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ROAD 16583 EHIKKI-JUOKSLAHTI

Mode 2 Rutting Site on Peat

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 16583 from Ehikki to Juokslahti in Jämsä, Central Finland. The section was located on a peat subgrade and was reinforced with a geogrid. The road had been deforming and widening significantly over the section mainly due to clogged side ditches, a low outlet ditch, and settlement of the road structure into the peat subgrade. As it was very difficult in practice to improve the operation of the outlet ditch, it was decided to reduce the further development of permanent deformations on the road by the addition of a new base course layer reinforced with a geogrid. As a reference structure, half of the test section was built with the addition of a new base course layer underlain by a geotextile, which could be considered as a standard solution in this type of problem site.

After the first year of service, it only can be concluded that both the test structure 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 four cross sections of the road will reveal any differences in the development rate of permanent deformations between the test structure and the reference structure. According to the life cycle analysis performed, the section reinforced with geogrid needs to last at least 1.5 years longer to be cost effective in comparison to the reference structure, assuming that the reference structure will have a typical service life of 8 years.

KEYWORDS

Rutting, permanent deformation, rehabilitation, low volume road, reinforcement, geogrid, geotextile, peat, 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 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 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

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

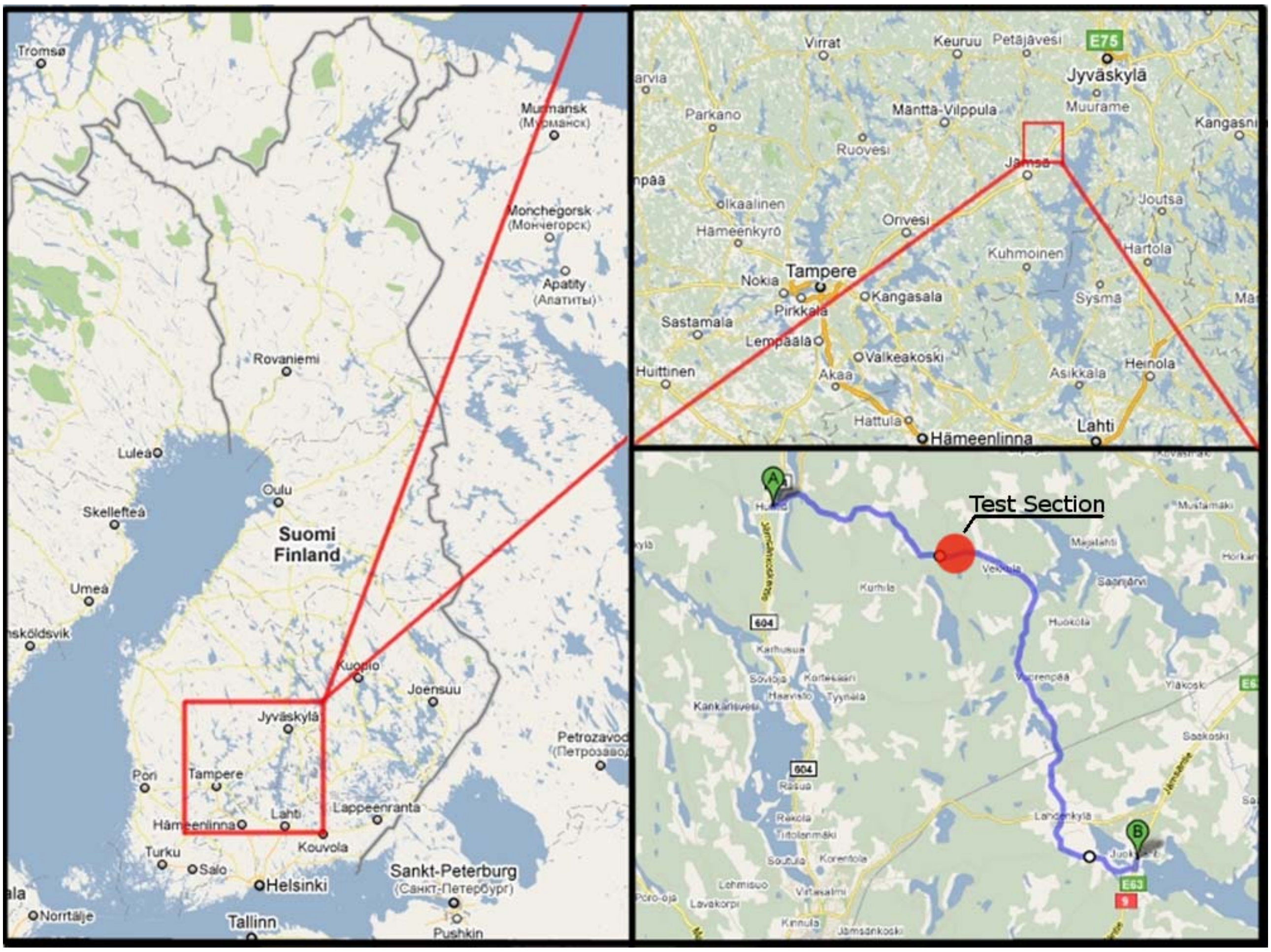

***Figure 2.1** Location of Road 16583 Ehikki – Juokslahti (Google Maps)*

2.2. TRAFFIC

The 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. An example of this topography is shown in Figure 2.2. This range of topography results in challenging conditions for 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. The road crosses two peat-land areas one of which has been chosen for the test section in this study.

Figure 2.2 *Typical 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 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 a low water permeability in 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 *A late thaw weakening damage of the road in the spring (17.6.2010)*

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 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 *Checking the depth of the ditch*

Figure 3.2 *Filled up ditch*

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 during winter 2009-2010. The resulting GPR interpretations are shown in Appendix 1, 2 and 3. Neither bedrock nor large rocks were detected in the interpretations. The road structure seems to have settled between chainages 2/175-2/220.

GPR cross-sections were also measured with 3D-radar. Measured cross-sections were on chainages 2/115, 2/120, 2/125, 2/175, 2/180, 2/185, 2/210, 2/215, 2/220, 2/245, 2/250 and 2/255. The interpretations of these cross-sections are shown in Appendix 2 and 3.

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]

3.1.3. DCP Measurements

Dynamic cone penetrometer (DCP) measurements were carried out in July 2010. It had been two weeks long hot weather period before the measurements; therefore the wearing course was nearly impenetrable and had to be drilled through first. The DCP points at Ehikki-Juokslahti road are on poles 2/140, 2/180, 2/215 and 2/250. Four points was measured per pole. Examples of the measurements obtained are given in Figure 3.5.

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 Measurement points on Road 16583 Ehikki-Juokslahti*

Figure 3.4 *DCP equipment on Road 16583 Ehikki-Juokslahti*

Figure 3.5 shows an example of the DCP measurements from road 16583. On the x-axis is the DCP Penetration Index and on the y-axis is depth. Measurement point D1 (blue) is 50 cm from the right side of the road, D2 (red) is 130 cm from the right side, D4 (green) is 145 cm from the left side and D5 (purple) is 60 cm from the left side. The figure shows that the road structure is softer on the edges (blue and purple) between the depths of 0-50 cm and the DPI is lower under the wheel paths (red and green). The base of the road structure is at a depth of circa 50 cm on a soft subgrade that causes the DPI to rise rapidly. The same road structure's layer thicknesses can be seen in the GPR cross-section at the pole 2/250. In the cross-section the highest red line is the base course + wearing course, the middle red line is the lowest surface of the road structure and the lowest red line is the frost depth.

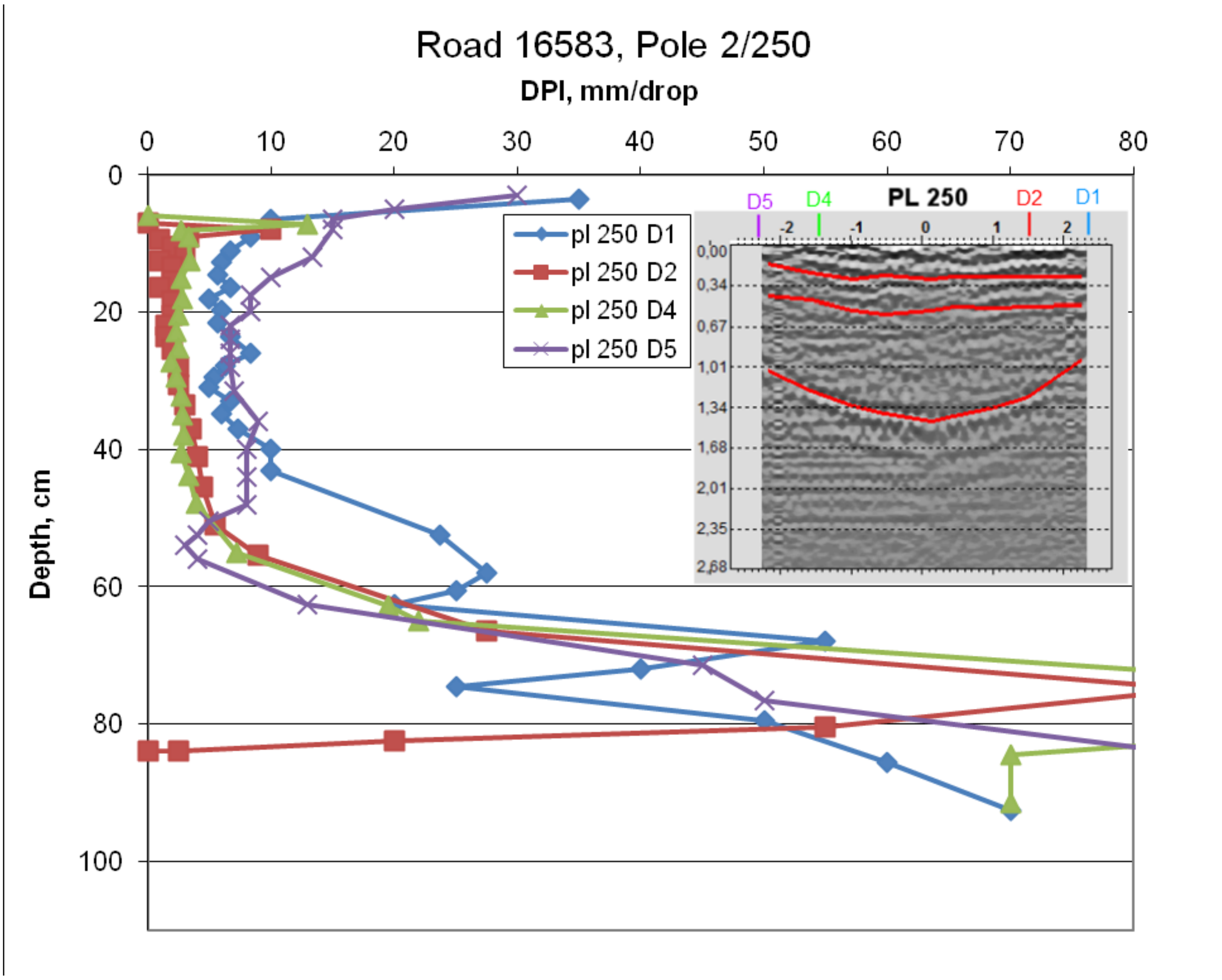

Figure 3.5 *The DCP measurements from pole 2/250*

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 of 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 site visits helped the understanding of the peat-land surface features (ditches, watercourses, culverts, surface topography, waterlogged areas and areas of free water) and the design of rehabilitation structure. One problem identified was a filled up outlet ditch, as shown in Figure 4.1. This ditch was not permitting water to drain from the roadside ditches and as a result the ditches were always wet and never dried out, as seen in Figure 4.2, taken after the two weeks of dry season in July. This clogged outlet ditch caused the trapped water in the roadside ditches to soak into the road structures and subgrade causing subgrade deformation and widening of the road.

The behaviour of peat under load has long been recognized to be a complex process with settlement taking a long time as the peat compresses under the weight of the road. To investigate this, GPR measurements were carried out on the peat section to examine how deep the road structure had sunk and obtain an indication of the structural layers of the road. DCP points were additionally used to measure the stiffness and thickness of the structural layers, and as a calibration of the depth of layers from the GPR surveys. [5]

Figure 4.1 *Filled up outlet ditch*

Figure 4.2 *Wet ditches*

5. REHABILITATION SOLUTION

Road 16583 Ehikki-Juokslahti was selected for a test structure against permanent deformation (Mode 2 rutting) on a peat subgrade. The test section was located at chainage 02/100 - 02/266 and the rehabilitation solution chosen is discussed in the following section.

5.1. PROPOSED REHABILITATION STRUCTURE

The main defects visible on the site are subgrade deformation and poor drainage. The test section was selected to be 166 metres long, divided into two sections.

The first section from chainage 02/100 to chainage 02/200 is a traditional rehabilitation solution normally used for improving unpaved gravel roads. This section will be the reference section for the test section that will contain a geogrid. In this section the wearing course will first be removed and a new structure will be built onto the exposed old structure. The ditches will be cleared after the structure is improved. The rehabilitation structure used is shown in Figure 5.1 and 5.2.

The new structure in the reference section from chainage 02/100-200 comprises:

- 50mm wearing course
- 150mm crushed aggregate layer
- Geotextile
- Old road structure with wearing course removed

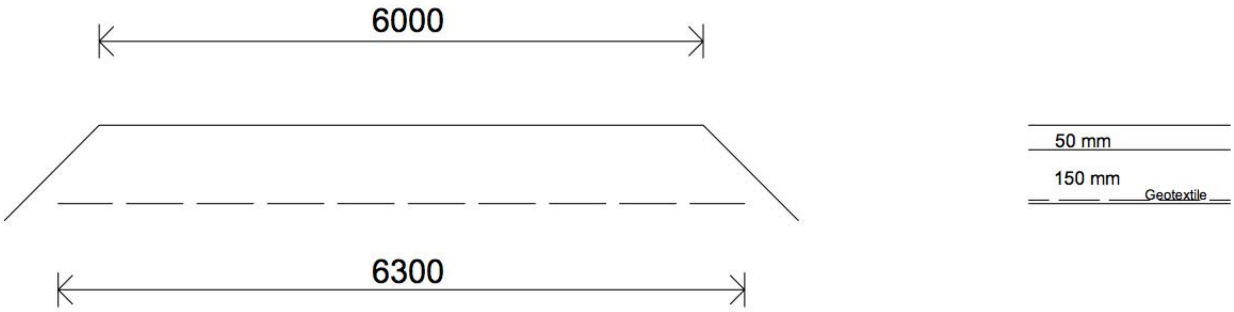

Figure 5.1 *The rehabilitation structure*

Figure 5.2 *Crushed aggregate on the geotextile*

The second section, the test structure, is from chainage 02/200 to chainage 02/266. In this section the structure is almost similar to the reference section but the geotextile is replaced with a geogrid. The purpose of the test structure is to compare traditional improvement with an improvement with a geogrid. The rehabilitation structure for the test section is shown in Figure 5.3.

The new test structure in the geogrid section from chainage 02/200-266 comprises:

- 50 mm wearing course
- 150mm crushed aggregate layer
- Geogrid (Secugrid 40/40 Q1)
- Old road structure with wearing course removed

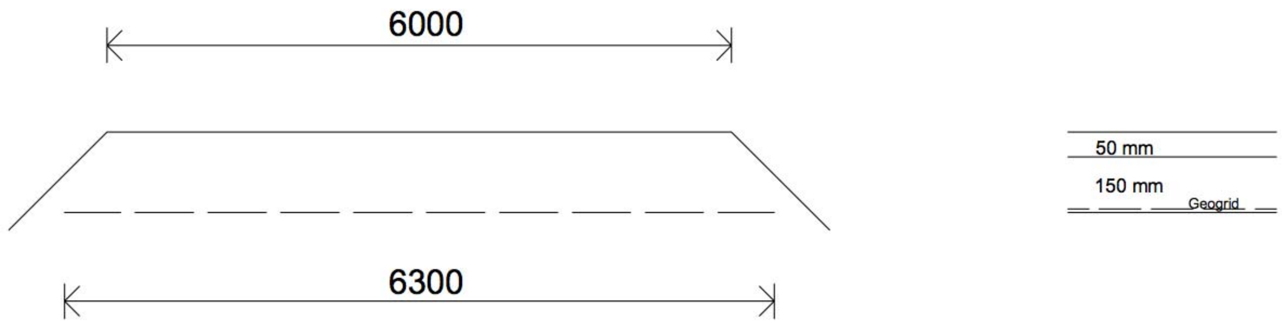

Figure 5.3 *Rehabilitation Structure*

Figure 5.4 *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's structure. 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 section. A diagram illustrating the lateral base course effect is shown in Figure 5.5.

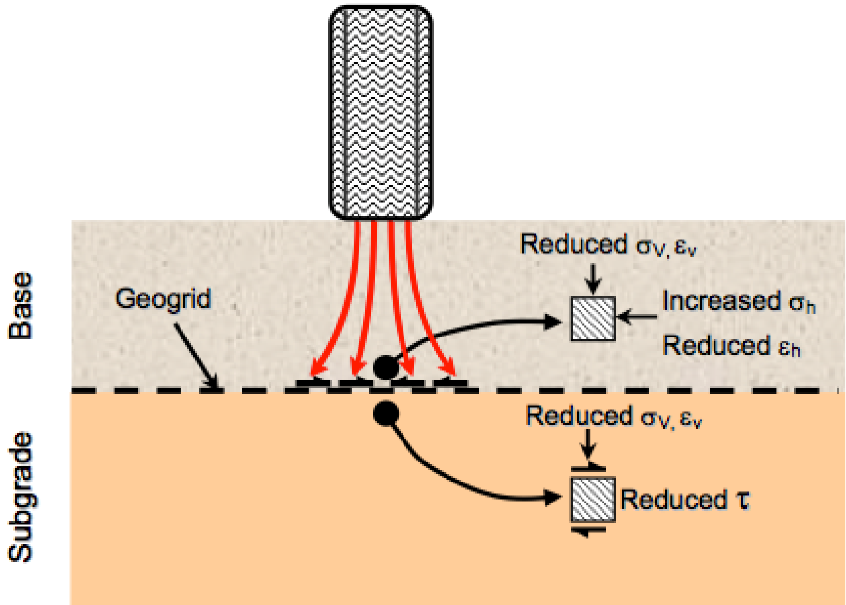

Figure 5.5 *The lateral base course effect [6]*

"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.

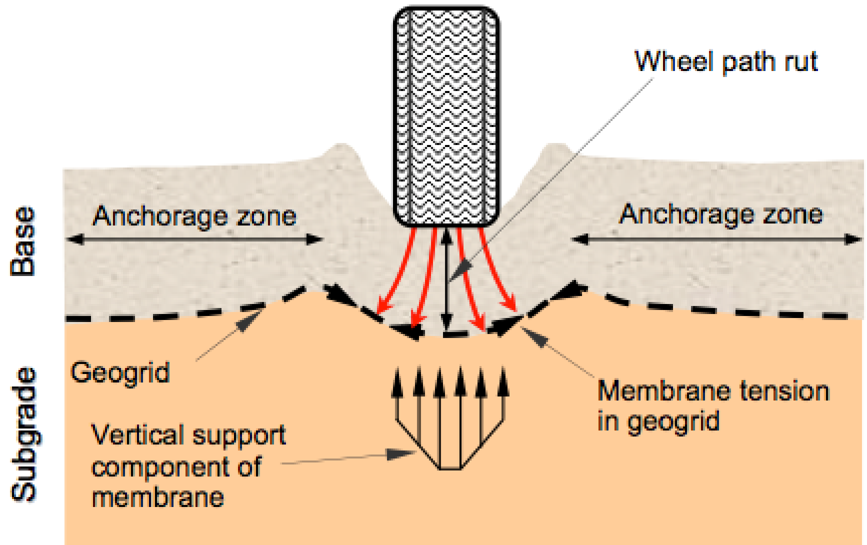

Figure 5.6 *Tensioned Membrane effect [6]*

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 section as the aggregate thickness was the same as the reference section.) Geogrids can also increase the service life and maintenance interval of base courses.

The use of 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. [6]

6. DESCRIPTION OF THE REHABILITATION WORKS

The rehabilitation works were ordered by The Centre for Economic Development, Transport and the Environment and the contactor was Destia.

The works at the test section started early in the morning 23rd of August 2010 and were finished by the following morning. The weather condition during the works was variable but mainly good. At the beginning the weather was cloudy and the temperature was +14 Celsius. As the works progressed the weather cleared and the rest of the day was partly cloudy. The next day started with slightly rain but this did not affect the works. The working methods used during the rehabilitation works, are described in the following section.

6.1. WORKING METHODS

Work started by removing the old wearing course from both sections. For this a 50 mm thick layer was planned to the sides of the road by a road grader, as shown in Figure 6.1. This old wearing course was used to support the soft edges of the road. The width for the new base layer was 5.8 metres.

Figure 6.1 *Grader removing the old wearing course*

After the wearing course was removed, settlement pipes were installed in the surface of exposed road. 100 mm deep grooves were excavated for the pipes so that they would be protected from the passage of the construction trucks. The ends of the pipes were covered with duct tape to prevent rocks and sand entering and blocking them. The exact locations of the pipes were surveyed to help finding them afterwards if the ends became covered with road structure materials. The principle of the settlement pipe is explained in detail in Section 7.1.

Figure 6.2 *Installing settlement pipe*

Figure 6.3 *End of the settlement pipe*

After the settlement pipes were placed in position, the geotextile and geogrid were installed above the settlement pipes in the reference and the test section respectively. The installation of the geotextile and geogrid was easy and a quick operation. Both materials were supplied in a roll and were easily rolled out over the road by two men, as shown in Figure 6.4. The width of the geogrid roll was 4.7 metres and an overlap arrangement was necessary to bring it up to the planned road width of 5.8. This was achieved by cutting the 100 meters long roll at 66 metres to obtain the extra material and overlapping the geogrid strip by 1.3 metres. Cutting was done with a simple knife and the splitting was carried out with a chainsaw. The cutting and splitting processes are shown in Figures 6.5 and 6.6. Cutting the geogrid and splitting the roll was not a problem in the test section as it was short but if a long section of road is to be rehabilitated with geogrid it is recommended that a full width geogrid should be used. The finished installation width for the geotextile was 5.25 metres, and 5.7 metres for the geogrid. The planned installation width for the geogrid was 6 metres, but only 5.7 metres of road was available after the grader removed the old wearing course. A lapped joint of one metre was provided at the junction of the reference section and test section.

Figure 6.4 *Installing the Geogrid*

Figure 6.5 *Cutting the geogrid*

Figure 6.6 *Splitting the geogrid roll*

A 150 mm thick layer of crushed aggregate was laid on top of the geotextile and geogrid by a rear discharge truck. The total amount of crushed aggregate used was 200 tons for 166 metres of road. A 50 mm thick wearing course was then laid on to the aggregate layer in the same manner. The total amount of crushed aggregate used for the wearing course was 100 tons. After both structural layers had been laid, the road surface was shaped with an underbody blade on a truck. At the conclusion of the work the ditches on both sections were cleaned out. Over all, the whole rehabilitation work employed three men and two vehicles; an earth-hauling truck and a van, as shown in Figure 6.7. The installation of the geogrid could have been the same as the geotextile, if it had been supplied wide enough.

Figure 6.7 *Equipment and the workmen*

Figure 6.8 *Applying the new base course*

Figure 6.9 *Depth of the new structure*

Figure 6.10 *Wearing course*

Figure 6.11 *Improved test section after two weeks from construction (ditches are not cleared yet)*

6.2. PROBLEMS ENCOUNTERED ON SITE

Although the rehabilitation work did not take long, it was not without problems. The biggest problem was the behaviour of the geogrid under the moving truck. When the truck had emptied the load and was driving off to get a new load, the geogrid did not hold still under the truck and became undulated, as shown in Figure 6.13. It was felt that if the widening geogrid strip had been attached to the main geogrid part most of undulating could have been avoided. The widening strip was easy to straighten where it was unloaded, but where crushed aggregate had been laid this remained deformed. The section of geogrids with undulations was at chainage 02/250-266. Another problem also occurred when the truck drove over the exposed geogrid. The geogrid net got stuck in tyres of the truck and strands of the net were ripped off, as shown in Figure 6.12.

Figure 6.12 *Ripped off geogrid*

Figure 6.13 *Undulated geogrid, widening part on the right hand side*

7. SITE MONITORING

In order that 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 four settlement pipes were installed under the geotextile and geogrid. These pipes were 40 mm thick normal water pipe and were cut into 7 m long pieces. Four pipes were installed on chainage 2/140, 2/180, 2/215 and 2/250. 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 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 a meter 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 initial baseline measurements (blue) and the measurements taken after one year (green) for chainage 1/1610. The figure shows that there might have been minor deformation between the measurements.

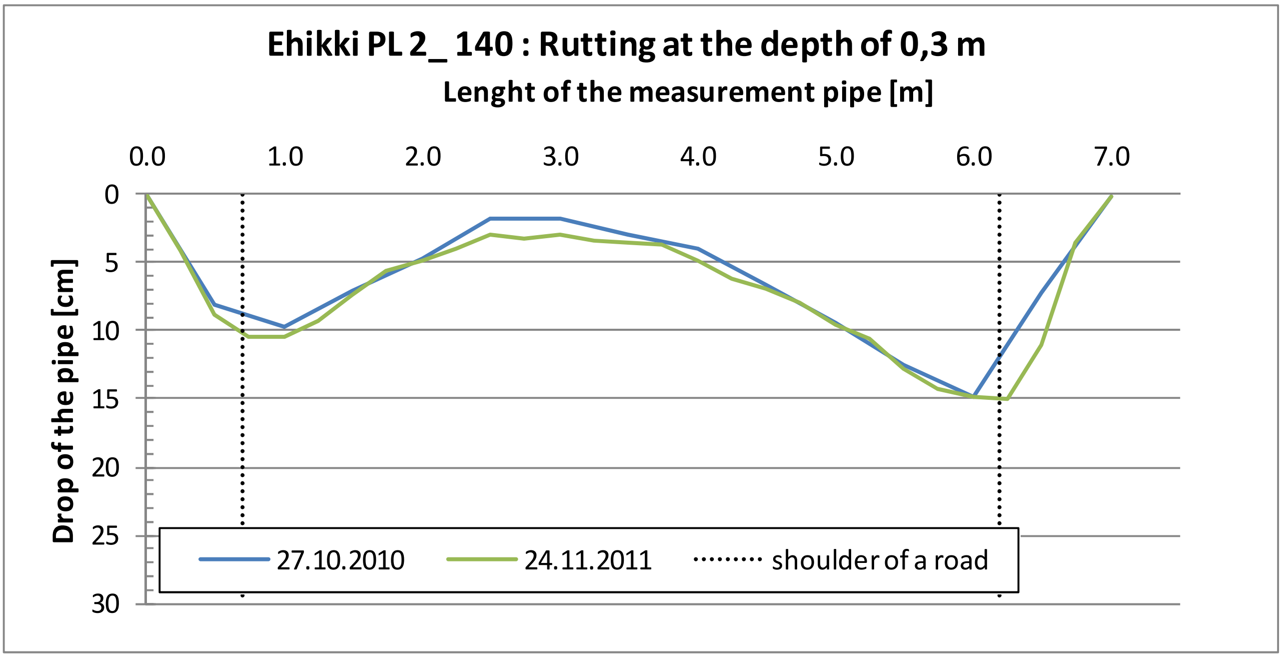

Figure 7.1 *Settlement measurements from chainage 2/140*

All measurements taken of the settlement pipes are shown in Appendix 7 and a few measurement problems were noted. One end of the settlement pipe at chainage 2/215 was most likely badly damaged by a harvester. It might also be that the position of the other ends has changed a little by the incident. It is possible that especially the left side of the road had settlements at chainage 2/215. Rutting may already be observable at chainage 2/185 according to the pictures in Appendix 7, but further measurements will be needed to confirm this.

Figure 7.2 shows the test section after the first spring thaw. The test section was found to be in good condition. 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 condition of the road.

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

7.3. RECOMMENDATIONS FOR FUTURE MONITORING

In the future, it will be very important to monitor the reference and the test section 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. Other critical parameters that should be monitored are weather conditions, temperature and information regarding heavy traffic. The condition of the road will also be dependent on these parameters.

The settlement of the base course can be monitored with the settlement pipes and it should be checked at least once in the year. This will enable the behaviour and development of the relative deformation of the pipe to be sufficiently observed. 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 condition of the road. The situation is the same with the other three settlement pipes.

8. LIFE CYCLE ANALYSIS

The life cycle analyses have been calculated in accordance with the method described in TPPT 20 (Petäjä and Spoof 2001) [7]. 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 an earlier research project focusing on low volume road at TUT.

The calculated construction costs for the reference structure is 30,625 €/km and for the test structure is 34,475 €/km. Prices which were used are: Geotextile 1€/m^2, Secugrid 40/40 1,7€/m^2, base course layer (150 mm) 19,125 €/km and wearing course (50 mm) 6,000€/km.

In addition, both sections of road are expected to require addition of the wearing course every fourth year and dust suppression every second year. The estimated price for the wearing course addition is 1,450 €/km and for the dust suppression is 300 €/km. The discounted prices for renewal period of 20 years for the different structures are:

- Reference structure 36,700 €/km
- Test structure 40,600 €/km

The annual costs for the reference structure and test structure are shown in Figure 8.1. This figure shows that the test structure needs to last 1.5 years longer than the reference structure, assuming 5,000 € annual costs, in order to be as cost-effective as the reference structure. If the test structure lasts longer, it will be more cost-effective than the traditional reference structure, assuming the traditional structure will last only 8 years.

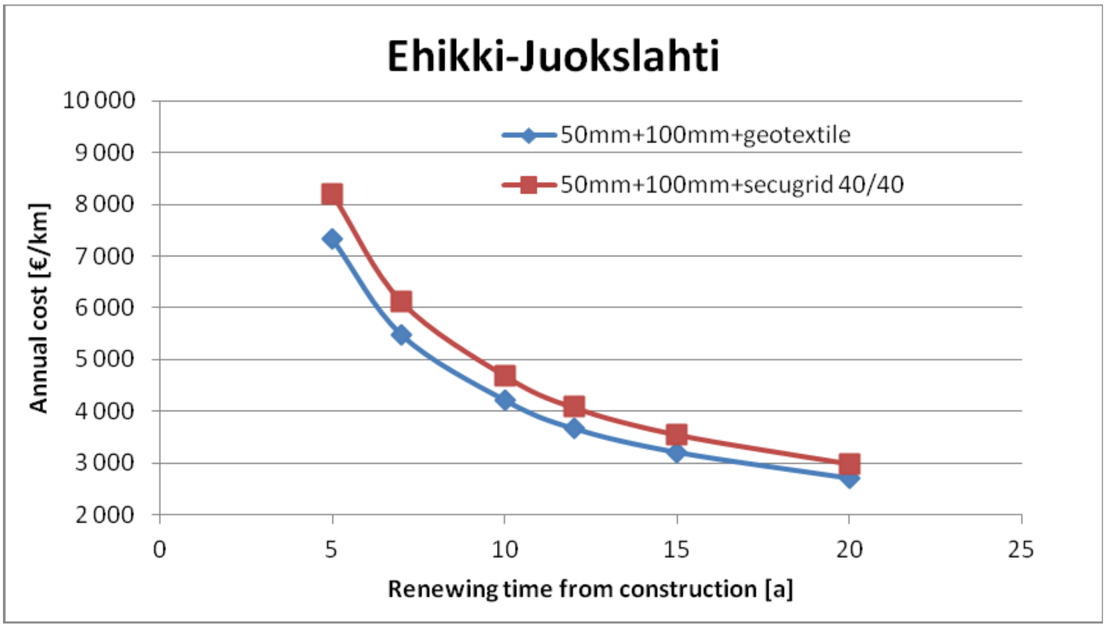

Figure 8.1 *Annual costs for reference structure (blue) and test structure (red)*

9. CONCLUSIONS

This report presents the early results of a demonstration site on which a geogrid reinforcement was used to retard the development of permanent deformations on a low volume gravel road section located on a peat subgrade.

Prior to the works the road had been suffering from deformations primarily taking place in the soft subgrade, resulting in a marked widening of the road cross section. As a consequence of this widening the side ditches had become clogged which had further exposed the road structure to both Mode 1 and Mode 2 rutting phenomena, i.e. rutting modes taking place both in the road structure itself and in the underlying subgrade. According to the GPR profiles the subgrade had also been settling markedly in the middle of the test section which had naturally further worsened the drainage problems on the site.

It was not practical to improve the drainage condition of the site by making the outlet ditch deeper, and the decision was made to rehabilitate the site by reinforcing the road structure with a geogrid. On one half of the test section length, from chainage 02/200 to 02/266, a 150 mm layer of new base course and a 50 mm layer of wearing course were laid on top of a geogrid installed on the old base course layer. A reference structure was built on the other half of the test section length, from chainage 02/100 to 02/200, in an identical fashion to the demonstration section, except that under the new base course layer a geotextile was used instead of the geogrid.

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 the reinforced section, and in the reference structure, to enable later follow up of the development of permanent deformations in the cross-section of the road. Based on these measurements and visible observations after one year of service, it can only be concluded that both sections have performed equally well and that more time is needed to identify any differences. According to the life cycle analyses performed, the section reinforced with geogrid needs to last at least 1.5 years longer to be cost effective in comparison to the reference structure, assuming that the reference structure will have a typical service life of 8 years.

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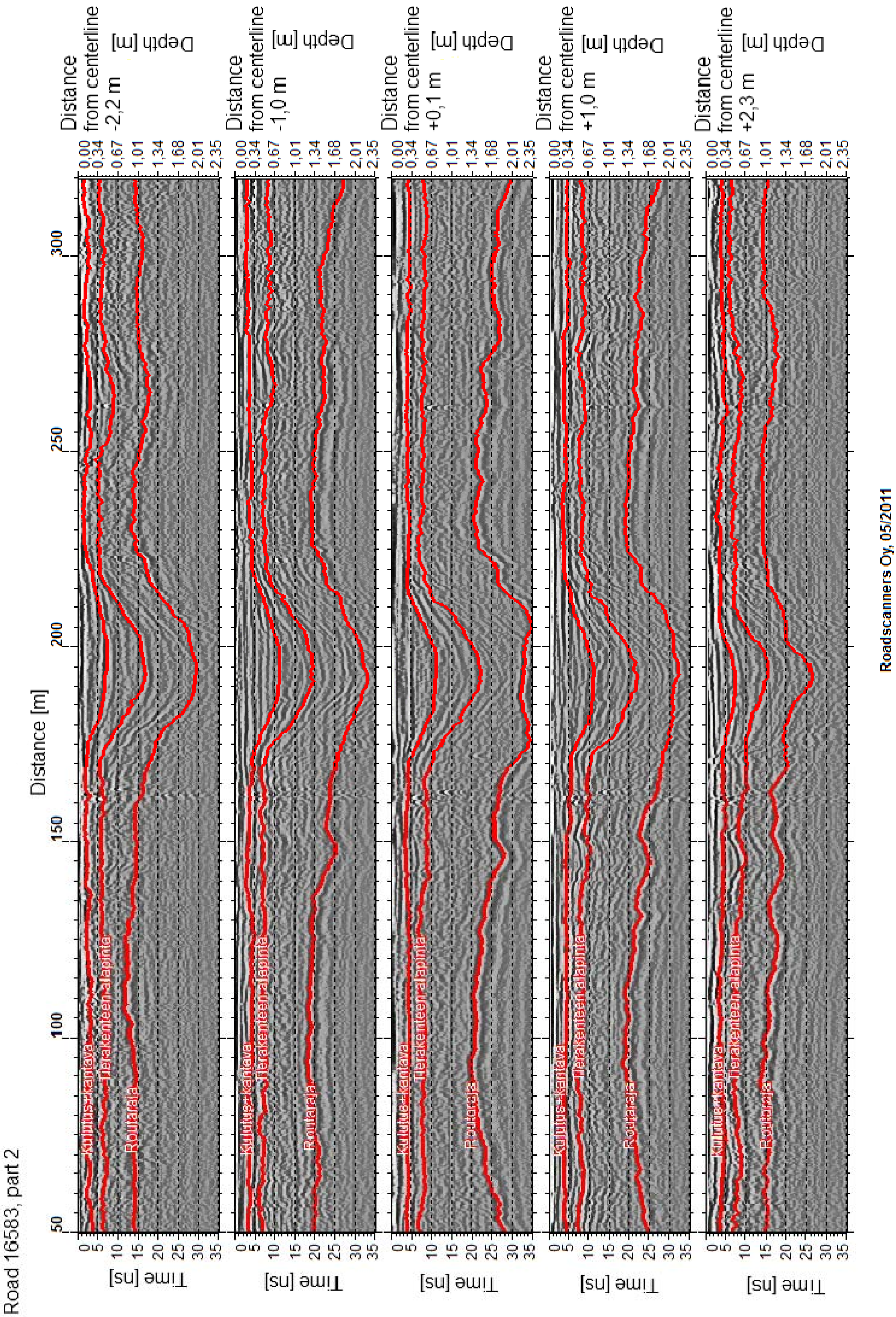
APPENDIX

APPENDIX 1



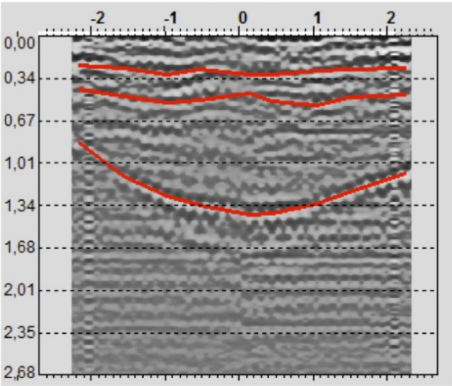
Road 16583, part 2

Highest line:
Wearing and base course

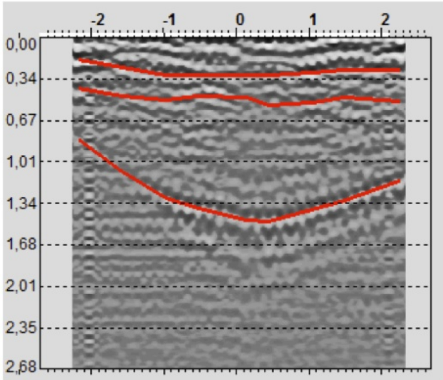
Middle line:
Lowest surface of the road structure

Lowest line:
Frost depth

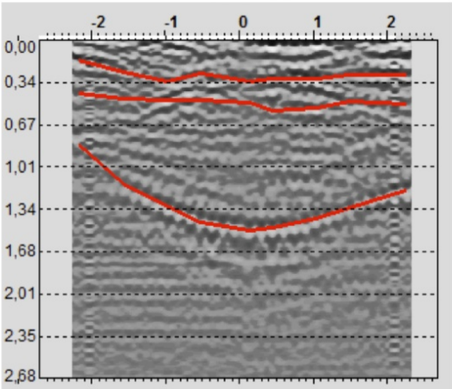
PL 115



PL 120



PL 125



Roadscanners Oy, 05/2011

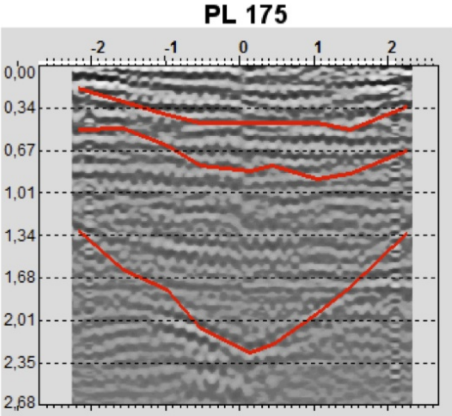
Road 16583, part 2

Highest line:
Wearing and base course

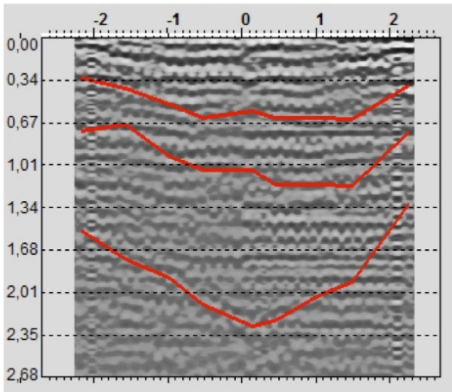
Middle line:
Lowest surface of the road structure

Lowest line:
Frost depth

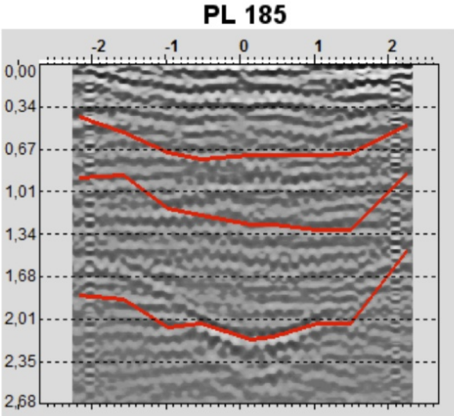
PL 175



PL 180



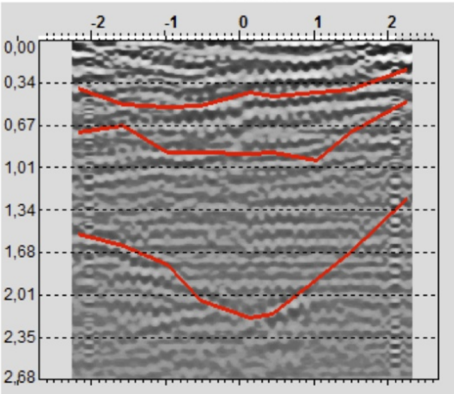
PL 185



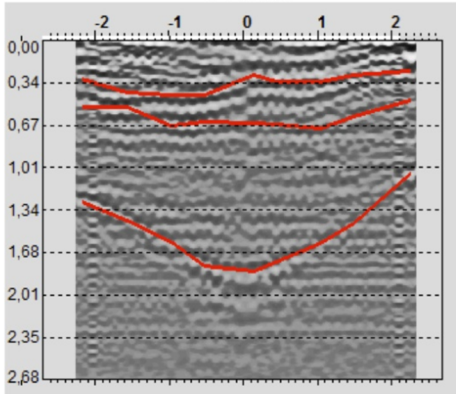
Roadscanners Oy, 05/2011

Road 16583, part 2

PL 210



PL 215

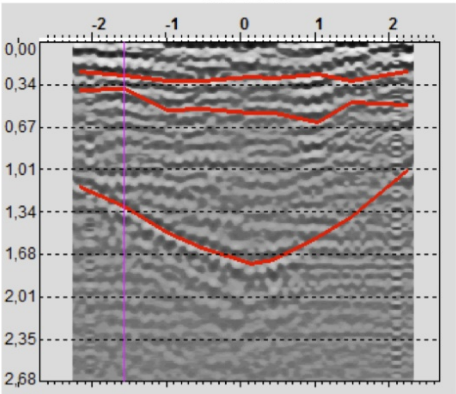


Highest line:
Wearing and base course

Middle line:
Lowest surface of the road structure

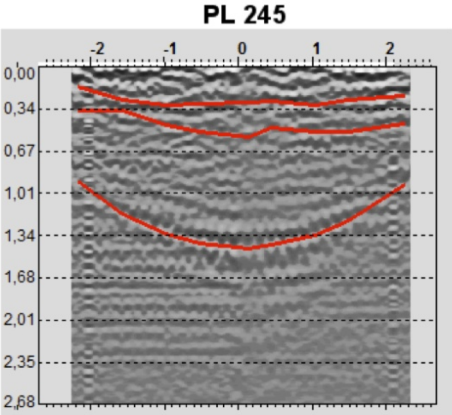
Lowest line:
Frost depth

PL 220



Road 16583, part 2

PL 245



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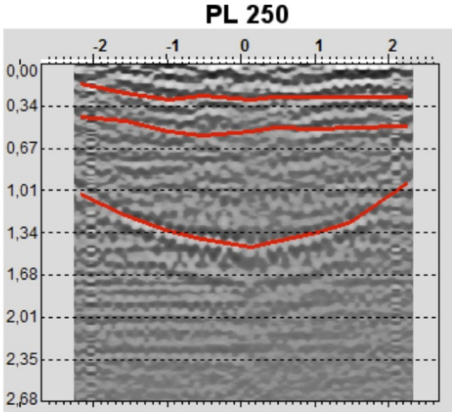
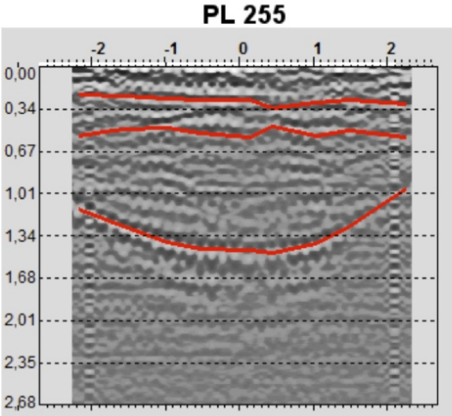


Highest line:
Wearing and base course

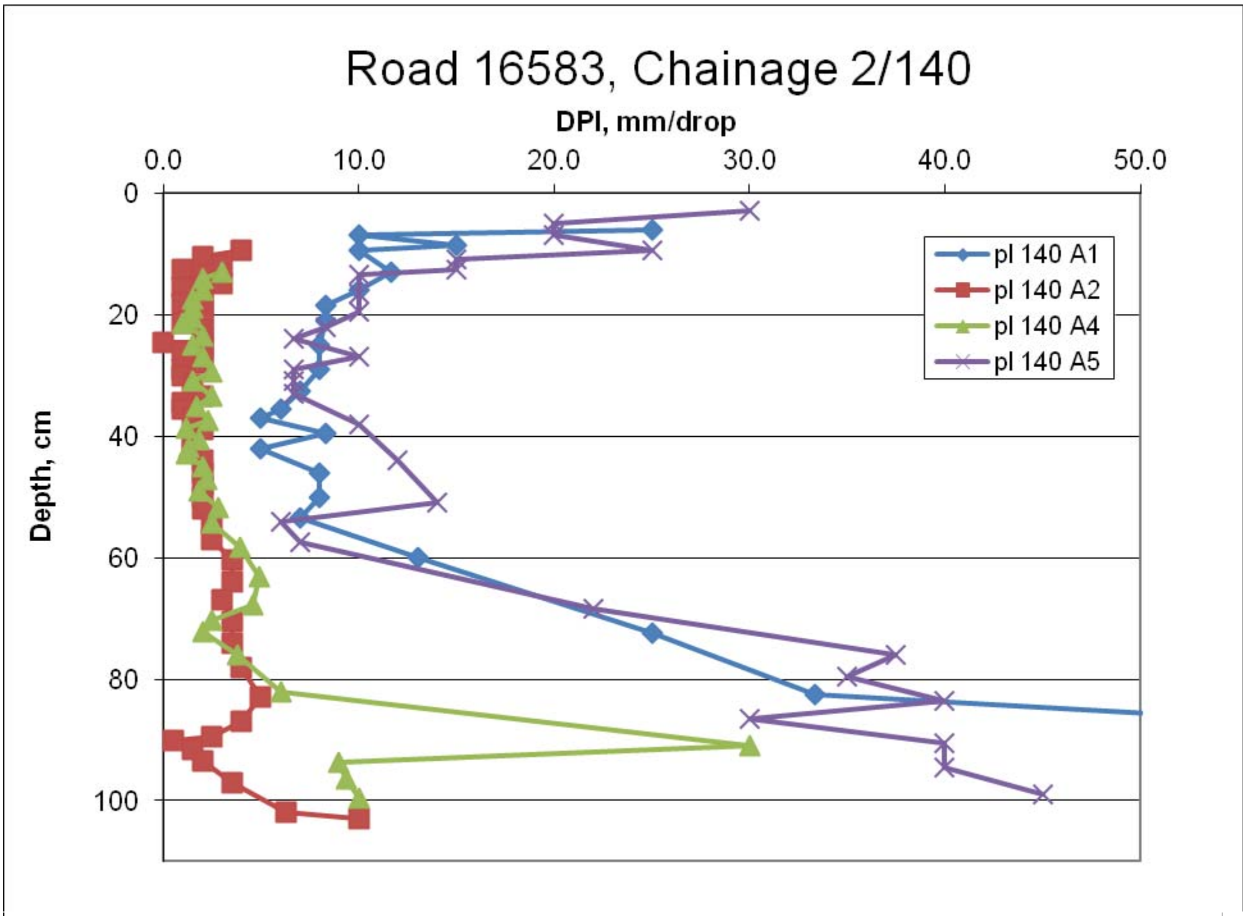
Middle line:
Lowest surface of the road structure

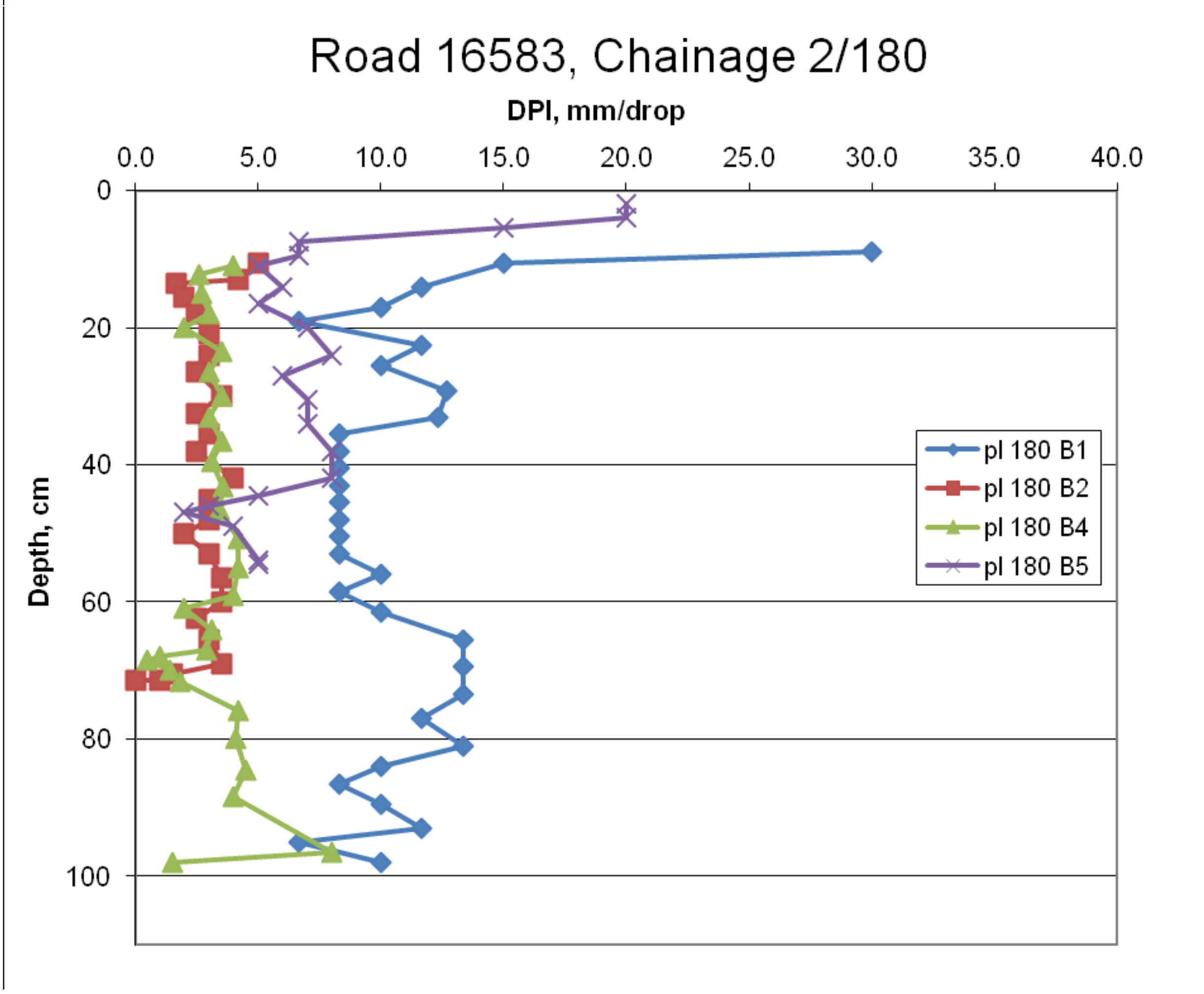
Lowest line:
Frost depth

PL 255



Roadscanners Oy, 05/2011


Road 16583, Chainage 2/140
DPI, mm/drop
0.0
10.0
20.0
30.0
40.0
50.0
Depth, cm
0
20
40
60
80
100
pl 140 A1
pl 140 A2
pl 140 A4
pl 140 A5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DPI, mm/drop
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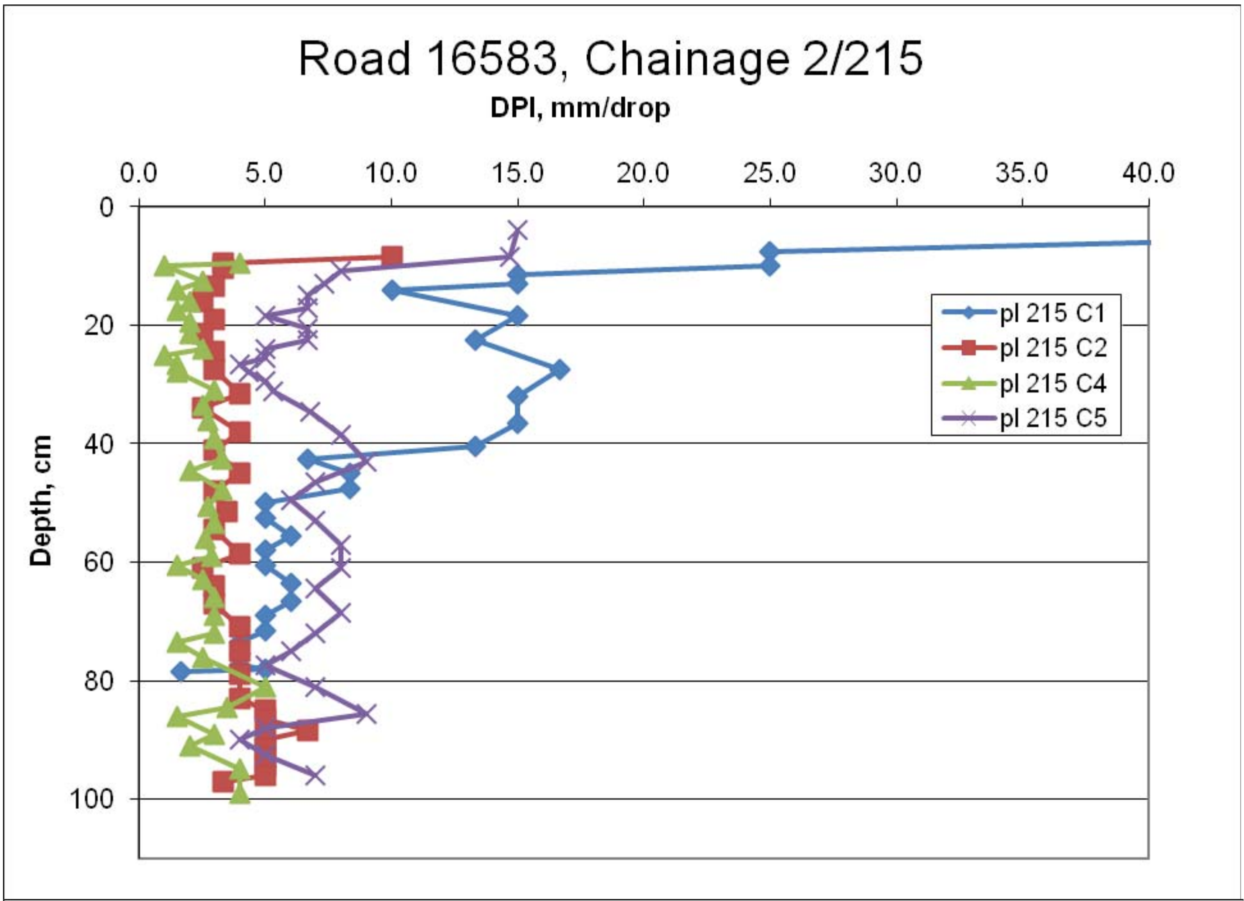
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Depth, cm
0
20
40
60
80
100
pl 180 B1
pl 180 B2
pl 180 B4
pl 180 B5



Road 16583, Chainage 2/215
DPI, mm/drop
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5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Depth, cm
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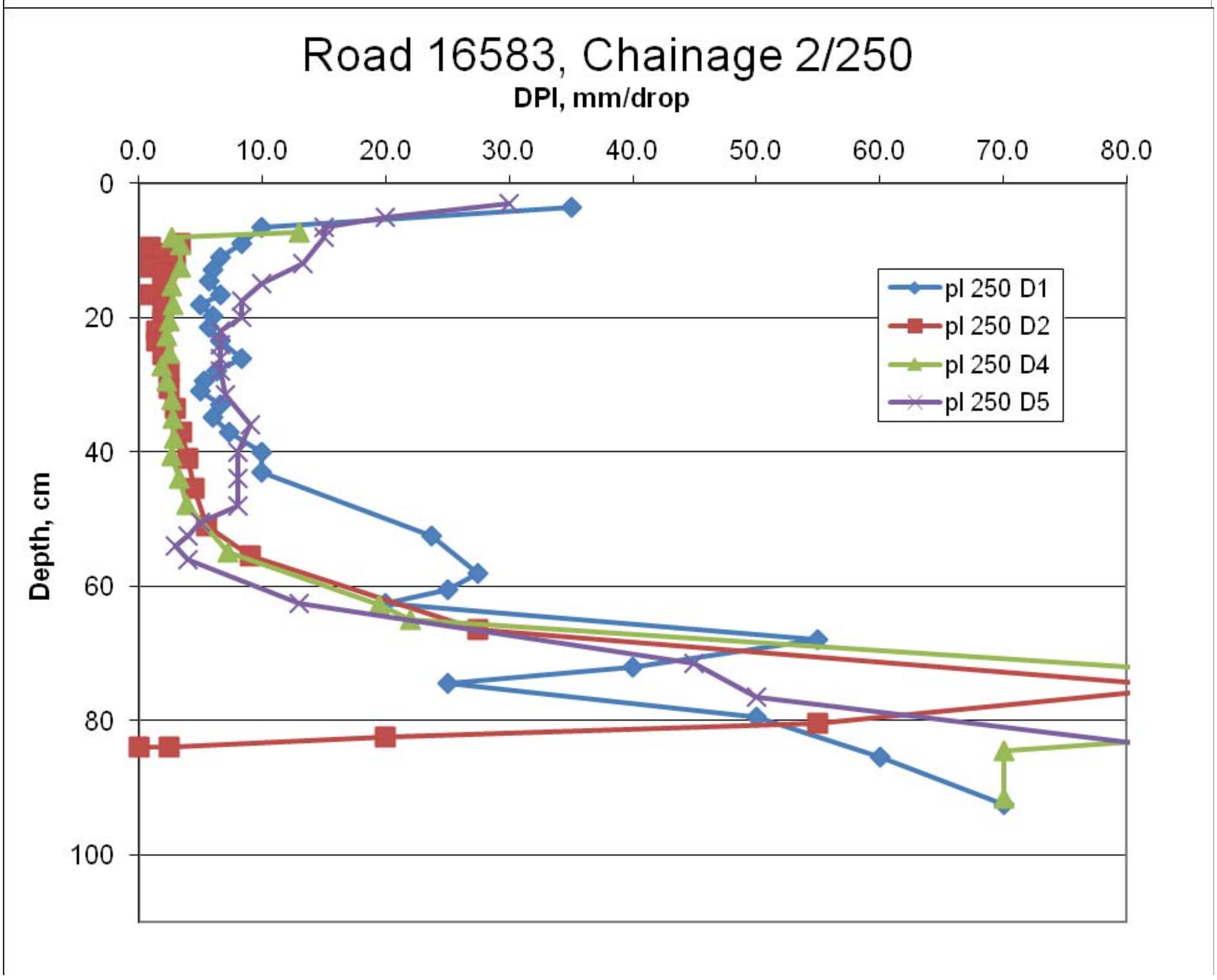
20
40
60
80
100
pl 215 C1
pl 215 C2
pl 215 C4
pl 215 C5



Road 16583, Chainage 2/250
DPI, mm/drop
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Depth, cm
0
20
40
60
80
100
pl 250 D1
pl 250 D2
pl 250 D4
pl 250 D5

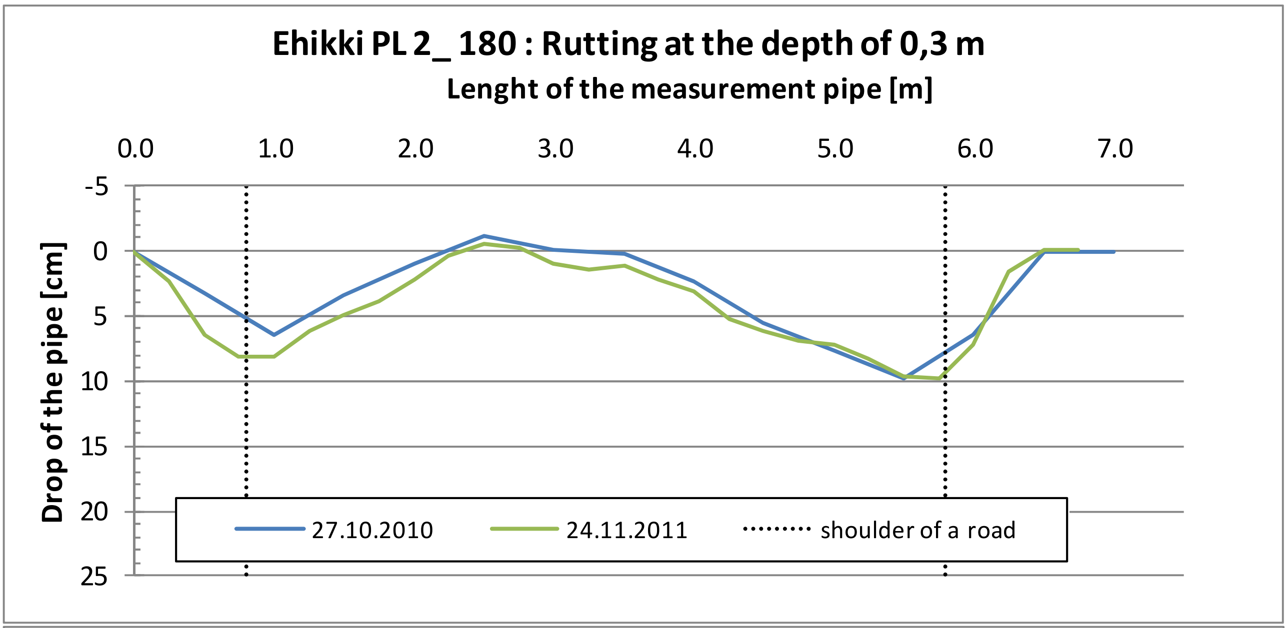
Road 16583 Ehikki-Juokslahti

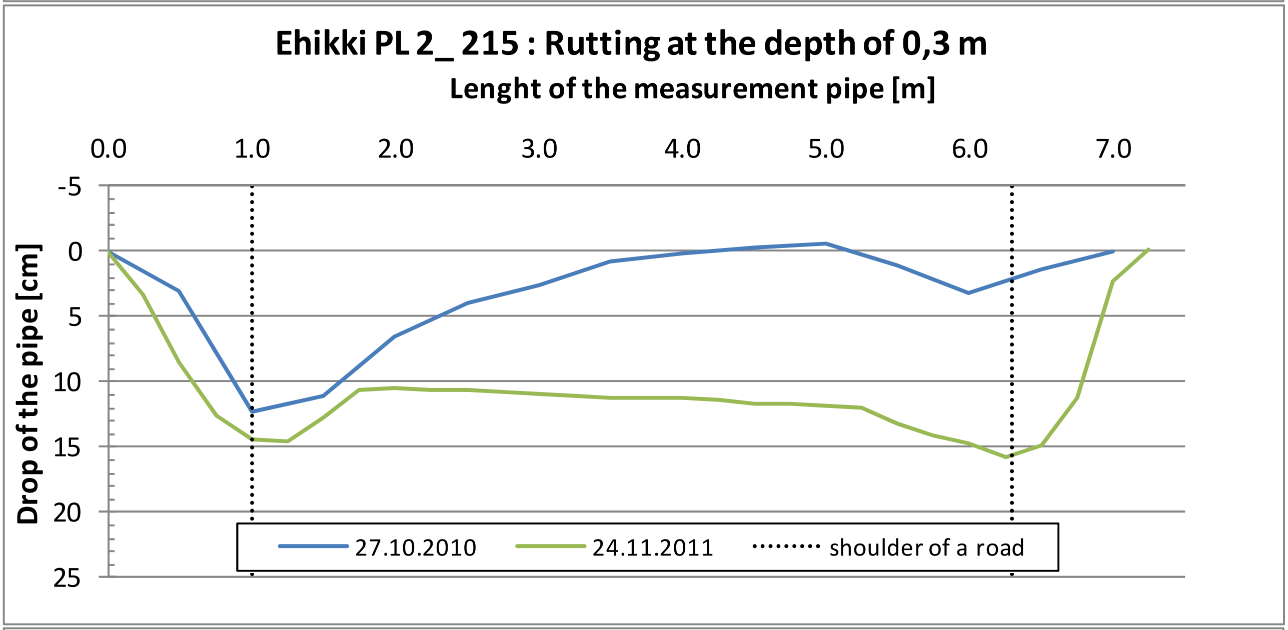
California Bearing Ratio (CBR)
log CBR = 2,46 - 1,12* log DPI

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

	Chainage 2/140			Chainage 2/180			Chainage 2/215			Chainage 2/250		
		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR
Base	A5	0,10-0,60	24	B5	0,06-0,43	34	C5	0,08-0,33	41	D5	0,10-0,50	29
	A4	0,13-0,52	152	B4	0,11-0,67	78	C4	0,10-0,28	153	D4	0,07-0,50	94
	A2	0,10-0,55	163	B2	0,10-0,70	87	C2	0,10-0,83	76	D2	0,08-0,32	146
	A1	0,07-0,60	29	B1	0,09-0,98	22	C1	0,10-0,42	14	D1	0,05-0,44	35
	Chainage 2/140			Chainage 2/180			Chainage 2/215			Chainage 2/250		
		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR
Subbase	A5			B5	0,43-0,55	42	C5	0,33-0,75	31	D5		
	A4	0,52-0,80	65	B4	0,70-0,97	53	C4	0,28-1,0	91	D4		
	A2	0,55-0,95	65	B2			C2	0,83-		D2	0,32-0,52	51
	A1			B1			C1	0,42-0,77	43	D1		
	Chainage 2/140			Chainage 2/180			Chainage 2/215			Chainage 2/250		
		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR		Depth [m]	CBR
Subgrade	A5	0,60-1,0	5	B5			C5			D5	0,58-0,94	2
	A4	0,80-1,0	12	B4			C4			D4	0,50-0,92	3
	A2	0,95-1,05	35	B2			C2			D2	0.53-0,83	4
	A1	0,60-0,90	4	B1			C1			D1	0.44-0.92	4

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


Ehikki PL 2_ 180 : Rutting at the depth of 0,3 m
Lenght of the measurement pipe [m]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Drop of the pipe [cm]
-5
0
5
10
15
20
25
27.10.2010
24.11.2011
shoulder of a road


Ehikki PL 2_ 215 : Rutting at the depth of 0,3 m
Lenght of the measurement pipe [m]
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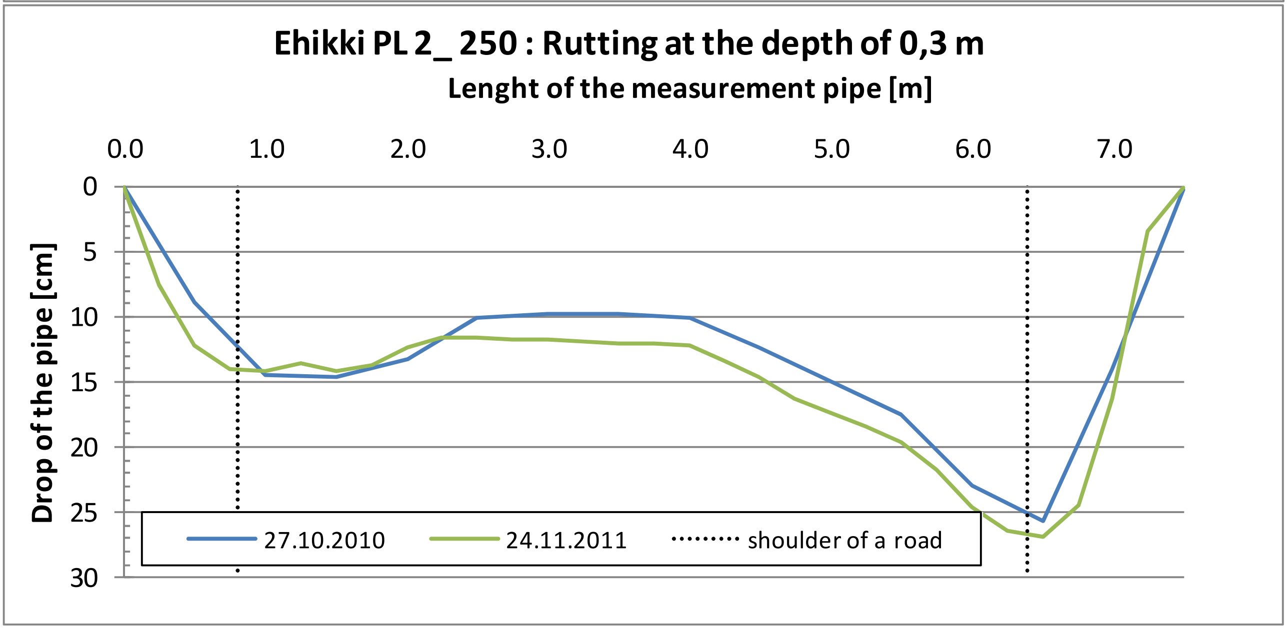
3.0
4.0
5.0
6.0
7.0
Drop of the pipe [cm]
-5
0
5
10
15
20
25
27.10.2010
24.11.2011
shoulder of a road


Ehikki PL 2_ 250 : Rutting at the depth of 0,3 m
Lenght of the measurement pipe [m]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Drop of the pipe [cm]
0
5
10
15
20
25
30
27.10.2010
24.11.2011
shoulder of a road

ROADEX
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- Managing peat related problems on low volume roads
- Managing permanent deformation in low volume roads
- Managing spring thaw weakening on low volume roads
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