FINNCONTACT

Quarterly Newsletter of the Finnish Highway Transportation Technology Transfer Center, FinnT[2]

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LONG-TERM STRATEGIC PLAN OF ROAD MANAGEMENT IN FINLAND

ONE OF THE MAIN TASKS OF FINNCONTACT, WHICH OPERATES IN THE FIELD OF TECHNOLOGY TRANSFER, IS TO INFORM THE READERSHIP ABOUT ROAD TECHNOLOGY AND METHODS USED IN FINLAND. FOR EXAMPLE, THE ARTICLES OF THIS FINNCONTACT ISSUE DEAL WITH THE FINNISH BRIDGE MANAGEMENT SYSTEM, PROBLEMS AND SOLUTIONS OF ROAD CONSTRUCTION AND MAINTENANCE IN COLD REGIONS AND GROUND PENETRATING RADAR TECHNOLOGY.

BUT WHAT KIND OF STRATEGIC PLANS FOR FUTURE ROAD MANAGEMENT LIE BEHIND THE TECHNOLOGICAL ISSUES WE INTRODUCE IN OUR NEWSLETTER?

THIS TIME, I SHALL BRIEFLY INTRODUCE THE 15-YEAR STRATEGIC PLAN FOR ROAD MANAGEMENT IN FINLAND. THE DOCUMENT WAS APPROVED BY THE BOARD OF THE FINNISH NATIONAL ROAD ADMINISTRATION (FINNRA) IN MARCH THIS YEAR.

Road Management Guidelines 2015 is a long-term strategic plan on road management in Finland. The guidelines convey Finnra's road management targeting and its focal points at the present level of financing. The guidelines put forward here are nationwide. Because the local needs and conditions differ in various part of the country, the guidelines give some leeway to exercise regional planning.

Today, road management constitutes an integral part of social development, and it must serve the goals pursued by society at large. Social development will place many expectations on road management. These national and regional needs constitute a starting point for road management planning.

Client-centredness and societal responsibility are the most important values of road management. The quality of products and services, their availability and timing are based on the goals, needs and expectations of the clientele and awareness of their activities.

With this in mind, objectives have been set for road management, supporting the EU's transport policy, projections of the Finnish Government and policies of the Ministry of Transport and Communications. The objectives set for road management are grouped under five categories:

- Socio-economic efficiency
- Operational requirements of business life
- Regional and social equality
- Road safety
- Environment.

The road managemant guidelines 2015, which are presented and thorougly analyzed in the recently published document, are the following:

- Co-operation will be emphasised
- Increasing emphasis on traffic safety
- More responsibility for the environment
- Economy target in a key role
- Main roads will be developed in a balanced way
- Metropolitan areas are at the forefront
- Road maintenance will remain at present level
- Deterioration of network condition will be stopped.

Despite the great expectations, the most likely level of financing was selected as the starting point for these guidelines, and no major changes in road management responsibilities and the related funding were anticipated. The official document highlights signposts which have guided our work at Finnra.

JARMO IKONEN

European main road E 18 near Kotka in Finland.

Also In This Issue:

ANALYSIS OF BMS REFERENCE BRIDGES

In Finland, a set of about 120 bridges has been selected for regular special observation to improve knowledge of bridge age behaviour and durability. This reference group consists of bridges of different material and type, age and condition located throughout the country.

The research programme consists mainly of studies of concrete as bridge construction and repair material. Concrete chloride content and carbonation are of particular interest. Samples have been analysed in the laboratory and various non-destructive testing methods have been used. The collected information is used to improve age behaviour modelling in the Bridge Management System (BMS).

BACKGROUND

The Finnish National Road Administration (Finnra) started the Bridge Management System development in 1986. At that time there was no bridge inspection and damage data available in the Bridge Register database to create age behaviour models for BMS. The road districts have been carrying out regular inspections since the 1970's, but the information was not stored electronically.

In 1999 Finnra was maintaining 10 686 bridges and 2 763 culverts (span length ≥ 2.00 m) with a total length of 315 km, a total deck area of 3.16 million m^2 and an estimated replacement value of 18 billion Finnish marks (3 billion Euros).

The modelling of deterioration acceleration and age behaviour of these bridges is based on the information of damages gathered during the inspections. Because there was lack of information of this kind in the beginning, expert evaluations were made for getting the first age behaviour curves and models.

The inspection period of a bridge is about 4 to 8 years depending on the condition. Thus a set of 99 bridges and 23 culverts, which as a sample group represent the whole bridge stock, has been selected for regular special observations to improve both knowledge of bridge age behaviour and durability and modelling in the management system.

The reference bridges are also used to compare bridge maintenance costs and life span costs for different bridge types. The economical and structural suitability of different bridge types and materials for various purposes will be analysed to improve future bridge design.

The first large analysis of the investigation results was reported in the end of 1998. This analysis gives information especially on age behaviour of concrete as bridge construction material. Also recommendations for further research are given.

REFERENCE BRIDGE GROUP

General

The reference bridge group has been chosen as a purposive sample to represent the whole bridge stock in the country. The reference bridge group consists of bridges of different material and type, age and condition, geographically situated throughout the country. The reference bridge group is graphically described here only by the overall condition of these bridges (see Figure 1). Finnra, naturally, has statistical information e.g. about the material distribution, age distribution and maintenance class distribution of this reference bridge group.

Inspections and concrete core sample investigations have been made since 1992. All the 122 bridges were inspected at least once in 1997. The inspections were carried out according to a special inspection plan. The yearly reports give an estimate for the condition of the bridge structural parts for every inspected individual bridge. Also samples were taken for laboratory tests.

Surface deterioration which is usually preceded by map cracking is the greatest problem in the reference bridge group. These damages are mostly located in edge beams and substructures like retaining walls and wingwalls. Also erosion of front slopes and cones are often observed damages. More serious damages are cracking and water leakage among surface deterioration and reinforcement corrosion of concrete deck superstructures. The most usual damage in steel bridges is rusting: many of the steel culverts constructed in the 1960's are in a very bad condition.

Statistical reliability

The statistical reliability analysis proved that the reference bridge group is a fairly representative sample of the whole bridge stock.

The proportion of steel bridges is greater in the reference bridge group than compared with the whole bridge stock. There are plans to add some short spanned concrete bridges in the reference group.

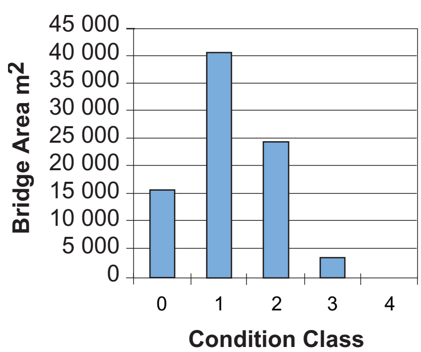

Figure 1. Calculated overall condition (0 means very good, 4 very bad) of the reference bridge group.

Figure 2. A core sample is being taken of one of the reference bridges near Kemi in Northern Finland.

INSPECTIONS

Investigations on the bridge site

The reference bridges have been inspected twice since 1992 for BMS purposes. The inspections are very similar to general inspections but they are carried out by a leading consultant specialised in bridge inspection and repair together with a bridge management expert from Finnra. The inspection interval varies with the research needs. Not all of the 122 bridges are inspected in a year, but every year bridges are inspected in different districts. The inspection interval for one bridge will be about two to five years.

The inspection data, bridge condition data and damage data are updated in the Bridge Register on the bridge site using a portable computer and a mobile phone connection. Non-destructive testing methods are used together with concrete core samples (see Figure 2) among others.

The following tests are used in the field investigations:

- Carbonation depth of the concrete is determined from core samples which are taken 50 mm corecase drill. The cores are cleft and phenolphthalein indicator sprayed on the cleavage surface.
- Acid soluble chloride contents of the concrete is determined using a Rapid Chloride Test equipment. The concrete powder samples are taken from the depth of 0 to 20 mm using a hammer drill.
- Concrete deck covers are measured using an electromagnetic covermeter (Proteq Profometer 4).
- Thickness of coatings in railings and steel structures are measured using Elcometer 245F.
- Concrete compressive strength is measured using the rebound Shmidt hammer (Proceed N).
- Relative humidity of the concrete is measured using Vaisala HMI sensoring elements and data logger.

All the tests are taken according to a plan made by the Technical Research Centre of Finland (VTT).

Also radar measurements for bridge decks can be used for bridges which are planned to be rehabilitated in the near future. The suitability of radar measurements was proved by a research programme in 1990-1993. The bridge deck surfacing, the protective course and waterproofing were opened up to the slab upper surface after the measurements. Comparisons with the radar results and empirical studies could be made and so valuable information gathered.

Tests in the laboratory

During the inspections, concrete core samples were taken for laboratory tests in VTT according to the sample plan. Altogether 112 cores were tested between 1992 and 1998. Carbonation depth, porosity and concrete compressive strength were measured from the core samples with a diameter of 75 mm. The samples needed in the tests were worked out of the cores as shown in Figure 3.

Also micro structure investigations were applied to a part of the cores. Concrete porosity, micro cracking, carbonation depth and possible ettringite occurrences were studied.

The following main quantities were measured:

- Total, protecting and capillary porosity of concrete
- Protecting porosity ratio
- Water penetration resistance factor
- Capillary factor
- Concrete compressive strength
- Concrete density and dry density
- Carbonation depth, minimum and maximum.

SAMPLE ANALYSIS

The samples were divided into groups by bridge structural parts according to location. The same bridge structural parts were used as in the Network Level BMS. Samples were divided into two environmental categories: structures exposed to sea water or de-icing salt and other structures.

Statistical analysis of the test results was made by calculating the mean values, deviations and numbers of tests of those quantities listed above. From this information a statistical reliability index related to the (0,1)-normal distribution was solved to give a probability of mean value deviation for the structural part in question, compared with all tested structural part samples.

The statistical analysis gives a quite exact description of the concrete used as a construction material in the Finnish bridges. Information on compression strength, porosity, density, carbonation speed and concrete cover of the reinforcement can be used when estimating bridge deterioration and remaining life.

BRIDGE AGE BEHAVIOUR MODELLING

Models Developed for the Network Level BMS

When creating the first bridge deterioration and age behaviour models there was not enough data of damages gathered during the inspections. Instead, opinion surveys (Delphi studies) and expert evaluations were carried out in order to set up the first age behaviour curves and models. One result from these expert evalua-

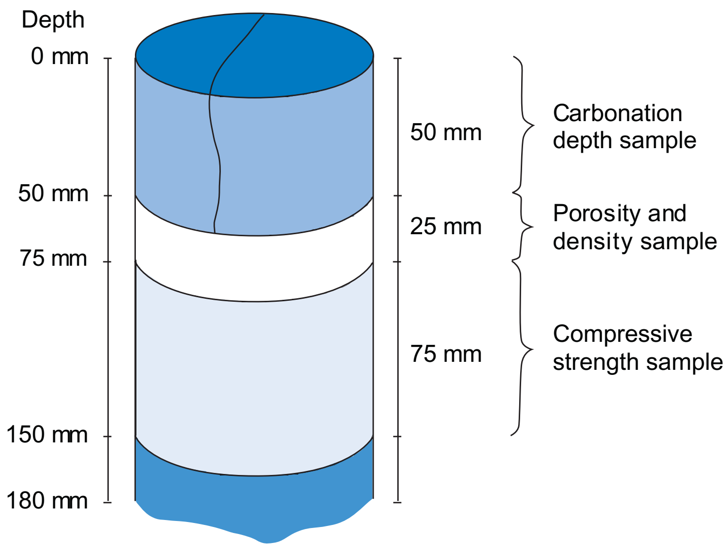

Figure 3. Partition of the concrete core samples for laboratory tests.

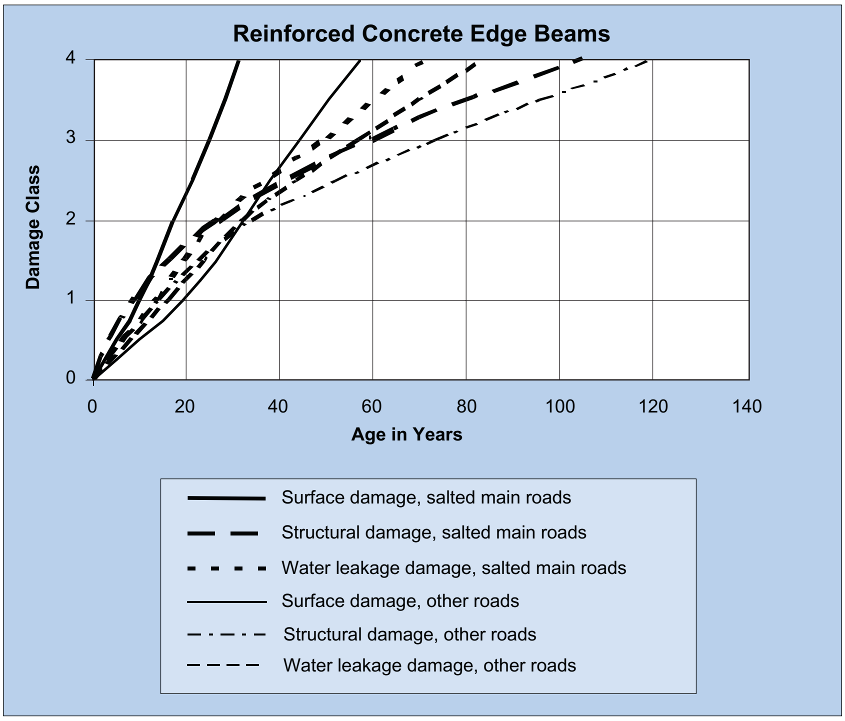

Figure 4. Age behaviour curves for reinforced concrete edge beams.

tions is given as an example in Figure 4. These polynomial curves can be presented mathematically as the following equation:

$$S(t) = a_1\,[t/(1-k)] + a_2\,[t/(1-k)]^2 + a_3\,[t/(1-k)]^3 ,$$

where S is the damage degree,
t is the time in years,
k is the relative shortening on account of the parallel damage type,
a_1, a_2 and a_3 are constants.

Model Simulation

A research project on service life modelling of durability against freeze-thaw weathering and reinforcement corrosion of concrete structures was carried out in the years 1996 and 1997 in the Technical Research Centre of Finland, VTT. The goal was to develop a calculation method based on computer simulation for predicting the deterioration speed and service life of concrete structures in real circumstances and for getting knowledge of the effects of different material parameters and structural and environmental elements on the service life of the structures.

The simulation research was useful in developing new age behaviour models. Information on material and both damage and deterioration data from the measures gathered from the inspections and from research on the reference bridges were very suitable for the calibration of simulation models for the bridge management system needs. For this reason the simulation program was developed further in 1998. In the first phase, statistical mean values from the laboratory tests were used to calibrate the calculation models. The main models in the simulation program are among others:

- model for freeze-thaw weathering of concrete
- model for reinforcement corrosion.

Project Level BMS Model Development

To produce age behaviour models for bridge structural parts using the simulation program means that the empirical and experimental information from the reference bridges will be combined with the calculation formulas of the simulation program. The models can be easily calculated after this calibration.

The final age behaviour models for the Project Level BMS will be interactive. They can be adjusted by bridge material properties and structural and environmental information of a specific structure given by the BMS user. The user determines the bridge structure, location, chloride stress, concrete cover, concrete compression, porosity and width of the crack. If all the information is not available, the default models based on the research mean values of the reference bridge group will be used. In addition to this data the user can also specify the following deterioration information:

- The age of the bridge at the time of inspection
- Carbonation depth
- Critical depth of the chloride content
- Deterioration depth of the concrete
- Depth of the reinforcement corrosion in the crack.

The reliability and quality of service life predictions depend on the available bridge-specific information.

BENEFITS OF THE REFERENCE BRIDGE GROUP

The reference bridges are not only inspected by the experts but also separately by the bridge engineers in the road districts. So the reference bridge group serves very well as a data quality control method for the inspection data carried out by the bridge engineers.

The main target is to get improved age behaviour models for both the whole bridge stock and the main bridge structural parts on the network level and specified age behaviour models suitable for individual bridges on the project level . The first results from the analysis are very promising.

FURTHER RESEARCH

The research of the reference bridges continues. About 10 to 15 new bridges will be added on grounds of the statistical analysis recommendations. There are needs to special samples taken out of bridges which are mainly exposed to de-icing salts or sea water and thus have a high chloride content. The models need new information in order to be improved continuously.

Investigations of the reference bridges have until now concentrated mainly on solving the basic properties of concrete and on studying the first stages of concrete damaging, that is, carbonation and chloride penetration. In the future, more attention should be drawn to the second stage damages like freeze-thaw weathering and corrosion which determine the end of the bridge life cycle. Also cracking surveys should be included in the future research programmes.

The steel bridges in the reference group mostly have a concrete deck. The steel superstructures, girders and especially culverts, will be investigated as its own group in a research programme in the near future. Timber bridges will have their own research programme, too.

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Ms. MARJA-KAARINA SÖDERQVIST, Finnra

NEW TECHNOLOGIES IN ROAD SURVEYS AND REHABILITATION DESIGN

Now when the basic road network in the industrialized world has almost been completed, more and more activities of the national road authorities will be focused on maintaining and improving the standard of service of the current road network. At the same time, national road administrations are having to face the fact that their financing has been decreased.

Roadscanners Ltd consultants, in cooperation with the Finnish National Road Administration (Finnra), have developed a solution for this situation. The new Road Analysis method is based on techniques such as Ground Penetrating Radar (GPR), which allow maintenance and rehabilitation measures to be focused only on those road sections where measures are required.

These tools for precise design have been developed and tested over the past few years in Finland and Sweden. Using new technologies to give a real 'insight' into a road's problems enables each maintenance and rehabilitation measure to be specifically focused on that road section where the measure is most needed. Savings of 20% to 60% have been achieved in reparation measures alone. In addition, the more effective rehabilitation measures, working as 'precise medicines' against each local defect, help to extend the lifetime of the rehabilitated road.

Figure 1. A GPR survey vehicle on road.

The GPR software specially tailored for the road management system of the road administration will further increase the value of GPR-based road surveys.

SCANNING THE ROADS

The GPR method involves the transmission of electromagnetic radar pulses into the earth, as well as the measurement of the elapsed time between transmission, reflection off an electrical interface, and reception back to a surface radar antenna. Portions of the downward propagating electromagnetic energy reflect back to the surface when it encounters changes in electrical properties, such as in the pavement or base course interface. See a GPR vehicle at work in Figure 1.

Interpreted measurement results give a longitudinal profile of the road, indicating layer interfaces and anomalies such as settlements or moisture traps in the road structure. GPR techniques, especially when integrated with other road research data, show great potential as a tool for modern road condition management.

INTEGRATION

Alongside the GPR results, Road Analysis combines the results of falling weight deflectometer (FWD), rutting and roughness measurements, core samples, pavement distress inventory data and video filmed images from the road. A key tool for the integrated analysis of different data is Road Doctor™ software (a result printout in Figure 2).

SURVEYS GLOBALLY

Other successful GPR applications, such as network level pavement and base course thickness surveys (with outputs given to GIS-based PMS), quality control of road paving projects, gravel road wearing course surveys, spring-thaw weakening surveys of gravel roads, bridge deck surveys, detection of sub-surface defects such as stripping in surfacing layers and voids beneath slabs and evaluation of moisture susceptible base materials, have also been developed during recent years.

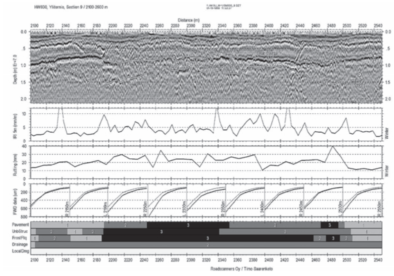

Figure 2. Road Doctor™ printout with GPR profile, IRI and rutting measurement results, and an analysis output that classifies the displayed section with four different parameters.

In May 1998, Roadscanners Ltd together with the Office of Minnesota Road Research, USA, performed a series of GPR tests in Minnesota, in order to determine the level of accuracy of GPR technology in pavement and subgrade soil testing. The test sections represented a range of pavements materials, structures and soils found in the state. A number of GPR tests were performed to evaluate different types of pavement defect and ascertain their causes.

The results of this Minnesota GPR project clearly showed the benefits that GPR could offer in measuring layer thickness of various pavement structures. The Mn/ROAD project also revealed some previously unknown defects in test cells, e.g. stripping, voids and moisture anomalies. In 1999, development work was continued for the Texas Department of Transportation, USA, in the use of a low-frequency ground coupled antenna for road subgrade investigations. 2-D imaging based on resistivity measurements is another geophysical method with promising applications in geotechnical and environmental survey projects.

ADAPTING NEW TECHNOLOGIES, ACQUIRING NEW SKILLS

The training of GPR experts and rehabilitation design professionals is a further important task, imperative for the success of new methods of road condition management. Engineers and technicians need to be trained to collect and interpret GPR data. Rehabilitation design professionals at Finnra are being trained on the basis of a long-term R&D cooperation contract.

When the Technical Center of the Estonian Road Administration decided to acquire GPR equipment at the end of 1999, they selected this new survey system with the needed software and training. System delivery is a long-term process; without proper training and software support, new equipment is likely to be quite useless.

The Estonian project began in Rovaniemi, Finland, in November 1999 with a training course dealing with GPR techniques and applications. During the year 2000, the personnel responsible for operating the GPR units will be trained to use the specific units for different tasks under different conditions. The consultancy company will also assist the new Estonian GPR crew with their first survey projects.

An essential part of a working GPR survey system is effective software. The analysis software Road Doctor™ contributes to performing quick and accurate road investigations. This software is also included in the Estonian project, with the necessary user training and support. The software is customised to meet the national standards of road survey data. Short tutorials are an integral part of the contract during the first measurement season, after which cooperation will continue in the form of collegial advice and exchange of experiences.

CONTINUOUS R&D

Also other developments in the field of geophysical research applications in road engineering have been realised. An example of this work is the Percostation, developed in cooperation with Adek Ltd and the Road District of Lapland of Finnra. The idea for this measurement station for real-time moisture detection, bearing capacity monitoring and load restriction optimising was developed in the course of a series of research projects performed in Finland and Texas, which showed a clear relationship between electrical properties and strength and deformation properties of road materials and subgrade soils. High dielectric (Er) values of road materials and subgrade soils always indicate frost susceptible material, which is under a dynamic wheel load, sensitive to positive pore water pressure and permanent deformation. As little as a few load cycles can cause more than 2% permanent deformation in base course material whilst the material is thawing.

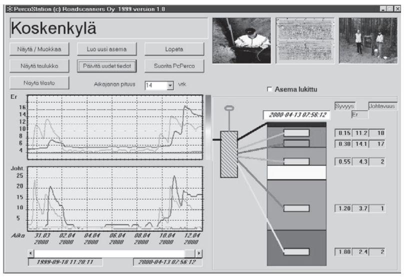

Figure 3. Percostation results from early spring 2000: dielectric values (Er) and electrical conductivity values show that the top part of the base thawed over two days (March,30-31), re-froze and then began to thaw again on April,9. The alarm value for high risk of permanent deformation was measured once late in the night of April, 11, although after this the moisture content in the road structure decreased. No load restrictions were required on the measured road (a road section in southern Finland).

The Percostation consists of five Perco-sensors installed into the road structure at different depths. These sensors measure dielectric value, electrical conductivity and in the future also temperature at certain time intervals. The measured data is transferred to the traffic information centre, where decisions for implementing or lifting the load restrictions can be made.

For more information about ground penetrating radar techniques, GPR and road analysis software, road aggregate research, condition surveys and rehabilitation design of roads and bridges, please contact Timo Saarenketo, Roadscanners Ltd, Valtakatu 21, 96200 Rovaniemi, Finland; tel. int. + 358 - 16 - 4200 521, fax int. + 358 - 16 - 4200 511, email timo.saarenketo@roadscanners.com.

Mr. TIMO SAARENKETO,
Roadscanners Ltd

COLD-CLIMATE EFFECTS ON ROAD CONSTRUCTIONS IN NORTHERN FINLAND

Finland is located quite far in the north and people are used to living and working in cold circumstances. Also constructions have been designed to survive and be protected over the cold winters. Even if there are only few permafrost deposits in the area, the seasonal frost is severe, and phenomena of seasonal frost are often similar to those of permafrost areas. The winter together with snow and freezing also demand effective maintenance.

1. CIRCUMSTANCES IN THE REGION

The population of Finland (5 million inhabitants) concentrates in the southern part of the country. The area of northern Finland, Lapland, is 100 000 km2 which is close to 30 per cent of the area of the country but has only about 200 000 inhabitants. The length of the area in north-south direction is about 500 kilometres. The population centres are far apart, which means long transport distances, ineffective time use and high costs.

Local rock and soil materials are in many cases of secondary quality, but they will be used because of transport distances. The transportation takes place on roads because the railway network reaches only the southern part of the area. The road network is in fair condition but it is not dense. The length of paved public roads is 6100 km and the length of gravel roads 2900 km.

The climate of Finland is a mixture of continental and marine climates. The Gulf Stream affects the climate so that in wintertime the climate is much milder than in other areas on the same latitude elsewhere in the world. However, the winter is long and cold. The length of thermal winter in Southern Finland is about 125 days, but in Northern Finland 195 days, which is 6.5 months. The mean annual temperature in Northern Finland is about - 1 °C, and the temperature is many times below - 40 °C.

It is very dark during wintertime in the area when the sun does not rise above the horizon in a couple of months. There are some works, like paving, which can not be done during the winter. Other construction work is done throughout the winter, even though the climatic conditions and darkness make the working difficult and raise the costs significantly.

Seven to eight months of the year precipitation is in snow form. The mean thickness of the snow is close to one metre and maximum thickness about 1.5 metres, so the removal of snow needs much work both in construction sites and on the road net. In Finland the policy is to keep all roads open throughout the year. This means we have to plough the roads very often.

There are no trees in mountainous areas and the drift snow tends to accumulate on some roads. Snow fences are used in windy terrain to prevent snow from piling up on roads (see Figure 1).

In some places there is a risk of avalanches The avalanches have an enormous momentum and they can cause much damage. Roads must be planned to avoid risk areas or the risky sections must be minimised.

2. FREEZING AND ITS CONSEQUENCES

2.1 Freezing of construction materials and constructions

In exposed snow free areas, like in road constructions, frost penetrates in Southern Finland to the depth of about 1.6 metres and in the north to about 2.5 metres. The average thickness of road constructions is less than one meter and it is normally economically impossible to build frost resistant constructions. We try to minimise frost heave so that it should not cause unreasonable inconvenience. Frost heave is not even and the heaves mean damages in constructions. An acceptable frost heave on primary roads is about 5...10 cm depending on the road class.

There is discontinuous permafrost in Nordic areas but there is no massive ice in mineral soils. The permafrost occurrence in rock and mineral soils has not been plotted because they have not presented any disadvantages for construction. The palsas (frost peat mounds) in bogs have been plotted and investigated. Sometimes a road line crosses a palsa and the road causes thawing of the palsa, which causes settlement of the road. Settlements have been levelled every year. A test section was constructed near Kilpisjärvi, where a thermal insulation layer was laid under the embankment and white aggregate was used in the asphalt pavement. The aim was to keep the palsa frozen. Only a minor settlement was observed on one of the shoulders.

Figure 1. A snow fence in Northern Lapland.

The seasonal frost is of course a very remarkable phenomenon all over Finland and it must be taken into account in all construction activities. The winter begins already in the beginning of October and the ground freezes. This is a considerable disadvantage for the handling of materials. The soil freezes and makes excavation of materials very difficult.

Frost damage of constructions can be prevented if we can eliminate the following factors: a frost susceptible material, access of water into the freezing zone, or the freezing of the material (by using thermal insulation materials etc). In practice, the materials are, in many cases, frost susceptible and the constructions are too thin. The ground water is close to the surface of the ground and the constructions are wet or even water saturated in the autumn. If the constructions freeze into a thickness of more than 2.6 meters, a lot of frost damages will result. The constructions will swell, which causes uneven heaving of the surface and constructions. In addition to frost heave, longitudinal and transversal cracking of roads occur. Other elements of roads, like pipes and cables, can be damaged, too.

Thawing of the frozen ground and road constructions lasts long into summer – many times until July or even until August. When the frost in a road thaws, it causes, at first, surface softening and, later on, softening of the whole structure. This results in rutting and potholes in all roads, especially in gravel roads. The weight of vehicles must be limited for a certain time. When the road constructions contain an excess of water, the bearing capacity of a road remains low until all the construction is thawed. The bearing capacity can decrease to less than a half of its summer bearing capacity. In paved roads a decreased bearing capacity of the construction causes ruts and alligator cracking in the pavement.

Frost is restricted by using non-frost susceptible materials and by draining the constructions and subground. Frost insulation materials are used to protect the drainage installations and, in many cases, to repair frost damage sites. Besides cellular plastic insulation also peat is used as insulation material (see Figure 2).

2.2 Creeping of slopes

Instability exists in cut slopes as well as in natural slopes especially when frost is thaw-

Figure 2. Sacked peat is used as thermal insulation in a road structure.

ing. The amount and pressure of water will lower the strength of the soil so that creeping and slope slides takes place. The freezing and thawing of slopes can also cause falling of stones along the slope to the road.

2.3 Icing phenomenon

Icing occurs also in Southern Finland but the phenomenon is much more severe in the north. Ground water or surface water running to the road area will freeze on the dikes and various constructions like culverts. Groundwater icing, surface water icing and channel icing are common. Groundwater icing develops when a road embankment freezes deeper than the surrounding area. In an inclined terrain the frozen zone dams the ground water flow and it penetrates onto the surface. The water freezes on the ground and when new water penetrates on top of the previous ice, the thickness of the ice will grow layer by layer.

There are constructions where the ground water flow is collected by hidden ditches to one point or well. From there the water is led into frost insulated subsurface drains (pipe lines) under the road to the lower side of the road, where it cannot cause any harm to the traffic.

Drainage systems need some maintenance but they have been working well and there has been no need to dig out ice from the side ditches or thaw out ice from the culverts. These operations would usually call for much work and expenses.

3. FLOODS

3.1 River erosion

The spring break up and thawing of snow are rapid phenomena in the north. Great changes in daily temperatures do slow down the thawing. This is, however, difficult for drainage facilities. Some of the water melted during the day freezes in culverts, ditches and on the constructions during the night. This creates new icing.

There is a flow of thaw water from the terrain to the river channels which are still frozen. The water finds out new routes along the sides of the channel and in the surrounding nature causing erosion. When a part of the river ice starts moving it develops ice dams. The water level can rise several meters. Water has risen up to six meters in the River Teno. The flood water and ice blocks spread out to the surrounding terrain causing damages also for roads, buildings and other constructions.

If the bridge openings and culverts are frozen or otherwise blocked, the flow can destroy also bridge constructions or sections of road.

3.2 Erosion on slopes

The slopes of cuts and embankments are exposed for erosion because the vegetation roots very slowly. Both wind and water erosion takes place. The intensity of erosion depends on the soil type and other circumstances. Both types of erosion are difficult to control. Especially water erosion can be very fast, causing also slope failures like small landslides. The material driven by the water can accumulate in ditches and make dams which prevent the drainage, and, thus, constructions remain wet. Secondary failures can result. Gravel, crushed rock or vegetation will be used to prevent erosion. To hinder erosion, also honeycombed cell constructions have been tested on surfaces.

4. MAINTENANCE

The northern location and circumstances effect both winter and summer maintenance of roads in Lapland. In winter, snowfall means difficulties on a construction site and a need of ploughing on roads. Different road categories have standardised snow depths which are not allowed to be exceeded. If the depths are exceeded, ploughing is necessary. We use casting ploughs on roads in Finland. Salt for de-icing is not used in the north because the temperature is so low that the friction is sufficient. Drift snow means special difficulties in open areas where snow tends to accumulate on roads.

In spring, ditch ploughs are used to open side ditches of roads so that thaw water can run in ditches and embankments dry earlier and more rapidly. Road planes are used to level compacted snow on roads and roughen the surface. We use also planes mounted under a truck. These are multi-purpose vehicles having usually a plough, plane and sanding (or salting) accessories.

The fact that the drainage of a road is working well prevents frost. In practice, however, frost often exists. If frost heaves are too high, the speed of vehicles must be limited. In the worst places, drainage is improved or the construction must be dismounted and rebuilt the following summer. In many cases thermal insulation materials, e.g. cellular plastic, are used. If pavement cracking exists, also steel wire nets have been used below the bound surface layer (wearing course) to prevent cracking.

Digging crown ditches will prevent creep in slopes. They collect water to places where it does not cause any harm. In many cases we make revetments on slopes. Main revetment materials are gravel, crushed aggregate and grass. Honeycomb mats can also be used on slopes to prevent creeping of soil before the slope will settle down.

Icing phenomenon needs follow-up all the time but mostly in springtime. If drainage installations do not work, we may have to remove ice from the side ditches several times during the winter. If the culverts block due to freezing, ice must be thawed out either by using steam, iron rods heated by welding transformer or in some cases with electric cables.

5. CONCLUSIONS

The climate and circumstances are quite harsh in Northern Finland. The constructions and life must be adapted to fit in with nature. Icing can in many cases be prevented or at least diminished. Constructions and maintenance have been developed to work in these circumstances even if they are more expensive than in Southern Finland. We know very sophisticated constructions and methods but in many cases they are not economically justifiable.

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