Iikka Hyvönen, Nuutti Vuorimies, Pauli Kolisoja

ROAD 16583 EHIKKI-JUOKSLAHTI

Demonstration of a Possible Drainage Solution for a Sloping and Rocky Terrain

Demonstration Project Report

ABSTRACT

Rutting of the road surface due to the development of permanent deformations, both in the road structure itself and in the underlying subgrade, is in most cases the dominant distress mechanism on low volume roads of the Northern Periphery area.

From road users' point of view rutting both lowers driving comfort and reduces traffic safety. This is particularly the case when surface water is trapped in ruts, thereby increasing the risk of aquaplaning in summertime and of icing in the wheel path in winter when temperatures fall below 0°C. In addition, rutting can also be very harmful to the structural condition of the road, as it speeds up water infiltration into the road structure, increases the effects of dynamic wheel loads etc.

Rutting can develop in a road for a number of reasons. It may develop in the structural layers due to poor quality material, or as a result of poor drainage making the material more susceptible to permanent deformations. It may also develop in a weak subgrade material if the overall thickness of the structural layers is low. This is a very typical situation on the low volume roads of the Northern Periphery area, particularly during the spring thaw if the subgrade material is frost-susceptible. Rutting mechanisms are discussed in greater detail in the ROADEX reports available at www.roadex.org, together with a new method of classifying rutting modes.

This report describes a ROADEX demonstration exercise carried out on a low volume road section of Road 16583 Ehikki-Juokslahti in Jämsä, Central Finland. The demonstration consisted of a drainage improvement using an innovative ROADEX solution. This comprised a combination of a French drain and an outer slope protection structure consisting of a geotextile and a layer of coarse grained aggregate. The aim of the solution was to prevent the fine-grained slope and subgrade material eroding and collapsing into the roadside ditch and thus causing differential frost heave and loss of bearing capacity on the road due to inoperative drainage. This had regularly taken place over the years on the site, especially during the spring thaw. A special feature on the site was the very limited road area available on the uphill slope. This was a main reason for the selection of the specific type of drainage structure used.

Now following the first spring thaw, the improved drainage system has been found to be in very good condition and, as a result, no areas of spring time bearing capacity loss have been observed on the road. Frost heave was noted on only one cross section. In comparison, immediately after the demonstration section, towards Juokslahti, there were severe frost heave damages and areas of poor bearing capacity on the road.

A special feature with the demonstrated drainage structure is the shallowness of the visible ditch in comparison to the road surface level. For this reason it was decided to install road marking poles to indicate the exact location of the road edge next to the drainage structure.

KEYWORDS

Rutting, permanent deformation, frost heave, rehabilitation, low volume road, geotextile, drainage, French drain, Northern Periphery

PREFACE

Tampere University of Technology has been responsible for the design, follow up and documentation of a number of demonstration sites carried out under the ROADEX project task D4 ‘Rutting, from theory to practice’. These demonstration sites showcase innovative ROADEX solutions to various types of rutting problems on low volume roads of the Partner areas. This report presents the early results from the demonstration site located on Road 16583 Ehikki-Juokslahti in Jämsä, Central Finland. On this site a section of road was rehabilitated by improving its drainage system using an innovative combination of a French drain and an outer slope protection structure consisting of a geotextile and a layer of coarse grained aggregate. The aim of the solution was to protect the roadside ditch from being clogged by frost susceptible slope material eroding and collapsing into the ditch, especially during the spring thaw.

The report has been compiled by Iikka Hyvönen and Nuutti Vuorimies under the supervision of Pauli Kolisoja, all from the Laboratory of Earth and Foundations Structures at the Tampere University of Technology, TUT.

Special thanks are given to Heikki Parviainen from the Centre of Economic Development, Transport and the Environment of Finland. Without his open-mined attitude on the new ROADEX solutions the demonstration sites in Jämsä area would have never been realised. Equally important has been the co-operative attitude of the staff of the contractor Destia Ltd, especially that of Jukka Järvenpää.

Ron Munro from Munroconsult Ltd checked the language.

Finally, last but not least, the authors would like to thank the ROADEX IV Project Steering Committee for their guidance and encouragement during the work.

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CONTENTS

1. INTRODUCTION

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between road organisations across northern Europe that aims to share road related information and research between the partners. The project was started in 1998 as a 3 year pilot co-operation between the districts of Finland Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005, a third, ROADEX III from 2006 to 2007 and a fourth, ROADEX "Implementing Accessibility" from 2009 to 2012.

Figure 1.1 *The Northern Periphery Area and ROADEX IV Partners*

The Partners in the ROADEX "Implementing Accessibility" project comprised public road administrations and forestry organisations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland and the Western Isles Council from Scotland, The Northern Region of The Norwegian Public Roads Administration, The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency, The Centre of Economic Development, Transport and the Environment of Finland, The Government of Greenland, The Icelandic Public Roads Administration and The National Roads Authority and The Department of Transport of Ireland.

The aim of the project was to implement the road technologies developed by ROADEX on to the partner road networks to improve operational efficiency and save money. The lead partner for the project was The Swedish Transport Administration and the main project consultant was Roadscanners Oy of Finland. The project was awarded NPP funding in September 2009 and held its first steering Committee meeting in Luleå, November 2009.

A main part of the project was a programme of 23 demonstration projects showcasing the ROADEX methods in the Local Partner areas supported by a new pan-regional "ROADEX Consultancy Service" and "Knowledge Centre". Three research tasks were also pursued as part of the project: D1 "Climate change and its consequences on the maintenance of low volume roads", D2 "Road Widening" and D3 "Vibration in vehicles and humans due to road condition". All of the reports are available on the ROADEX website at www.ROADEX.org.

1.2 THE DEMONSTRATION PROJECTS

Twenty three demonstration projects were planned within the ROADEX IV project. Their goal was to take selected technologies developed by ROADEX out on to the local road networks to have them physically used in practice to show what they could achieve. The projects were funded locally by the local Partners, designed and supervised by local staff, and supported by experts from the ROADEX consultancy.

The demonstrations were managed in 6 groups by a nominated lead manager from ROADEX:

D1 - “Drainage Maintenance Guidelines”, lead manager Timo Saarenketo

D2 - “Road friendly vehicles and Tyre Pressure Control”, lead manager Pauli Kolisoja

D3 - “Forest Road policies”, lead manager Svante Johansson

D4 - “Rutting, from theory to practice”, lead manager Pauli Kolisoja

D5 - “Roads on Peat”, lead manager Ron Munro

D6 - “Health and Vibration”, lead manager Johan Granlund

1.3 D4 “RUTTING, FROM THEORY TO PRACTICE”

The aim of the ‘Rutting, from theory to practice’ task was to demonstrate the practical applications of innovative ROADEX solutions in the rehabilitation of low volume roads suffering from permanent deformation problems in the Partner areas. The leading idea in the demonstrations was to use ‘fit for purpose’ solutions selected after a sound analysis and understanding of the reasons behind the problems encountered on the individual sites. As the name of task suggests, the main focus was on those problems that appear in the form of permanent deformations, i.e. rutting, which can be the result of different forms of underlying mechanisms. These mechanisms are dealt with in greater detail in a range of ROADEX reports available at www.roadex.org.

The first stage in the problem analysis of each site was to develop a clear understanding of the deterioration mechanisms at work using simple, low cost means of investigations, such as visual observation. This was then supplemented, when required, by Ground Penetrating Radar (GPR) measurements, easy to use site investigation methods, e.g. the Dynamic Cone Penetrometer (DCP) test, and some basic laboratory tests like grain size distribution analysis and Tube Suction (TS) tests. More sophisticated laboratory investigations were not used as these are seldom available to the ROADEX Partners due to the limitations of both budget and time.

All of the demonstrations were carried out as part of scheduled road rehabilitation projects by the local ROADEX Partners, and in practice this meant that some operational adjustments were necessary to suit their needs, i.e. none of the demonstrations were carried out just for the ROADEX project alone. This fact naturally set some limitations for the design of the demonstrations, particularly with regard to the available time for preliminary investigations, but this was accepted to be a normal fact of life in practice for most Partner roads operations, and in fact added realism to the work.

2. DESCRIPTION OF ROAD

2.1. LOCATION

Road 16583 is located in the middle part of Finland about 45 kilometres south-west from Jyväskylä. The road's Location is shown in Figure 2.1 and the test section is identified with the red circle.

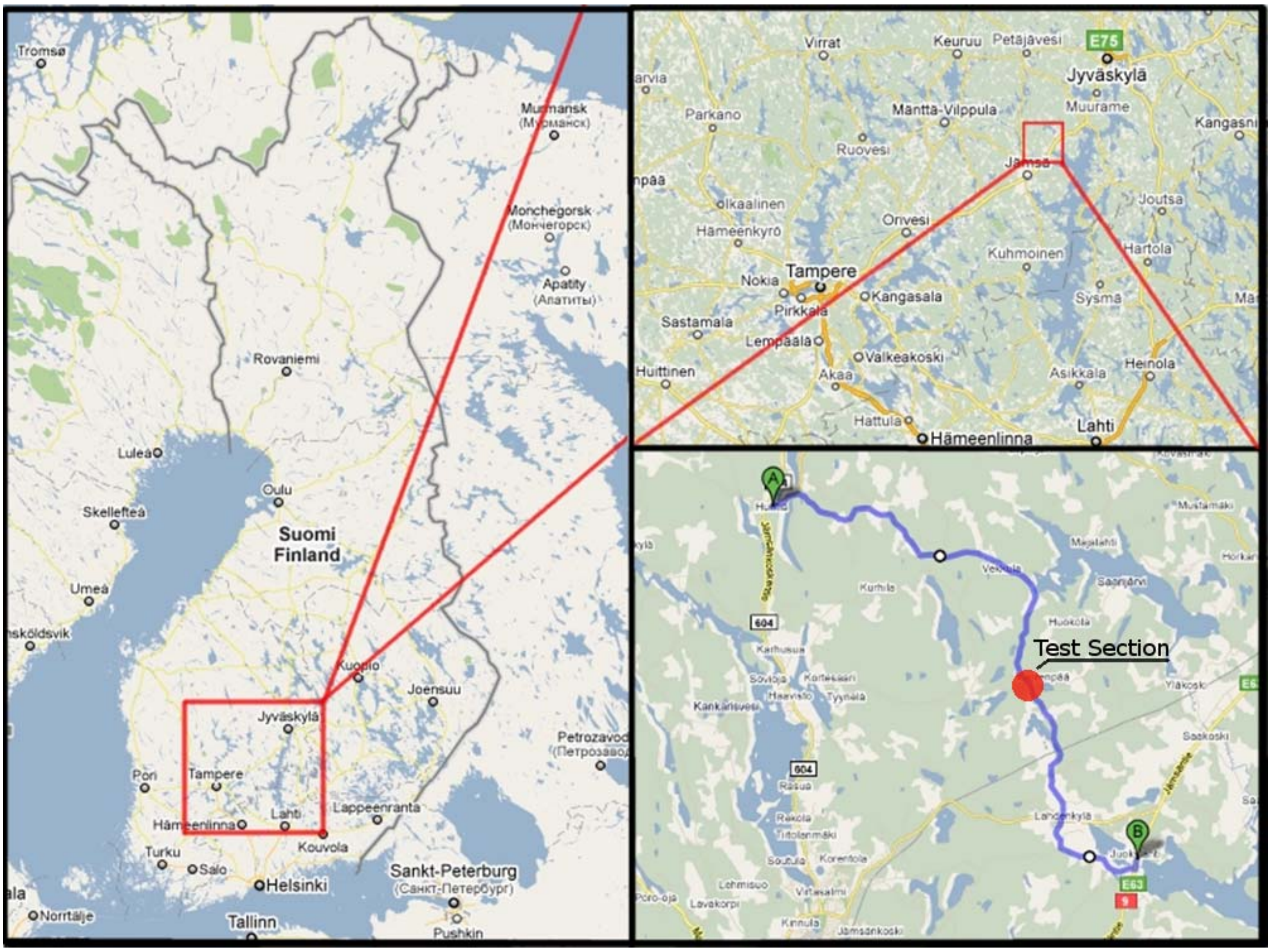

Figure 2.1 *Location of Road 16583 Ehikki – Juokslahti (Google Maps)*

2.2. TRAFFIC

Road 16583 connects the two small villages of Ehikki and Juokslahti. Typical road users are local inhabitants, farmers and logging trucks. The traffic volume is low. The Annual Average Daily Traffic (AADT) is only 48 vehicles per day for the first and second part of the road (1/0 – 3/5207) and 156 vehicles per day for the third part of the road, which is located at the eastern end of the road (3/5207 – 6886) [1]. Although the traffic volume is low, the road is important to logging companies. In the future there will be an increase in logging in the surrounding areas and this is one of the reasons that the road was scheduled for improvement now.

2.3. ROAD STRUCTURE

Road 16583 Ehikki-Juokslahti is a 20.5 kilometres long unpaved gravel road. It is a gravel road throughout except for a short section with asphalt pavement on the second part of the road. This asphalt pavement section is only 200 metres long and located on the approaches to a railroad bridge. Road 16583 is a typical example of a gravel road in Central Finland and there are many other roads like it across Finland. It has all the typical features of gravel roads: narrowness, hilliness and lots of curves. Other typical features are sections of side sloping profile and the closeness of adjacent fields and lakes.

2.4. LOCAL LANDSCAPE AND TERRAIN

Road 16583 passes through a variable topography of hills, hummocks, lakes and peat-lands between hills, which creates challenging circumstances for the road. An example of this topography is shown in Figure 2.2. This range of topography results in the road, having a range of different features, such as side sloping ground and morainic hummocks. The terrain is mostly frost-susceptible morainic soil and in some places the bedrock is close to the surface.

Figure 2.2 *Topography of the area*

Figure 2.3 *Water erosion on the side of the road*

2.5. ROAD PROBLEMS

The condition of road 16583 is generally good for most of the year, but problems can appear during springtime. These are generally caused by spring thaw weakening which can be divided into two phases.

Phase 1: When the air temperature rise above zero the surface thaw weakening phase starts. This causes softening of the wearing course making it plastic. The higher the fines content, the greater is the plasticity of the road's surface. The road then becomes slippery and uncomfortable to drive.

Phase 2: As the air temperatures keep rising the frost thaws deeper into the road and the structural thaw weakening phase starts. The thawing frost produces excess water in the lower structure and subgrade. If the subgrade has low water permeability it may become plastic causing permanent deformations with Mode 2 rutting, the subject this report. In addition the passage of heavy vehicles can create increased hydrostatic pressures which can force excess water to flow up and to the side. As a consequence of this damaged roads sections which have suffered structural thaw weakening can also experience embankment widening to the ditches. [2]

Figure 2.4 *Damages of the road in the Spring*

3. DATA COLLECTION / AVAILABLE DATA

3.1. FIELD INVESTIGATIONS

3.1.1. Site Investigation

Normally site investigations are carried out only once for a road rehabilitation but in this site they were carried out twice. The first site investigation was carried out during the spring thaw process in April 2010 when road damages could be seen. The second visit, the 'official' site investigation, took place in the beginning of June when the road was in better shape and only severe damages remained. Inventory photos were taken during this investigation and the damaged sections of drainage systems were checked for location and condition.

Figure 3.1 *Filled up ditch in the beginning of the summer 2010*

3.1.2. Frost heave inventory

Frost heave inventory is a visual method, where all the damages caused by spring thaw are inventoried annually. In Finland, the inventory takes place in the spring during the structural thaw phase. The purpose of the inventory is to gather information on damages to the road users and to the Ministry of Transport and Communications. The gathered information on road damages is also exploited in repairing and maintaining the roads.

Chart 3.1 shows part of the frost heave inventory for the Road 16583. The damages are categorized from one to five, five being the severest damage. The repairs carried out are also categorized from A to C, C being the biggest improvement. The chart shows that from chainage 566 to 770, the test section in this report, there were 7 different reported damages between the years 1998 and 2006.

Chart 3.1 *Part from frost heave inventory of Road 16583*

Road	Section	From chainage	To chainage	Length	Year	Damage category	Repair carried out
16583	3	566	605	39	2005	3	B
16583	3	570	630	60	2002	3	B
16583	3	588	609	21	2004	3	B
16583	3	590	770	180	1999	3	B
16583	3	590	770	180	1998	3	B
16583	3	600	720	120	2000	3	C
16583	3	601	605	4	2006	4	C

3.2. LABORATORY INVESTIGATIONS

No laboratory investigations were carried out in this demonstration project.

4. PROBLEM ANALYSIS

4.1. DIAGNOSIS OF THE PROBLEMS ON SITE

Open ditches are most common kind of roadside drainage systems on low volume roads. The function of such ditches is to drain both surface water and water from the road structure. Usually the depth of the ditch must be 0.30 m to 0.35 m below bottom of the road structure to function properly. [3]

The main problem in the demonstration section was that the outer slope of the road embankment was too steep. The presence of bedrock was additionally causing problems by forcing groundwater and water from rainfall, up through the ground surface to collect locally in places. The presence of bedrock was also preventing water draining in the ditches. As a consequence of these circumstances part of the outer slope had collapsed into the ditch and the road had widened towards the ditch. A further contributing factor was that the ditch had not been cleared for some time and had filled up with vegetation, as shown in Figure 4.1 and 4.2. The consequence of this was that the drainage capacity of the ditch had been reduced. This had caused the ground water table to rise in the road structure and reduce its bearing capacity with the result that uneven frost heave damages had regularly occurred along the road on the hill side.

Figure 4.1 *Filled up ditch*

Figure 4.2 *Side sloping profile*

5. REHABILITATION SOLUTION

The problem on the test section is poor drainage, as a result of mud and vegetation filling in the ditch. The planned test section is 170 metres long. The chosen rehabilitation solution is from earlier studies in the ROADEX II project and shown in Figure 5.1.

5.1. PROPOSED REHABILITATION STRUCTURE, CHAINAGE 03/430-610

The rehabilitation solution comprised:

- Removal of the old banking material
- Installation of a separation grade geotextile
- A carrier drain in the bottom of the ditch
- Backfill with 250 mm coarse graded aggregate

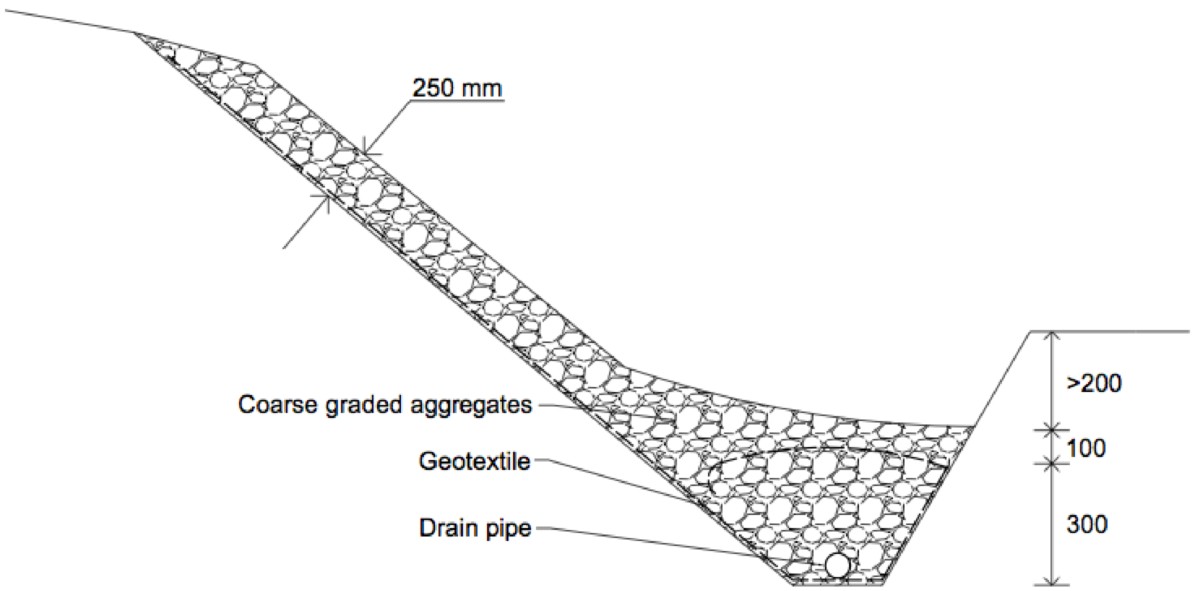

Figure 5.1 *Principal of the rehabilitation Structure (Note: The construction was accomplished in a slightly different way, see chapter 6)*

5.2. RATIONALE FOR THE SELECTED SOLUTION

The subsoil in the demonstration section was variable. The uphill side of the road was very steep and rocky, and the downhill side was a fine graded soil. Improving the slope stability in the upper slope with a geotextile and coarse aggregate was intended to reduce the potential for the slope to erode, and reduce the need for frequent ditch clearing. Fine graded soils have a low bearing capacity at high moisture content and require a well working drainage system to perform at their best. In the ditch, the coarse graded aggregate was wrapped inside a geotextile to keep the aggregate clean and prevent fine particles from clogging the ditch. A carrier drain pipe was additionally placed in the base of the drain to enhance the flow capacity of the drain.

A further rationale for selecting the chosen solution was that the available road area on the uphill side was very limited. This required the rehabilitation structure to be constructed in as narrow space as possible.

6. DESCRIPTION OF THE REHABILITATION WORKS

The rehabilitation works were ordered by the ELY Centre of Central Finland. The contractor was Destia. The works at the test section started early in the Friday morning 3rd of September 2010 and were finished by the evening of the following Monday. Weather conditions during the works were poor on Friday and good on Monday. On Friday it rained the whole day and the temperature was +10° Celsius. When the works continued on Monday the weather was clear and sunny. The working methods used at the rehabilitation works are described in the following section.

6.1. WORKING METHODS

The work on site started with clearing the filled ditch and removing the vegetation. At the same time the excavator shaped the slope and ditch. Three men, excavator and two earth-hauling trucks were used for the work.

After the whole ditch was cleared and reshaped, the geotextile and drain pipe were installed in the bottom of the ditch. The geotextile was cut into manageable pieces for ease of installation. A 300 mm thick layer of coarse graded aggregate was laid over the drain pipe. This stage of the drain installation is shown in Figure 6.1.

Figure 6.1 *Constructing the drain structure*

The actual constructed drain structure was slightly different than the original plan. Because of the width of the side slope, it was found to be easier to first install a short ditch liner under the drain pipe and then roll the new layer of geotextile on top over the completed ditch and side slope, as shown in Figure 6.2. This structure results in a similar arrangement to the planned structure and should work just as well. The completed ditch then drains to a culvert at the end of the test section and which takes the water forward. The end of the drainpipe and the culvert is shown in Figure 6.3.

__Figure 6.2__ Rolling the second geotextile layer

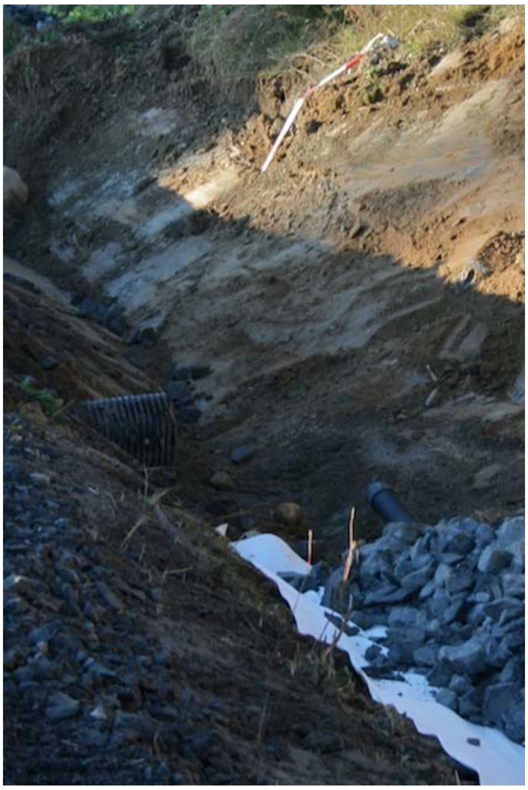

__Figure 6.3__ End of the drainpipe and culvert

A 250 mm thick layer of coarse graded aggregate was then laid on to the second geotextile layer and outer slope together with a 200 mm thick layer smaller graded aggregate on the inner slope. The excavator finished the work by compacting the aggregates with its dipper.

On completion of the work it became apparent that the aggregate used in the inner slope looked very similar to the aggregate on the wearing course of the road and as a safety measure the edge of the road was marked with road marking poles. The finished drainage improvement is presented on Figure 6.4.

__Figure 6.4__ Finished drainage improvement

6.2. PROBLEMS ENCOUNTERED ON SITE

The rehabilitation works did not encountered any major problems on site. Nearby logging areas and local inhabitants caused minor traffic problems on the narrow road that required excavator and earth-hauling truck to halt their work for a moment to let the logging trucks and cars to pass, as shown in Figure 6.5.

Another minor problem was the presence of bedrock on site as shown in the right corner of Figure 6.5. At the beginning of the rehabilitation works only a small piece of bedrock was visible and it was not known if the inclination of the slope could be reduced. In the event exposures of bedrock were found to be very localized and only visible in two places after the rehabilitation was complete.

Figure 6.5. *Passing vehicle and bedrock on the right*

6.3. DEVIATIONS FROM THE PLAN

The actual structure constructed in the test section is shown in Figure 6.6. The difference from the original plan is that the geotextile is installed in two pieces instead of one.

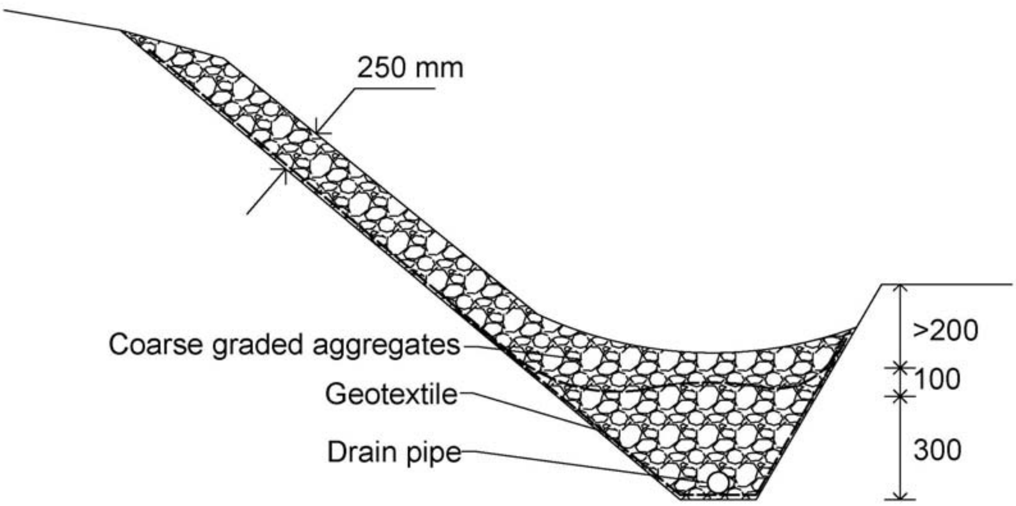

Figure 6.6. *The final rehabilitation structure*

7. SITE MONITORING

7.1. INITIAL SITE MONITORING, 5 MAY AND 24 NOVEMBER 2011

An initial site investigation was carried out on 5th of May 2011, after the spring thaw. The road was found to be in good condition and the drainage was found to be working well, as shown in figures 7.1 and 7.2. No areas of poor bearing capacity were observed on the section of the road next to the drainage improvement structure, and only one cross-section with differential frost heave was noted (figure 7.3). However, immediately after the end of the drainage structure, in the direction of the village of Juokslahti, a number of severe frost heaves and areas of poor bearing capacity could be seen on the road (figure 7.4).

Figure 7.1 *The test section after the first spring thaw (05.05.2011)*

Figure 7.2 *Well working drainage*

A site investigation was also carried out on rainy 24th of November 2011. The road was found to be in generally good condition with some low potholes and a slightly softened wearing course in some parts. The drainage was found to be working well, although a harvester had used the ditch as an access to cut trees as shown in figure 7.5. It was noticed that some fine sand and course silt from the outer slope and the forest road had accumulated into the ditch as shown in figure 7.6. It appeared that the presence of the geotextile in top of the drain had prevented the material infiltrating into the drain.

Figure 7.3. *The only cross section with differential frost heave along the drainage structure in the spring 2011.*

Figure 7.4. *Severe frost heave and bearing capacity damage after the end of the drainage structure. The damage is not as visible in the picture as it was on the site.*

Figure 7.5. *The marks of a harvester on the ditch and road (24.11.2011)*

Figure 7.6. *Photograph of the fine sand and coarse silt from the slope and forest road being held by the geotextile on top the drain*

7.2. RECOMMENDATIONS FOR FUTURE MONITORING

It is recommended that the performance of the test structure should continue to be monitored in the future to enable further conclusions to be made on the effectiveness of the work done. This can be done by means of simple site investigations as already carried out.

7.2.1. Future site investigations

The site should be inspected after the freeze-thaw cycles in the spring. It has been proved that a major part of the road damages develops during the spring and any damages incurred are likely to be more visible at this time. The parameters that should be monitored in future site investigations are weather conditions, temperature and information regarding heavy traffic. These are likely to have an effect on the condition of the road on the day.

8. CONCLUSIONS

This report describes a ROADEX demonstration exercise carried out on a low volume road section of Road 16583 Ehikki-Juokslahti in Jämsä, Central Finland. The demonstration consisted of a drainage improvement using an innovative ROADEX solution. This comprised a combination of a French drain and an outer slope protection structure of a geotextile and a layer of coarse grained aggregate. The aim of the solution was to prevent the fine-grained slope and subgrade material from eroding and collapsing into the ditch and thus causing differential frost heave and bearing capacity loss on the road due to inoperative drainage. This had regularly happened over the years on the site especially during the spring thaw. A special feature on the site was the very limited road area available on the uphill slope. This was a main reason for the selection of the specific type of drainage structure used.

Now following the first spring thaw, the improved drainage system has been found to be in very good condition and, as a result, no areas of spring time bearing capacity loss were observed on the road. Frost heave was noted on only one cross section. In comparison, immediately after the demonstration section towards Juokslahti, there were areas of severe frost heave damage and poor bearing capacity on the road.

A special feature with the demonstrated drainage structure is the shallowness of the visible roadside ditch in comparison to the road surface level. For this reason it was decided to install road marking poles to indicate the exact location of the road edge next to the drainage structure.

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ROADEX
Implementing Accessibility

ROADEX PROJECT REPORTS (1998–2012)

This report is one of a suite of reports and case studies on the management of low volume roads produced by the ROADEX project over the period 1998-2012. These reports cover a wide range of topics as below.

- Climate change adaptation
- Cost savings and benefits accruing to ROADEX technologies
- Dealing with bearing capacity problems on low volume roads constructed on peat
- Design and repair of roads suffering from spring thaw weakening
- Drainage guidelines
- Environmental guidelines & checklist
- Forest road policies
- Generation of 'snow smoke' behind heavy vehicles
- Health issues raised by poorly maintained road networks
- Managing drainage on low volume roads
- Managing peat related problems on low volume roads
- Managing permanent deformation in low volume roads
- Managing spring thaw weakening on low volume roads
- Monitoring low volume roads
- New survey techniques in drainage evaluation
- Permanent deformation, from theory to practice
- Risk analyses on low volume roads
- Road condition management of low volume roads
- Road friendly vehicles & tyre pressure control
- Road widening guidelines
- Socio-economic impacts of road conditions on low volume roads
- Structural innovations for low volume roads
- Treatment of moisture susceptible materials
- Tyre pressure control on timber haulage vehicles
- Understanding low volume pavement response to heavy traffic loading
- User perspectives on the road service level in ROADEX areas
- Vehicle and human vibration due to road condition
- Winter maintenance practice in the Northern Periphery

All of these reports, and others, are available for download free of charge from the ROADEX website at www.ROADEX.org.