Thin Layers of Ice

Brine is better on thin layers of ice than dry or prewetted salt is. After 5 min it becomes effective and remains so for at least 12 hr. All the salt remains on the road. Just as on frost, brine can be used down to −10°C (14°F) but should not be used below −6°C (21°F) when humidity is above 85 percent. It should be used in quantities of 10 to 30 g/m² (0.033 to 0.099 oz/ft²). There is a danger of freezing when traffic is less than 30 vehicles per hour.

Preventive Action Against Snow

To be effective against snow, brine should be spread out before the snowfall. It will take effect immediately; the duration of its effect depends on traffic volume and precipitation. All the salt remains on the road. It can be used down to −6°C (21°F), in quantities of 40 to 60 g/m² (0.132 to 0.197 oz/ft²). Brine is better than dry salt and equal to prewetted salt.

Snowfall

Brine generally gives good results in snowfall. It takes 30 min to become effective and stays effective from 1 to 4 hr, depending on traffic volume and precipitation. All the salt remains on the road. Brine can be used for temperatures down to −6°C (21°F); recommended quantities are 40 to 60 g/m² (0.132 to 0.197 oz/ft²). However, inadequate clearing can create packing, and in this use brine requires about 50 percent more spreading runs than dry or prewetted salt in a long-lasting snowfall. Overall, brine requires a greater effort to achieve the same effect as dry or prewetted salt.

Freezing Rain

Brine is adequate in light precipitation but not suited to heavy precipitation. It should be used in quantities of 40 to 60 g/m² (0.132 to 0.197 oz/ft²) for the same effect as dry and prewetted salt.

Packed Snow and Thick Ice

Brine is unsuitable for packed snow and thick ice.