finncontact

FINNISH ROAD ADMINISTRATION

VOL. 10 / No. 1
April, 2002

Quarterly Newsletter of the Finnish Highway Transportation Technology Center, FinnT²

FINNISH ROAD ADMINISTRATION IS WORKING FOR ROAD USERS

THE FINNISH ROAD ADMINISTRATION (FINNRA) IS RESPONSIBLE FOR THE PUBLIC ROAD NETWORK IN FINLAND. ITS MISSION IS TO PROVIDE SMOOTH, SAFE AND ENVIRONMENTALLY FRIENDLY ROAD CONNECTIONS TO SATISFY THE TRANSPORT NEEDS OF CITIZENS AND BUSINESS LIFE ALIKE.

WORKING UNDER THE MINISTRY OF TRANSPORT AND COMMUNICATIONS OF FINLAND, FINNRA IS IN CHARGE OF OFFICIAL AND ADMINISTRATIVE TASKS IN THE FIELD OF ROAD MANAGEMENT. FINNRA DEVELOPS THE TRANSPORT SYSTEM IN CO-OPERATION WITH OTHER ORGANIZATIONS AND PARTNERS.

THE ACTIVITIES OF FINNRA FORM A BASIS FOR THE WELL BEING OF SOCIETY AT LARGE. SOCIAL DEVELOPMENT LEADS TO MANY, AND SOMETIMES CONTRADICTORY, EXPECTATIONS. THE GUIDELINES FOR ROAD MANAGEMENT AND DEVELOPMENT 2015 PROVIDE SIGNPOSTS FOR ROAD MANAGEMENT AND FINNRA'S ACTIVITIES IN DECADES TO COME.

Finnra supervises planning, construction and maintenance of the Finnish public road network as well as draws up investment plans in this respect. The agency's tasks also include the promotion of a well-functioning market in the road sector field. An efficient market is conductive to the cost-effective use of appropriations and innovative road management.

Finnra, being divided into a headquarters and nine road management regions, commissions all road management products and services through competitive bidding. The agency specifies quality criteria for the work and supervises compliance with them. The contractor acquires materials, selects work methods and technical solutions and is responsible for the outcome.

A wintry motorway section belonging to Finnra's responsibility.

Customer (i.e. road user) satisfaction is monitored through surveys. The results are utilized in developing the agency's activities and services further.

Finnra provides road users with auxiliary services to ensure smooth traffic flow.The agency disseminates information about road and weather conditions, traffic congestion, disruptions and recommendable routes.

Finnra as an agency has defined certain values of its own. The values adopted are:

- Societal responsibility
- Customer-orientated activities
- Know-how
- Co-operation.

The Finnish Road Administration is active in international co-operation, too. Some examples: it is now the tenth annual volume in which the Finncontact newsletter is appearing in English for our foreign colleagues. Winter traffic and winter maintenance being particular Finnish know-how, this Finncontact issue includes two abridged versions of papers given by Finnish experts in the World Road Association's (PIARC) XI International Winter Road Congress in Sapporo, Japan, at the end of January this year. Altogether about dozen papers were given by Finns in the Sapporo congress.

JARMO IKONEN

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ROAD WEATHER INFORMATION FOR ROAD USERS IN FINLAND

The Road Weather Information Service is a Traffic Information Service in Finland that started in the winter 1997–1998. The service provides drivers with continual forecasts on road and weather conditions in winter in order to improve traffic safety. The forecasts are based on road conditions, weather and maintenance actions. The information is presented in a systemised way on national television and radio in connection with weather forecasts. The service has established its position as a source of information for road users – 9/10 recognise the service, and the effect on drivers' behaviour is estimated as large.

INTRODUCTION

Traffic information relating to weather and road and traffic conditions is an area under constant development by the Finnish Road Administration (Finnra). Despite the continuous improvement of winter road maintenance, hazardous road conditions in winter cannot be avoided entirely and drivers must occasionally cope with bad conditions. The risks drivers face in adverse weather conditions in Finland are many times those encountered on a bare road surface. For example, in one study it was estimated that the risk between different road conditions in Finland can be classified as follows: bare 1, snow 9, slush 12 and ice 17. The large variance in risk figures shows that drivers do not adapt their behaviour well enough in different conditions.

ROAD WEATHER INFORMATION SERVICE

The Road Weather Information Service provides drivers with forecasts on road and weather conditions in winter between October and March. The service has been developed jointly by the Finnish Road Administration, the Finnish Meteorological Institute, the Central Organisation for Traffic Safety in Finland, the Finnish Motor Insurers' Centre and the Finnish Broadcasting Company. Service is based on Finnra's information on road conditions and knowledge of maintenance operations, combined with weather information from the Meteorological Institute.

The Road Weather Information Service sets three levels for conditions on main roads: "normal", "poor", and "hazardous". Road weather forecasts were added to the national weather forecasts starting on 1 October and are compiled three times a day: early morning, forenoon and afternoon. The information is presented for each of the 19 provinces, thus it is an overall description of road conditions.

"Normal road conditions" indicates light snowfall that is not expected to continue. The "normal conditions" are slightly different in different areas of the country. In "normal" conditions in southern parts of Finland the main roads are relatively bare; further north road surfaces can often be worn into grooves by the passage of vehicles. Road weather is "poor" when there is heavy snowfall or snowfall is expected to continue for a long time, visibility is clearly reduced because of the snow, or changing temperatures cause slipperiness. Conditions are "hazardous" when freezing rain causes slipperiness that cannot be prevented through maintenance, or when the snowfall is so heavy that roads cannot be adequately ploughed. The "normal conditions" are not actively presented in the forecast, only the "poor" and "hazardous" conditions are. Figure 1 presents an example of how the Road Weather Information is presented on television.

The primary aim of the Road Weather Information is to provide drivers with continual updates on road conditions for improving safety. With the help of the service the drivers can also estimate the conditions in advance and thus adapt their travel behaviour. The service also aims at reducing the number of warnings of poor road conditions. One specific aim was to have distinct warnings for days with the most dangerous conditions, which typically occur on 5 to 10 days every winter.

EVALUATION OF THE ROAD WEATHER INFORMATION SERVICE

The service was evaluated to study how well the objectives of the Road Weather Service have been met. The studied issues were: how well do drivers know the service and their opinion of it, correctness of Road Weather Information, difficulties and problems producing the service and the experts' opinions on the service.

The evaluation was conducted with various methods, including interviews of car drivers, evaluation of the forecasts with log sheets, comparison with the numbers of accidents and forecasted Road Weather classifica-

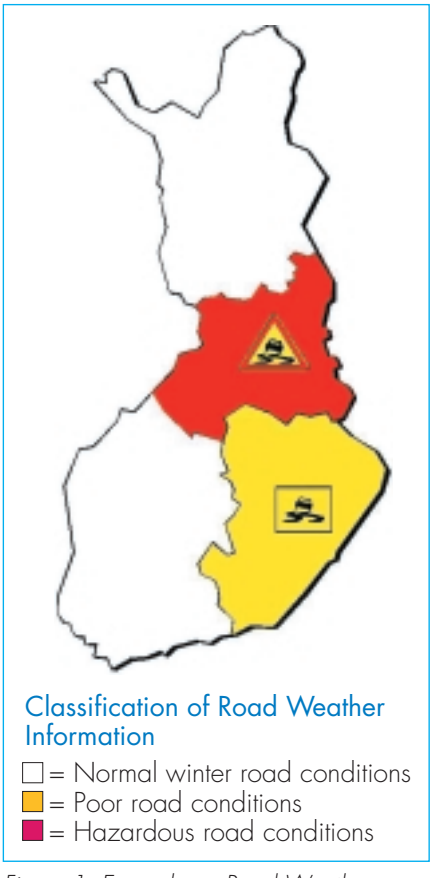

Figure 1. Example on Road Weather Presentation on television.

tion and also by interviewing various experts on the area. These different methods were used to tackle various issues of interest. Various sets of methods have been used since the start of the service so that more focus was naturally put into the early years of the service.

Interviews of Car Drivers

The service has been evaluated after each winter to see the effects of the service. The main result was that the service was very well recognised already after the first winter: 87% of the interviewees recognised the service in two independent studies. After three winters of the service, 90% of interviewees recognised the service.

The road users estimated that the effect of the Road Weather Service on their own behaviour was notable (Figure 2). For example, after the first winter 63% of interviewees said that road weather had a strong or very strong influence on their time reserved for the journey. Furthermore, 71% of interviewees said that the information had an influence on their driving. Between 20% and 70% of subjects answered that the service had a "marked or very marked" effect on their behaviour on all the presented issues.

Women answered more often than men that the Road Weather Information Service had an effect on their behaviour. This trend was observed in all the answers to this part of the questionnaire. When asked whether they had benefited from the new road traffic information compared with the regular national weather forecast, around 75% of drivers responded that they had. Professional drivers felt more often than others that they had benefited from the service

The estimated effects of the Road Weather Information Service were often greater than in previous studies covering various traffic information types. For example, in this study the service was said to have a strong or very marked effect on the time reserved for travel (63%) and on the driving behaviour (71%). The respective figures in an earlier study were 42% and 58%.

Road Weather Information and Days with High Numbers of Accidents

The aim was to study how well very difficult road conditions and weather situations had been forecasted on days with a high number of road accidents. Based on findings from earlier years it was estimated that roughly 5–10 days per year would have close to double the average daily rate of accidents. Some winters have seen even more days that this, with 15 in 1995.

The days were divided into three categories depending on the daily number of accidents. The day was classified as "normal" if the number of accidents was below the average + 20%. The accident number was "high" when there were more accidents than 80% above the average. Such days were also called "peak days". Between these two categories, the accident number was categorised as "somewhat higher". The comparison with the number of accidents in each Road Weather categories "normal", "poor" and "hazardous" and the respective accidents in these conditions showed that there occurred clearly more accidents when "poor" conditions had been forecasted. This result was even more evident in the case of "hazardous" conditions. These findings show clearly that the service provides adequate information to the difficult driving conditions. The weather situations for the "peak days" are being studied after each winter to further develop the quality of information.

CONCLUSIONS OF EVALUATION STUDIES

The Road Weather Information Service has been operating since 1997. It has established its position as a source of information on road conditions and forecasts on road conditions – 90% of the interviewees recognised the service and a vast majority of them claimed that they get the Road Weather Information almost daily. Most drivers found the frequency of broadcasts on road conditions to be adequate and the effect of the Road Weather on their own driving behaviour was said to be marked. For example, 63% of drivers after winter 1997–1998 answered that the road weather information had a strong or very marked effect on the time they reserve for travel, and 71% said has a strong or very marked effect on their driving behaviour. These results indicate that the Road Weather Information affects not only drivers' comfort but also traffic safety.

In conclusion it can be said that the Road Weather Information Service achieved a fair degree of success already in its first winter. The service was well known among car drivers and the effects were estimated to be large. The quality of the service also has been improved during the years of its operation. The positive results of Road Weather Information contributed to the development of "road conditions" information directed to pedestrians. This new service was tested in the Helsinki region in Finland and it got very high acceptance especially among the elderly people. The problem of slipping accidents is a significant socio-economic problem in Finland.

The evaluation results showed that the users feel that the service is important and they claim to use it in

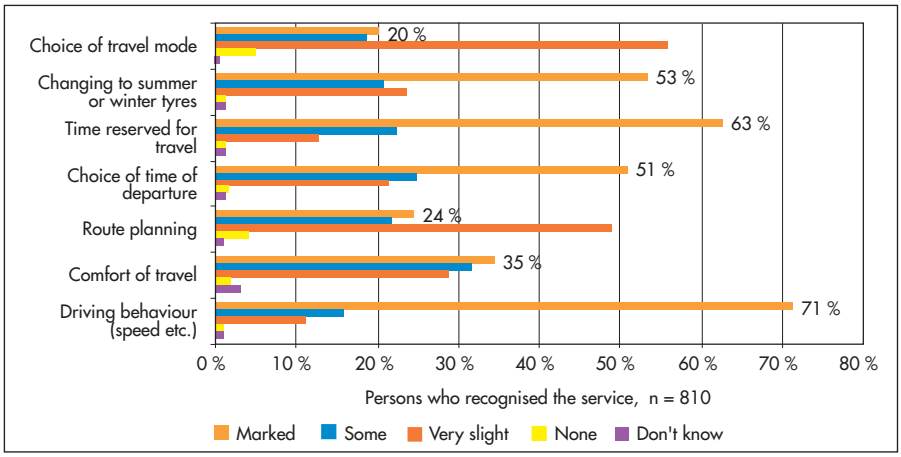

Figure 2. How great an effect has the Road Weather Information Service had on your driving behaviour?

wide extent. The accuracy and fast distribution of the information are important so that the people will benefit from these kinds of information services even more when making their travel decisions. Road Weather Information is now widely distributed through radio and television. In current situation, these are the two main channels for information provision, but in the future it is likely that this kind of information will be broadcasted to the road users' vehicle.

FUTURE

The Road Weather Information Service will be in operation every winter. It can be seen as a "real content" for example, for in-vehicle information systems, even though it should probably be modified to cover smaller areas etc. This is especially true in the situations and areas where the changes of weather are difficult to forecast. Also, the time span of 24 hours, even though the changes during this period are reported, is quite long, which makes it desirable to develop more local forecast services that concentrate more in the next couple of hours. However, the overall picture of Road Weather Information will be valuable for road users in the future also.

One next step in the near future is to study on site the effects of Road Weather Information in the situations when the road conditions are hazardous. This will be done during the winter 2001–2002 and the main object is to study how the information actually affected the road users.

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Mr. MAGNUS NYGÅRD, Finnra and Mr. JORMA HELIN, Finnra

MINIMISING SALT CONSUMPTION ON GROUND WATER AREAS

1. INTRODUCTION

The Uusimaa Road Region began the experiment on reducing salting for controlling slipperiness in the 1999 autumn. A reduced amount of salt is applied in particular when freezing weather is growing warmer, causing a thin layer of ice (frosting) to form on the road surface and a slight increase in slipperiness. The use of salt for preventing slipperiness following a snow storm is also being reduced in the experiment.

Slippery conditions resulting from a damp, warm road freezing are, however, being controlled on the roads in the experiment by normal salting. Similarly, slipperiness due to supercooled rain is being managed by applying salt in the normal way.

On the roads chosen for the experiment the new maintenance practices were assessed as reducing the use of salt by 20 - 30 % compared to previous salting. According to the normal salting practice, 7.5 - 10 tons more salt per road kilometre is used on roads equivalent to those included in the experiment. The purpose of this experiment was to determine what the chances are of reducing salting for preventing slippery conditions, as well as how the reduced use of salt affects the chlorine concentration of groundwater, road safety, the speed adopted by traffic, and feedback from road users. In addition, the changes required in other control of slippery conditions when making reductions in the amount of salt were studied.

2. GENERAL GUIDELINES FOR WINTER ROAD MANAGEMENT IN FINLAND

According to the general requirements set for winter maintenance, the freezing of wet road surfaces is also prevented by pre-salting before and after the actual winter period (11.12.-15.3.) in surface frosting and road conditions where there is no precipitation. For this purpose, soluble salt is used, as on other roads.

Figure 1 and Figure 2 gives the general requirements for preventing slippery conditions:

3. EXISTING GUIDELINES FOR CONTROLLING SLIPPERY CONDITIONS ON THE ROADS IN THE EXPERIMENT

Salting should be reduced on roads in groundwater areas.

For the salt reduction experiment a lower friction requirement (0.25) than normal (0.30) is accepted. Skidding is effectively eliminated below a friction level of 0.25. Friction values of less than 0.20 are not acceptable.

In addition to the daily weather and road condition forecasts serving the needs of road maintenance, 2-3 day forecasts are prepared. It is particularly important to take temperature changes into account when the weather is growing warmer after a bout of frost. Also, as the temperature continues to fall, it is important to contact road maintenance teams to give them time to eliminate any packed snow before the road surface becomes colder.

The correct timing of salting is extremely important. An attempt should be made to carry out salting before traffic uses the road, so that a good result is obtained even with a small amount of salt. In autumn and spring, problems arising due to black ice should be resolved using soluble salt by precisely predicting the weather conditions. Road condition forecasts in this kind of situation are in a key position. The amount of salt used for dealing with black ice per application should be only 2-5 gr/sq.m.

When frost forms on the road surface, the friction values must be carefully followed. No salting is carried out unless the situation looks as though the friction value is going to drop below 0.25. In this kind of situation, there is a real risk of road junctions becoming slick. Road junctions should be maintained on an individual basis, by either salting or grit application. Slippery conditions should only be dealt with where a definite need exists. During a frosty spell, road junctions should be managed by gritting. In awkward situations, small amounts of CaCl2 solution can be used. The aim is for a maximum of 5 t of salt to be applied per road kilometre.

4. MONITORING THE SALT CONCENTRATION OF GROUNDWATERS

As the aim of the experiment is to prevent a rise in the concentration of chlorine in groundwater, groundwater quality monitoring is one of the main tasks of the experiment.

Limit of chlorine concentration in household water

A limit has been placed on the chlorine concentration of household water for technical-aesthetic reasons. In Finland, the limit set by the Road Administration for chlorine is 100 mg/l. Should this level be exceeded, compensation has to be paid to the consumers of the water. If the chlorine concentration exceeds 25 mg/l, a study is undertaken to determine whether road salting is affecting the chlorine concentration of the groundwater. The limit set by the World Health Organisation (WHO) is 250 mg/l, this value having been set on the basis of taste. The high level set by WHO is most likely a consequence of the groundwater in many hot countries being appreciably salty. Concentrations of over 250 mg/l make household water rather unpalatable. Natural chlorine concentrations in Finland in the formations typical to groundwater areas generally fall below 10 mg/l.

QUALITY REQUIREMENTS FOR CONTROLLING SLIPPERY CONDITIONS							
Winter care category	Is	I	Ib	II	III	K1	K2
Normal	0.30	0.28	0.25	according to traffic requirement	according to traffic requirement	according to traffic requirement	
Friction requirement	road surface under -6ºC 0.25	road surface under -4ºC 0.25	point gritting 0.25 route application 0.20-0.22				
At night	22.00 hrs 05.00 hrs 0.28	22.00 hrs 05.00 hrs 0.25	22.00 hrs 05.00 hrs as required	22.00 hrs 06 as required	22.00 hrs 06 as required	after 2200 hrs K1 05.00 hrs K2 by 06.00 hrs	
From start of procedure	2 h	2 h	salt 3 h grit 4 h	6 h route gritting	10 h route gritting	2 h	

Figure 1. Quality requirements for controlling slippery conditions in Finland.

Friction value	0.00 - 0.14	0.15 - 0.19	0.20 - 0.24	0.25 - 0.29	0.30 - 0.44	0.45 - 1.00
Description of road surface	dangerous conditions, i.e. wet ice extremely slippery	icy slippery	compacted snow and ice satisfactory winter conditions	coarse compacted ice and snow good winter conditions	bare and wet good friction	bare and dry good conditions

Figure 2. Reciprocity of friction value and road condition.

5. CHANGES IN ROAD CARE

On the roads in the experiment it was possible to reduce the use of salt by 40% compared to the average use in previous winters. On these roads an average of 5.5 tons per road kilometre were used. Previously 10 tons/road km have been used on these roads.

The costs of winter maintenance in total have not decreased on the roads in the experiment because it has been necessary to control slipperiness in other ways in proportion to the decrease in salting. The real benefit is obtained from the groundwater salt concentration over the long term remaining at a lower level compared to a continuation of previous maintenance practices.

6. ACCIDENTS

The total number of accidents under winter road conditions were counted from the beginning of October to the end of April. When the accidents occurring in the 1999-2000 winter period are examined, it can be observed that there were 14 such accidents, which is exactly the same level as in the 1996-97 and 1997-98 winters. By contrast, 25 accidents occurred during the 1998-99 winter, which is a markedly higher number than in other winters, even though the traditional maintenance practice was used at that time. This large number of winter accidents was due to exceptional weather conditions.

7. CHANGES IN THE AVERAGE SPEED OF TRAFFIC

On the roads used for the experiment there are three points at which the speed of traffic is continuously recorded. Over the 1999-2000 winter period the monthly average speeds of the traffic have been compared with those of previous years. Changes in speed are extremely small. The lowest average speed for any one month was 82.9 km/h, the highest average speed being 95.5 km/h. On average, the average speeds during the 1999-2000 winter have decreased by only 0.1 km/h. The change is insignificant when one takes into account that changes of less than 0.5 km/h fall below the measuring accuracy of the equipment used for recording speeds. One can thus state that the speeds adopted by traffic have not changed during the experiment.

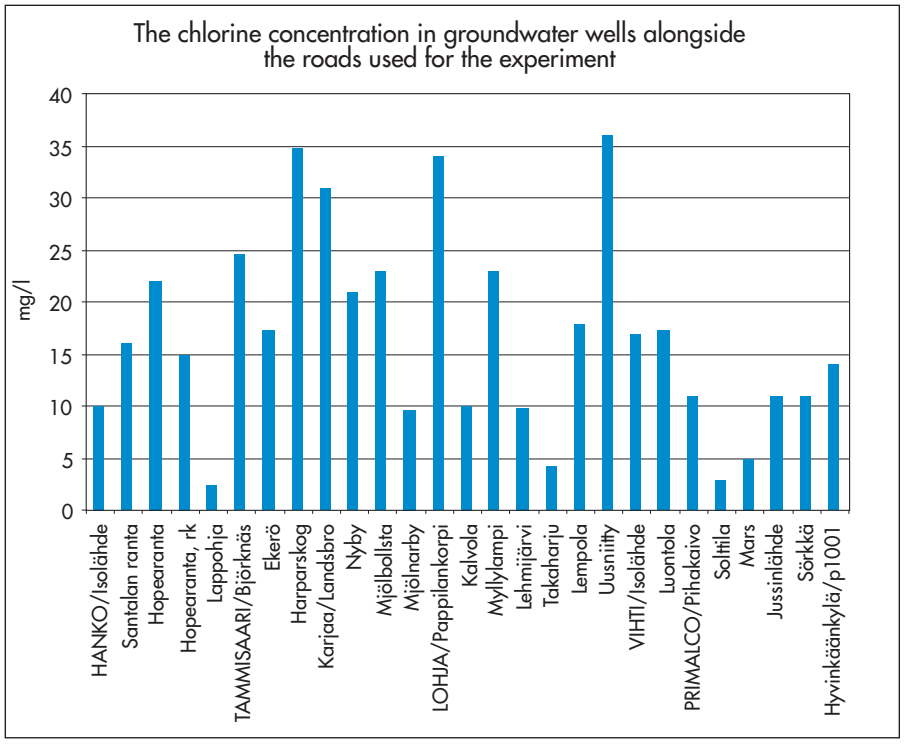

Figure 3. Fluctuations in the chlorine concentration in groundwater wells alongside the roads used for the experiment.

8. FEEDBACK FROM ROAD USERS AND IMPARTING OF INFORMATION

In conjunction with the experiment, feedback from motorists was gathered. The information received contained nothing at all directly connected with the experiment. It can thus be concluded that the salt reduction experiment carried out in the 1999-2000 winter period caused neither a negative nor a positive reaction among the road users, at least to the extent that somebody or other would have bothered to provide feedback.There was a second questionnaire in March 2000. This was directed at those road users who use those roads that are parallel to motorways and on which salting had been reduced in the 2000-2001 winter. The purpose of this questionnaire was to discern whether people were aware that salting had been reduced on these roads, and what their opinions were on the matter. Almost all the respondents had been driving either passenger cars or vans. The use of salt was widely criticised. Approximately one driver out of three expressed the hope that salting would cease completely. Around 30% of the respondents did not want little used roads to be salted at all. Most of them felt that salting should be reduced.

9. FINAL CONCLUSIONS

The reduction in the salting experiment produced some encouraging results in the 1999-2000 winter period.

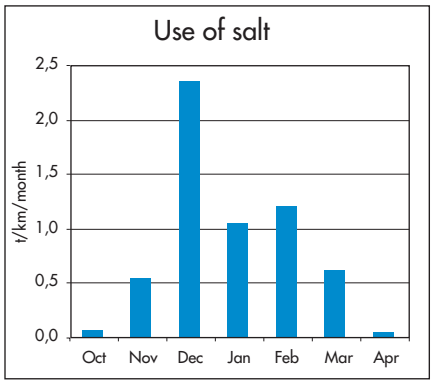

Figure 4. Monthly use of salt on the roads used for the experiment.

During the first year of the experiment the chlorine concentration of groundwater has decreased on average by 1.36 mg/l.

It proved possible to reduce the amount of salt by about 40% compared to the average for the previous winters. An average of 5.8 tons of salt was used per road kilometre. Other control of slippery conditions has had to be resorted to in order to compensate. No change is detectable in the number of accidents compared to the control years. Changes in the speed of traffic have been extremely slight.

A decision has been taken to continue and expand the experiment. During the 2000-2001 winter period, certain roads parallel to motorways were incorporated in the experiment. This experiment is aimed at offering motorists an opportunity to use roads on which less salt than normal has been used. Groundwater quality monitoring, the monitoring of road safety, traffic speed monitoring, and the gathering of feedback from motorists will also continue; opinions will also be sought and changes in road maintenance will be determined.

This experiment also constitutes a learning process for those personnel using salt; salt does not need to be used in the quantities which they have grown accustomed to.

Mr. SEPPO MÄKINEN, Finnra

Figure 5. Road users were warned of slippery conditions by means of road signs.

THE USE OF GLACIAL CLAY IN PROTECTION OF THE MOST IMPORTANT GROUNDWATER AREAS

1. BACKGROUND

Railroads and highways in Finland are often built on areas of glacial sand and gravel. These areas are also the location of most of the important groundwater areas, the water reserves of which are utilised by municipalities, cities and industrial plants. The Finnish Road Administration (Finnra) uses approximately 10-12 tons/km of salt (sodium chloride) annually for the winter (November-March) maintenance of highways. Another risk for groundwaters, for which there has been concern about, is the transportation of dangerous goods, which has increased by approximately 20 % during the last ten years. Over 300,000 tons of dangerous goods are transported on a main road in Southern-Finland annually.

According to the guidelines for the protection of groundwater of Finnra (1993), glacial clay material may be used as protective material of groundwater. According to the new guidelines (Draft 2000) only geosynthetic clay liners (GCL) or soil bentonite may be used for 'demanding chloride protection'. Thus glacial clay may not be used because it is feared that the clay material will dry in summer and freeze in winter and the resulting cracks will clearly increase the permeability of clay to water.

In the R&D project of the Finnish Road Enterprise it is examined by laboratory tests and field experiments as well as in a 'real construction site', the suitability of glacial clay for groundwater protection material. The project started in 1996 and continues at least till 2003. The results of this project can be exploited to road slope protection and dumping place protection construction.

2. EXISTING STUDIES

According to the guidelines of Finnra (1993) for the protection of groundwater, the suitability of a mineral liner (glacial clays, moraine) as protective material of groundwater will be examined in laboratory tests. Also the homogeneity and amount of the material to be used as a mineral liner will have to be examined at the extraction site of the soil. In this study the suitability of glacial clay as protective material of groundwater has also been examined with the help of test construction, a follow-up study and as a 'real construction site'.

2.1. Laboratory tests

The samples taken from the extraction site of glacial clay (in Utti and Jurvala) show that the grain composition of the clay material is lean clay with a fine-grained material content of 32 %. The other technical properties of the clay material examined are: water content 17-32 %, optimal water content 17 %, organic impurity 0 %, maximum dry density 1.80 tons/m3. The clay material is so-called dry crust clay, the water content of which is relatively low, approximately 25 %.

Figure 1 shows the quality requirements set for compact structures of soil by the guidelines of Finnra (1993) for the protection of groundwater as well as the properties of the Utti and Jurvala glacial clay. The figure shows that, as far as the laboratory specifications are concerned, the quality requirements are clearly met: the fine-grained material content is 92 % and the value of permeability to water is 1,000 times lower than the base value. Also at the soil extraction site the clay material is homogenous in its grain composition and quality.

2.2. Test construction

Groundwater protections were constructed in the Utti groundwater area on Highway 6 over a distance of 1.5 km in 1996. Sand bentonite (fine-grained sand mixed with 4 % of bentonite clay) was used as the protective material. The groundwater protections were constructed on the slopes of the highway, so that the protections reached at a distance of 9 meters from the edge of the pavement of the carriageway. At the same time a groundwater protection test-target area of 200 m in length was constructed of Utti glacial clay. Figure 2 shows a cross-section of the test-target area and the compaction of the clay material.

Figure 3 shows a structural drawing of the test structure. The thickness of the mineral liner of glacial clay at the test-target area is 500 mm or 700 mm and the thickness of the protective layer on top of it is approximately 400 mm. The uppermost layer is a grass-covered 100 mm thick layer of soil. There are 6 separate test structures in all:

1) mineral liner of glacial clay 500 mm
2) mineral liner of glacial clay 700 mm
3) mineral liner of glacial clay 500 mm + 100 mm of turf on top
4) mineral liner of glacial clay 700 mm + 100 mm of turf on top
5) mineral liner of glacial clay 500 mm + 50 mm of saw dust on top
6) mineral liner of glacial clay 700 mm + 50 mm of saw dust on top.

The studies showed that the compactness of the mineral liner (glacial clay) at the time of constructing the test target

Property	Quality requirements	Utti/Jurvala glacial clay
Fine-grained material content (percentage passing through a 0.074-mm sieve)	>70 %	92 %
Modified Proctor density	>85 %	90 %
Value of permeability to water (k-value) in the laboratory (modified Proctor density 90 %)	$<5 \times 10^{-8}$ m/s	7×10^{-11} m/s
Value of permeability to water (k-value) in the field	$<5 \times 10^{-6}$ m/s	3×10^{-8} m/s
Homogeneity of mineral liner (no sand layers, stones or plant waste)	Yes	Yes

Figure 1. The quality requirements of mineral liners (Finnra, 1993) and the properties of the Utti and Jurvala glacial clay.

Figure 2. Construction of the Utti glacial clay test-target area in August, 1996. The compaction of the clay material was done with an excavator scoop. The groundwater protection of the edge of the pavement (inner slope of the road) was made by using the GCL visible in the picture (light-coloured strip).

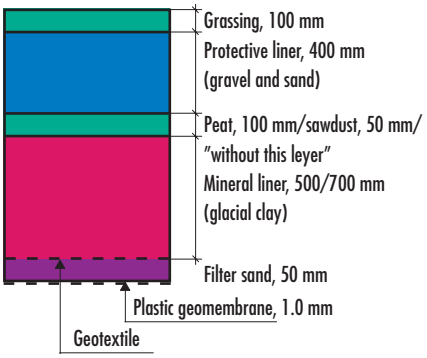

Figure 3. Cross-section of the test structure for groundwater protection at Utti.

area was approximately 90 % of the dry unit weight achieved through modified Proctor density and the value of permeability to water was approximately 3 x 10^{-8} m/s. These values are clearly better than those suggested as threshold values in the quality requirements of Finnra (Figure 1.)

2.3. Follow-up studies

According to the new guidelines of Finnra (Draft 2000) for the protection of groundwater, glacial clay may not be used for groundwater protections of 'demanding chloride protection', because it is feared that the clay material will crack due to drying in summer and freezing in winter and thus the values of permeability to water will become high. This issue has, however, not been sufficiently studied.

In November, 1998 a total of 16 temperature sensors and 6 humidity sensors were installed in 6 separate test structures at the Utti test target area. The temperature sensors were installed so that 3 sensors were placed at different depths in each of the 500-mm mineral liners and 2 sensors in the 700-mm mineral liners. Additionally one sensor measured the ambient temperature.

The winter follow-up study (25 November 1998 – 13 April 1999) showed that no freezing occurred in the mineral liner of glacial clay. When the ambient temperature was at its coldest, at –30.5 °C (8 February 1999), the temperature of the clay material was over 0 °C. In February the thickness of the snow cover on the slope of the road was approximately 700 mm.

3. FURTHER STUDIES

A new test site was built in the Utti groundwater area in the autumn of 2000. 30 meters long test structures were constructed in the slopes of Highway 6 by using the following materials as the impermeable layer: geosynthetic clay liner (GCL), sand bentonite and glacial clay. These test structures are monitored for temperature, moisture, and water permeability. Permeability is resolved by electrical conductivity measurements. Pressure sensors are used to measure the height of the water column above the bottom of the ditch. The aim of these tests is to study temperature related behaviour (freezing/drying) of the materials and to clarify the differences in their permeability. The results will be reported in the autumn of 2002.

4. SUMMARY

Laboratory tests and field experiments, as well as a 'real construction site', were utilized in this study to make clear the suitability of glacial clay for groundwater protection material. Based on the results, the clay material found in the area of Salpausselkä I and the moraine area (Utti and Jurvala) is suitable also for protection of the most important groundwater areas. The clay is homogeneous and has sufficiently low permeability. No freezing during winter or drying during summer was observed in the clay liner; thus, no fracturing occurs in the clay. Expenses for the use of glacial clay as groundwater protection material are only about 40 % of the expenses of geosynthetic clay liner. Also, the clay provides better protection in accident situations that involve transports of hazardous substances.

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