Road Condition Management in the Northern Periphery

ROADEX SUB PROJECT A

EXTENDED SUMMARY AND CONCLUSIONS

PROJECT IS FUNDED BY ERDF,
ARTICLE 10
NORTHERN PERIPHERY PROGRAMME

PREFACE

The road districts of Lapland in Finland, Northern Region in Sweden, Troms County in Norway, and the Highlands in Scotland have initiated a technical, trans-national collaboration. The aim of this collaboration is, through the exchange of experience, to identify best practice strategies and develop procedures for dealing with common challenges associated with the maintenance of low traffic volume road networks in sparsely populated northern regions.

The Roadex project is partly financed by an EU (ERDF, Article 10) funded Northern Periphery Programme, a programme of cooperation between the northernmost regions of Finland, Scotland, Norway and Sweden.

The project was started in 1998 as a pilot project between the four road administration bodies. The work was divided into two sub-projects: Sub project A deals with road condition management issues; and sub project B studies winter maintenance problems common to the partner road districts. Both sub-projects aim at technical exchange through studies, discussions and trials, and at identifying the most effective strategies, in the examined issues, which could be applied in other Northern Periphery road districts.

The Roadex steering committee nominated Timo Saarenketo from Roadscanners Oy, Rovaniemi, Finland to be the Sub Project A (SPA) work group chairman. The other nominated work group members, representing each district, were: Stuart Bell from the Highland Council, Scotland, who is the committee secretary, Geir Berntsen from Troms County, Norway, Peder Henriksson (1999) and Sara Sundberg (2000 -) from the Northern Region, Sweden and Erkki Vuontisjärvi from the road district of Lapland, Finland.

This extended summary report is based on results of questionnaire answers, interviews and field trips, literature review and on the results of the field tests conducted in each partner district. The language of this report has been amended by Kent Middleton from Roadscanners. Several people in each partner district as well as in Roadscanners have also helped with this report and a special thanks is addressed to them. Roadex Project Steering Committee and its chairman Tapani Pöyry have provided encouragement and valuable guidance for the work.

Rovaniemi September 14, 2001

Timo Saarenketo, chairman

1. INTRODUCTION

The main road network's role is to provide effective transport channels for industrial products, small services, and various small and medium sized business enterprises. In the Northern Periphery region, the critical role of low and middle class roads is apparent. By estimation, one third of all transport traffic is dependent on low or middle class roads. These are typically transports that keep the local fish plants, saw mills, pulp mills, steel industry and their suppliers working. Modern logistical systems in basic industries do not tolerate contingencies in raw materials supply; economical losses quickly mount from discontinuities in production flow. Tourism is an additional regionally important user of the road network.

At present, the main inter-urban highways of Scotland, Norway, Sweden and Finland are recognized by road users to generally be in satisfactory condition. In comparison, the less frequently trafficked rural roads have suffered from financial neglect and are falling well below modern standards. They have not been designed to cope with the combination of seasonal freeze/thaw cycles of the northern climate and the heavy axle loads of modern transport. Recent development in transport and in industrial logistics have substantially increased the stress on road structures as the total weight of heavy transport has been increasing and modern super-single tyres are replacing traditional twin tyres on heavy transport vehicles.

The focus of this sub project is the low traffic volume roads of the partner districts of Lapland, the Northern Region, Troms County and the Highlands, which have less than 1000 vehicles average daily traffic (AADT). In the four partner districts, these roads total 32.800 km, which accounts for 85% of their total road network (Figure 1). Gravel roads are also given special attention, as they have some distinct characteristics and a notable role in the local road networks of the Nordic partner districts.

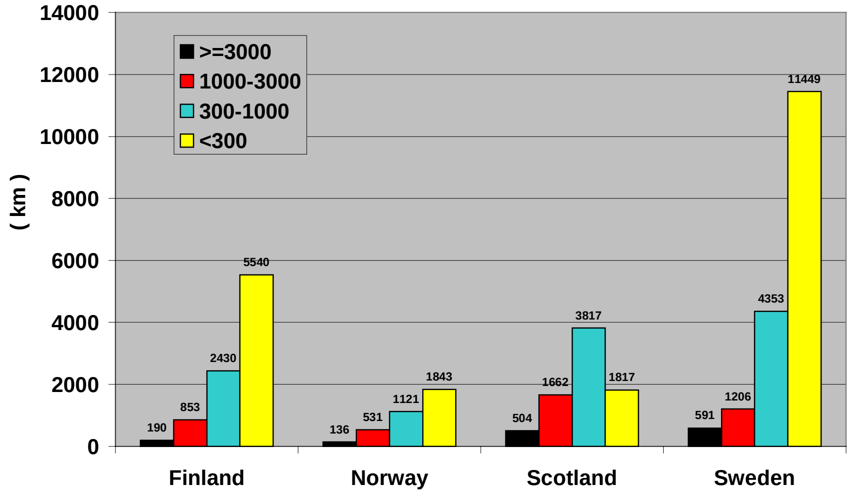

Figure 1. Traffic volume in NP partner districts.

A special interest for sub project A was the use of traffic restrictions in the partner districts. During the spring thawing period especially, a road structure can deteriorate dramatically in a very short time. Traditionally road districts, who are responsible for the road network performance, have dealt with the problem in two ways: (a) by imposing load restrictions for sensitive road sections, or (b) by improving the road structure layers (Figure 2). Reduction of financial resources has prevented strengthening of the road network to the degree required, as such there is increasing pressure to implement load restrictions so that the level of road network performance can be kept at the current level. On the other hand traffic restrictions cause major logistical disadvantages for local livelihood. According to calculations done in Sweden, the implementation of load restrictions has cost the national paper industry 700 million SEK (77 million Euro) annually.

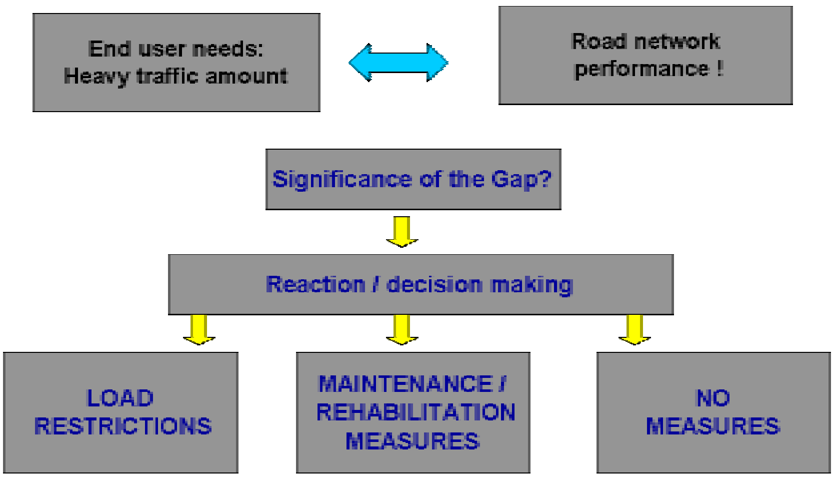

Figure 2. A chart describing the decision making process for weak roads in the Northern Periphery

With that background the goals given for the Sub Project A (SPA) were to seek the best practises in the region for lower class road condition management, focusing especially on ways to 1) optimise the use of traffic restrictions or 2) to minimize the damages if restrictions are not applied.

Because the general goals of the Roadex project were to establish networks among road district personnel and to exchange ideas and experiences about solving common problems in Northern Periphery, the work group also decided to collect extensive, but general, descriptions of the environment, people and society in the partner regions. This will help people to understand, more easily, the background of the current road management techniques used in each NP partner district.

This report provides a brief summary of the Roadex SPA activities and some key results and observations made during the project. The detailed State-of-the-Art report has been published in the form of a printed publication in September 2000, detailed results of Roadex field tests are published in the Roadex CD-rom and as *.pdf reports on the Roadex www-pages.

2. WORK GROUP ACTIVITES AND RESEARCH METHODS

The SPA Road Condition Management work group started its activities in a February 1999 meeting in Rovaniemi where it decided to undertake data collection for this study through a large questionnaire, work group sessions, interviews and field excursions in each partner district. The first seminars and interviews were held in April 1999 in Scotland and the interviews in Sweden, Norway (Figure 3) and Finland were completed in autumn 1999. Based on the questionnaire results, excursions, interviews and literature review a state-of-the-art report was published in September 2000.

In October – November 2000 a series of field tests were performed in 8-9 test sections in each partner district, representing standard structures, best practise structures and problem structures. The tests were done using a ground penetrating radar unit and in the Scandinavian partner districts a Road Master roughness and rutting survey unit, owned by Roadscanners, was also used. The road sections were also photographed and digital video was recorded. In the field test analysis planning documents and other data collected from the survey sites were also used.

The field test data was analysed in spring and summer 2001 at the same time as data collection and processing for the Roadex CD rom was being done.

The SPA work group has had work meetings in Luleå, Sweden, in Dingwall, Scotland, in Troms, Norway and in Kukkolafors, Sweden.

Figure 3. Roadex seminar and interview participants in Troms region in 1999.

3. RESULTS

3.1 General

Road condition management factors, in the NP partner districts, are described in figure 4. The political decision makers assign economic resources and efficiency goals. On the other side road engineers collect information about the traffic volume and its development, the amount of heavy traffic and road condition. In road condition management decision-making there is also a need for information on the maintenance and rehabilitation measures and the effectiveness of these measures in the network. Finally in modern democracy it is also important to gather road user feedback and monitor the development of public opinion. It is with all of this information that road districts have made decisions about what kind of policies they will choose for managing their road network but the same information should affect every single road condition management decision.

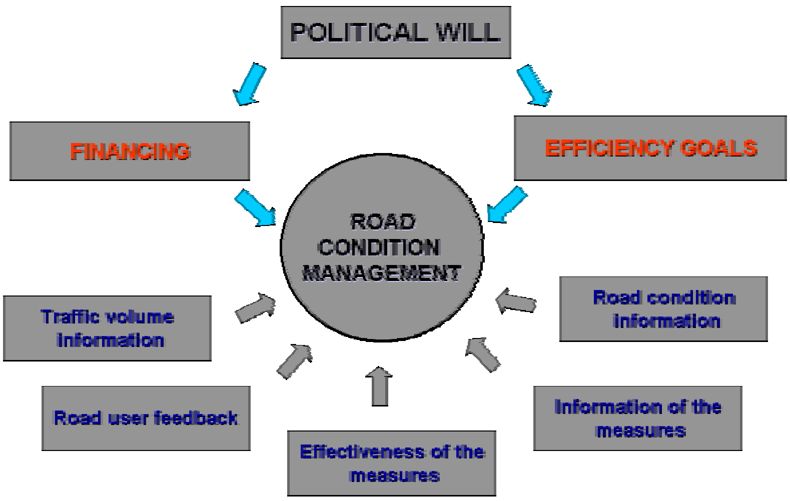

Figure 4. The factors affecting road condition management decisions.

In the following sections, a brief description will be given of what kinds of policy and techniques have been adopted by each Roadex partner district to overcome the daily challenges in the field of road condition management.

3.2 Load Restrictions

The policies of the national road authorities, on the issue of load restrictions, vary a great deal, as do the practices in each Roadex partner road district. Finland and Sweden allow the heaviest normal transport weights on almost all the public roads, 60 tonnes, and implement temporary load restrictions especially during the spring thaw periods. Region Norr faces the most difficult situation among the partner districts and about 1/3 of the road network has permanent or temporary load restrictions (Figure 2). Norway has implemented another policy where temporary load restrictions are not used but many Troms County roads have permanent load restrictions, of 40 – 50 tonnes, throughout the year. The maximum total weight permitted in Scotland is 41 – 44 tonnes.

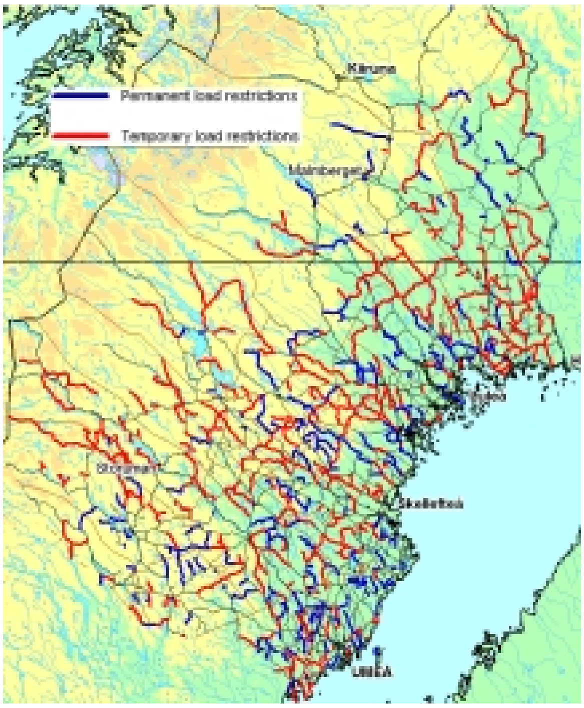

Figure 5. Permanent and temporary load restricted roads in the Northern Region in Sweden.

The maximum allowed tire pressures are basically the same in each country and there is general agreement that these pressures are too high and that modern super single tires especially are causing problems for the pavement materials.

Sweden and Scotland have more protective policies towards road structures, Northern Region uses temporary load restrictions if there are indications of pavement structure defects and Scotland sets permanent load restrictions if there is a concern that increasing heavy traffic might break the road.

There are also some new solutions for dealing with the problem. Modern information technology has opened the possibility of utilising new methods to minimize the additional costs for the heavy traffic due to temporary load restrictions. Real time road structure monitoring stations, one prototype is currently being tested in Lapland, can give real time information as to when and what level of load restrictions should be applied in each area. The technique is based on scientific research and objective measurements and as such is more easily accepted by the transportation industry.

The enforcement of load restrictions also varies in each country: while the Troms county road office can order fines or other sanctions for over-loaded trucks the Highland Council and Lapland can only report the offenders to the police.

3.3 Road Condition Monitoring

In order to effectively utilise the resources addressed to the low traffic volume road network, road districts need a road condition information system. Troms County and the Northern Region evaluate their road network performance mainly through a roughness and rutting information data collection system and use pavement distress information and bearing capacity data only in project level surveys. The road condition monitoring system in Troms region is well organized and measurements are repeated annually. In the long term this database will provide extremely useful information regarding the durability and service length of different kinds of road structures in the area. However both Troms County and the Northern Region do not have a routine system for evaluating gravel road condition.

Lapland has the most complete road condition evaluation system. Besides monitoring the road surface condition through roughness and rutting information and pavement distress data, the district also collects structural data using FWD and GPR techniques. Lapland also has a thorough system and database for gravel road condition evaluation. The Highland Council faces the biggest challenge in this field: at the moment there are no routine objective measurement systems to evaluate and compare road network condition and performance in different parts of the Highland area. However the first steps have been taken during the Roadex project and currently Highland Council is starting to implement a PMS system for their road network.

Road condition evaluation systems are, in the long term, very cost-effective because they allow long term planning of rehabilitation measures. Without this type of data it is not possible to invest in precise design and rehabilitation projects. The Roadex field test results have clearly shown that with the new NDT technologies it is possible to evaluate the causes of defects as well as profile these areas so that rehabilitation measures can be focused and effective on these problems sites.

Experience from road analysis projects, done in Finland and Sweden, has shown that the roads, that are considered to be totally damaged and requiring total reconstruction, have severe defects on only about 30 % of the road length. This can be interpreted conversely that 70 % of the road is in relatively good condition and may only require some light repair. Thus the savings in rehabilitation projects gained through these pavement condition databases are multiple when compared with the annual cost of collecting the data.

3.4 Maintenance and Rehabilitation Techniques

The Roadex project did not reveal any major new maintenance techniques but there were numerous special rehabilitation and repair techniques and materials used successfully in some districts that could easily be transferred to the other partner districts and other countries. The Roadex field tests provided some interesting results showing new problems related with these techniques that are in turn causing problems in the roads.

In the area of maintenance and rehabilitation there are several techniques, materials and practices especially for stabilising the pavement and base course, reinforcing and insulating the road structure. Especially the road mix, remix stabilisation and steel mesh reinforcement techniques were frequently mentioned in discussions with the district staff and questionnaire answers. An economical method to protect pavement structure and at the same time add friction is the surface dressing technique that especially Scotland and Norway are using successfully.

A short description of these best practise techniques is given in the following sections.

Surface Dressing

The surface dressing technique is an excellent method for pavement treatment and maintenance when the first signs of pavement distresses appear on low traffic volume roads. This technique seals the existing pavement and prevents water from infiltrating the pavement structure where it can cause disintegration of the pavement structure or permanent deformation in the unbound base course.

The surface dressing technique has been used quite extensively in Highlands (Figure 6) and is one of the reasons why roads in the Highlands are still in relatively good condition despite major reductions in financial resources during the last decade. Surface dressing is also a popular method in Troms and it has been used on some roads in the Northern Region in Sweden. However the Lappi District has hardly used this technique in recent years. One of the arguments against using this technique has been that it is sensitive to the weather conditions. However if surface dressing has been successful in Troms and Highlands, districts with much higher summer rainfall figures than Finland or Sweden, then the technique should work even better in these regions.

Figure 6. Surface dressing project in Highlands.

Bitumen stabilization and pavement remix

Stabilization of the top part of the pavement structure (Figure 7), using foam bitumen or emulsified bitumen as binder, has gained increasing popularity among Scandinavian NP partners. It has also been tested in the Highlands but is not routinely used in the area. The advantage of stabilization is that it is possible to treat and strengthen the unbound base course that, in many cases, has problems with high fines content and is susceptible to permanent deformation.

Figure 7. Remix stabilization machinery.

In the Roadex field tests, bitumen stabilized section were tested in Norway, Sweden and Finland. The results from each test section showed that the road was quite even and functioning well. However a few observations about problems related to the stabilized test sections can be made. One important thing is the effect of road shoulder support on the performance of the stabilized structure. If road shoulders were narrow and/or if they were steep, shoulder deformation or cracking was observed in the tested sections. Poorly functioning drainage was also causing damage to the stabilized pavement structure. Another important factor that should be considered when planning stabilization projects is that the road should not have problems with uneven frost heave.

Recycling pavement, using pavement remix techniques, was not especially tested in this project but some test sections have had this treatment. This technique has proven, after some “growing pains”, to be an excellent tool for road sections that have thick enough pavement and do not have major problems with bearing capacity. Pavement remix is widely used in Troms, the Northern Region and in the Lappi Region and can also be recommended for use on low traffic volume roads in the Highlands.

Steel reinforcement

Steel mesh reinforcement has been becoming an increasingly popular strengthening method, during the last few years, in Lapland and in the Northern Region and has also been successfully used also in the Highlands. The steel reinforcement technique has been used, in most cases, to prevent longitudinal cracking but there have also been positive results from reinforcement of weak road sections resting on peat. Steel mesh has been installed either in the pavement or in the unbound base course. General experience from the steel reinforcement was that the structures had been working well if the installation instructions were carefully followed.

In the Roadex field test sections steel reinforcement was used in four sites. The results of the analysis of the test provided some interesting results. The results from road 398 Lappträsk in Sweden showed that rutting was much less in the test section where steel reinforcements were installed deeper in the base course instead of at the bottom of pavement. The test section in Mellajärvi demonstrated the importance of using proper lengths for the reinforcements. In this case, reinforcements that were too short caused longitudinal cracking near the road shoulder. The test section in Killimster Moss in the Highlands, where the old concrete road resting on peat was reinforced with steel reinforcement, has been working well.

3.4 Shared Problems

The Roadex project clearly showed a few major problems shared by all the partner districts: drainage of roads located on transverse sloping ground, permanent deformation due to freeze-thaw cycles, bad quality road materials and their treatments, and road sections resting on peat. The first three problems are more or less related to water content and freeze thaw cycles. Peat roads are clearly another kind of problem that require a different approach

Drainage of the road constructed on a sloping hill

The Roadex project did not find any superior drainage improvement techniques even though drainage was a major problem in each country. Several drainage techniques had been tested but all the techniques had some problems, or they were very expensive. The Highland Council especially has major problems with poorly performing drainage and this is most likely the main reason for shoulder deformation in the area. The problems in other districts are mainly found on roads located on sloping hills where the rutting increases in the lane on the upper side of the slope (Figure 8).

Figure 8. Pavement defect related to the poorly working drainage on the upper side of the road.

Roads constructed over a peat subgrade

A very common subgrade soil type in each Roadex partner district is peat. Most low traffic volume roads have been constructed without excavating away the peat and thus the roads are resting on a peat subgrade. This has caused various problems for the roads. Especially differential settlements, which reflect the changes in the thickness of the peat layer beneath, are major problems in the NP area (figure 9).

Figure 9. A road section from B871 in the Highlands, constructed on peat, with depression problems.

Another problem for the roads with peat subgrade, indicated by the Roadex field test results, was related to the widening of the road structure and the fact that compaction time, of the peat under a load, is very long. The widened road shoulders are suffering, in many places, from severe rutting or cracking due to the slow subgrade compaction beneath the widened roads (figure 10).

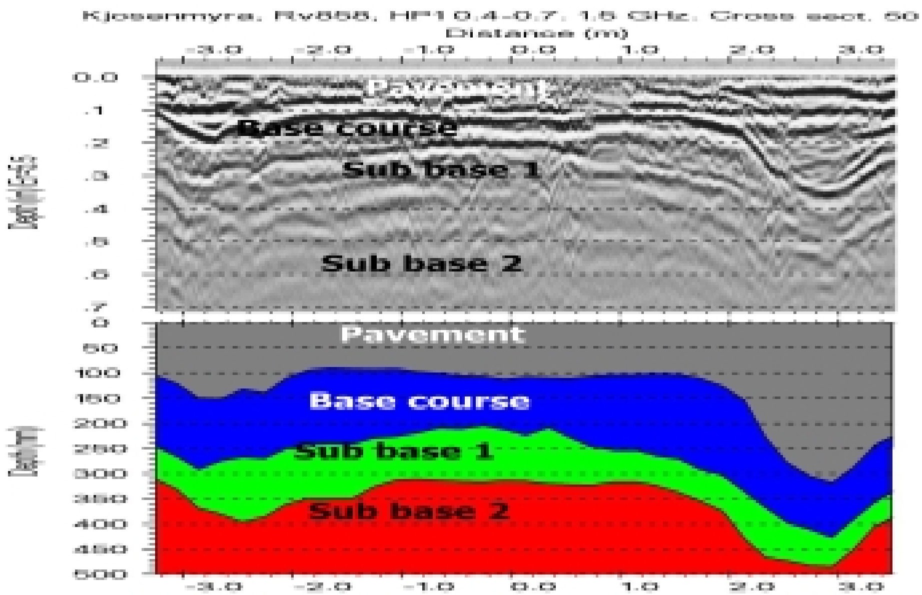

Figure 10. A 1.5 GHz GPR cross-section at 50 m from road Rv 858 at Kjosenmyra, Region Troms showing should deformation of a road constructed over peat.

Gravel roads have special problems with peat subgrade. There are many places where the most severe spring thaw defects are located in gravel road sections with peat subgrade.

Roadex field tests did some surveys over sections with peat subgrade. In the Highlands, a special Leca lightweight fill structure, in Ledbeck, was surveyed as a best practise example. Another survey was carried out in Killimster Moss. In Norway and Sweden, Roadex field tests were done on special road section where the road, over a peat subgrade, was strengthened and widened, through soil replacement excavations on road shoulders on both sides of the road. In Finland, Roadex field tests were done, besides the Mellajärvi test section (see steel reinforcement), on two special frost insulation structures where the insulation properties of peat were utilised. The results of these surveys are presented in the Roadex CD-rom and on the Roadex www-pages.

Permanent deformation due to freeze-thaw cycles and poor quality road materials

Currently in the NP partner districts, one of the most significant causes of rutting is permanent deformation in poor-quality unbound base course and sub base. The deformations can develop rapidly, when the base course is partly or entirely saturated with water. The situation is common in Scandinavia particularly in springtime, as the frost is thawing, but also during rainy autumns, roads with poor-quality base course have been observed to display damage in a short period of time. In the Highlands freeze-thaw cycles occur numerous times each winter.

A central factor in the development of damage is excess pore water pressure in the aggregate, caused by dynamic axle loads, which decreases effective stress between soil particles. Because the ability of the material to resist deformations under a wheel load depends on the effective stresses between soil particles, the increase in pore water pressure leads to deformations in the material. The laboratory research project, conducted at the Tampere Technical University, on poor quality base materials from Lapland and Vaasa district, showed that permanent deformations can take place only after a few truck passes during the base course thaw period. Laboratory tests also showed that the bigger the load, the larger the degree of permanent deformation (figure 11).

Permanent deformation, due to poor quality base materials, was surveyed in the Roadex field test at Vähäniva test site on HW 21. According to the Roadex state-of-the–art study, bitumen stabilization has worked quite well in fixing the problems caused by poor quality base materials. However, special problems arise if the material is located deeper in the road structure and cannot be treated by stabilization. A good example of such a case is the Roadex Koskenkylä Percostation test section where the problems are caused by poor quality sub base material at depth of 0.50 – 0.70 m. The test results have shown that this 200 mm thick layer can cause 60 mm frost heave measured in the road surface. The formation of the segregation ice and frost heave took place when the layer started to freeze at the temperature range of 0 to -2^{o}C. Periods of such cold also exist in the Highlands area and this phenomenon should be considered in this area when monitoring reasons for the road defects.

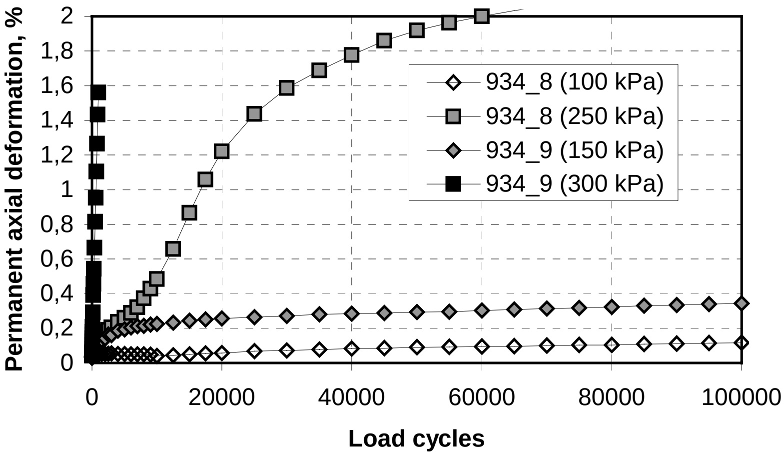

Figure 11. Permanent deformations measured in Vuorenmaa base aggregate of normal grain size distribution during cyclic loading triaxial test performed using different load levels after a freeze-thaw cycle. The results clearly show that load level (axle loads) in the material have a significant role in the measured permanent deformation values. In the case of Vuorenmaa base aggregate, at least 200 mm of bound layers over the aggregate would be required to ensure the elimination of permanent deformations in this material (Saarenketo et al. 2001).

Gravel roads with spring thaw problems

Gravel roads with spring bearing capacity problems (figure 12) are perhaps the biggest headaches for the engineers responsible for the road network because, in the worst circumstances, these roads have to be closed for several weeks every spring. For instance, the Roadex field test section in Siekkasjärvi, in Sweden, has had, between 1994-1999, 24-54 days of road closures each spring. The reason for these problems is a mixture of poor and frost susceptible subgrade, poorly working drainage and poor quality road structures. Plastic deformation of the road structure is having an effect on wearing course thickness, which should normally be only 50 – 100 mm, whereby it can almost be 1m as it was in Siekkasjärvi (figure 13).

Figure 12. Gravel road with spring thaw problems.

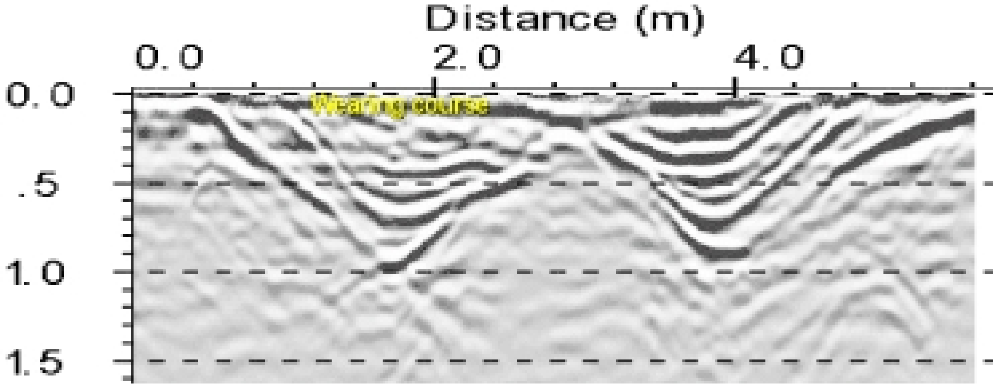

Figure 13. A 400 MHz GPR cross section over a gravel road in Roadex test section in Siekkasjärvi, Sweden. The GPR profile shows that the wearing course thickness in wheelpaths is almost 1.0 m when in the road centre it is only 0.1 – 0.2 m. The profile also shows at least seven lifts of wearing course in this problem section.

4. FUTURE ASPECTS

The results of the Roadex subproject “Road Condition management” show that, in spite of similar basic problems in each partner district, each country has emphasized slightly different strategies and techniques when trying to resolve bearing capacity problems in their low traffic volume road network.

A significant problem for low traffic condition volume road management, shared by all partner districts, is that almost all the structural maintenance funds and resources are allocated to main roads at the expense of medium and low traffic volume roads. As a result, the performance of main roads has been improving over the last few years, while the state of low traffic volume roads has become worse. Another aspect gaining more publicity and placing pressure on road districts has been that due to increasing logistical demands of the industry, using the lower class network for their transportation routes, complaints about load restrictions and bad quality road network have increased from that sector.

In the future, research should also focus on the following questions:
1) How much do road closures and load restrictions affect road structure deterioration?
2) What is the lowest acceptable road standard and what are the social benefits and costs, for road users and owners, for having adequate road performance?
3) How much funding is required to maintain the low traffic volume road network at a sufficient level of service?

One solution could be new and smarter types of restrictions like the following: 1) optimising (& shortening) the period of load restrictions, 2) defining time and distance between heavy load vehicles, 3) defining vehicle speed and 4) defining truck tire pressure.

In the road structure and material research field the focus should be made to 1) improve drainage on sloping hills, 2) understand better permanent deformation due to freeze-thaw cycles, 3) identify poor quality road materials and find better and cheaper treatments techniques and 4) find better rehabilitation solutions for roads resting on peat.