Snow Removal and Ice Control Technology on Swiss Highways

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Winter road maintenance in Switzerland is vital because of the alpine nature of the country. The basic requirement of winter maintenance is to maintain the highway capacity and the safety of the roads without harming the environment. A successful program begins with a well-trained staff; it also depends on meteorology; road sensors; equipment for removing snow, spreading salt, and controlling ice; maintenance centers; and economic operation.

Switzerland is situated in the heart of Europe, in the central alpine region. The southernmost tip of Switzerland has roughly the same latitude as Minneapolis, Minnesota. Two-thirds of the country is mountains, some of which reach more than 4500 m (14,000 ft) in altitude.

The Swiss national highway network is situated at altitudes between 200 and 1200 m (650 and 4,000 ft). Some passes, which must be kept open all winter, even reach 2000 m (6,500 ft). This helps explain why Switzerland, along with other alpine countries that have the same problems, has always been among the pioneers in winter road maintenance technology.

The importance of winter maintenance is also clear in the expenditures of the road maintenance centers. For a four-lane highway, the yearly cost per kilometer reached $50,000 last year ($80,000/mi). The cost for winter activities (which, of course, varies from year to year depending on the weather) runs between 16 and 36 percent, or $8,000 to $18,000/km ($13,000 to $29,000/mi).

REQUIREMENTS FOR MODERN WINTER ROAD MAINTENANCE

Up-to-date winter road maintenance is not just a costly affair—it also brings many benefits. Without it, routine daily activities, business and private, would simply not be possible in a Swiss winter. Winter activities on the Swiss highways have three principal requirements:

- Maintain the highway capacity: full capacity from 7:00 a.m. until 10:00 p.m., and reduced capacity in between;
- Maintain the safety of road users at all times; and
- Avoid damaging the environment.

Put into concrete terms, this means

- Fast and complete snow removal, starting the moment that the snow no longer melts on the road surface;
- Effective ice control whenever slipperiness on the road surface occurs; and
- Minimum use of salt—the ecologists say to use none at all.

When analyzing the various tasks and the different demands, one soon realizes that a single item will not solve the problem. Applied alone, the most powerful vehicle, the most efficient alternative thawing agent, or the newest road sensor that tells the future will not bring the expected results; it will only be a disappointment. Winter road maintenance must be a whole philosophy, one that considers and makes use of every promising aid available.

Successful winter maintenance starts with a well-trained staff that has been instructed in every item from basic meteorology to minimal salt dosage with a sophisticated, electronically controlled spreader. Next comes the use of local weather forecasts or any weather information that gives an accurate forecast of snowfall or ice formation. Road sensors are a must. Automatic salt spreading equipment on structures must be considered. The equipment must be up to its tasks and in top condition. The various assignments with their respective equipment must be organized, and the standby planned. Finally, it is important to have a maintenance center with a practical layout to avoid unnecessary movement and loss of time.

METEOROLOGY AND ROAD SENSORS

No maintenance crew can do its job in time if it doesn't know, some hours in advance, what kind of weather and road conditions to expect. In Switzerland several public services are at the disposal of road users:

- A general weather forecast issued by the Swiss Meteorological Institute. The forecast is updated five times a day and is available on radio, videotex, and telephone.
- A forecast of road conditions. It is also issued by the Meteorological Institute at 6:00 p.m. on radio and made available on videotex and telephone.
- Actual road conditions. These are issued by the automobile clubs, updated twice a day, and made available on radio, videotex, and telephone.
- Special warnings about dangerous road or weather conditions, such as freezing rain. These are given directly to the maintenance centers by the meteorological office.

Missing in all this information, nevertheless, is an accurate, local forecast for the coming 2 to 6 hr. [Local here means the

Swiss Federal Highways Office, Monbijoustrasse 40, Berne 3003 Switzerland.

area of activity of a maintenance center—about 50 km (30 mi) of highways.] To fill this gap, the appropriate tools have been developed, some of which are still being researched.

The maintenance centers have an on-line connection to the national weather radar, so they get the newest radar picture every 10 min on a PC monitor. With a loop function it is possible to run through a batch of 12 pictures and follow a precipitation front as it has moved in the past 2 hr. With some experience, the responsible person can estimate the speed, direction, and intensity of the front and make decisions accordingly.

There are still some difficulties, though. It is, for instance, not possible to distinguish snow from rain on the radar picture, and to predict the direction and speed of a front remains a bit of a gamble. One possibility for overcoming these difficulties is to blend wind speed and direction, as well as actual measured snow depth or rainfall on the ground, directly onto the radar picture.

Another tool, introduced two winters ago, is a system called SWIS (Street Weather Information System). The principle is simple. The data from all road sensors in a certain area are transmitted to the meteorological office, where a meteorologist, with all the other weather information at his or her disposal, makes a forecast for that specific area. The forecast is transmitted on the monitor in the center, using a standardized mask (Figure 1). This local forecast is for 24 hr, segmented in 6-hr periods. When necessary—necessity is clearly indicated by the actual road sensor data—the forecast is updated after 6 hr.

The experiences with the system are extremely promising, but there are difficulties. First, the extremely small-scale forecasts are not always very accurate, and second, the forecasts require additional staff at the meteorological office.

In a research project, physicists found valid relations between air temperature, temperature above ground, dewpoint, and psychometer temperature to predict quite accurately the formation of ice on a hard surface. And, when considering the temperature profile to detect an inversion, it appears possible to forecast freezing rain—at least under certain conditions. This discovery is very interesting, because the Swiss Meteorological Institute has access to more than 60 automatic measuring stations, which deliver these data every 10 min. All that is left to do is to analyze the data and, when a critical situation is found, tell the maintenance people where it is and what is happening.

In the last few years, the major part of the Swiss highway network was equipped with road sensors. The chosen system, GFS 2000, is manufactured in Switzerland. Roughly 200 sensors are installed, which means an average of one sensor per 8 km (5 mi). They are generally installed at places where freezing occurs earlier than elsewhere: on bridges with thin slabs, at the exits of tunnels, on shady stretches, and so on. This should allow the person in charge to intervene locally when freezing is not generally expected.

The results from the sensors are quite satisfactory. However, the best sensor is only a tool. The decision about what must be done is made by the person in charge.

There are two other facts to bear in mind when considering the installation of a road sensor system. First, the forecast of road conditions is not possible with road sensors alone: the best sensor gives only the reading of an actual state at a certain point of the road surface. Second, every sensor system needs regular service, and even then it will occasionally produce false information. It is vital that a manufacturer's serviceman can be called to the spot within a reasonable time; otherwise, the system is of limited value.

GFSZ000 BOSCHUNG 07:34 16-02-93

Strassenzustands und WetterInformationsSystem SCHWEIZ

Klimagebiet: KANTON SCHWYZ Höhenstufe 200 - 600m.
Wettervorhersage für 24 Stunden 15.02.93 15:42

Zeit Von-bis	16:00-22:00	22:00-04:00	04:00-10:00	10:00-16:00
Bewölkung (0-8|Trend)	8 Gleich	8 Gleich	8 Gleich	6 Abnehm
Niederschlag Form|Menge	0	0	0	0
Schneefallgrenze(m.ü.M)	0	0	0	0
Wind Richtung|Stärke	v 5	v 5	v 5	v 5
Temp.Luft 2m. Minim.°C	- 1	- 2	- 2	- 1
Temp.Luft 5cm.Minim.°C	- 1	- 2	- 2	0
Glätteart				
Hinweise:				

Erläuterungen: Niederschlag: Schnee in cm., übrige Mengen in mm.
Windrichtung: Windrose, Windstärke: Km/h

Anzeige:
SWIS Wettervorhersage

FIGURE 1 SWIS prognostic as transmitted onto PC monitor in maintenance center.

Sensor technology is in progress. A major step was taken lately by developing a freezing-point temperature sensor. It works by cooling down the sensor surface until the humidity on the surface freezes. The corresponding temperature is measured and indicated on the monitor in the maintenance center as the freezing point. The advantage is obvious, as the remaining salt on the road surface is taken into account. The road master knows the temperature at which the surface of the road in question is likely to freeze and can react accordingly.

In the last two winters about 40 sensors of this type have been installed on the highways. Switzerland has had two rather mild winters, so a final judgment of the sensor cannot be given, but it is expected that the experience will confirm the convincing theory.

EQUIPMENT

The importance of top-quality equipment for winter activities can hardly be overemphasized. In Switzerland the highways are not kept white. The principal roads too are kept bare, with the exception of higher regions or during the night hours. Furthermore, Swiss legislation requires that snow removal be carried out with mechanical means before any thawing agents are used. The equipment for snow removal is chosen accordingly. Decisive factors are as follows:

- Speed of a snow-removal team on the highway. It is important to maintain an average speed between 50 and 60 km/hr (30 and 40 mph) to avoid being overtaken by the traffic.
- Minimization of the remaining snow behind the vehicle.

Obviously, the second object is harder to achieve. In past winters a newly developed machine called a Jetbroom was tested. It is a two-axle vehicle with an attached sweeper and blower unit between the axles (Figure 2). The sweeper brush has a length of 4.30 m (14 ft), which in diagonal position gives a cleaning width of 3.90 m (about 13 ft). The blower duct, mounted in front of the brush, blows the loosened snow out sideways. The results achieved with the Jetbroom are gen-

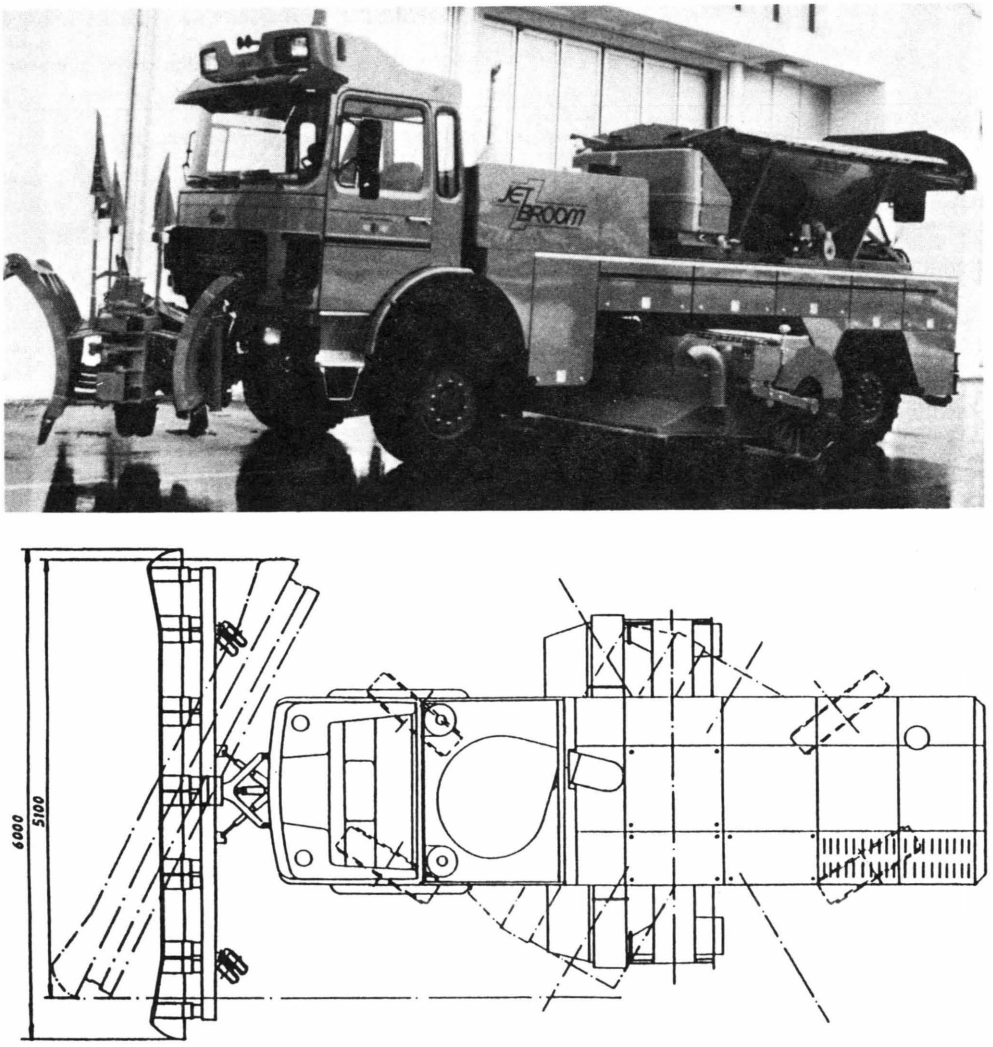

FIGURE 2 Jetbroom with attached sweeper and blower unit between axles: photograph (*top*) and diagram (*bottom*).

erally promising. Because the vehicle is remarkably more expensive than a normal truck, the manufacturer has developed suitable attachments for summer use to achieve a better all-year use.

An important piece of equipment is the salt spreader. The Swiss legislation only licenses spreaders that guarantee to maintain the chosen amount of salt per square unit, independent of speed. This decree forced the centers to replace all the old spreaders. The Federal Highways Office used the opportunity to promote the wet salt technique.

The common wet salt technique consists of mixing dry salt and brine on the spreader disc. The brine is stocked in containers in front or at the sides of the spreader. The brine is a calcium chloride–water solution with a concentration between 15 and 30 percent. In a few cases, sodium chloride is used instead of calcium. The brine is prepared in the maintenance center. The necessary installation consists of a mixing tank and a storage container (Figure 3). The storage capacity is usually about 6 months' consumption or more. The stored brine has a concentration near the maximum. The desired concentration for a particular operation can be obtained by adding fresh water, a process that is electronically controlled.

The use of wet salt on the road offers several advantages. First, the dosage of thawing agents can be reduced. A survey in all Swiss highway maintenance centers showed that with the wet salt technique, the average dosage can be reduced up to 25 percent compared with the use of dry salt. Next, wet salt starts the deicing process immediately, which means that the road surface is free of ice faster than when using dry salt. Finally, preventive salting is much more efficient with wet salt. It adheres to the road surface and cannot be blown away by the wind, as often happens with dry salt.

A disadvantage is the higher investment cost. Slipperiness on the road surface has been reported elsewhere, but not in Switzerland.

The automatic spray system for thawing agents must be mentioned. Many maintenance centers have a stretch of highway that regularly freezes earlier than the rest. It may be a long bridge or a stretch exposed to the wind or climatic peculiarity. If it happens to be at the far end of the operational area, it either reduces driver safety or causes excessive costs. Because it is not economical to launch an early separate spreading action for a short, faraway stretch, the whole length of the highway is normally done—"it must be done sooner or later, anyway," goes the reasoning. This may be so, but it may not—and the salt is on the road and the hours are spent, sometimes not in the most cost-efficient manner.

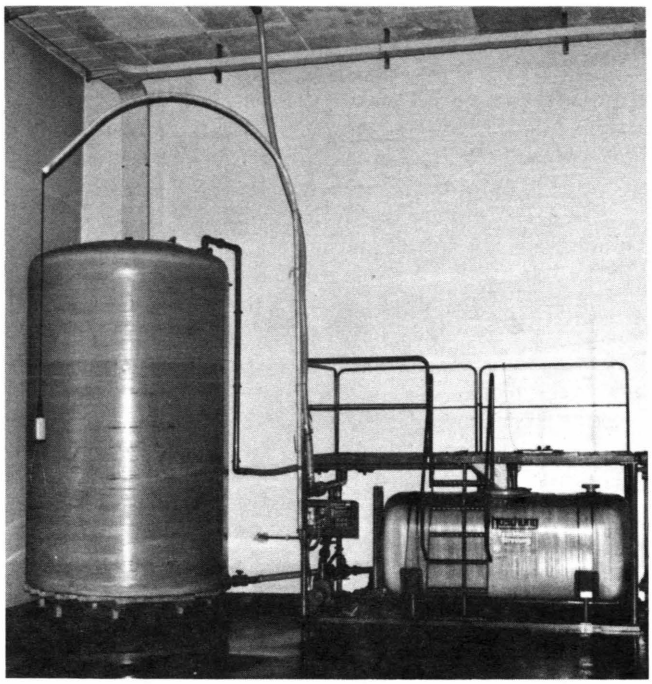

FIGURE 3 Wet salt installation: storage container (*left*) and mixing tank (*right*).

The installation of an automatic spray system offers a solution here. Not only is it economical in the long run, but it offers a higher security for the road user. In Switzerland two such installations are in operation, both on long and exposed bridges, and a third is being built. The latest generation of this device has overcome its earlier shortcomings. The distributor case with the spray nozzles is built into the pavement, and the necessary pressure is built up at the site (Figure 4). The pressure is sufficient to burst through any pack of dirt or snow that might occur.

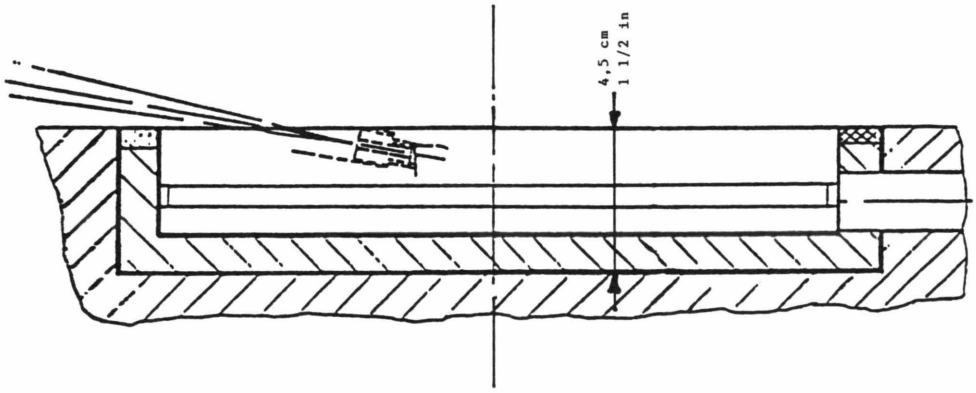

FIGURE 4 Automatic spray system: distributor case with spray nozzles built into pavement.

MAINTENANCE CENTERS

What was said about the importance of top-quality equipment also applies to the centers. It is very difficult to do a good job with an outmoded device, or with an old and unpractical center. Time is the most important factor in successful snow removal and ice control. Thus the maintenance crews need a home base, where the necessary activities do not lead to a loss of time.

A look at a professional fire department base reveals the decisive factors to save time; they are equally valid for a road maintenance center:

- An efficient alarm system;
- A spacious garage that allows the trucks to be parked beside one another, with plows attached and spreaders mounted;
- Motor-driven garage doors;
- A protected garage exit that cannot be blocked by any amount of snow;
- Crew quarters and lavatories adjacent to the garage;
- The supervisor's or road master's office overlooking the whole area of activity;
- Traffic lights, if necessary, to give precedence to the center exit.

The list is not complete. Other parts of the center need special consideration: salt storage in silos allows a much faster filling of the spreaders. According to the disposition of the silos, several trucks can be filled at the same time and, important for economical reasons, the drivers can do it themselves, without additional help. A well-equipped workshop in the center guarantees that any trouble or breakdown of a truck or engine can be seen to without delay, and a diesel oil and gasoline station in the center facilitates the refuelling during operations and in the evenings before closing.

Of equal importance is, of course, the organization of the work, the relief, and the standby. Only in exceptional cases is a night standby foreseen in Switzerland. One or several crews are on call at their homes. There they get the alarm of the ice detection system automatically by telephone. On a laptop they can read back the latest sensor data and react accordingly. Of course, they can also be called by a police patrol.

STAFF TRAINING

Behind every activity there is the person. A successful operation on the road, even with the most sophisticated equipment, requires a well-trained crew. It is the faculty and the skill of all concerned—the head of the center, the crew leaders, the mechanics, and the drivers—on which a successful operation depends. Therefore, instruction and training is essential, and even more so, the more complex and sophisticated modern tools become. It is an important task for the head of the center to set up a training program for all the activities of the unit. A few examples are driving of new vehicles, handling of new equipment, using the appropriate salt dosage for any given road condition, implementing the wet salt technique, removing snow on highway junctions, and installing signalization for maintenance work on the highway. Furthermore, the director must ensure that specialists, mechanics, and electricians are getting the necessary instruction to keep up with developments in their fields.

In addition, the Swiss Federal Highways Office started a course of instruction for heads of centers and crew leaders. One course takes 2 days. The last course program included basic meteorology, Part 1 (atmosphere, pressure, temperature, formation of clouds and precipitations, cold and warm front, prognostic), reading weather radar pictures for use in winter maintenance, and ice detection systems (functioning, alarms, use of data, errors). The reaction to the course was very positive. A continuation program for three consecutive years is in preparation.

Continual instruction and training is the only way to meet with the ever-increasing demands in winter maintenance. It not only enables the staff to keep up with their task, but it motivates them to do it better, which is the decisive asset.

ECONOMY

In Switzerland, the national highways are owned and operated by the cantons (Swiss states), and the federal government subsidizes their expenditures between 55 and 95 percent. The subsidy is not paid out as a global sum but in proportion to the expenditure of every canton.

Ten years ago operational accounting for all highway maintenance centers was introduced; it enables the federal administration to analyze the economy and the efficiency of any center. Operational accounting shows the hours of drivers, mechanics, vehicles, engines, and such used for winter maintenance on a given stretch of highway. It also shows the operating cost of any given truck or engine. It is therefore possible to compare these data with those of a neighboring center or with a given average or standard. The results are discussed with the head of the center or the person in charge, and, if necessary, a different strategy is developed or different goals are set for the next year.

An interesting fact is that all the heads of centers are the first to compare their own results with the given average. If theirs are lower in cost, they are pleased; if theirs are higher, they will look for the reasons and do something about it. It is a necessary competition that is only healthy for a public agency.

Personal experience of 10 years of activity in the field of winter maintenance on federal level can be summed up as follows: maintain a close look at new developments and test every promising device, but do not expect miracles. An excellent job can be done only when all factors blend into an integral whole.