ROADEX
Implementing Accessibility

Northern Periphery Programme
2007–2013

Innovatively investing in Europe's Northern Periphery for a sustainable and prosperous future

European Union
European Regional Development Fund

Iikka Hyvönen, Nuutti Vuorimies, Pauli Kolisoja

ROAD 16589 SAALAHTI

Mode 2 Rutting Site on a Soft Subgrade

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 a 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, increasing 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 where 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 16589 Saalahti in Jämsä, Central Finland. A geogrid reinforcement was used in the demonstration to retard the development of permanent deformations of a gravel road section located on a silty subgrade. The demonstration section had been suffering from deformations primarily taking place in the subgrade material that had become very soft during the spring thaw of the seasonal frost. This had also resulted in severe widening of the road cross-section and almost total clogging of the side ditches. According to the GPR profiles the total thickness of the structural layers was much higher in the middle of the road than towards the edges of the road which was a clear indication of Mode 2 rutting.

The reinforced structure consisted of two subsections in addition to which there was a reference section. One subsection was constructed with one layer of geogrid, rather than the standard rehabilitation solution of a geotextile. The second subsection was constructed with two layers of reinforcing geogrid 150 mm apart from each other. The standard rehabilitation structure of a geotextile was used in the reference structure.

After one year of service it only can be concluded that both of the test structures and the reference structure have been performing equally well, and that the road is still in very good condition. Further monitoring of the settlement tubes installed in six cross sections of the road will reveal any differences in the development rate of permanent deformations between the test structure and reference structure. According to the life cycle analysis performed, the subsection reinforced with one layer of geogrid needs to last at least one year longer and the subsection reinforced with two layers of geogrid at least three years longer to be cost effective in comparison to the reference structure, if that is assumed to have a service life of 10 years. This is slightly longer than the typical assumption of 8 years life as in this case the reference structure was also about 50 mm thicker than would have been the standard solution.

KEYWORDS

Rutting, permanent deformation, rehabilitation, low volume road, reinforcement, geogrid, geotextile, silty subgrade, 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 16589 Saalahti in Jämsä, Central Finland. On this site a section of road built on peat subgrade was rehabilitated using geogrid reinforcements.

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. Other persons from the TUT team who have been involved in the project include Riitta-Maria Sjöberg, Marko Happo, Kauko Sahi and Heikki Luomala. The two persons first mentioned assisted in the site investigations while Kauko Sahi and Heikki Luomala were the key persons behind development of the settlement monitoring system installed on the site.

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.

Petri Varin from Roadscanners Ltd organised the GPR measurements and analysed the results. 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.

ROADEX "Implementing Accessibility" Lead Partner: The Swedish Transport Administration, Northern Region, Box 809, S-971 25 Luleå. Project co-ordinator: Mr. Krister Palo.

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 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 16589 is located in the middle part of Finland about 45 kilometres south-west from Jyväskylä. The location of the road is shown in Figure 2.1 and the test section is identified with red circle.

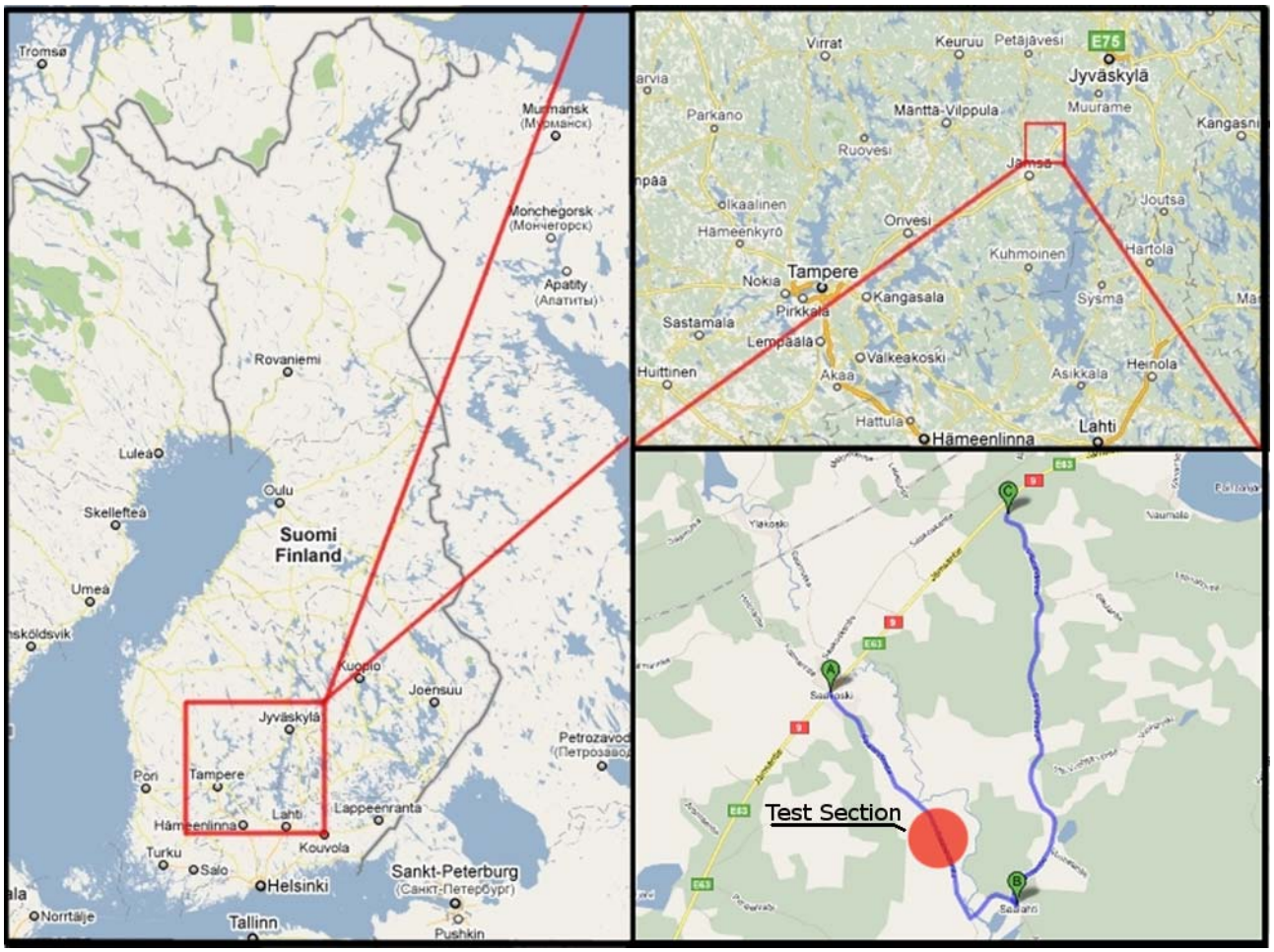


Figure 2.1 *Loacation of Mt 16589 Saalahti*

2.2. TRAFFIC

Traffic on the road is very low. Typical road users are local inhabitants and farmers. The Annual Average Daily Traffic (AADT) is only 141 vehicles per day [1]. An elementary school is located in the village of Saalahti which increases traffic during the winter. Although the traffic is low, the road is important to the local economy and it is the main road to the school.

2.3. ROAD STRUCTURE

Road 16589 Saalahdentie is a 7 kilometres long unpaved gravel road. It runs from the Jämsäntie, Highway 9 between Jyväskylä and Tampere, to the village of Saalahti and then back to Jämsäntie The road travels through beautiful views of the Finnish countryside and mostly the road winds between fields.

2.4. LOCAL LANDSCAPE AND TERRAIN

Road 16589 is located in a generally even topography with gentle undulations, as can be seen in Figures 2.2 and 2.3. There are couple of hills near to the road where bedrock outcrops. The subgrade is generally soft and frost-susceptible. This has caused widening of the road at some locations and poor drainage conditions. A 300 metre homogenous straight section of road was selected as the test section for this report.

Figure 2.2 *Typical topography of the area*

Figure 2.3 *Typical topography of the area*

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 temperatures 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 the plasticity of the road's surface is. 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 *Typical damages of the road in the summer*

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 2010 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 *Widened road and filled up ditch*

Figure 3.2 *Water stays on the road*

3.1.2. GPR Measurements

Ground Penetrating Radar (GPR) measurements were taken with Roadscanners three dimensional 3D-radar. Measurements were carried out in one direction in late June 2010. The resulting GPR interpretations are shown in Appendix 1, 2, 3 and 4. These show that the road structure becomes thinner at chainage 1/1700-1/1750, possibly due to the presence of bedrock.

GPR cross-sections were also measured with the 3D-radar on chainages 1/1605, 1/1610, 1/1615, 1/1655, 1/1660, 1/1665, 1/1695, 1/1700, 1/1705, 1/1725, 1/1730, 1/1735, 1/1815, 1/1820, 1/1825, 1/1855, 1/1860 and 1/1865. The interpretations of these cross-sections are shown in Appendix 2, 3 and 4.

GPR is a non-destructive method to investigate road structures. It is based on short electromagnetic pulses which are transmitted into the road. These travel, reflect and refract as they meet changes (e.g. surface layers) in dielectric properties. GPR equipment consists of a transmitter and receiver electronics, which are connected to an antenna and a central unit to control the data collection and store the collected data. Through the antenna an electromagnetic pulse is sent into the ground. A part of the energy of the pulse reflects back when there is a change in material electrical properties, and a part goes through this material and reflects from the next surface, etc. Electric conductivity and dielectric value are the main parameters that affect the GPR signal. The signal attenuates as a function of travel time due to geometrical spreading, scattering, reflections and thermal loss. A high amount of fine materials and salt in the structure increases electric conductivity. This weakens the GPR signal and diminishes its ability to penetrate further. The GPR data collection system records travel time and amplitude of the pulses, which are then displayed. When these measurements are repeated, it is possible to present a continuous profile of the analysed structure. [3]

The GPR profiles gathered clearly indicate that the cross-section of the road had been severely deforming primarily due to Mode 2 rutting i.e. deformations that take place in the subgrade. The highest structural layer thicknesses (up to 0.7 m) appeared in the middle of the road, and became very thin towards the edges of the of the road, in some cross sections down to about 0.2 m. The most likely reason for this type of deformation profile is that the few heavy vehicles travelling along the road have been driving almost in the middle of the road, on the one hand due to the very low traffic volumes and on the other because the visibility on the test straight section is very good.

3.1.3. DCP Measurements

Dynamic cone penetrometer (DCP) measurements were carried out in July 2010. Prior to his there had been two weeks of hot weather that made the wearing course nearly impenetrable such that it had to be drilled through first. Measurements were carried out on chainages 1/1600, 1/1660, 1/1700, 1/1800 and 1/1880. Four points were measured from first three chainages and five points from last two chainages. Examples of the measurements obtained are given in Figure 3.4.

The dynamic cone penetrometer is a device for evaluating thicknesses and stiffness of road structure layers. The main idea is that the cone tip is penetrated into the ground by the force of an 8 kg drop hammer. The penetration depth for one or more drops is registered and measurement stops when the cone reaches the target depth or after the penetration rate is less than 3 mm/drop. Once the measurements have been obtained, the DCP Penetration Index (DPI), California Bearing Ratio (CBR) and moduli values at each depth can be estimated based on empirical correlations. Through these values the bearing capacity of the road can be assessed. [4]

Figure 3.3 *DCP equipment on Road 16589*

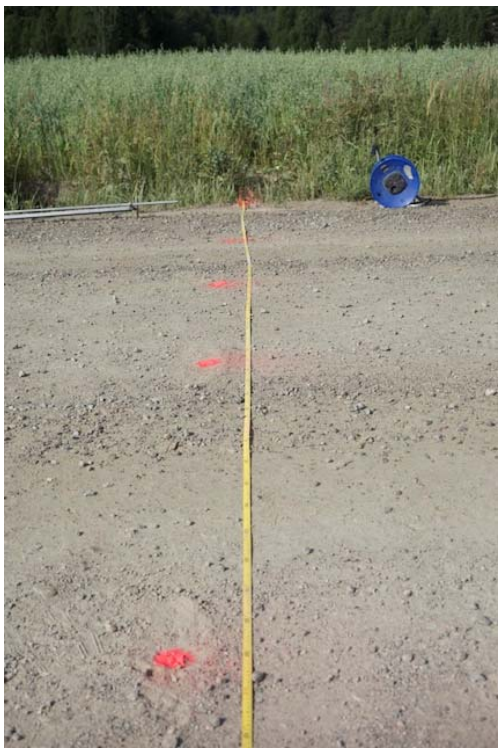


Figure 3.4 *DCP Measurement points on Road 16589*

Figure 3.5 shows an example of the DCP measurements from road 16589. On the x-axis is the DCP Penetration Index and on the y-axis is depth. Measurement point D1 (blue) is 1.0 m from the right side of the road, D2 (red) is 2.4 m from the right side, D4 (green) is 2.1 m from the left side and D5 (purple) is 1.0 m from the left side. The figure shows that the road structure is softer on the right edge (blue) than in the middle and left edge. The DPI is lower under the wheel path (red) and on the left edge (purple). Measurement point D3 probably stops at the depth of 0.25 m because of a large boulder or rock. The same road structure's layer thicknesses can be seen in the GPR cross-section at the chainage 1/1815. In the cross-section the highest red line is the base course + wearing course and the lowest red line is the lowest surface of the road structure. The full DCP measurement results are given in Appendix 5, 6 and 7.

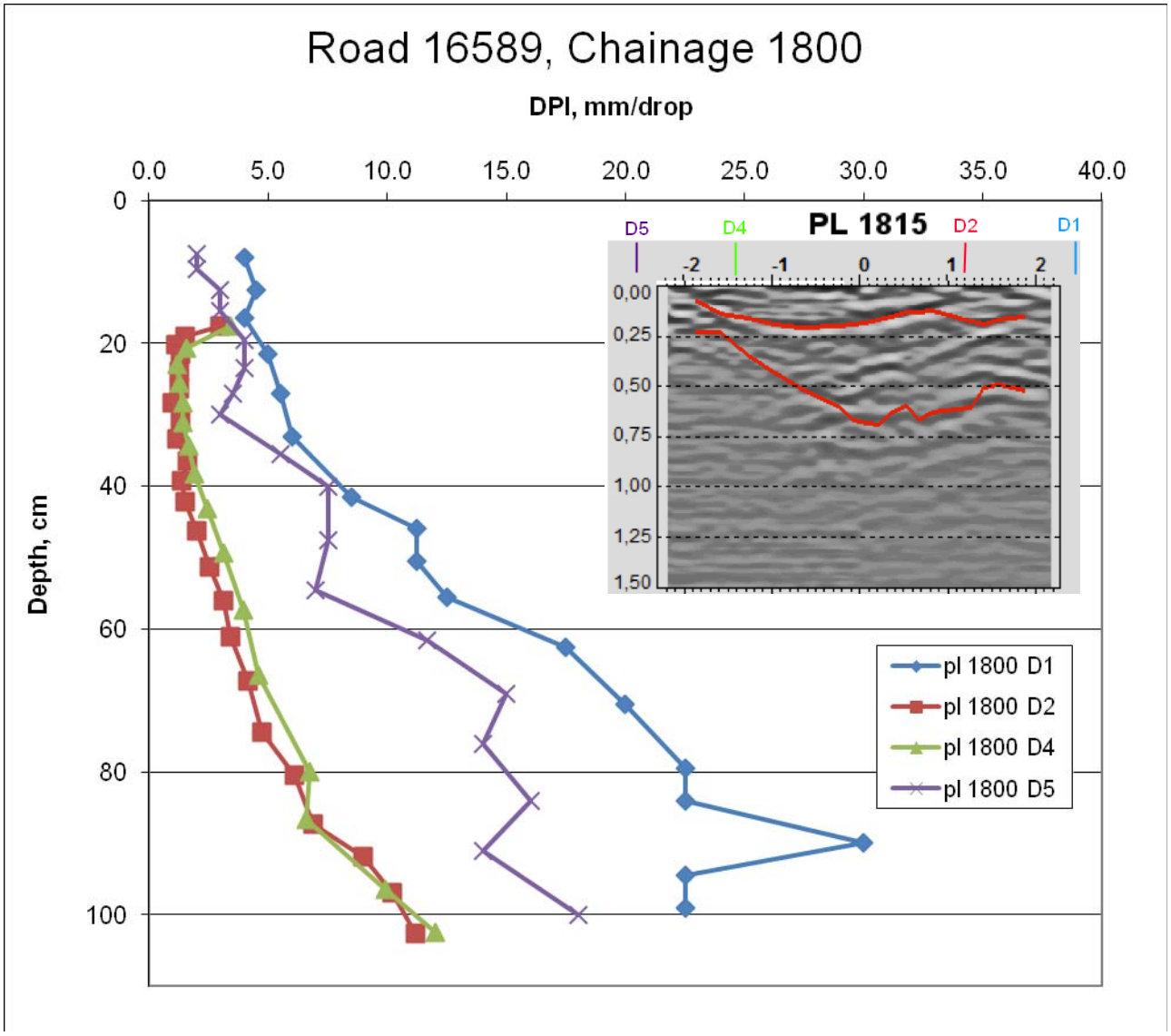


Figure 3.5 *The DCP measurements from chainage 1/1800 with GPR data*

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

Both old and new site investigation data were used for the diagnosis of the road problems at the site. New data gathered during site investigation visits in spring, June and July 2010 was used together with GPR records, results of DCP measurements and a frost heave inventory list from the Finnish Traffic Agency (former Road Administration). This had been regularly updated since 1995.

The two site visits helped the understanding of the general features of the road, such as ditches, watercourses, culverts, surface topography, waterlogged areas and areas of free water. They also helped to inform the design of the rehabilitation structures against the weak frost susceptible subgrade material that was seen to be prone to Mode 2 rutting.

The site investigations identified that the main problem on the test section was poor drainage and possibly also the result of poor material in the road structure. When the moisture content of a road and subgrade increases, the road softens and widens to the ditches. In a few places widening had already gone so far that there was no ditch at all, as is shown in Figure 3.2. The normal width of a gravel road in central Finland is about 6 metres, but road 16589 had places where the road was up to 9 metres wide. Because of the poorly functioning drainage system, water stays on the road and soaks through the road structure and subgrade. The excess water in the road structure and subgrade creates problems such as subgrade deformation and widening of the road. In addition the excess water makes the road surface plastic and uncomfortable to drive.

Figure 4.1 *Widened Road 16589*

5. REHABILITATION SOLUTION

A 200 metres long straight road section of Road 16589 was selected for two test structures. The terrain on the section was considered to be sufficiently homogenous to permit a comparison of the test structures and a traditional reference rehabilitation improvement.

The section was known to have a weak subgrade which was causing problems during the frost thaw period. The road had widened so badly that the ditches between the field and road had almost been closed. It was decided that the existing wearing course should be removed and the new structures built onto the exposed surfaces. Ditches would be cleared after the improvement. The reference structure and the two rehabilitation solutions selected are shown in the following sections.

5.1. PROPOSED REHABILITATION STRUCTURES

New reference structure 1A:

- 120 mm wearing course
- 250 mm crushed aggregate layer
- Geotextile
- Old road structure

New structure 1B, chainage 01/1640-1760:

- 120 mm wearing course
- 250 mm crushed aggregate layer
- Geogrid Fornit 40/40
- Old road structure

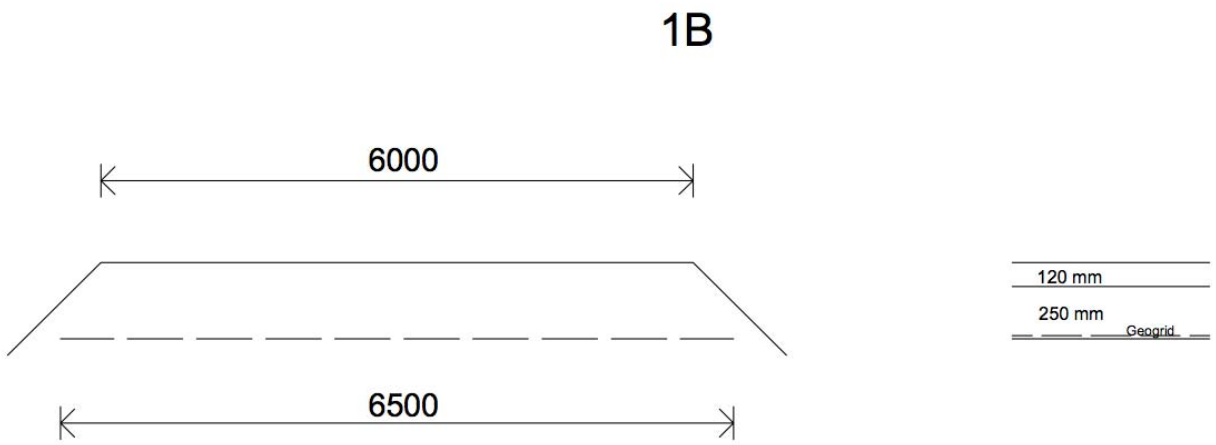


Figure 5.1 *Rehabilitation Structure 1B*

New structure 1C, chainage 01/1760-1830:

- 120mm wearing course
- 100 mm crushed aggregate layer
- Geogrid Fornit 40/40
- 150 mm crushed aggregate layer
- Goegrid Fornit 40/40
- Old road structure

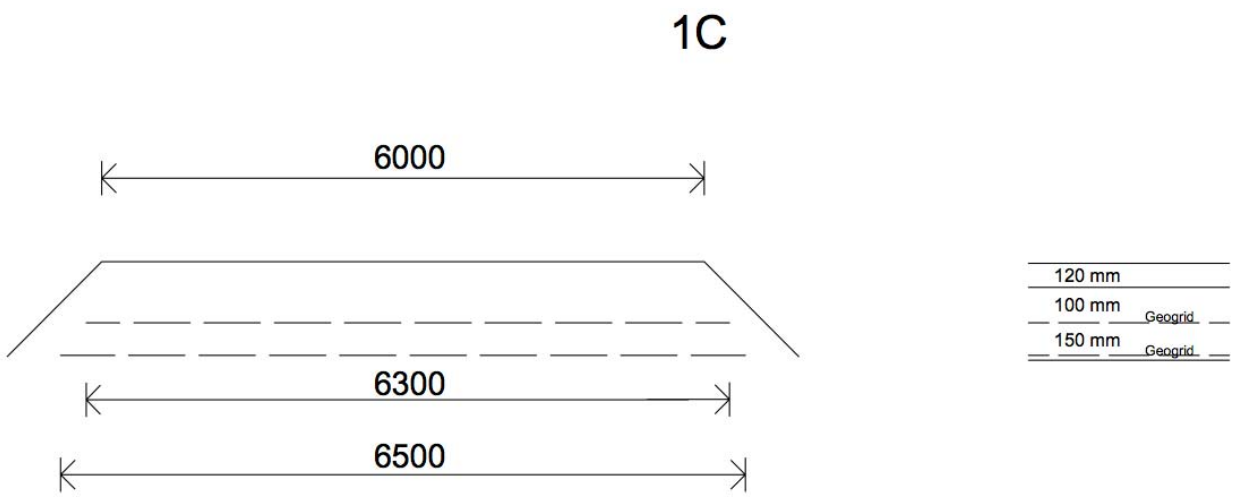


Figure 5.2 *The Rehabilitation Structure 1C*

Figure 5.3 *Crushed aggregate on the geogrid*

5.2. RATIONALE FOR THE SELECTED SOLUTION

The idea behind using geogrid reinforcement is the ability of the geogrid to strengthen the mechanical properties of the subgrade or materials used in the road layers. A geogrid provides two main structural functions which are “lateral base course restraint” and the “tensioned membrane” effect.

“Lateral base course restraint” develops when the base course aggregate interlocks with the geogrid. In the interlocking effect, the aggregate is restrained laterally and tensile forces are transmitted from the aggregate to the geogrid. This can prevent the widening of the road, which is problem in the test sections. A diagram illustrating the lateral base course effect is shown in Figure 5.5.

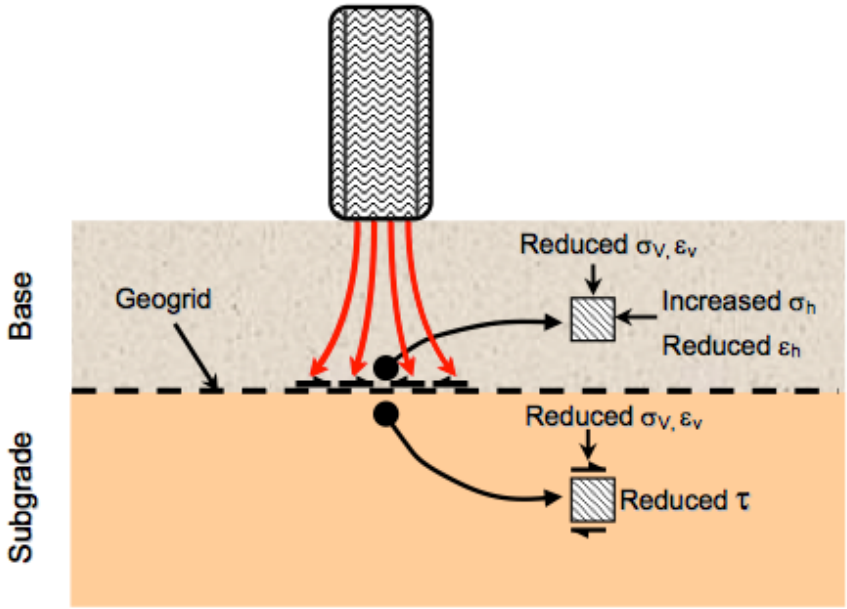


Figure 5.5 *The lateral base course effect [5]*

“The Tensioned membrane” effect develops when the subgrade is extremely soft. As the geogrid is anchored/interlocked beyond the developed rut, the geogrid becomes stressed and acts as a tensioned membrane. The tensioned geogrid loaded by traffic reduces the stresses applied to the subgrade which leads to reduced rutting in the subgrade. A diagram illustrating the tensioned membrane effect is shown in Figure 5.6.

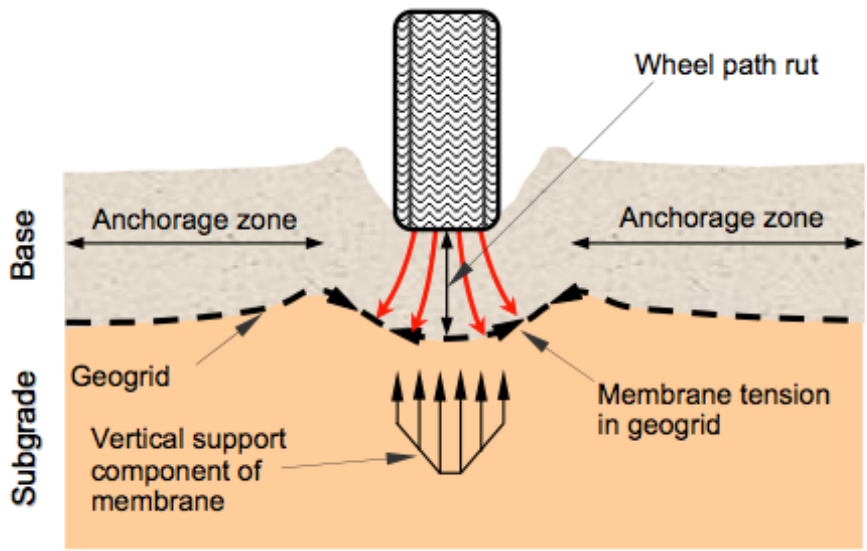


Figure 5.6 *Tensioned Membrane effect [5]*

Although a geogrid is slightly more expensive than a traditionally used geotextile, savings can potentially be made in the overall cost of improving unpaved roads. Money can be saved in the cost of aggregates due to the fact that geogrids can reduce the thicknesses of aggregate layers in comparison to un-reinforced aggregate layers. (This did not apply in the case of the test sections as the aggregate thicknesses were the same as the reference section.) Geogrids can also increase the service life and maintenance interval of base courses.

The use of a geogrid can have a few possible drawbacks. A geogrid does not prevent hydraulic flow and pumping of fines to the upper part of the road structure like a geotextile does. Although pumping can be particular problem where the road is constructed on a very wet subgrade, in this case the old structure of the road will prevent most of the pumping action. Choosing an inappropriate aperture size for the aggregate being used can result in the geogrid losing its restraining functions and becoming ineffective. If this is the case, the base aggregate will not interlock with the geogrid. Finally if the geogrid is installed loose and undulated, a greater elongation of the geogrid will be needed to mobilise its tensile strength. [5]

The idea of rehabilitation structure 1C originated from discussions with Allan Bradley of FPInnovations on 28th June 2010. This type of multi-layer reinforcement structures has been used on forest roads in Canada. In the arrangement the aggregate is confined both below and above by layers of geogrid and assumed to act as a slab structure under traffic loads of heavy vehicles. To enable mobilization of the tensile compressive stresses of the slab, however, the structure must have a certain minimum thickness which has, in the case of the demonstration project, resulted in a fairly high overall thickness of the rehabilitation structure. To enable direct comparison between the different sections of the test site the rehabilitation structure 1B and the reference structure 1A were built using the same layer thicknesses, even though in normal cases they would have been built using somewhat thinner layers.

6. DESCRIPTION OF THE REHABILITATION WORKS

The Rehabilitation works were ordered by the ELY Centre of Central Finland and the contractor was Destia. The works at the test section started early in the morning 22nd of September 2010. Weather conditions during the works were poor. The weather in the morning was cloudy and the temperature was +10 Celsius. As the works progressed it started raining. This lasted for the rest of the day but did not affect the rehabilitation works. The working methods used in the rehabilitation works, are described in following section.

6.1. WORKING METHODS

Work started by removing of the old wearing course. For this a 50 mm thick layer was planed to the sides of the road by a road grader. The width for the new base layer was 6.1 metres. When the wearing course was removed, settlement pipes were installed in the surface of the old base layer. Shallow trenches, approximately 100 mm deep ruts were excavated for the pipes so that they would be protected from the passage of the construction vehicles, as shown in Figure 6.1. The ends of the pipes were covered with duct tape to prevent the aggregate blocking them. The exact locations of the pipes were surveyed to help finding them afterwards if the ends of the pipes became covered with the road structure material. The principle of the settlement pipe is explained in detail in Section 7.1.

Figure 6.1 *Installing the Settlement pipes*

After the settlement pipes were placed in their position, the geogrid was installed above the old base layer and the settlement pipes. Installation of the geogrid was easy but the weight of the geogrid roll caused a slight problem which is described in Section 6.2. The installation was carried out by two men, as shown in Figure 6.2. The width of the geogrid was 5.2 metres, and an overlap arrangement was necessary to bring it up to the planned road width of 6.1 metres. For this the 200 metres long roll had to be cut into smaller pieces to get the wider coverage area. The cutting was done with an ordinary knife and the splitting with a chainsaw. The cutting and the splitting operations are shown in Figures 6.3 and 6.4.

Figure 6.2 *Installing the geogrid*

Figure 6.3 *Cutting the geogrid*

Figure 6.4 *Splitting the geogrid*

A 150 mm thick layer of base course aggregate layer was laid on top of the geogrid, the old base layer and settlement pipes, as shown in Figure 6.5. A further layer of geogrid was laid on top of this layer in test section 1C from the chainage 1760 to chainage 1830, as shown in Figure 6.6. Test section 1B was given an additional layer of 100 mm of crushed aggregate to bring its total thickness of base course up to 250 mm. Both sections were then completed with a 120 mm thick wearing course. Over all, the whole rehabilitation work employed four men and three vehicles; two earth-hauling trucks and a van.

Figure 6.5 *Applying new base layer*

Figure 6.6 *The second geogrid layer installed*

Figure 6.7. *Wearing course material on the left and base course material on the right*

Figure 6.8 *Improved test section after two weeks from construction. The side ditches have not yet been cleaned and shaped.*

6.2. PROBLEMS ENCOUNTERED ON SITE

A few minor problems were encountered on site during the rehabilitation works. One problem was the weight of the geogrid rolls. The full geogrid rolls could not be moved manually. The rolls had been delivered to site by a truck previously and left in the field beside the road. Due to their weight these rolls had then to be pulled on to the road with a van. Pulling the rolls on to the road took time and had the potential to damage the geogrid.

The weight of the geogrid roll also necessitated a change in layout of the test sections. The original plan was to install the second geogrid layer in the first test section. However after rolling out the bottom layer of grid along the section the half roll, that had been planned for the upper layer, was at the end of the test section. In view of this, and the weight of the roll, it was decided to construct the structure 1C on the second test section from chainage 1760-1830.

A further difficulty encountered on site was keeping the road open for vehicles. Even though the test sections were located on a low volume road delays in operations were caused by passing cars. The geogrid roll had to be moved to the side of the road so that the cars could pass, as shown in Figure 6.9.

Other than these minor issues the installation of geogrid did not cause any major problems. Passing vehicles travelled safely on the grid without adverse effect, except for one occasion when the net got stuck in tyre of an earth-hauling truck and parts of the net ripped off, as shown in Figure 6.10.

Figure 6.9 *Passing car on Road 16589*

Figure 6.10 *Ripped off geogrid*

7. SITE MONITORING

In order that the performance of the test structure can be observed in the longer term it was decided to install some monitoring on site. Monitoring is an important part of the project and will be the basis for any final conclusions that can be reached. In this case settlement pipes, DCP measurements and site investigations will be used.

7.1. INSTALLED INSTRUMENTATION

At the beginning of the rehabilitation works six settlement pipes were installed under the geotextile and geogrid. These settlement pipes were 32 mm thick normal water pipe and were cut into 9 m long pieces. Six pipes were installed on chainage 1610, 1660, 1700, 1730, 1820 and 1860. The purpose of the pipes is to observe the different settlements of the base course along the cross section without the necessity of excavation. Settlement pipes use the principle of hydrostatic pressure. The changes in level of the pipe are measured with a very sensitive pressure sensor which is pushed through the liquid filled pipe. A change in hydrostatic pressure means a change in elevation level.

7.2. FIRST MEASUREMENTS

The first measurements were recorded at half metre intervals on 27th October 2010. These will be the baseline against which all the further measurements will be made. Measurements should be taken at 0.25 m intervals as was done on 24th November 2011. Figure 7.1 shows the initial baseline measurements (blue) and the measurements taken after one year (green) for chainage 1/1610. The figure shows that there has been hardly any deformation between the measurements. Winter 2010-2011 came fast and there were no additional freeze-thaw cycles in the road surface during the winter. Later the dry weather in the spring did not affect the good visible condition of the road.

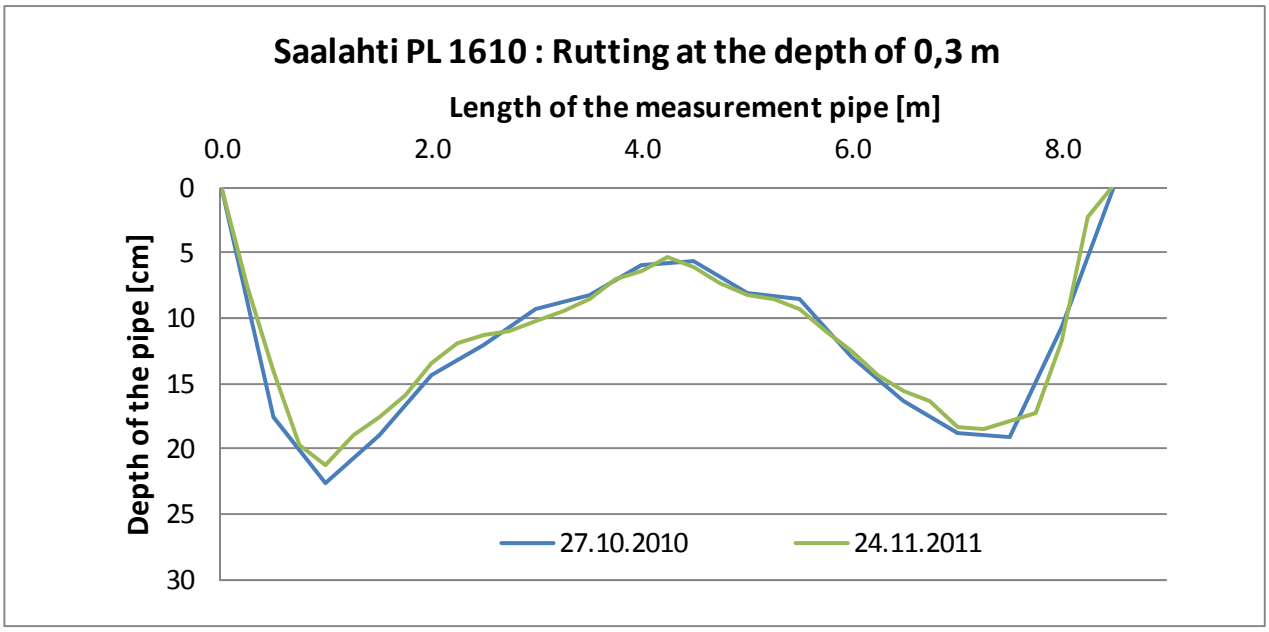


Figure 7.1 *Settlement measurements from chainage 1/1610*

All measurements taken of the settlement pipes are listed in Appendix 9 and a few measurement problems were noted. One end of the settlement pipe at chainage 1730 was probably bent against the ground by a farm tractor. The wooden prop indicating the position of the end of the pipe was broken at chainage 1660. The position of the other end may have also. The road may have suffered some form of deformation at chainage 1860.

Figure 7.2 shows the test section after the first spring thaw. The test section was found to be in good condition at this time. However, there were some visible cracks caused by differential frost heave near to the edges of the road as shown in the Figure 7.3. These indicated that the subgrade had been heaving more that the surrounding area as it had been covered with temperature isolating snow. The reinforcement had however kept the structure in one piece.

Figure 7.2 *The test section after the first spring thaw (5.5.2011)*

Figure 7.3 *Crack caused by differential frost heave near to the edge of the road (5.5.2011)*

7.3. RECOMMENDATIONS FOR FUTURE MONITORING

In the future, it will be very important to monitor the reference and test sections after freeze-thaw cycles in the spring. It has been proven that the major part of the road damages develop during the spring and any damage is likely to be visible at this time. The critical parameters that should be monitored, in addition to the settlement pipes, are frost-thaw damages and the shape of the ditches. Weather conditions, temperature, information regarding heavy traffic are important information should also be noted as the condition of the road will be dependent on these parameters.

The settlement of the base course can be monitored with the settlement pipes. This was checked twice in the first year; after the spring thaw and in late summer to give a baseline for measurements. Following this it will be enough to measure only once in the year. This will enable the behaviour and development of the relative deformation of the pipe to be sufficiently observed.

8. LIFE CYCLE ANALYSIS

The life cycle analyses have been calculated in accordance with the method described in TPPT 20 (Petäjä and Spoof 2001) [6]. Annual costs have been based on 5, 7, 10, 12, 15 and 20 years renewal time from construction as an accurate duration for the geogrid test structure is not known. Expenses, which are assumed to be same in both structures, are excluded from the calculations. The prices used in the calculation have been taken from the Väkäste 2 project [7].

The calculated construction costs for the reference structure is 51,775 €/km, for the single geogrid structure is 34,475 €/km and for the double geogrid structure 68,275 €/km. Prices which were used are: Geotextile 1 €/m^2, Fornit 40/40 2.0 €/m^2, base course layer (250 mm) 31,875 €/km and wearing course (120 mm) 14,400 €/km.

In addition, all three road sections are expected to require ballast every four year and dust suppression every second year. The price for the ballast is 1450 €/km and for the dust suppression is 300 €/km. The discounted prices for a renewal period of 20 years for the different structures are:

- Reference structure 57,900 €/km
- Single geogrid structure 63,400 €/km
- Double geogrid structure 74,400 €/km

The annual costs for the reference structure and the test structures are shown in Figure 8.1. The figure shows that the single geogrid structure needs to last one year longer than the reference structure assuming 7000 € annual costs, and that the double geogrid structure needs to last 3 years longer in order to be as cost-effective as the reference structure. If the geogrid structures last longer, they will be more cost-effective than the traditional structure, assuming the reference structure will last 10 years.

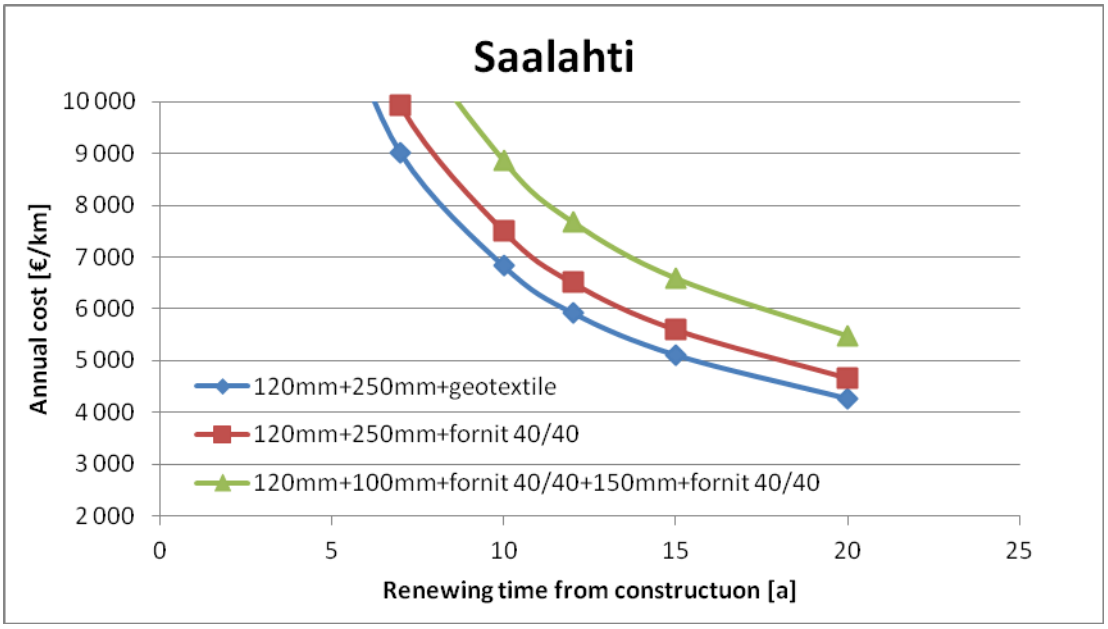


Figure 8.1 *Annual costs for reference structure (blue) and test structures (red and green)*

9. CONCLUSIONS

This report presents the early results of a demonstration project into the use of geogrid reinforcement to retard the development of permanent deformations of a low volume gravel road section located on a silty subgrade.

The road at the demonstration site had been suffering from deformations taking place primarily in the subgrade material that had been getting very soft during the spring thaw of the seasonal frost. This had resulted in severe widening of the road cross-section and almost total clogging of the side ditches. According to the GPR profiles the total thickness of the structural layers was much higher in the middle of the road than towards the edges of the road which was a clear indication of Mode 2 rutting.

The demonstration consisted of two reinforced subsections and a reference section. The first reinforced subsection (from chainage 1640 to 1760) was constructed using one layer of geogrid. The second demonstration subsection (from chainage 1760 to 1830) was constructed with two layers of reinforcing geogrid 150 mm apart from each other. The reference section used the traditional standard method of a geotextile.

The execution of the works on the site proceeded without any major problems other than the roll width of the geogrid posing some installation difficulties. In addition, there were some problems with undulation and ripping of the geogrid due to the construction traffic.

Two settlement monitoring tubes were installed in both reinforced subsections, and in the reference structure, to enable later follow up of the development of permanent deformations in the cross-sections of the road. Based on these measurements after one year of service it can only be concluded that all of the sections have performed equally well and more time is needed to identify any possible differences.

According to the life cycle analyses performed, the section reinforced with one layer of geogrid needs to last at least one year longer, and the section reinforced with two layers of geogrid at least three years longer to be cost effective in comparison to the reference structure assuming that the reference structure will have a service life of 10 years This is slightly more than the typical assumption of 8 years as, in this case, the reference structure was also about 50 mm thicker than would have been the standard solution.

REFERENCES

1. Tierekisteri Cited: 9.7.2010

2. Saarenketo, T., Aho, S. (2005). Managing Spring Thaw Weakening on Low Volume Roads, Roadscanners Oy 2005

3. Matintupa, A. (2009). AC 1093 Morkan-Dikanäs, Rehabilitation Plan According to ROADEX Design Methods, Roadscanners Oy 2009

4. ROADEX E-Learning, Permanent Deformation, Cited: 25.8.2010, Available at: http://roadexorg.adv2.nebula.fi/elearning/

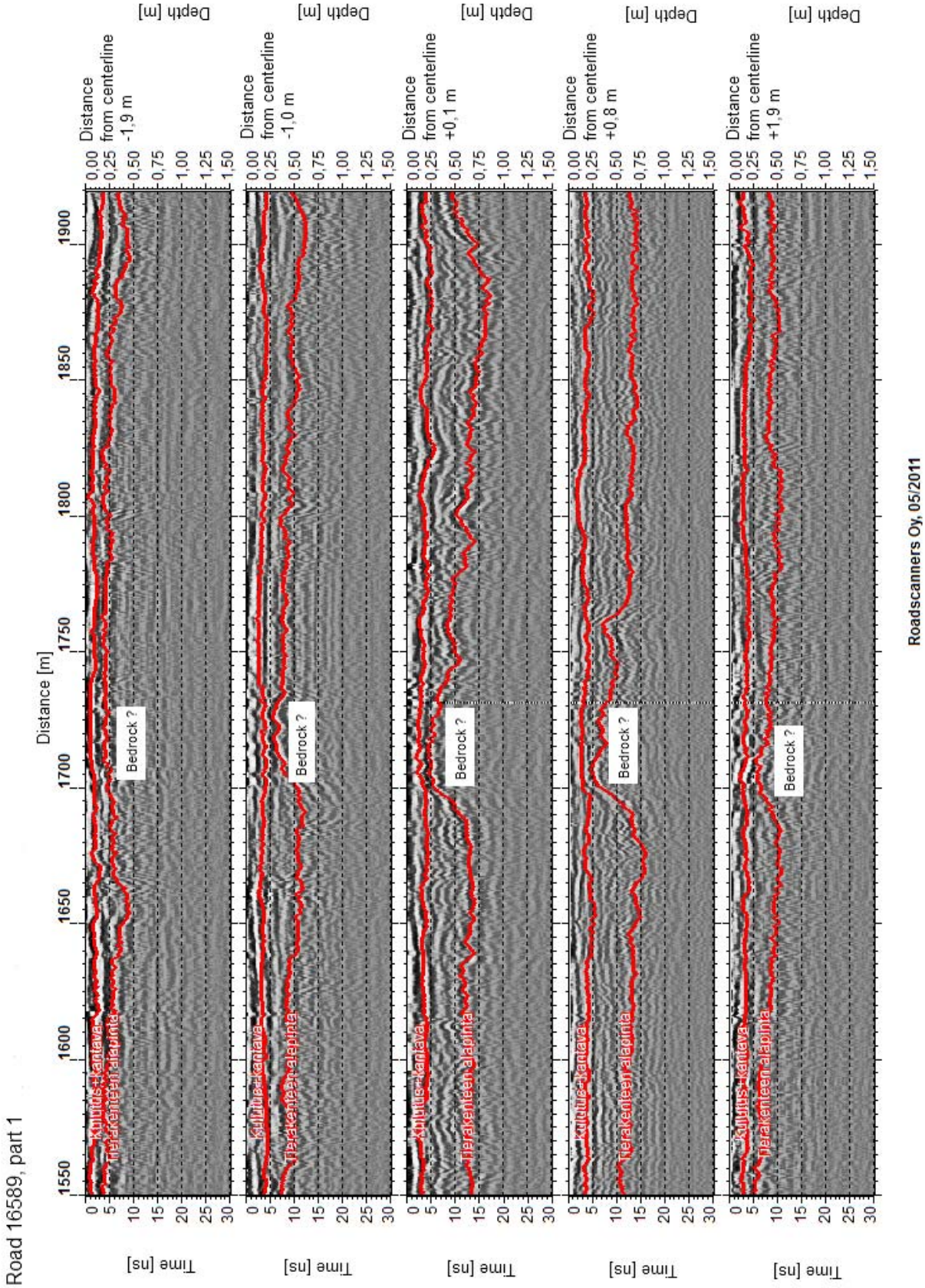
5. Geogrid Reinforcement Mechanism in unpaved Roads, Cited: 20.7.2010, Available at: http://www.globalsynthetics.com.au/files/Tech_Secant_Stiffness_Of_Secugrid.pdf

6. Petäjä, S., Spoof, H. (2001). Päällysrakenteen elinkaarikustannusanalyysi, VTT Rakennus- ja yhdyskuntatekniikka

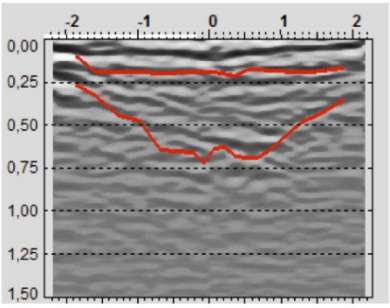
7. Vuorimies, N., Kolisoja, P. (2009) Sitomattomien väylärakennemateriaalien kosteustilaherkkyyden vähentäminen uusilla käsittelyaineilla. Tiivistelmäraportti (Reducing moisture susceptibility of unbound road materials using non-traditional treatment agents. Summary report). Tiehallinnon selvityksiä 19/2009. Available at: http://alk.tiehallinto.fi/julkaisut/pdf1/3201133_sitomatt_vaylarak_materiaali.pdf

APPENDIX

APPENDIX 1



PL 1605

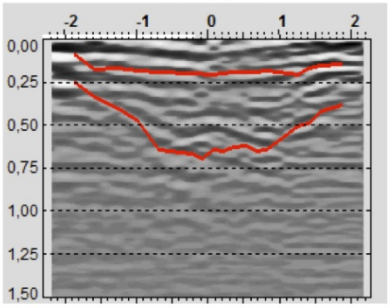


Road 16589, part 1

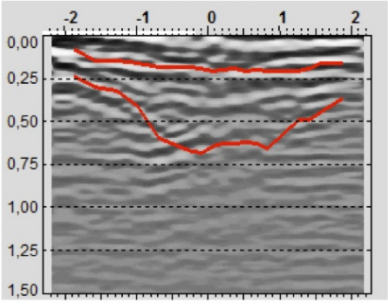
Highest line: Wearing and base course

Lowest line: Lowest surface of the road

PL 1610

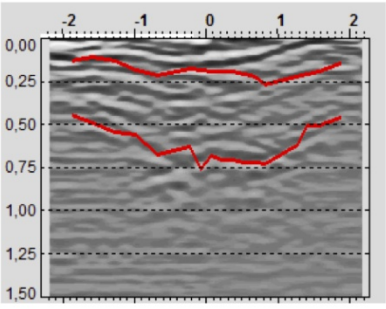


PL 1615



Roadscanners Oy, 05/2011

PL 1655

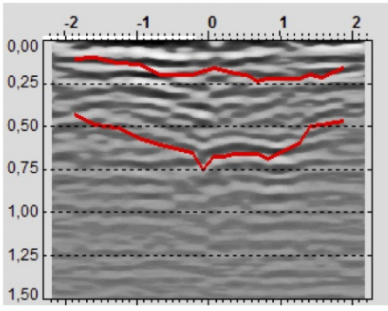


Road 16589, part 1

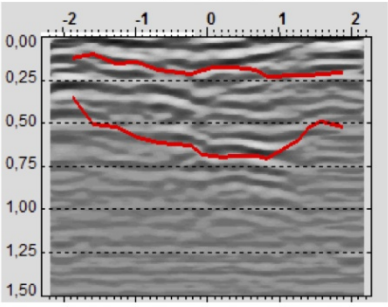
Highest line: Wearing and base course

Lowest line: Lowest surface of the road

PL 1660

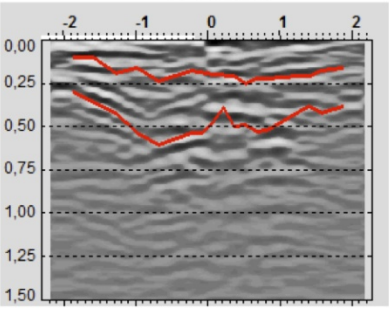


PL 1665



Roadscanners Oy, 05/2011

PL 1695

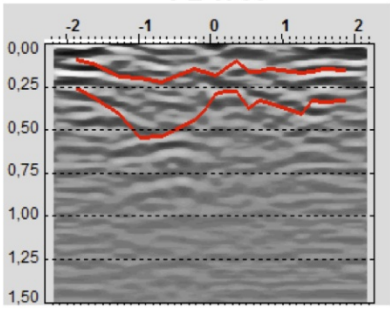


Road 16589, part 1

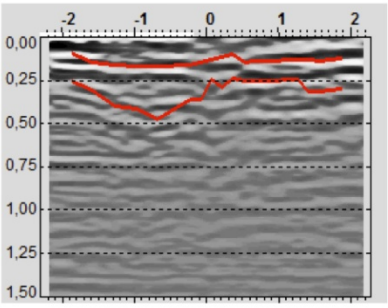
Highest line: Wearing and base course

Lowest line: Lowest surface of the road

PL 1700

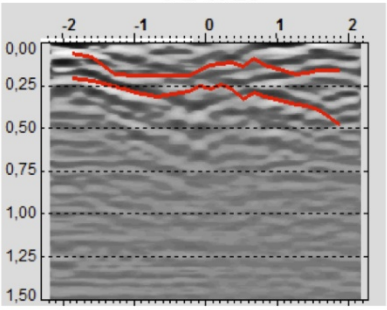


PL 1705



Roadscanners Oy, 05/2011

PL 1725

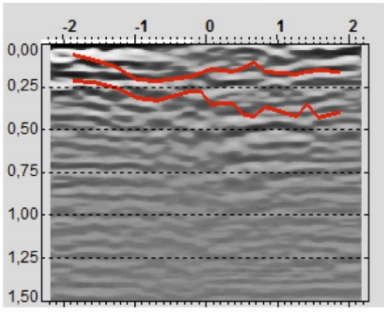


Road 16589, part 1

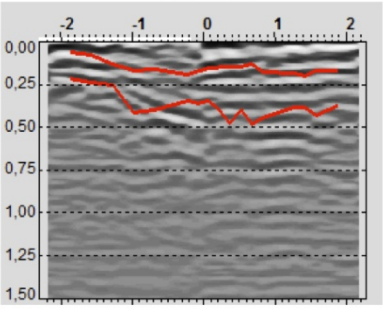
Highest line: Wearing and base course

Lowest line: Lowest surface of the road

PL 1730

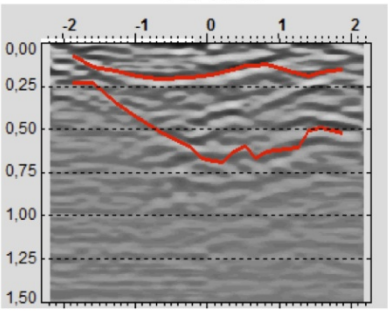


PL 1735



Roadscanners Oy, 05/2011

PL 1815

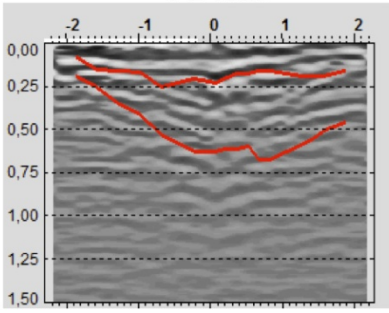


Road 16589, part 1

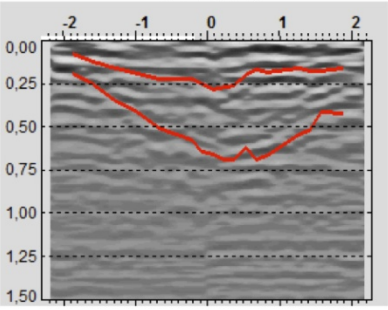
Highest line: Wearing and base course

Lowest line: Lowest surface of the road

PL 1820

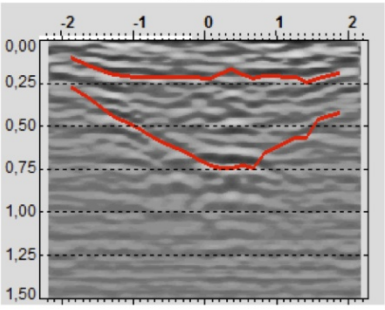


PL 1825



Roadscanners Oy, 05/2011

PL 1855

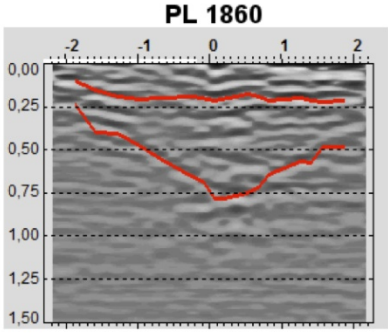


Road 16589, part 1

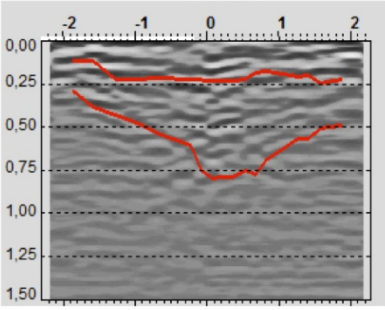
Highest line: Wearing and base course

Lowest line: Lowest surface of the road

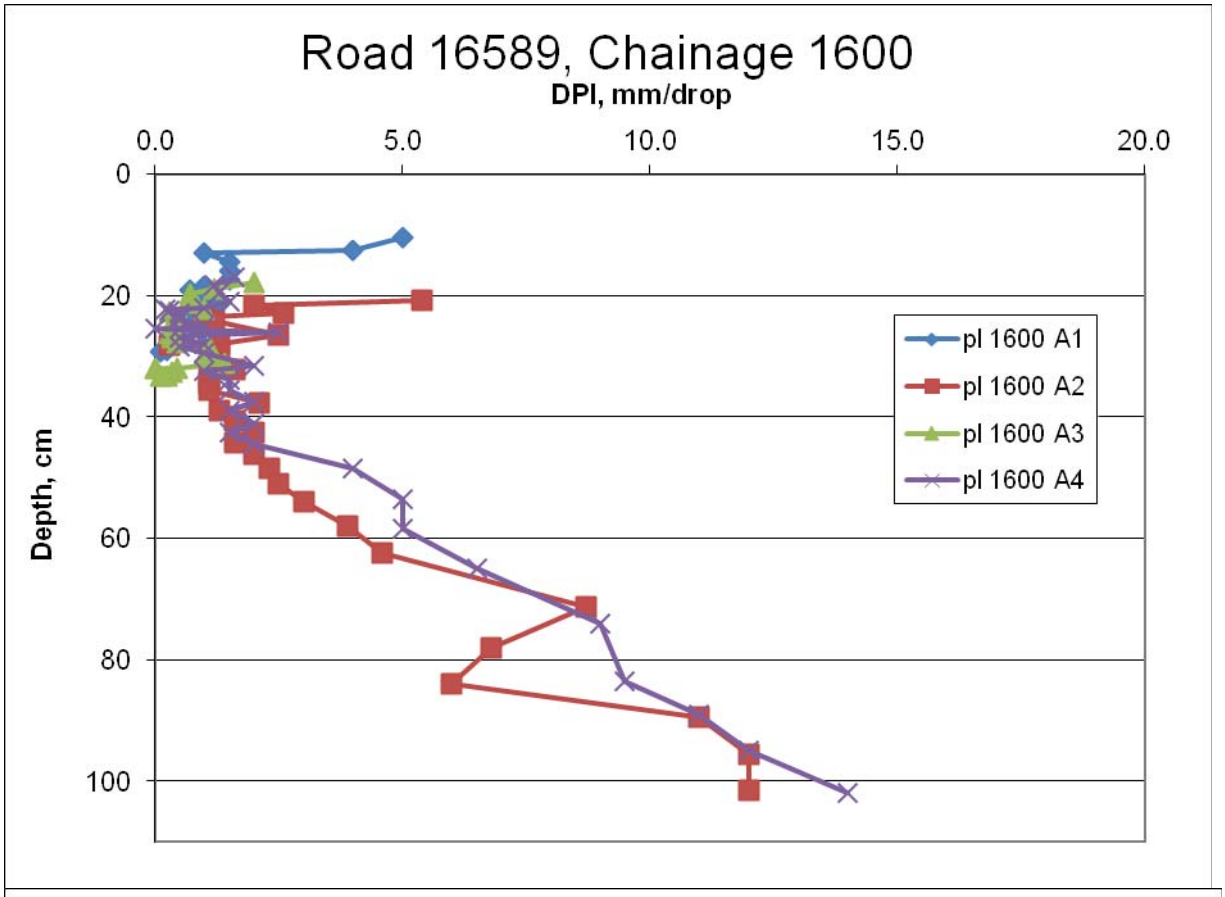
PL 1860

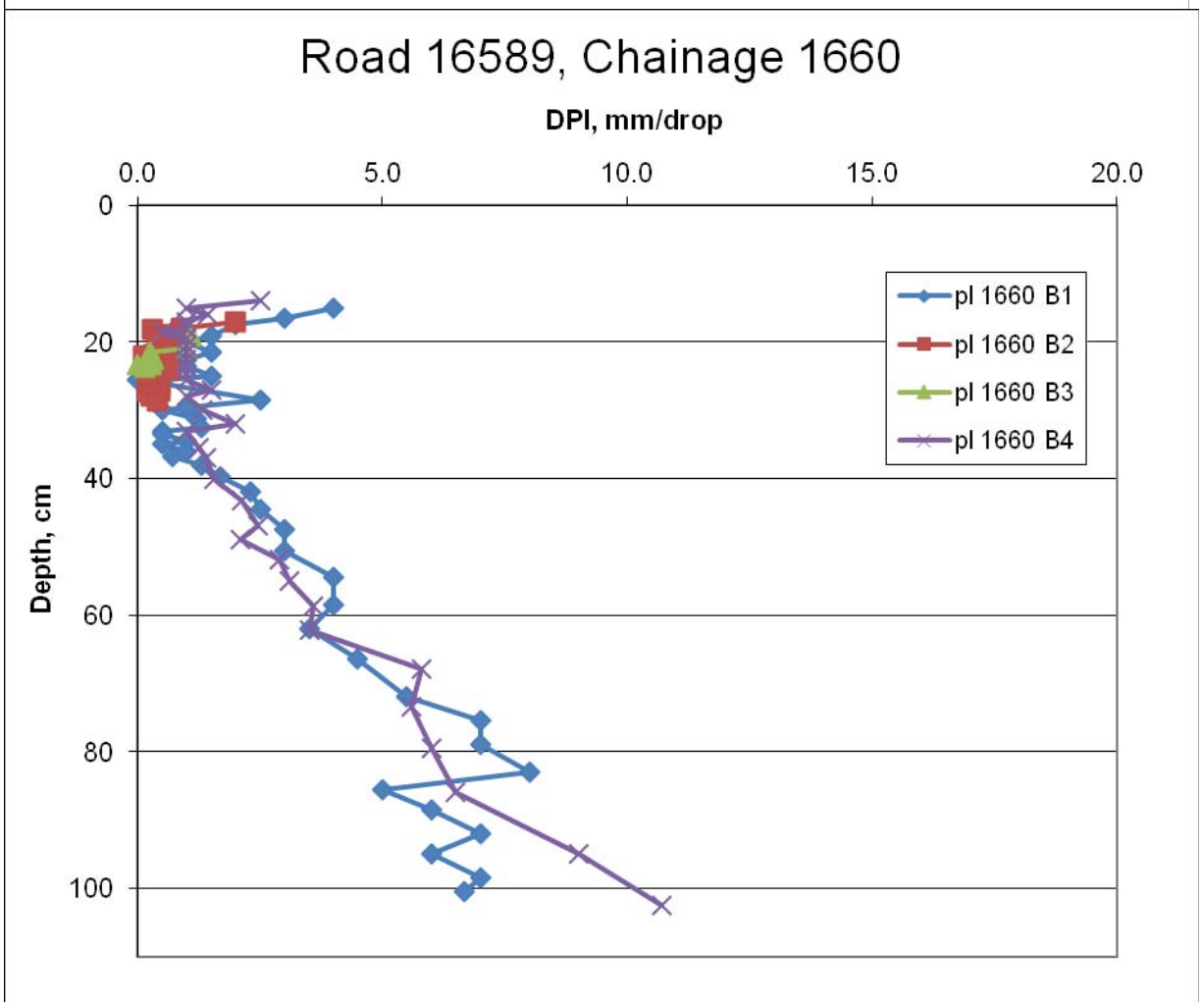


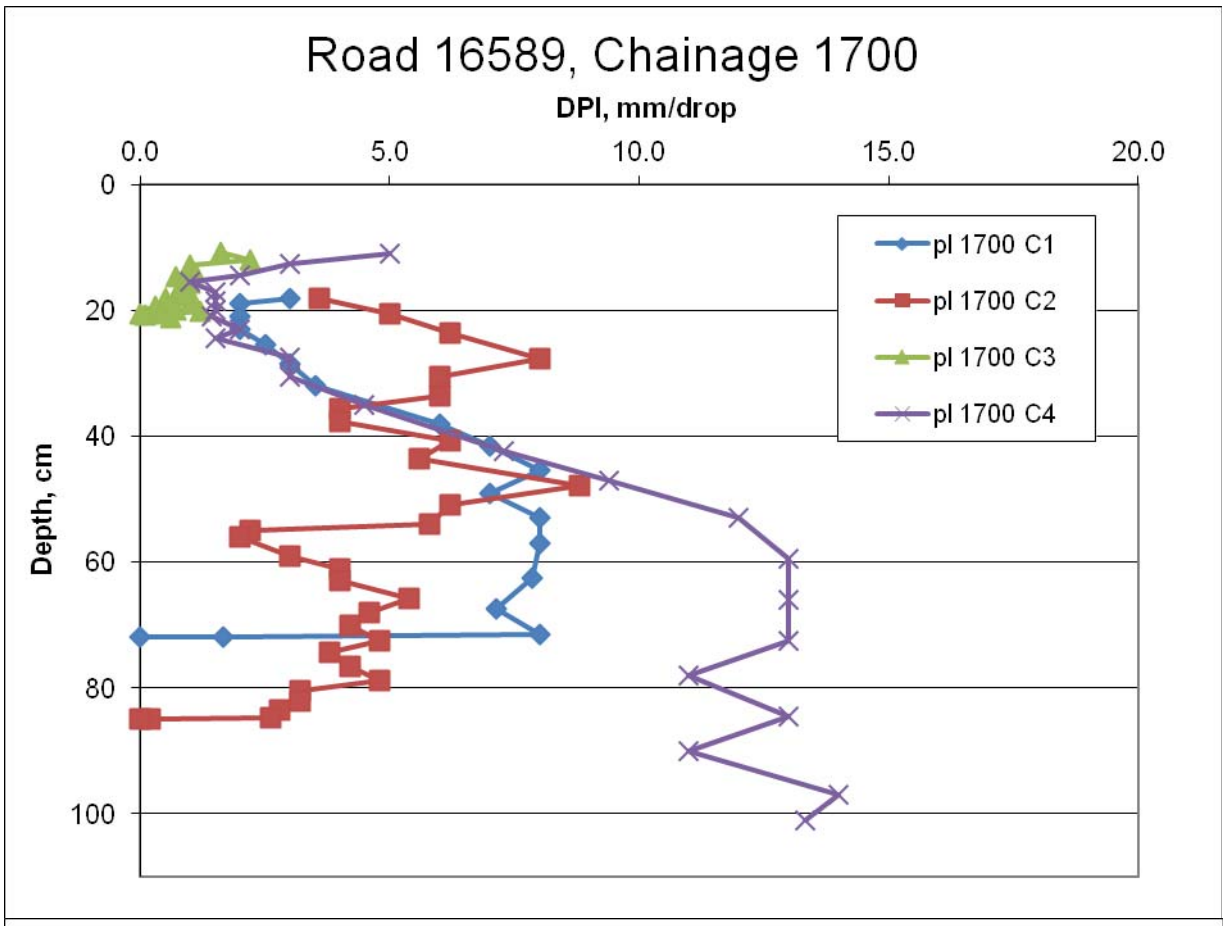
PL 1865

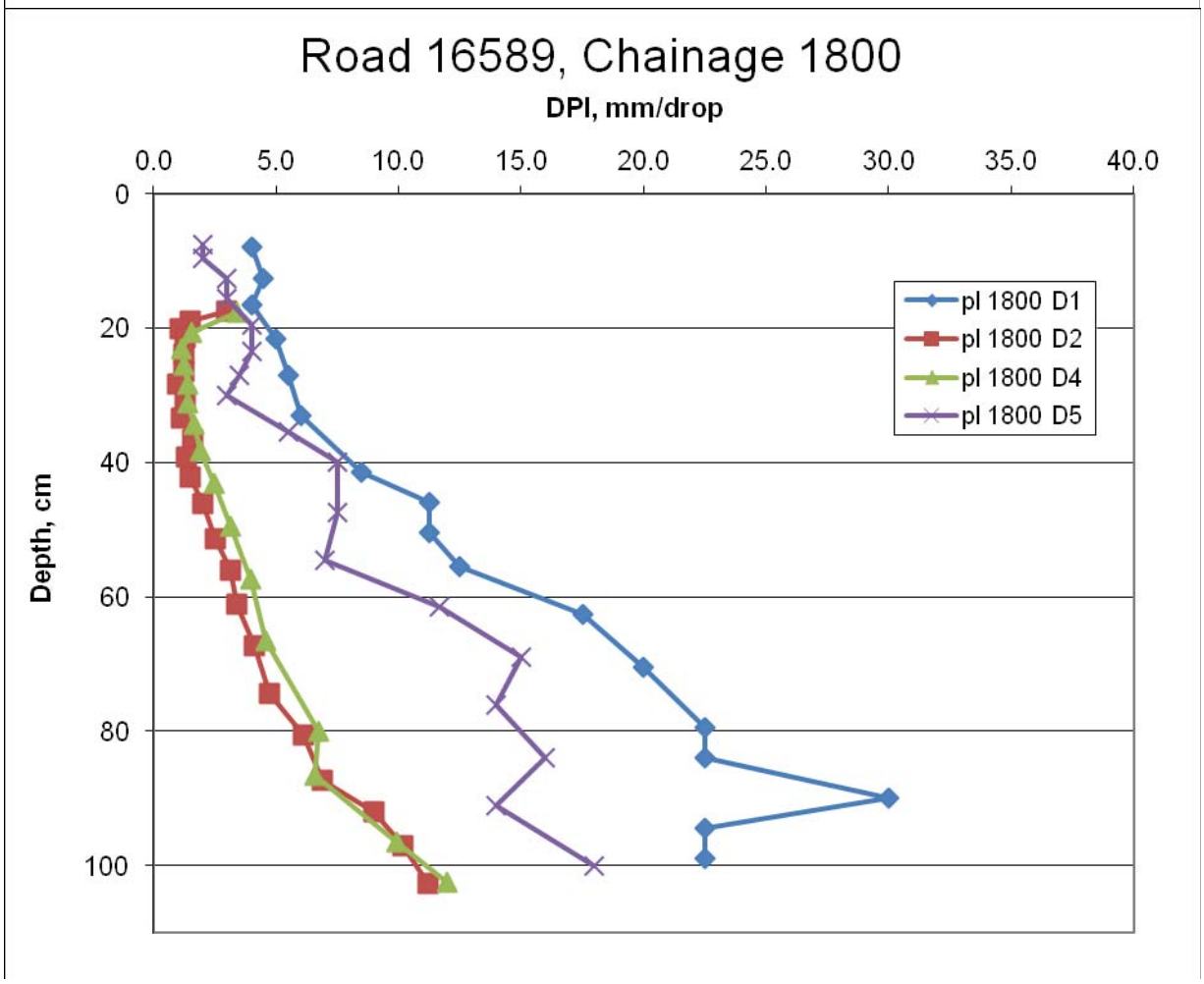


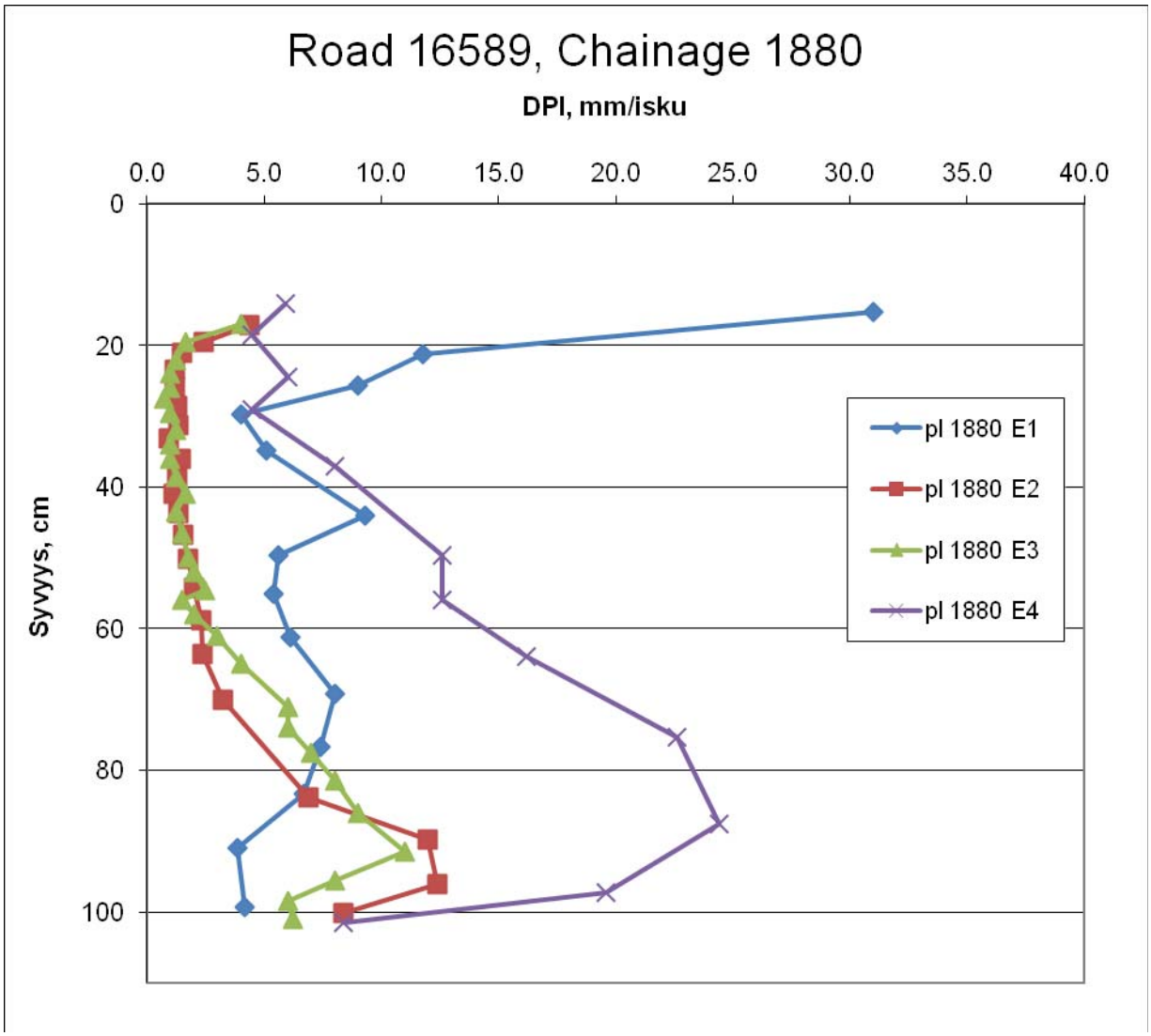
Roadscanners Oy, 05/2011


Road 16589, Chainage 1600
DPI, mm/drop
0.0
5.0
10.0
15.0
20.0
0
20
40
60
80
100
Depth, cm
pl 1600 A1
pl 1600 A2
pl 1600 A3
pl 1600 A4


Road 16589, Chainage 1660
DPI, mm/drop
0.0
5.0
10.0
15.0
20.0
0
20
40
60
80
100
Depth, cm
pl 1660 B1
pl 1660 B2
pl 1660 B3
pl 1660 B4


Road 16589, Chainage 1700
DPI, mm/drop
0.0
5.0
10.0
15.0
20.0
Depth, cm
0
20
40
60
80
100
pl 1700 C1
pl 1700 C2
pl 1700 C3
pl 1700 C4


Road 16589, Chainage 1800
DPI, mm/drop
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Depth, cm
0
20
40
60
80
100
pl 1800 D1
pl 1800 D2
pl 1800 D4
pl 1800 D5


Road 16589, Chainage 1880
DPI, mm/isku
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
0
20
40
60
80
100
Syvyys, cm
pl 1880 E1
pl 1880 E2
pl 1880 E3
pl 1880 E4

Road 16589 Saalahti

California Bearing Ratio (CBR)
log CBR = 2,46 - 1,12* log DPI

Note! The CBR values for the wearing course and base course represent dry season (summertime) conditions.

Base

Chainage 1600			Chainage 1660			Chainage 1700			Chainage 1800			Chainage 1880		
	Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR
A4	0,16-0,33	350	B4	0,13-0,38	258	C4	0,11-0,27	170	D5	0,07-0,32	72	E4	0,08-0,32	46
A3	0,17-0,25	420	B3	0,18-0,23	470	C3	0,10-0,20	288	D4	0,17-0,38	210	E3	0,16-0,43	260
A2	0,20-0,50	179	B2	0,17-0,28	700	C2	0,17-0,54	39	D2	0,05-0,44	215	E2	0,16-0,50	215
A1	0,12-0,27	250	B1	0,16-0,42	272	C1	0,16-0,31	110	D1	0,04-0,31	52	E1	0,16-0,83	34

Subbase

Chainage 1600			Chainage 1660			Chainage 1700			Chainage 1800			Chainage 1880		
	Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR
A4	0.33-0.47	143	B4	0,38-0,57	105	C4	0,27-0,41	46	D5	0,32-0,58	30	E4	0,32-0,60	17
A3	0,52-0,80		B3			C3			D4	0,38-0,76	55	E3	0,43-0,65	120
A2	0,50-0,65	53	B2			C2	0.56-0.84	56	D2	0,44-0,79	60	E2	0,50-0,72	100
A1			B1	0.42-0.67	67	C1	0,31-0,71	29	D1	0,31-0,59	19	E1	0,83-1,00	60

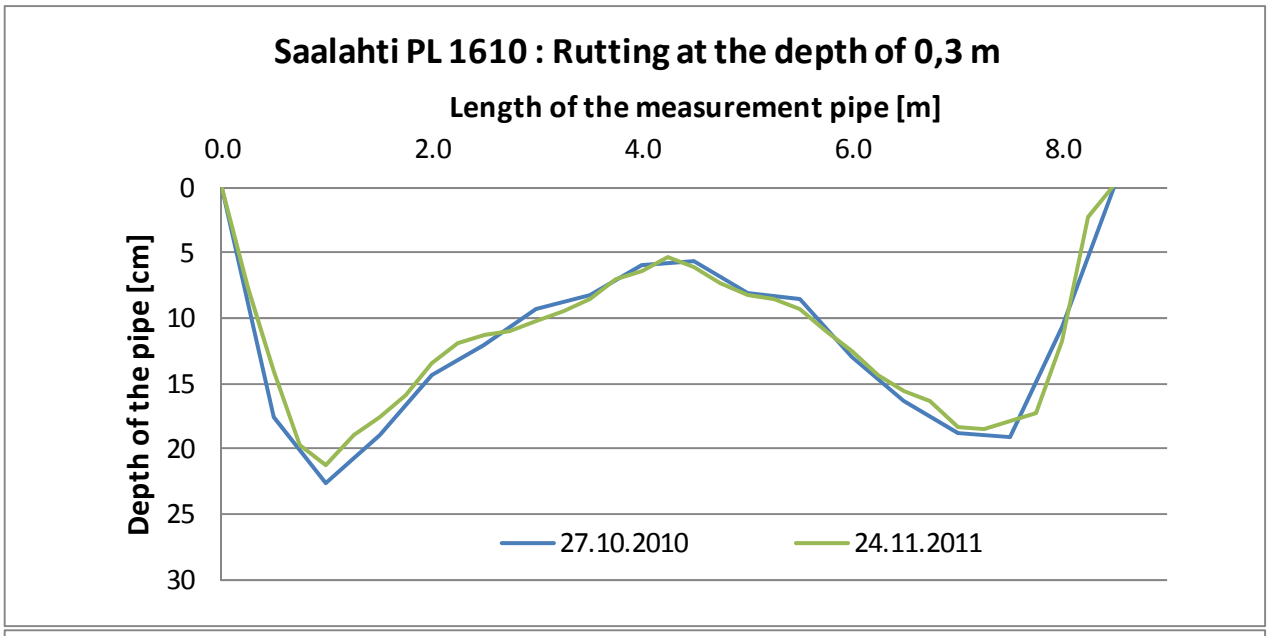
Subbase/Subgarde

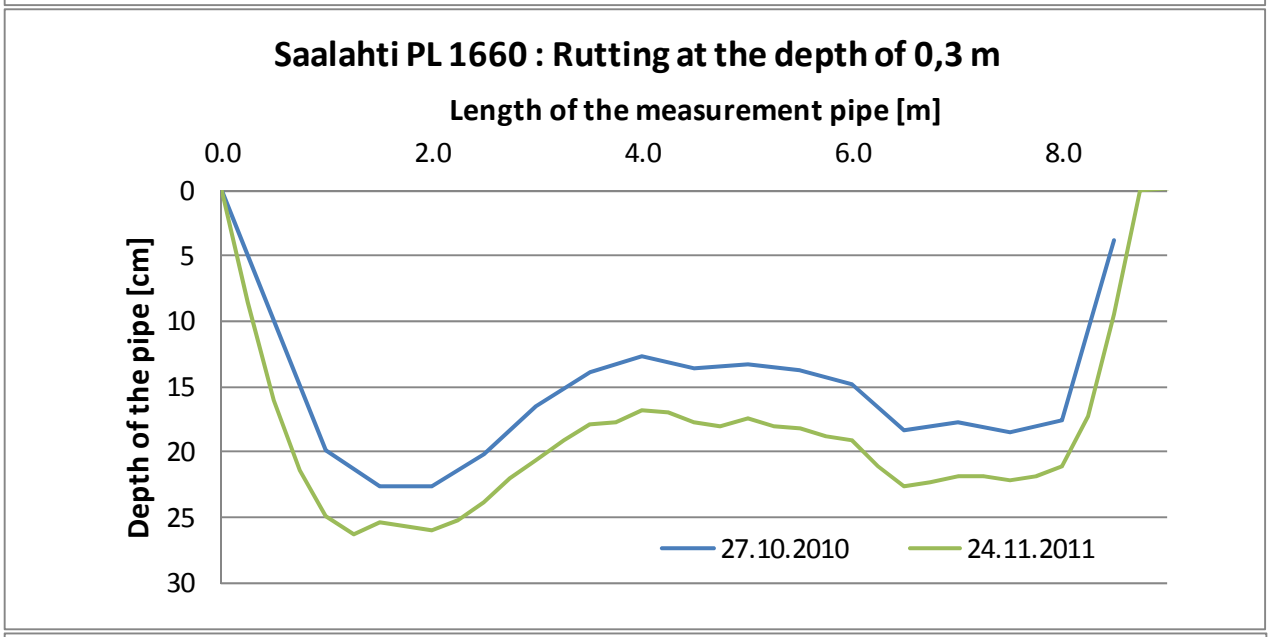
Chainage 1600			Chainage 1660			Chainage 1700			Chainage 1800			Chainage 1880		
	Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR
A4	0,47-0,74	35	B4	0,57-0,83	40	C4	0,41-1,02	17	D5	0,58-1,01	13	E4	0,60-0,98	9
A3	0,80-1,0		B3			C3			D4	0,76-1,02	20	E3	0,65-1,00	24
A2	0,62-0.86	29	B2			C2			D2	0.79-1,02	22	E2	0.72-1,00	17
A1			B1	0.67-1.02	34	C1			D1	0.59-1.0	8	E1	0.44-0.92	

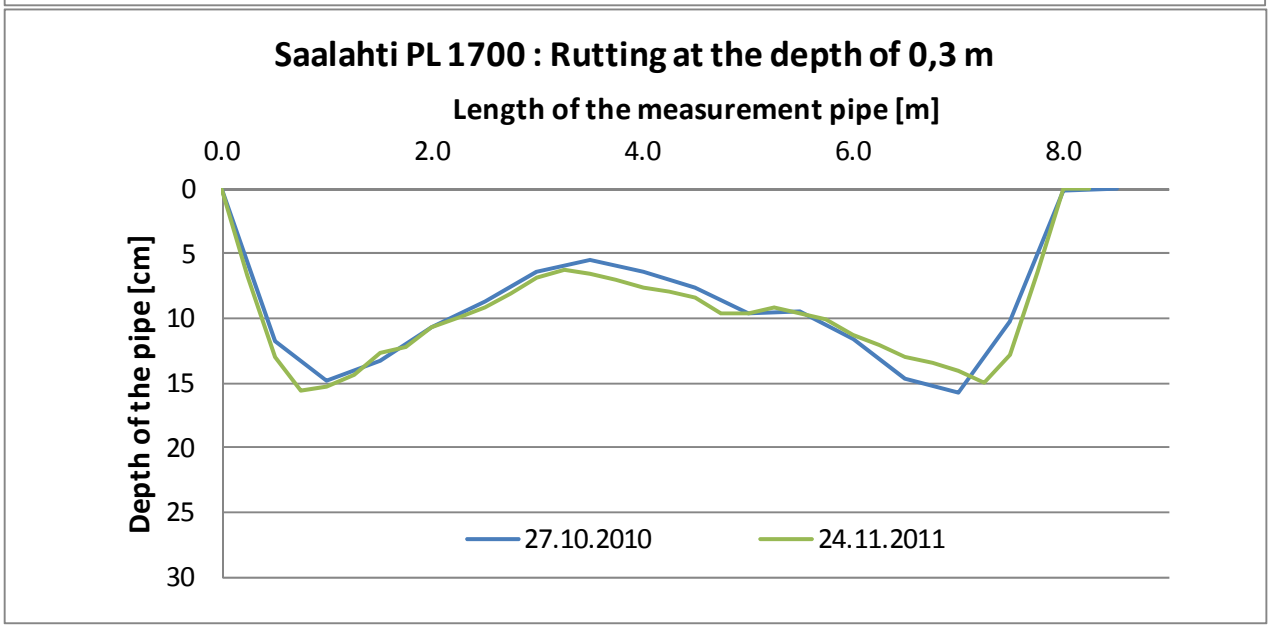
Subgrade

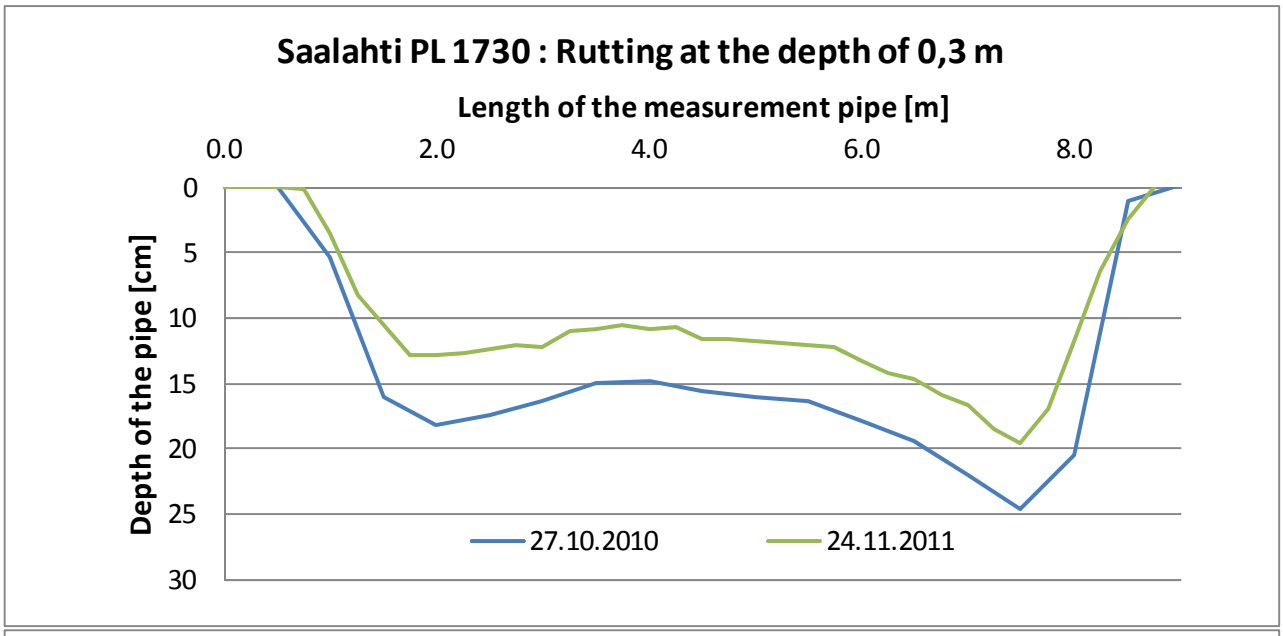
Chainage 1600			Chainage 1660		
	Depth [m]	CBR		Depth [m]	CBR
A4	0,74-1,02	16	B4	0,83-1,02	23
A3			B3		
A2	0,86-1.04	19	B2		
A1			B1		

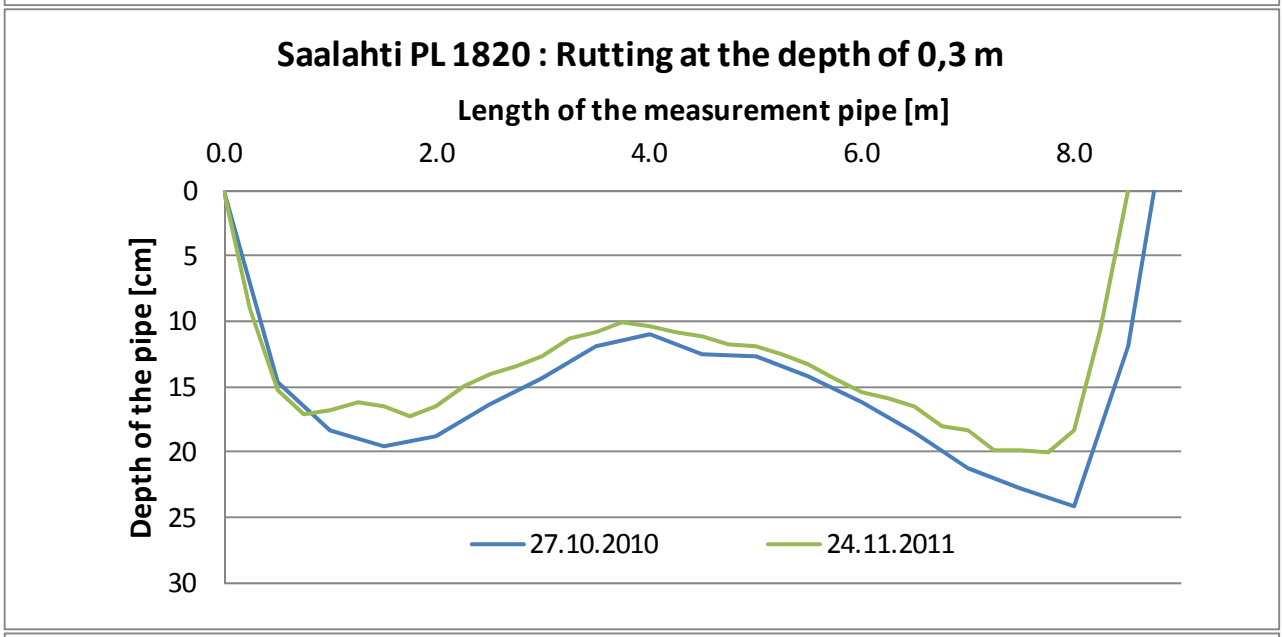
CBR [%]	General rating	Uses
> 50	Excellent	Base
20 - 50	Good	Base
7 - 20	Fair	Subbase
3 - 7	Poor to fair	Subgrade
< 3	Very poor	Subgrade

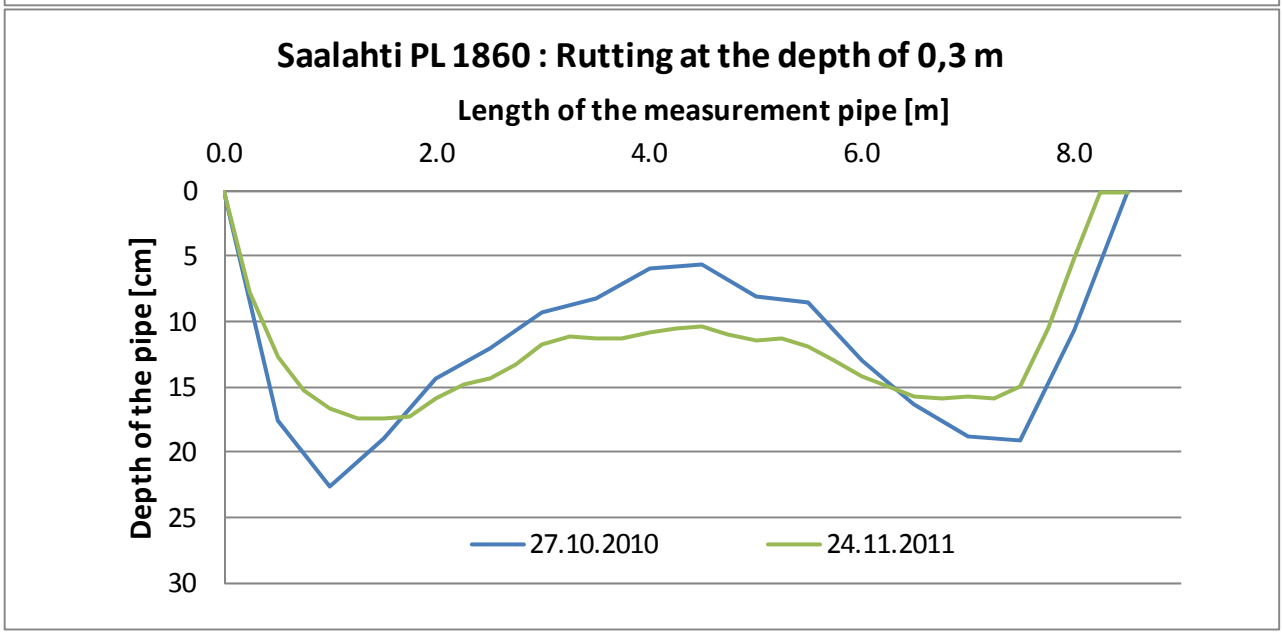

Saalahti PL 1610 : Rutting at the depth of 0,3 m
Length of the measurement pipe [m]
0.0
2.0
4.0
6.0
8.0
Depth of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011


Saalahti PL 1660 : Rutting at the depth of 0,3 m
Length of the measurement pipe [m]
0.0
2.0
4.0
6.0
8.0
Depth of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011


Saalahti PL 1700 : Rutting at the depth of 0,3 m
Length of the measurement pipe [m]
0.0
2.0
4.0
6.0
8.0
Depth of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011


Saalahti PL 1730 : Rutting at the depth of 0,3 m
Length of the measurement pipe [m]
0.0
2.0
4.0
6.0
8.0
Depth of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011


Saalahti PL 1820 : Rutting at the depth of 0,3 m
Length of the measurement pipe [m]
0.0
2.0
4.0
6.0
8.0
Depth of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011


Saalahti PL 1860 : Rutting at the depth of 0,3 m
Length of the measurement pipe [m]
0.0
2.0
4.0
6.0
8.0
Depth of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011

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.