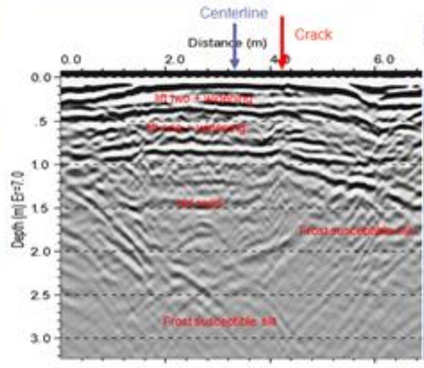

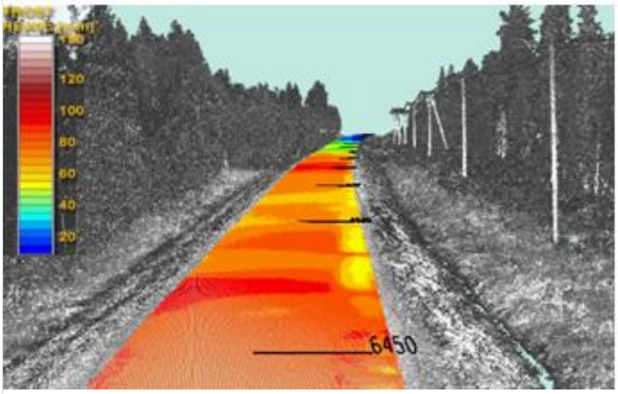

Petri Varin, Timo Saarenketo

ROAD WIDENING GUIDELINES

A ROADEX IV report for Task D2 “Widening of Roads”

PREFACE

This report is a part output of ROADEX IV project task D2 “Widening of Roads”. The project aims to provide practical information on the reasons why road widening fail, the critical parameters that the road engineer needs to know when designing a road widening, and the information on how to repair a widened road that is showing problems. The cost effective widening of roads is a major challenge that all the ROADEX Partners are facing and new design guidelines, specifically tailored to the harsh conditions of the Northern Periphery, are required to meet the demands of modern traffic loads.

The ROADEX road widening research task consisted of three phases. The first part was a literature review on current practices and guidelines for road widening in the ROADEX countries. The report entitled “Road Widening: literature review and questionnaire responses” was written by Samuli Tikkanen from Tampere University of Technology assisted by Timo Saarenketo from Roadscanners, Nuutti Vuorimies and Pauli Kolisoja from Tampere University of Technology and Ron Munro from Munroconsult Ltd. Also Haraldur Sigursteinsson of the Icelandic Road Administration, Per Otto Aursand of the Norwegian Public Roads Administration and Johan Ullberg from Swedish Road Administration provided information on existing road widening guidelines for the report.

The second part of the project dealt with field surveys on selected widening test sites in different ROADEX countries. A range of widened roads were surveyed using multiple technologies such as ground penetrating radar, video, laser scanners, thermal analysis and falling weight deflectometer. Some of the sites were same as in the first ROADEX project 1998 - 2001. The final report summarizing the research results was written by Petri Varin and Timo Saarenketo from Roadscanners.

The third part of the project is this report that provides information that can be used in national guidelines for the widening of low volume roads. The main purpose of this report is to act as a practical ‘pocket book’ and check list on what to keep in mind in road widening projects and repairing problematic widened road sections.

The report was written by Petri Varin and Timo Saarenketo. The language was checked by Ron Munro and Mika Pyhähuhta from Laboratorio Uleåborg designed the layout.

CONTENTS

1. INTRODUCTION

A road widening project is usually commissioned when the existing road width is not adequate for the traffic, or when extra lanes are needed. Road widening can improve traffic safety and capacity.

There are many critical issues in road widening projects and if widening is made poorly, several problems can occur. Many of these problems are common to all ROADEX countries. Typical of these are construction joint cracking between the old and new part of the road, non-uniform settlements between the old and new part of the embankment and stability problems. In colder climate countries frost action causes additional significant problems. Harmful effects however can be avoided by good survey and design. Damages can be avoided or repaired by using techniques such as geo-reinforcement, steel nets, stabilization and soil replacement, and by improving drainage. These methods usually increase construction costs, but they can decrease life cycle costs. Choosing the correct widening, or repair method, and structure is therefore very important in order to avoid additional long term costs.

There are a number of differences between nationally agreed guidelines on road widening across the ROADEX countries. Some of the countries have their own guidelines and some have hardly any at all. Widening instructions for existing roads are partly similar but there are also some differences as designing and construction can be carried out in many ways.

The 2010 ROADEX report “Road Widening: literature review and questionnaire responses” introduced existing national guidelines in the ROADEX countries and compared the differences and the similarities between them. Road widening tests and research reports were also reviewed within the report. One purpose of the report was to study road widening practice in the ROADEX countries. A road widening related questionnaire was formulated and sent to experts in the ROADEX countries in order to collect their experience and knowledge of road widening. Responses to the questionnaire were examined and discussed in the report.

This report provides the ROADEX guidelines for the road widening for low volume roads. It combines many good practices from different partner countries into one package. The main purpose of this report is to act as a practical ‘pocket book’, to be used alongside the national guidelines, on what to keep in mind in road widening projects and repairing widened roads with problems.

2. REASONS FOR ROAD WIDENING FAILURES

There are various reasons for road widening structures to fail. These may include for example construction related faults, climate factors, weak or compressive subgrade or just poor road drainage maintenance. The following chapters present a range of typical road widening failures, the reasons for them and examples of how they can be identified.

2.1. DIFFERENCES BETWEEN OLD AND NEW STRUCTURE IN STRUCTURAL THICKNESS, MATERIAL PROPERTIES AND DEGREE OF COMPACTION

A widening structure should be as similar as possible to the existing part. Typical reasons for road widening to fail are the differences between the old part and the new widened part in structural thickness, material properties and/or degree of compaction. These differences may cause various problems such as differential frost heave, uneven settlements, reflection cracking or different load bearing capacity between the old and the new part of the structure. Figure 2.1.1 presents an example of such a case from road 75 in Finland. The red arrow points to the location of the crack on the GPR cross section. From the cross section it can be observed that there is a discontinuity in the road, and a difference in base course thickness between the old and the new part of the structure, and also in total structure thickness. The photograph also shows that these problems seem to be related to the presence of a private access road junction and ROADEX research has shown that drainage problems with access road culverts can cause consequential problems to the adjacent main road.

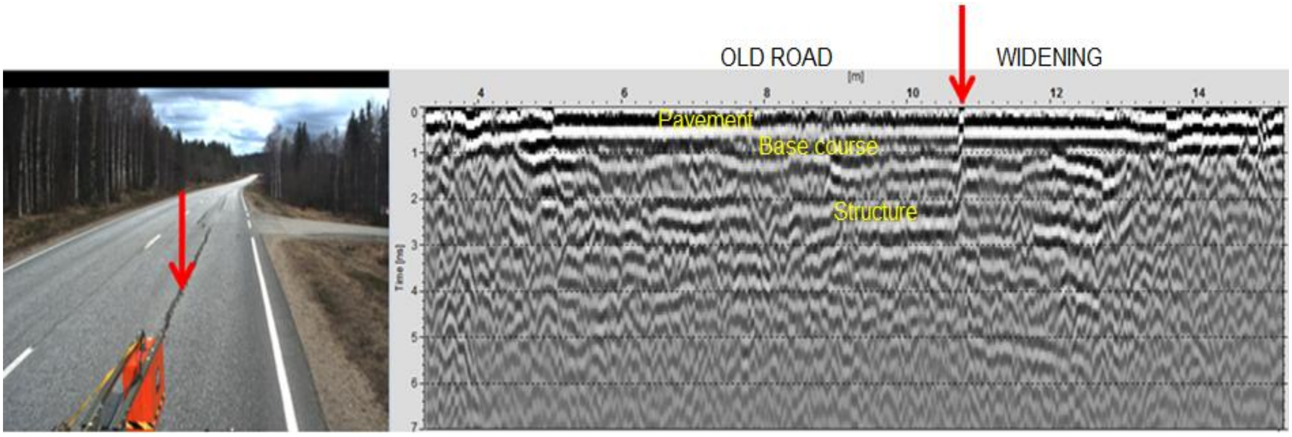

Figure 2.1.1. An example case from Finland showing a discontinuity and thickness difference between the existing road and new widening structure. Private access road drainage problems might have also partly triggered the distress process.

Another special problem in road widening projects is that a stiff layer, mainly the old bituminous pavement, can be left in the pavement structure and the edge of this pavement can cause reflection cracking (see Figure 4.2.3.).

2.2. PROBLEMS WITH JOINT CONSTRUCTION AND LOCATION

Inappropriate joint construction can result in road widening failures. Reflection cracking is likely to take place very rapidly, especially if the construction joint is located under the wheel path. Figure 2.2.1 shows a typical case from a ROADEX test site in Norway. The joint between the old road and the new widening is located close to wheel path. In addition, the structure thickness on the widening side is thinner than on the old road side, and the subgrade beneath is frost susceptible silt. As a consequence, a reflection crack has formed due to traffic loading, settlement and frost action.

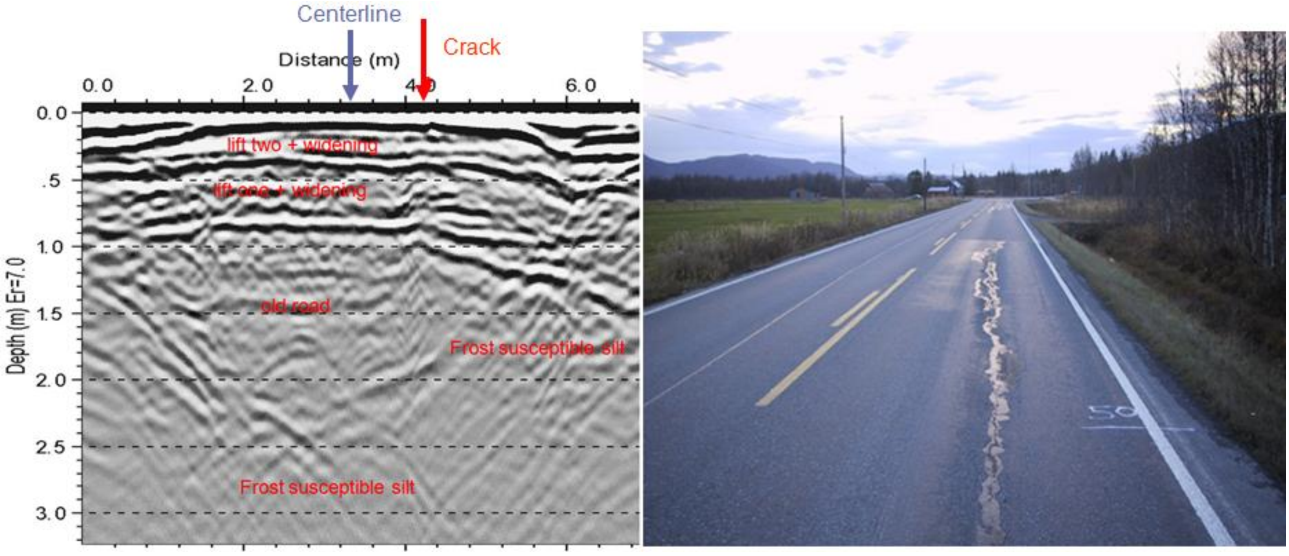

Figure 2.2.1. Reflection crack on the transverse construction joint, an example from Norway.

2.3. SETTLEMENT

Differential settlement between the old and the new part of a widened road is a significant problem that causes failures, especially on peat soils. It is essential that the old embankment and the new structure should settle together. In many cases the construction is made too quickly and not enough time is given for the peat to consolidate under the new part of the road and settle sufficiently before paving. Figure 2.3.1 presents an example case from a ROADEX test site in Norway. It can be seen from the cross section that there is already at least 20 cm of settlement on the right edge of the road. In addition to that, there are again approximately 10 cm deep ruts, so the settlement still continues.

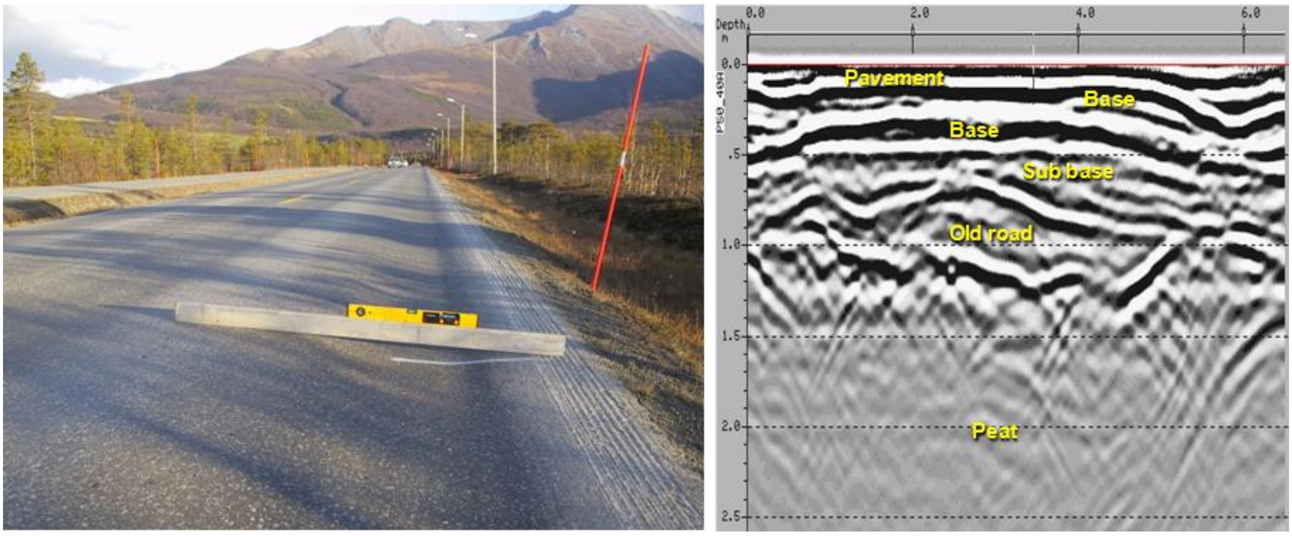

Figure 2.3.1. Settlement of a road shoulder on a widened road resting on peat soil, an example from Norway.

2.4. FROST ACTION AND SPRING THAW WEAKENING

Frost action and spring thaw weakening are major reasons for failures in cold climate areas. The failures caused by frost action or spring thaw weakening very often take place because of differences in structural thickness between the old part and the new part of the road, or in the frost properties of the materials used. This causes differential frost heave behaviour and also decreased bearing capacity during the thawing period. Another major reason for frost damages is poor drainage. Figure 2.4.1 shows an example of severe frost damage related to a widening joint on road 934 in Finland. Figure 2.4.2 shows an example of frost heave data from the road. The road was surveyed with 3D laser scanner mapping in winter and in summer, and the frost heave was obtained as the difference between the measurements. From the figure it can be observed that the frost heave on the widening side of the road is less than that on the old road.

Figure 2.4.1. Differential frost heave between an old and an widened road section on road 934, an example from Finland.

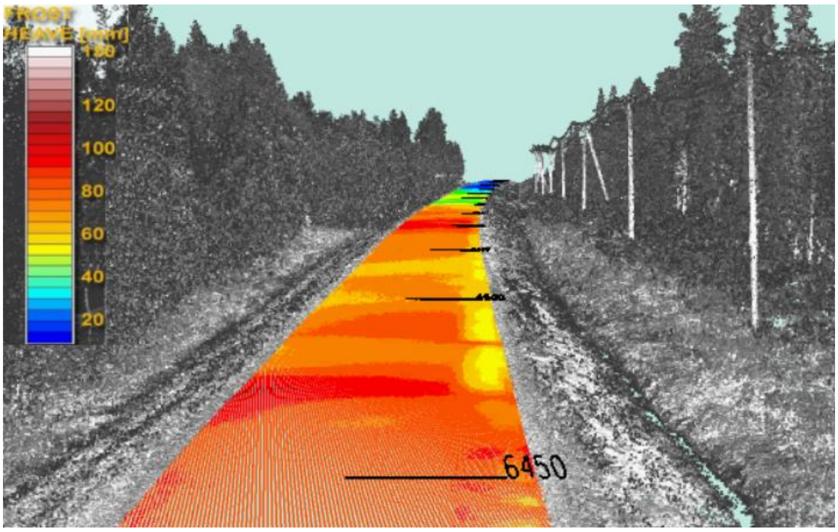

Figure 2.4.2. Differential frost heave on road 934. The frost heave on the widening side of the road is 40-50 mm smaller than the frost heave on the old road.

It is also important to keep in mind that a road could also widen by itself. Spring thaw weakening and Mode 2 rutting causes this unwanted widening, as the soft subgrade soil flows from beneath the road to both sides. Figure 2.4.3 shows an example of such a case. This phenomenon should be kept in mind in widening design, because the shoulder of the existing road may already be thinner and weaker than it should be.

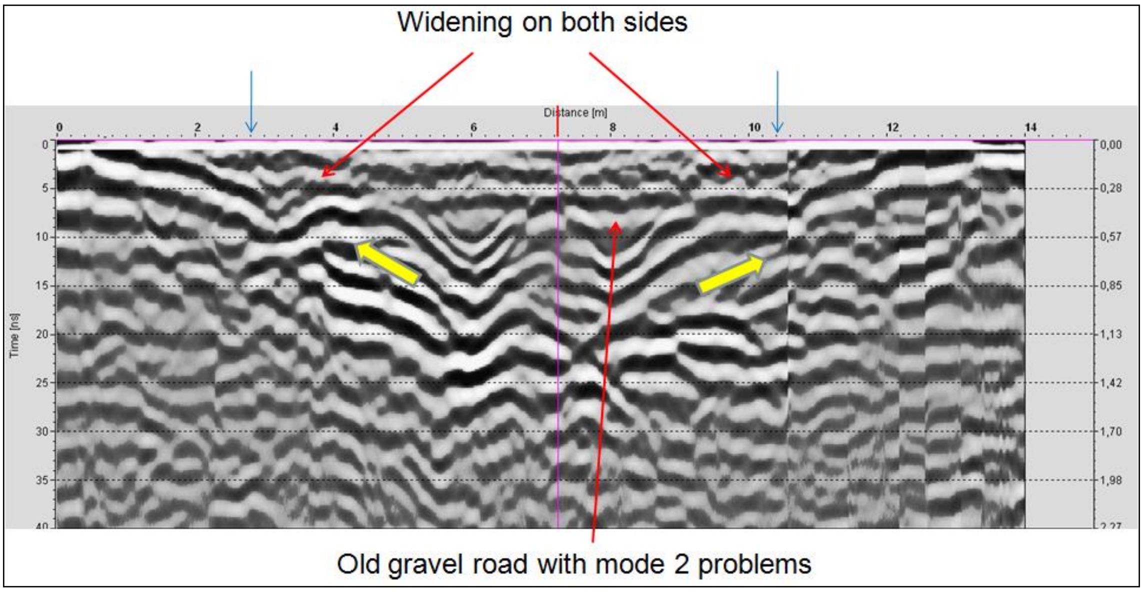

Figure 2.4.3. Soft subgrade soil is flowing from beneath the road to both sides (yellow arrows) causing deformation and unwanted widening of the road. The GPR data also shows that the old gravel road under the widened road is suffering from Mode 2 rutting. The blue arrows indicate the road edges. An example from Sweden.

Figure 2.4.4. Examples of paved roads with widening problems due to Mode 2 rutting, examples from Sweden

2.5. DRAINAGE PROBLEMS

Insufficient drainage can weaken the structure of a road, and in many cases widened roads, even those that are not built in the best way, will not fail until the road drainage system deteriorates. When this happens, the bearing capacity can decrease on the edges of the road where the structure thickness is very often thinner. As a consequence edge deformation can take place. Edge deformation causes ponding of water, which further accelerates the deformation. Figure 2.5.1 presents an example of this form of deformation from Hw 21 in Kilpisjärvi, Finland. In addition to decreasing the bearing capacity, poor drainage is also a major reason for frost problems.

Figure 2.5.1. Poor drainage causing edge deformation in a widened section of Hw 21 in Kilpisjärvi, Finland. Note the standing water in the ditch at the same location as the worst deformation.

2.6. STABILITY PROBLEMS

Widening can lead to steeper side slopes, if the space for the road is limited, and these steepened slopes can quickly have stability problems. When material on a slope flows, it fills the ditches and raises the ground water level leading to deformation and frost problems. The photographs in Figure 2.6.1 show examples of outer slope stability problems. The left photograph shows edge deformation and differential frost heave problems, and the photograph on the right shows a road that will face the same problems if urgent repairs are not carried out.

Figure 2.6.1. Poor outer slope stability causing problems for road performance, examples from Sweden.

Figure 2.6.2 gives an example of inner slope instability. In this case it appears that the compaction of the widened road section has been poor due to the steep inner slope and a shear failure has happened later as a result. The situation has been made worse by poor drainage. As a consequence severe edge deformation has taken place.

Figure 2.6.2. Edge deformation caused by a steep inner slope combined with poor drainage, an example from Norway.

2.7. CROSSFALL PROBLEMS

General practice in the Northern Periphery is to design the structures based on the centerline thickness. This means that the thickness of the structure in the inner curve is very often less than the thickness on the centerline (Figure 2.7.1). If the widening is made on the inner curve side, the bearing capacity of the widened structure may be too low and the road more exposed to frost heave. This can be a reason for pavement failures. Additionally, the development of failures may be accelerated by heavy vehicles that cut across corners and drive very close to the pavement edge. Figure 2.7.2 presents an example case from Finland, where the frost heave of the road has been measured with a 3D laser scanner. It can be clearly seen in this case that there is higher frost heave in the inner curve because of the thinner structure thickness.

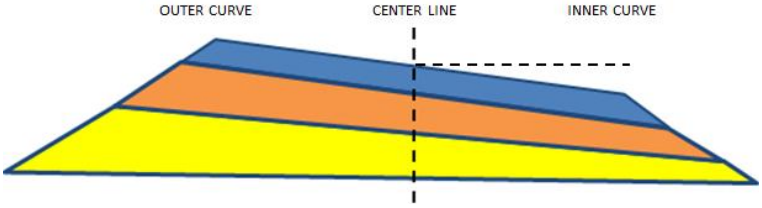

Figure 2.7.1. Thinner structure in inner curve

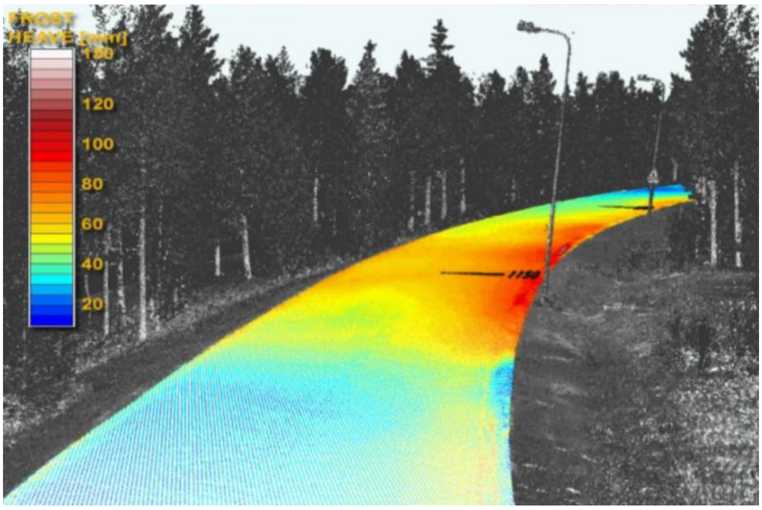

Figure 2.7.2. Higher frost heave in the inner curve due to a thinner structure thickness, an example from Finland.

3. PRE-DESIGN SURVEYS OF THE ROAD TO BE WIDENED OR REPAIRED

3.1. GENERAL

Carefully performed surveys and measurements are essential before the design of a road widening can be started. These should identify the actual conditions on the site such as the thickness of the old road structural layers, material properties of the subgrade, the layer materials used in the old embankment, road shape and its surroundings, problem areas and damages on the existing road, drainage condition, etc.

Traditionally the most important pre-design survey has been the designer site visit. This method is very dependent on the experience and the subjective opinion of the actual designer involved. This person however cannot see the structures and small local deformations that can be identified with modern road surveys technologies. For this reason ROADEX recommends that physical measurements should always be performed ahead of the design stage, as they give much more exact and more objective information on the existing conditions concerning the road. In this regard it is particularly important to find out the underlying reasons for failures when designing the repair of a widened road. Each case needs to be determined individually, but usually at least GPR measurements (longitudinal lines and cross sections), video recording, laser scanner measurement and drainage analysis should always be done.

The following sections summarize the different survey techniques that can, and should, be used in road widening projects, or when repairing or strengthening a widened road. All of the techniques are discussed and explained elsewhere in greater detail, and they can also be viewed in the ROADEX E-Learning package on the ROADEX website at www.roadex.org.

3.2. GPR SURVEYS

Ground Penetrating Radar (GPR) data collection and analysis is one of the most useful survey techniques available. It provides continuous information on the thicknesses and the quality of the existing road structural layers, so that the widening structure can be designed to be as similar to it as possible. The GPR measurements should be done in 3D by means of several parallel longitudinal profiles and some cross sections are also recommended (Figure 3.2.1). When designing the repair of a widened road, longitudinal GPR profiles should be measured both on the existing road side and on the widening side. This provides information on the possible differences in layer thicknesses and/or material properties that may have caused the failure. An example of the usefulness of GPR data in road widening diagnostics is shown in Figure 3.2.2.

A GPR survey can also provide useful information on other kinds of failure reasons. From the GPR data, especially from cross sections, the rutting mode can be determined. Mode 0 rutting takes place due to the compaction of the road structure. Mode 1 rutting happens in granular structural materials near to the pavement surface. Mode 2 is rutting that takes place at the road structure – subgrade interface. Mode 3 rutting, otherwise known as pavement abrasion, takes place due to tyre wear on the pavement of a paved road, or the wearing course of a gravel road. Information on the underlying reasons for rutting on the existing road helps in selecting the correct widening or repairing method. Figure 3.2.3 gives a diagrammatic summary of the ROADEX rutting classifications.

Figure 3.2.1. Cross section measurement with GPR provides excellent information about the road structures in the transverse direction.

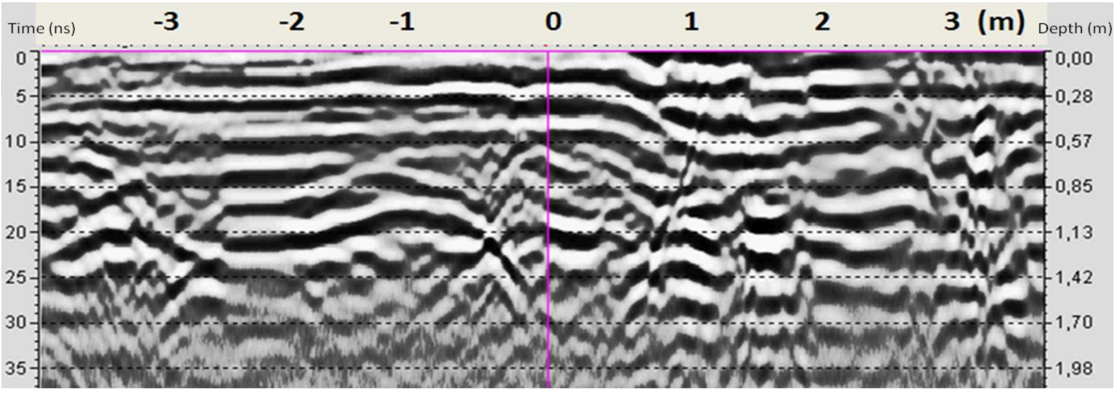

Figure 3.2.2. GPR cross section of a widened section of the N59 road in Ireland. This shows that road has been widened to the right side and that the structures on the widened side are totally different than those in the old road.

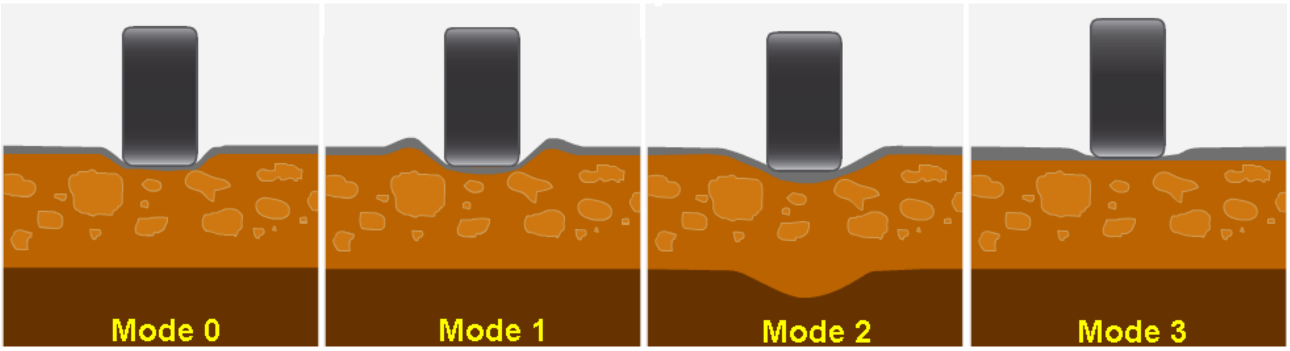

Figure 3.2.3. The ROADEX rutting classifications

Old structures below or inside the existing road structure can also be located with the help of GPR. These old structures may include for example an old gravel road below the existing structural layers, old reinforcement, old pavement layers inside the structure, etc.

3.3. DRILLING, SAMPLING AND LABORATORY ANALYSIS

Drill cores, sampling and laboratory analyses provide important information on the properties of the existing road and the subgrade. Sampling and drilling together with GPR measurements can be particularly useful. The structural layer thicknesses interpreted from GPR data can be verified and calibrated with excavation test pits and drill cores. However, drilling and sampling is expensive and it is not normally cost effective to take many samples. ROADEX recommends that the GPR survey should be done first and the locations of any test pits and sample points thereafter chosen on the basis of the GPR data. Figure 3.3.1 shows an example of drilling equipment used in Finland.

Another thing that one should be aware of is that there are increasing numbers of cables, pipelines and other utilities located under modern roads, shoulders and slopes. These should be mapped carefully before drilling or excavation is commenced in order to prevent damages.

Figure 3.3.1. Drilling a sample of the top part of the pavement structure

It is essential that the material properties of the existing road layers and the subgrade soils should be identified before any widening is carried out. Typically laboratory analyses can determine factors such as soil type, moisture susceptibility, frost properties and settlement properties. The most common material property determinations performed are grain size distribution, organic content and water content. In many cases these tests are already enough to characterize the material and to make sure that the corresponding material used to widen an existing structure is as similar to it as possible.

Tests to verify if the material is moisture susceptible are also important. These include three determinations; dielectric value and electrical conductivity (both obtained from the Tube Suction test), specific surface area and water adsorption index. With these tests materials can be confirmed as being suitable for the work, e.g. for a base course layer.

Special tests such as the Proctor test to evaluate the compaction properties, frost heave test and chlorides content can also be made, if the previous laboratory tests indicate that the material is moisture susceptible and that material treatment with stabilization agents is possible. In addition, there is a further special test method that is often used to obtain the material parameters required for strengthening design, and that is the triaxial test. The triaxial test is a useful test for determining the strength parameters of road materials, such as cohesion and angle of friction, that are needed for the ROADEX design approach against Mode 1 and Mode 2 rutting.

3.4. FALLING WEIGHT DEFLECTOMETER SURVEYS

The Falling Weight Deflectometer (FWD) is an automated stationary impulse load method used to measure deflections in the road surface, which can then be used in calculating the bearing capacity of the road (Figure 3.4.1). Using FWD measurements the elastic modulus value of each structural layer and the subgrade can be backcalculated, and the moduli can then be used for calculating the bearing capacity of the existing road and for the widening design. Besides bearing capacity measurement, the FWD can be used for many purposes, for example the investigation of reinforcement requirements, identifying weak spots of the road, establishing priorities for road strengthening, and monitoring the strength of layers during construction.

Figure 3.4.1. Falling Weight Deflectometer (FWD)

Figure 3.4.2 presents an example section of data from road 75 in Nurmes, Finland. The interpreted structure thicknesses are shown in the top window. The next three windows display the FWD deflections from the centre (between wheel paths) and both edges of the road. Finally, the bearing capacities calculated from each of the FWD data sets are presented in the bottom window. The black line represents the bearing capacity on the centre of the road, the red line represents the left edge and blue line represents the right edge. In this case the road edges are not significantly weaker than the road centre. The centre bearing capacity values are only slightly higher at a few locations.

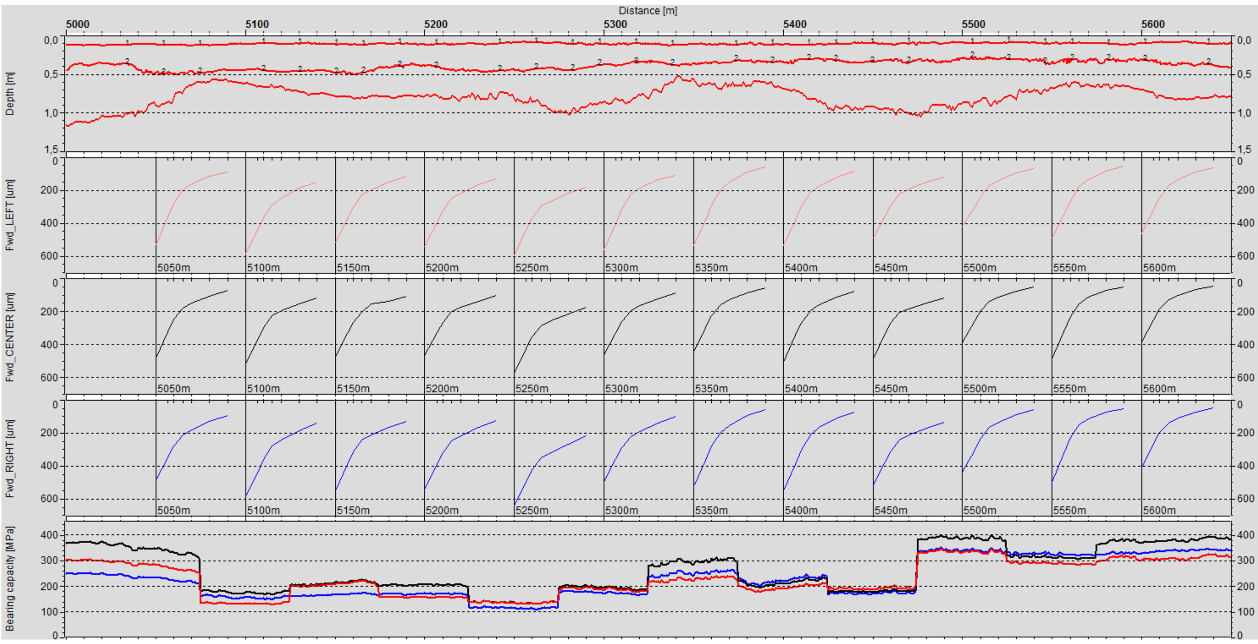

Figure 3.4.2. Interpreted structures, FWD deflections from the centre and both edges of the road, and the calculated bearing capacities

3.5. DIGITAL VIDEOS AND PAVEMENT DISTRESS ANALYSIS

Modern digital photo and video techniques provide very useful tools for documenting a road, its surroundings and pavement damages (Figure 3.5.1). Visual recording is vital for the correct diagnosis of problems on the existing road. Visiting, evaluating and documenting the actual site helps in locating problems and classifying the topography in the area. A good visual documentation can also help external experts to become familiar with the specific problems at each location, even though they have not visited the site. Video recording gives a continuous record of the road. It can detect road surface condition, pavement distress, road markings, traffic signs etc. It can also be a very useful aid in surveying the topography of the road and its surroundings. A video recording and pavement distress analysis can also give information on any problematic sections on the existing road, so that they can be repaired during the widening or taken into account in the widening design. A video recording of the road and ditches with an audio commentary is also an easy way to gather basic information for a drainage analysis. Video can be also used in the procurement process. It can help in comparing the road condition and surroundings before and after rehabilitation. Video recording can be carried out simultaneously with other surveys, e.g. GPR measurements, and all data files can be linked together.

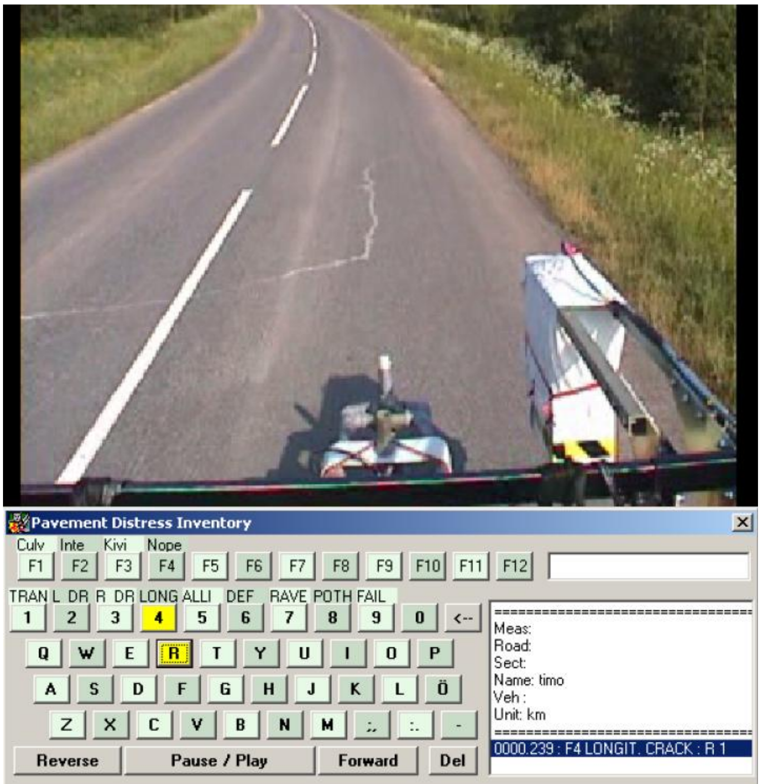

Figure 3.5.1. Digital video recording and pavement distress analysis

3.6. LASER SCANNING

Mobile laser scanning (or Lidar) makes it possible to make an accurate 3D surface image, a “point cloud”, of a road and its surroundings. The point cloud can have millions of points, with every point having x, y & z coordinates and additional reflection or emission characteristics. Two examples of typical laser scanner survey vehicles are shown in Figure 3.6.1.

Figure 3.6.1. Everyman´s RDLS Laser scanner survey vehicle (left) and a high precision Quantum 3D laser scanner survey vehicle (right) used in ROADEX surveys

The laser scanner technique can be used in many applications in road widening design. It provides a continuous cross section profile of the road. From this data such as the angle of side slopes can be obtained, which can help in evaluating the steepening of slopes due to widening. Other useful parameters such as road width and ditch depth can also be obtained from laser scanner surveys. Figure 3.6.2 gives an example from Hw 9 in Finland that shows the height and cross section information from a laser scanner survey before and after road widening.

With high precision 3D laser scanner surveys the frost heave and deformation behaviour of the road can also be mapped (Figure 3.6.3). A combination of laser scanner data together with other road survey data can provide an excellent basis for analysis of the reasons for the failures of the existing road.

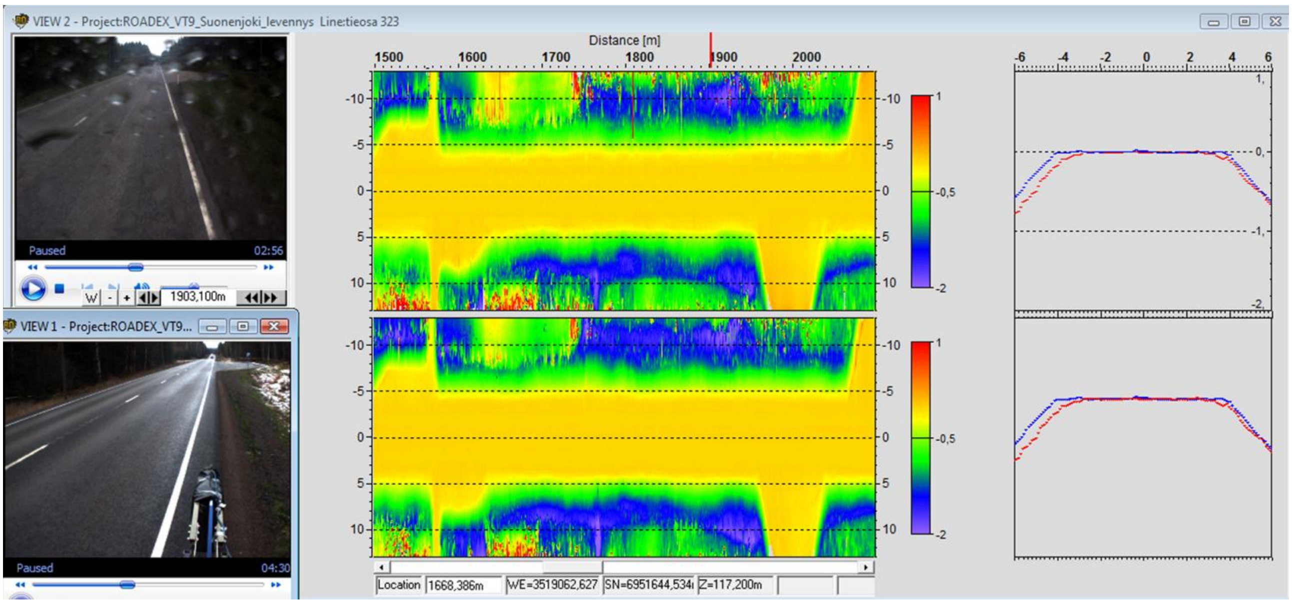

Figure 3.6.2. An example from Hw 9, Finland showing height and cross section information from a laser scanner survey before (above) and after (below) road widening

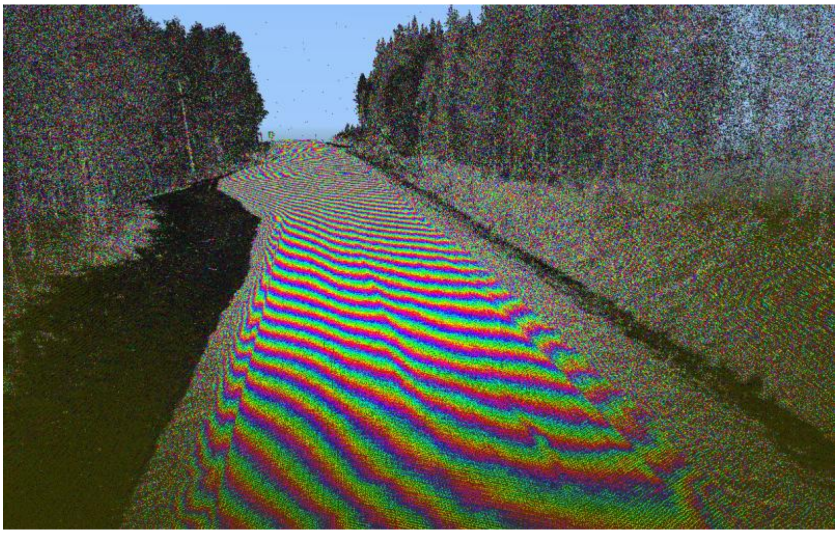

Figure 3.6.3. An example of a rainbow map obtained from a Quantum 3D laser scanner survey of road 934 in Finland. The frost heave and deformation behaviour on both shoulders is different from on the rest of the road. The step in the rainbow map represents a 50 mm change in height.

3.7. DRAINAGE ANALYSIS

Permanent deformation hardly ever exists in a road if the road structure and the subgrade soils are kept free of excess water. Results from the ROADEX project clearly show that keeping the road drainage system in a good condition is the most profitable maintenance action that can be carried out, especially on low volume roads. This rule applies to road widening cases as well. When the drainage is in a good condition, failures are much less likely to take place. The key to keeping the drainage working is an effective monitoring system. A drainage evaluation can identify any problematic drainage sections and define the need for any improvement actions. A good drainage monitoring and improvement strategy can be divided into three phases:

Phase 1. mapping the road sections suffering from inadequate drainage
Phase 2. making a basic diagnosis of the drainage problem sites
Phase 3. defining solutions for the problem sites

An example of a drainage analysis survey vehicle as used in ROADEX surveys is shown in Figure 3.7.1. An example of drainage analysis data from Ireland is given in Figure 3.7.2.

Figure 3.7.1. Digital cameras and GPS are normally placed on the roof of the survey vehicle for drainage analysis. Vehicle used in the Highland region of Scotland.

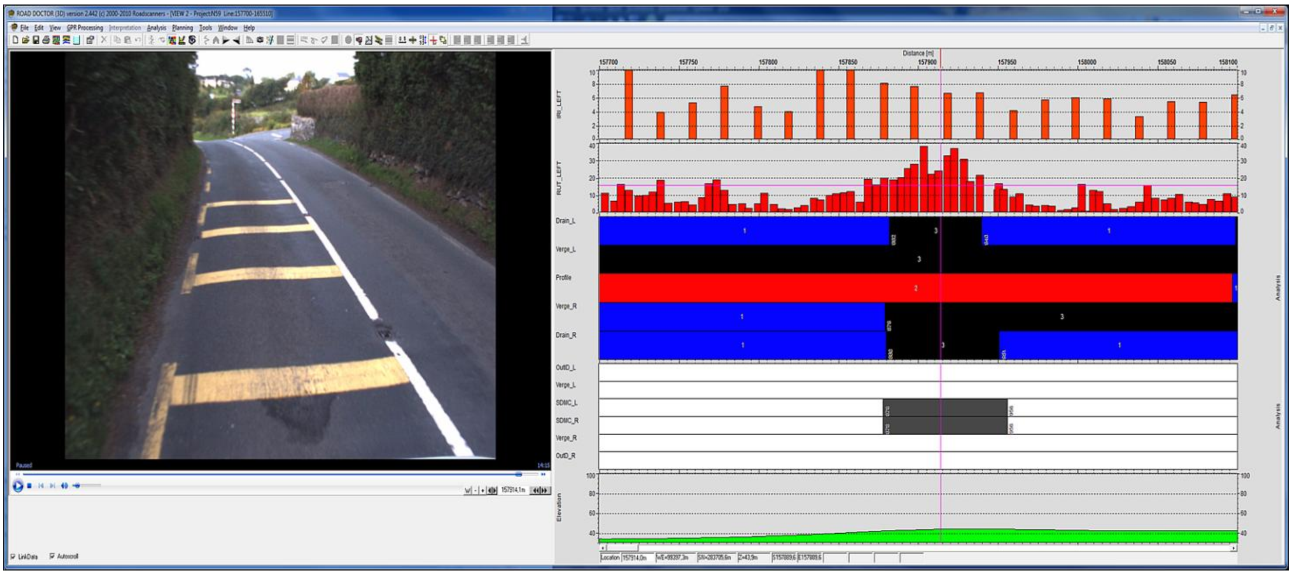

Figure 3.7.2. An example of drainage analysis results from Ireland. The top field on the right shows the rut depths and the second field the annual rut increase. The centre field presents the drainage analysis results and beneath that the sections needing improvements. The lowest green field presents the road surface level (z-coordinate).

3.8. PROFILOMETER DATA ANALYSIS

A laser profilometer is a device that is used to measure roughness and rutting on paved roads. It can also measure the crossfall of the road. Figure 3.8.1 shows an example of a survey van equipped with a laser profilometer. A history created from profilometer surveys can provide valuable information on the existing structure, such as rut depth, rut increase rate and the IRI values. This information can help to locate problematic sections on the existing road that need to be upgraded during the widening works. Profilometer data can also provide very useful additional information in support of a drainage analysis (see Figure 3.7.2). The downside of a standard road profilometer survey is that it does not provide information on the road shoulders and side ditches.

Figure 3.8.1. Survey van equipped with laser profilometer for roughness and rutting measurement

4. WIDENING AND REPAIRING DESIGN

4.1. TOPOGRAPHY, GEOMETRY AND CROSSFALL

The topography of the existing road, its geometry and crossfall, should always be taken into account when designing the widening structure. The widening of a road with limited space can result in steeper side slopes (Figure 4.1.1). In most cases where space is not a problem, e.g. on low-volume forest roads, the best way is to create more space is by felling trees adjacent to the road. On sites where space is limited steeper side slopes may be possible in the widening using reinforcement and/or retaining walls. . It will also be important to keep in mind that the old ditch will need to be backfilled with material equal to the surrounding subgrade, such as excavated material from the new ditch. The choice of the most suitable type of drainage system will also be a major consideration for sites with limited space.

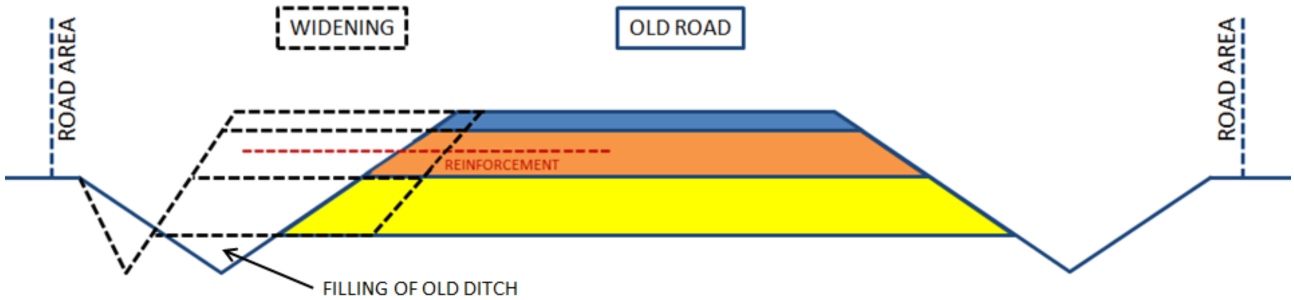

Figure 4.1.1. Widening can lead to steeper side slopes, if the space for the road is limited.

In many cases it will be beneficial to upgrade the horizontal geometry of the existing road during at the time of widening (Figure 4.1.2). It should be borne in mind however that the improvement of sharp curves on the old road can lead to diagonal construction joints between the new and the old structure. These may present problems if special attention is not paid to joint construction. However the improvement of the old road at the same time as the widening, e.g. by adding aggregate, is a good practice that can decrease the impact of traffic loading and frost action. Further, the risk of failures can also be diminished.

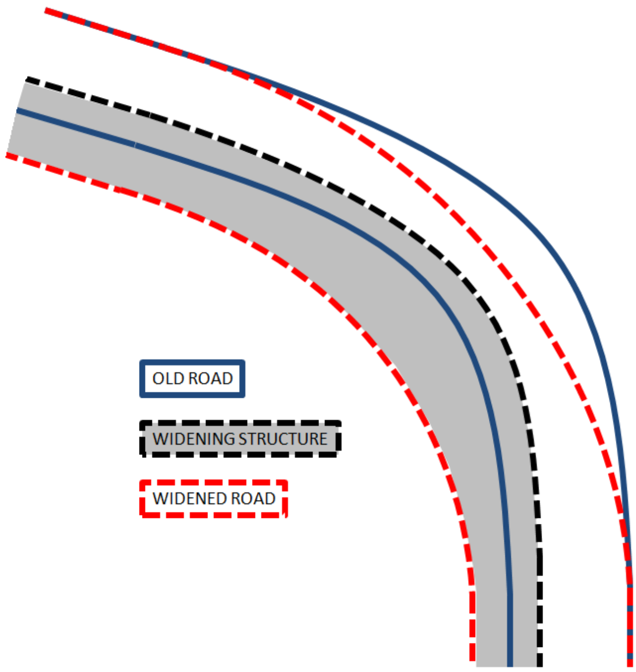

Figure 4.1.2. Diagram showing the upgrading the horizontal geometry of an existing road during a widening exercise

Careful attention should be paid to the design and construction of inner curves during a widening exercise. The general practice in the Northern Periphery is to dimension road structures based on the centreline thickness, but this can result in the thickness of the structure in inner curves being less than the centreline. Because of this widening on the inner curve side can have a higher risk for failures than widening on the outer curve side (Figure 4.1.3). Widening in the inner curve side is recommended however as the road geometry can be improved at the same time.

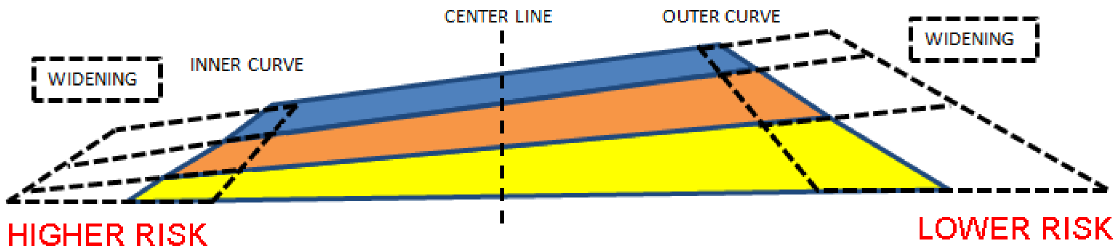

Figure 4.1.3. Thinner structure in inner curve

A potential error in the construction of a widening is that the crossfall is ignored when excavating into the existing embankment. If the excavation is made horizontally, this may lead to a thinner structure thickness in the side of the road compared to the centreline (Figure 4.1.4). This fact can lead to pavement failures, especially edge deformation, if not taken into account.

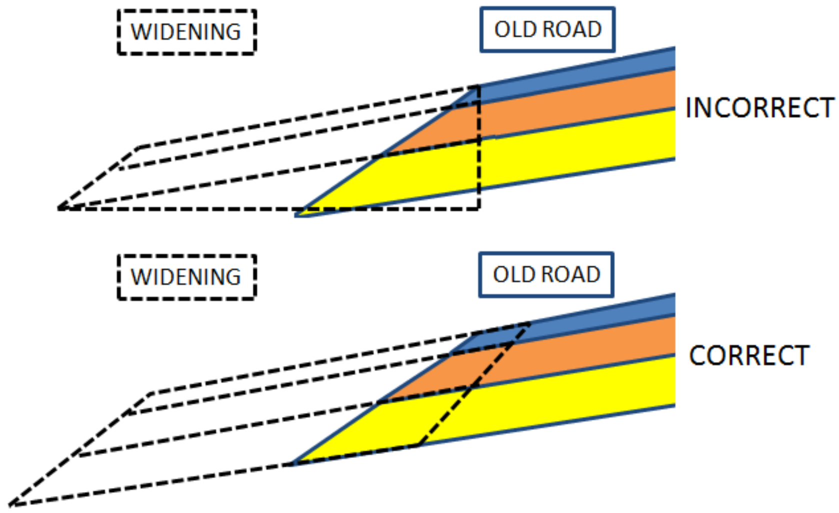

Figure 4.1.4. Due to crossfall, the thickness of the structure on the side of the road may become thinner than in the centreline during widening, if the bottom of the existing embankment is incorrectly excavated horizontally.

4.2. OLD ROAD STRUCTURES

Old structures below or inside the existing road structure can cause discontinuities and pose potential problems for widenings. These old structures may include for example an old gravel road below the existing structural layers, old reinforcement, old pavement layers inside the structure etc. On the other hand, the construction history of the existing road can give good information on the solutions that have worked well in the past on the existing part of the road. These same methods can be considered for use in the widening design in order to obtain a well working structure.

Figure 4.2.1 shows an example of a cross section of a road that has been upgraded from an old gravel road. The gravel road can be clearly seen in the middle of the picture. On both edges the structure thickness is much thinner than on the centre of the road. The red lines in the picture indicate how the excavation for widening should be carried out, in order to obtain as uniform a structure thickness as possible.

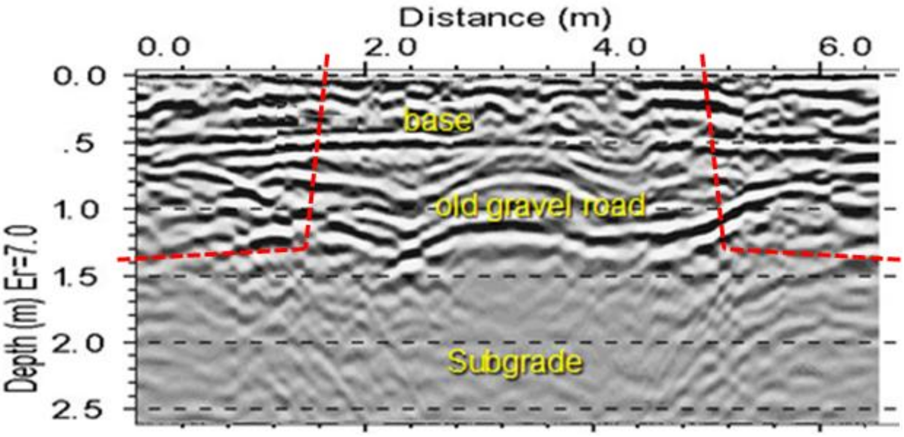

Figure 4.2.1. An example cross section from the ROADEX Ohtanajärvi test section in Sweden. The road has been upgraded from an old gravel road. The red lines indicate how the excavation should have been made before widening.

Figure 4.2.2 shows an example of a “rainbow map” produced from a 3D laser scanner mapping exercise. A rainbow map presents the surface topography of the road as a series of colours. In the map one rainbow colour palette scale represents a 30 mm change in surface level. An optimal road surface with a two-sided crown crossfall should resemble a perfect V-shape. In Figure 4.2.2 edge deformation can be seen on the right side of the road due to a thinner structure thickness, which is why in this case it would be beneficial to do the excavation and the widening on that side.

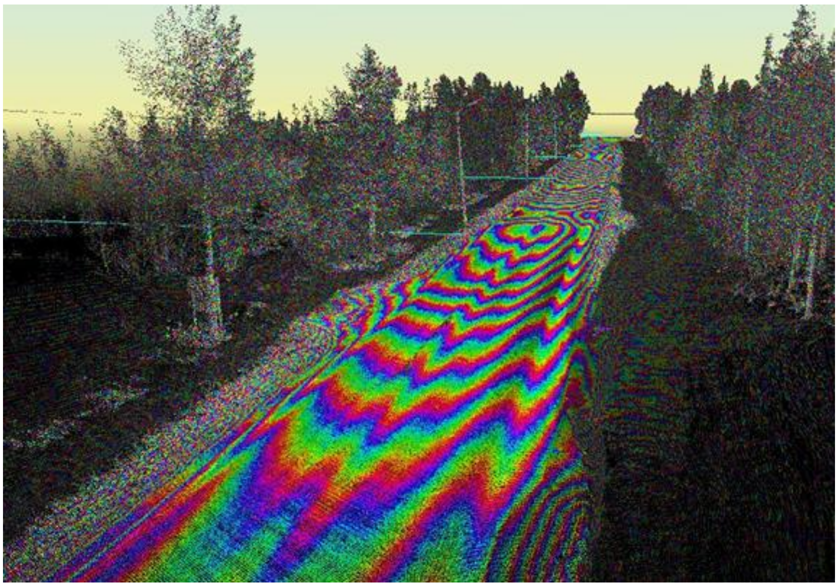

Figure 4.2.2. An example of a rainbow map from road 395 in Pajala, Sweden. Edge deformation can be seen on the right side of the road.

An example of a design and construction error is shown in Figure 4.2.3. The old pavement layer has been left inside the structure during the upgrade and widening of the road. A reflection crack can be seen on the road surface above the old pavement edge. This so called “sandwich structure” is a clear construction error and must be avoided when designing a widening or any other kind of road rehabilitation. If there is an old bituminous pavement inside the structure, it must be removed or crushed and homogenized before constructing the widening.

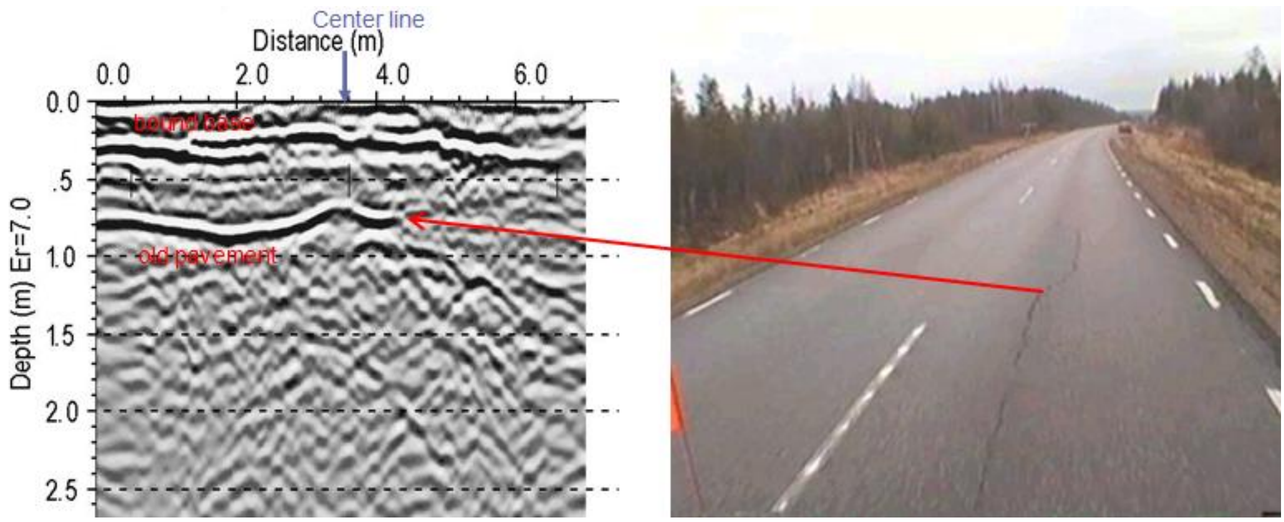

Figure 4.2.3. Old pavement inside the road structure causing reflection cracking, an example from Sweden

4.3. FROST ACTION

Differential frost heave between the old road and the widening structure can be a major problem. The recommended methods to minimise this type of frost action include good consistent drainage, the use of reinforcement, and above all maximum compatibility of the structures. It is strongly recommended that the structural thickness, the material properties, as well as the degree of compaction of the widening layers should be as equal as possible to those of the existing embankment. Often it is beneficial to improve the old road at the same time as the widening, e.g. by adding aggregate. This practice decreases the impact of frost action and the risk of failures. The following "rule of thumb" is recommended by ROADEX:

A. If the maximum frost heave on the old road is less than 10 cm, equal widening structures should be enough.
B. If the maximum frost heave on the old road is 10 cm or more, the old part of the road should also be improved during widening.

Voids in pavement joints can induce tearing of the joint in winter and therefore it is recommended that the entire road should be sealed on completion of the widening works to prevent this. Where the pavement is broken, surface water can be absorbed into the embankment, which can cause further frost problems.

A good solution for decreasing the effects of frost is the installation of steel grids (or sometimes geogrids) deep enough (20 - 25 cm) inside the structure to bind the old and the new parts together (Figure 4.3.1). Whenever there is any doubt that frost action could cause problems and damages, the use of reinforcement is always a recommended solution. Any differential frost heave “bumps” should however be repaired before installing the steel grid.

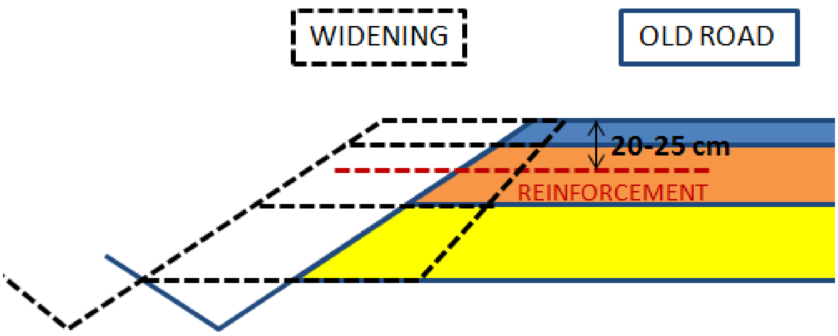

Figure 4.3.1. Reinforcement should be installed deep enough (20 - 25 cm) inside the structure.

4.4. DRAINAGE

Providing a well working drainage system is a very effective way, and absolutely the cheapest method, to improve the bearing capacity of a road and prevent frost problems. Road widening is not an exception to this and the design of a road widening should always include a drainage design as well. Generally, drainage should always be improved to good condition in any case, no matter whether the design is for a new widening structure or repairing an existing one.

In many road widening cases, drainage is not necessarily a major problem as the new drainage system is usually better after the widening works, particularly if enough space is available. However, the drainage system should be continuous from the old to the new structure, and any discontinuities should be avoided. New crossfalls in particular should tie in with the existing road and the roadside drainage, especially open channels, should be far enough away from road so as not to weaken the formation under the new road. A very important rule is that the bottom of the drainage system should always be at lower level than the bottom of the road structures. ROADEX countries usually recommend that roadside drains should be at least 25 - 30 cm below road structures (Figure 4.4.1).

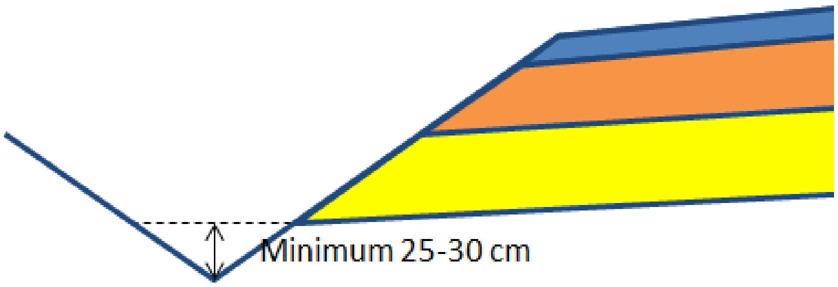

Figure 4.4.1. The bottom of the drainage system should always be at least 25 - 30 cm lower than the bottom of the road structure.

The surface shape of the local ground should also be considered in the design of the drainage system as it can restrict its efficiency. A good drainage system is dependent on the subgrade and the formation of the road. The available space at the side of the road has a great effect on the type of drainage system that can be chosen. Figure 4.4.2 presents an example of improving the drainage using so called “Adjusted ROADEX solution” to make a long-lasting and high quality drainage improvement in a sloping ground surface where the available space is a strict limited.

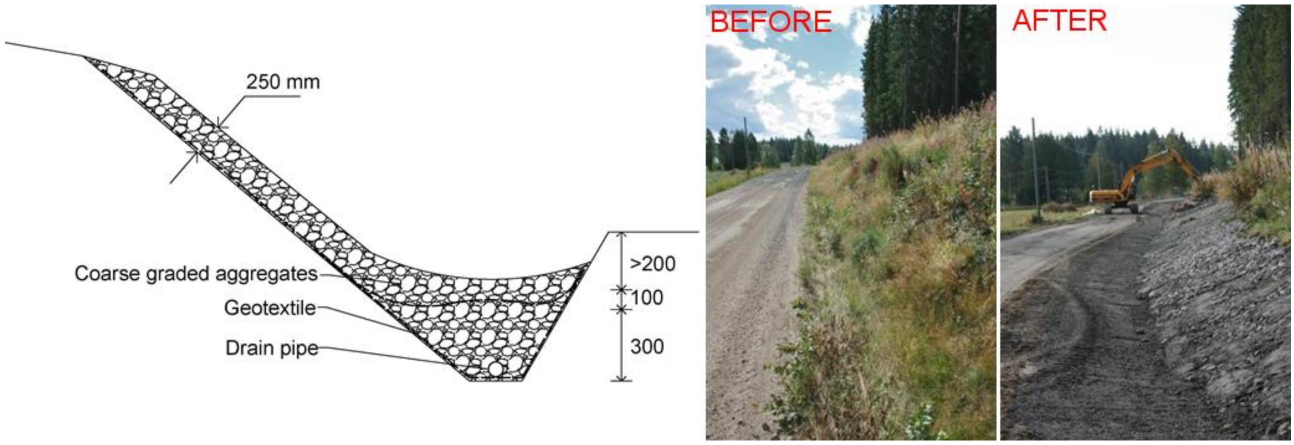

Figure 4.4.2. An example of a long-lasting and high quality drainage solution used in a problematic section with lack of space and side sloping ground

4.5. SETTLEMENT AND COMPRESSIVE SOILS

Road construction on compressive soils, especially on peat, can be regarded as a major problem. For further information on the topic, an extensive E-Learning package "Roads on Peat" is available on ROADEX website (http://www.roadex.org/index.php/e-learning).

When widening a road on compressive soil it is essential that a uniform settlement is achieved across the old and new part of the embankment. Assessing the settlement of the existing embankment can be difficult as it usually has already settled due to the weight of the structure and the traffic load. Settlement in the existing embankment can also be restarted or increased after widening part has been built, or during upgrading the road. It can also be difficult to evaluate the settlement of the new part of the road.

There are various methods for preventing uneven settlement and cracking between the old and the new part of embankment. Again it is recommended that the new widening part should be constructed to be as similar to the existing embankment as possible, but before that preloading is usually needed to achieve the designed initial settlement. The most common methods of dealing with widening on compressive soils are the use of preload embankments, geogrids, steel reinforcement and soil replacement down to the hard base. Piles, stabilization and lightweight structures are also possible solutions. In areas of deep soft ground it is also important to separate the new construction layers from the subgrade. This can be carried out for example by using a separation fabric to prevent the migration of materials, leading to settlement.

A common method to widen a road on peat is to excavate out the adjacent peat for the widening and build the new width of road on the exposed firm layer in the recommended fashion, the so-called "legs" solution (Figure 4.5.1).

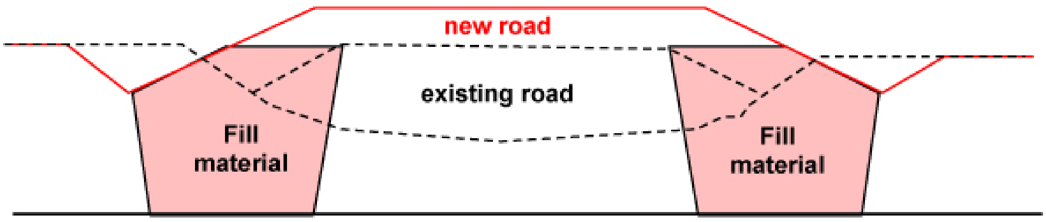

Figure 4.5.1. Diagram of road cross-section widened by excavating and replacing on each side of the existing road – the "legs" widening

This can however be an expensive practice for roads on peat, particularly for "floating roads" over deep peat, and can also pose real problems for the road if the new widened area is allowed to act as a linear drain through the peat. The new fill material can dewater the peat below the existing road and cause unnecessary settlement, consolidation and deformation to the road.

A cheaper, and less harmful, solution for widening "floating" low volume roads over peat is by preloading. This can be carried out with an overload embankment. When using a preload/overload embankment it is essential to design the settlement time. This is essential to ensure that the old and the new parts move similarly after the overload is removed. The construction sequence for widening by preloading is given below (see also Figure 4.5.2).

1. dig a new intercepting ditch 10m off the old road and use the excavated peat to refill the existing roadside ditch
2. remove any fine materials from the road shoulders, approximately 200 mm deep
3. lay a separator grade geotextile on the prepared shoulder and reform the cross-section with good material
4. lay a 5m wide reinforcement grade geotextile across the area to be preloaded
5. commence preloading of the road widening in 1m stages until the designed preloading height is reached

6. leave the preload in place for 90 days (or as instructed by the design geotechnical engineer) and monitor its performance by means of settlement plates
7. remove the excess preload material after the designed settlement has been achieved
8. construct the new widened road layers

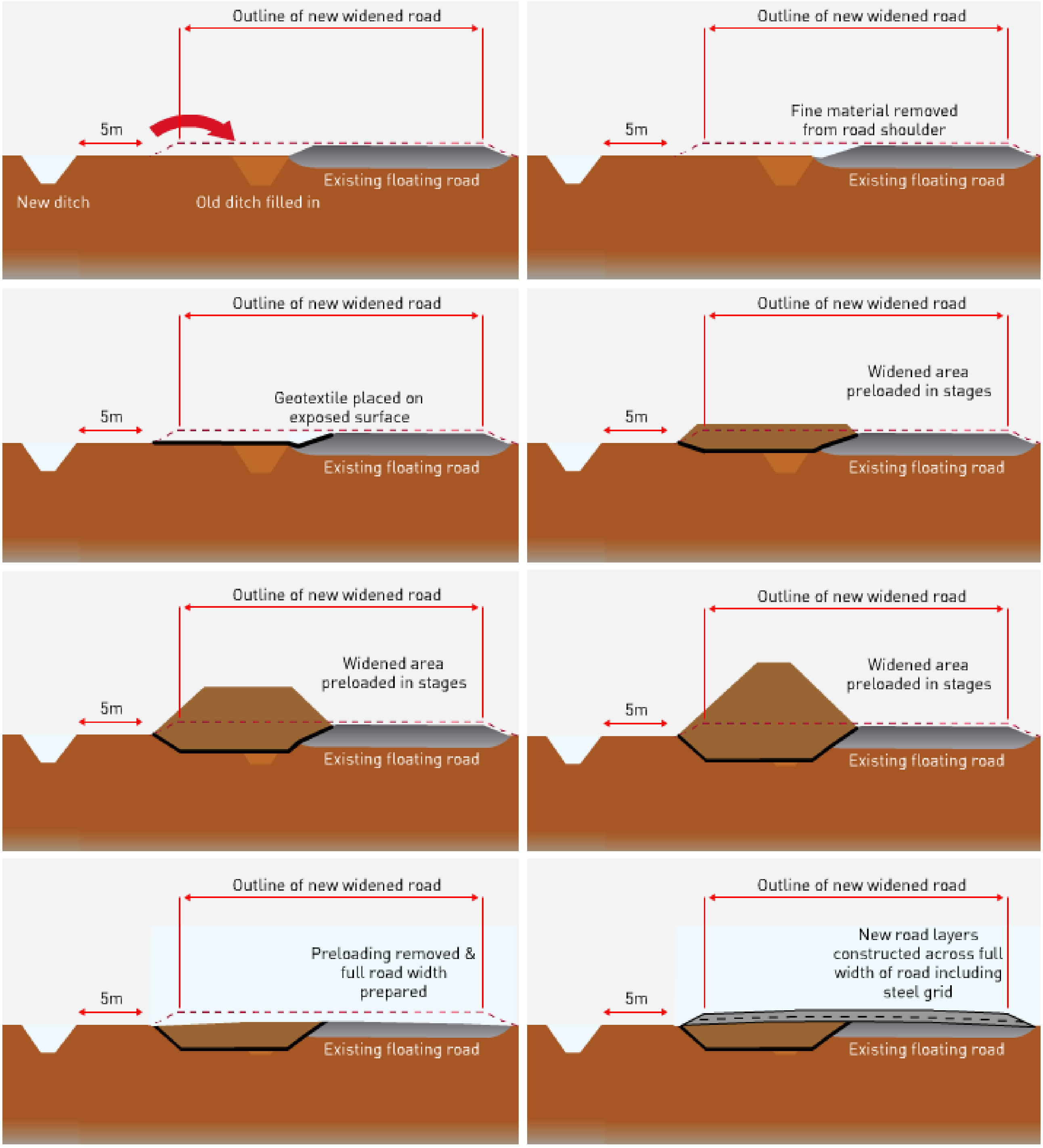

Figure 4.5.2. The construction sequence for widening by preloading on peat subgrade. The method is presented in the "Roads on Peat" E-Learning package available on ROADEX website.

This method can be a cost effective solution where the existing road construction has become stable enough over its lifetime to permit its retention in the new works. A geotechnical design expert input will be needed for this type of widening to estimate the height and duration of the preloading required together with the likely predicted settlement.

Ideally the new road structural layers should be constructed within the depth of the existing road to avoid adding new load to the peat. If however a higher, or heavier, road is to be built on top of the widened embankment the effects of the increased loadings must be understood. An additional benefit of this form of widening is that it can usually be carried out on the existing road without affecting traffic flows. A typical road widening project using the preloading principle is shown in Figure 4.5.3. The tops of the settlement rods can be seen sticking out of the top of the overload embankment.

Figure 4.5.3. Widening of a floating road over peat by preloading

Often it can be beneficial to delay the final paving of the finished widened road until the traffic has loaded and compacted the widening. This can reduce the lateral settlement. A temporary pavement is recommended during settlement period. It is essential to ensure that there is adequate time for the settlement to happen before paving. If there is not, it can lead to failures in the new pavement.

4.6. SLOPE STABILITY

The steepening of side slopes as a consequence of road widening due to lack of space can lead to slope stability problems. There are a number of methods that can be used to improve slope stability; e.g. using geotextiles, geogrids, steel reinforcement, heavy rip-rap to support the slope, retaining walls or stepped batters can be feasible alternatives. A workable drainage is also considered necessary to assure stability. On locations where space is not an issue, for example on low-volume forest roads, it is often easier to create space for gentle slopes by felling more trees. Figure 4.6.1 presents an example of improving slope stability and drainage using the so called “Standard ROADEX solution” to support the slopes and to make a long-lasting drainage system in a condition were the available space is not a limitation.

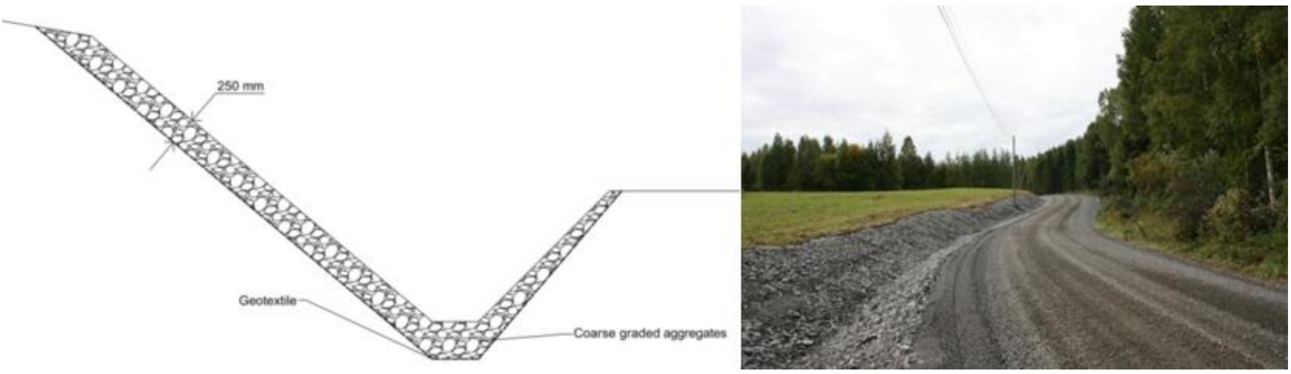

Figure 4.6.1. Improving slope stability and drainage using the “Standard ROADEX solution” to support the slopes and to make a long-lasting drainage system

Figure 4.6.2 presents an example of improving slope stability and drainage using gabions and heavy rip-rap in a problematic section with a lack of space on side sloping ground. Encouraging vegetation to grow on the slopes is usually one of the most economical ways to reduce local slope erosion. An example of supporting slopes using “hydraulic seeding” is shown in Figure 4.6.3.

Figure 4.6.2. An example of a high quality slope support and drainage solution using gabions and heavy rip-rap in a problematic section with lack of space and side sloping ground

Figure 4.6.3. An example of a slope support solution using hydraulic seeding

4.7. BEDROCK

Widening of roads constructed close to bedrock can be considered to be a special case (Figure 4.7.1) and it can be difficult to estimate the costs and rock masses involved. If there are no other constraints, the bedrock is usually blasted and excavated, and the resulting rock material used for construction depending on the quality of aggregate produced.

Transition wedges are usually considered necessary where the bedrock is near below the road. The variable surface of bedrock may pose non-uniform settlements and frost action if not dealt with correctly. Proper surface water runoff has to be ensured, and this may require surface reshaping. Drainage arrangements in shallow construction are a particular problem that should be planned carefully in order to keep the water table sufficiently low within the road. Sometimes the width of side drain will have to be reduced to reduce the cutting of bedrock. Rock netting is recommended for unstable rock faces.

Figure 4.7.1. Bedrock close to road

4.8. CROSS SECTION DESIGN

In many cases it will be beneficial that the widening is carried out to one side of the road only as this reduces costs. But there are also some clear advantages to widening on both sides of the road. When widening on both sides of the road, construction joint cracking and non-uniform settlement normally develops in the shoulders, and not in the loaded part of the road (Figure 4.8.1 and 4.8.2). Similarly, the need for soil reinforcement or additional land can be lessened and deformation can be expected to be smaller. The problem in this case can be the compaction of the narrower widened areas on the two sides of the road.

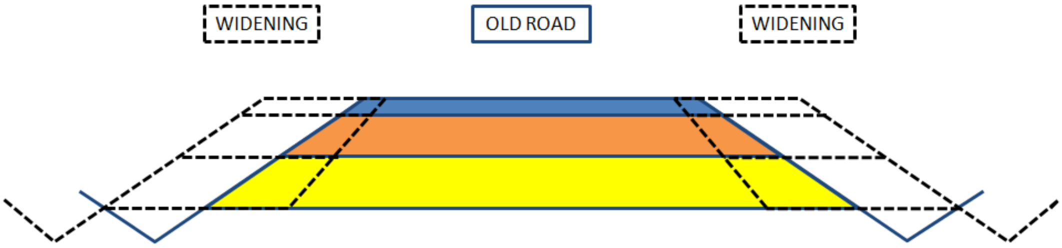

Figure 4.8.1. Road widening on both sides of an existing road. It can be economical to widen an existing road on both sides, especially if the pavement and the traffic load will remain on the old road and the widening used for the shoulder and safety area only.

Figure 4.8.2. Widening to both sides on HW9 in Suonenjoki, Finland. After widening the traffic load is still on the old lanes and the widening is for the shoulder and safety area only.

When widening is made to one side only, the crossfall of the road is often changed from 2-sided to 1-sided (Figure 4.8.3). Because of this, a crack may be formed on the location of the old road centreline due to traffic loading.

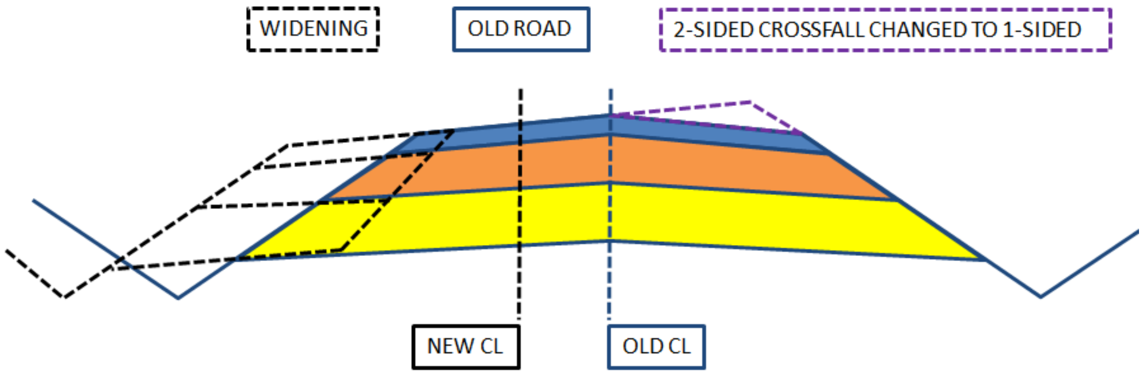

Figure 4.8.3. The crossfall of the road is often changed from 2-sided to 1-sided during widening

4.9. WIDENING TECHNIQUES AND STRUCTURES

When making a construction joint between the existing road and the new widening, the recommended basic method is always to construct the new structures equal to the structures in the old road. The joint construction type will depend on the formation type and the subgrade soil. A stepped joint and an angled joint are both recommended options (Figure 4.9.1). The recommended angle for an angled joint is 4:1 to 2:1. A vertical joint should not be used unless it is the only possible option. It is recommended that the pavement layers should be staggered in some way. The use of geogrids or steel grids is also recommended inside the pavement or inside the base course. The wrapping of unbound materials in a geotextile is also a recommended method. It is important to remember that these types of reinforcement must be firmly tied into the old embankment.

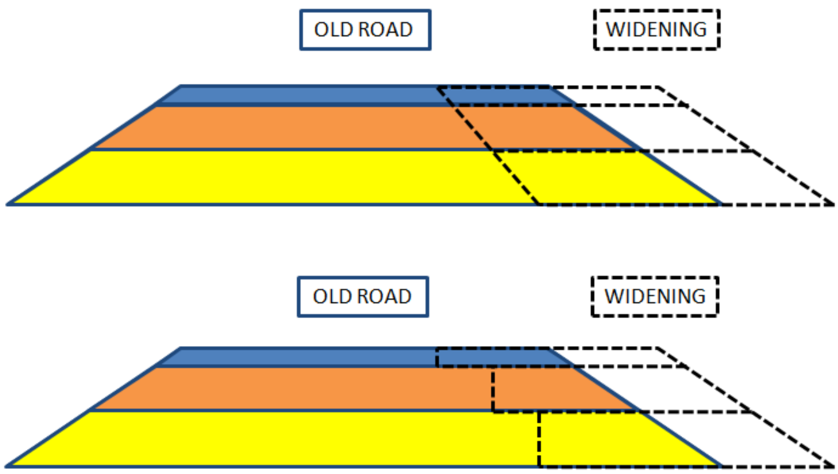

Figure 4.9.1. Recommended construction joint types

The construction joint of bituminous bound layers should always be located away from the joints of the other structural layers and the recommended distance is 0.3 – 0.5 m. In addition, there should also be stepped joint between the different bituminous pavement layers. Figure 4.9.2 presents a “treatment card” for a basic paved road widening. Many good road widening practices are presented in this card.

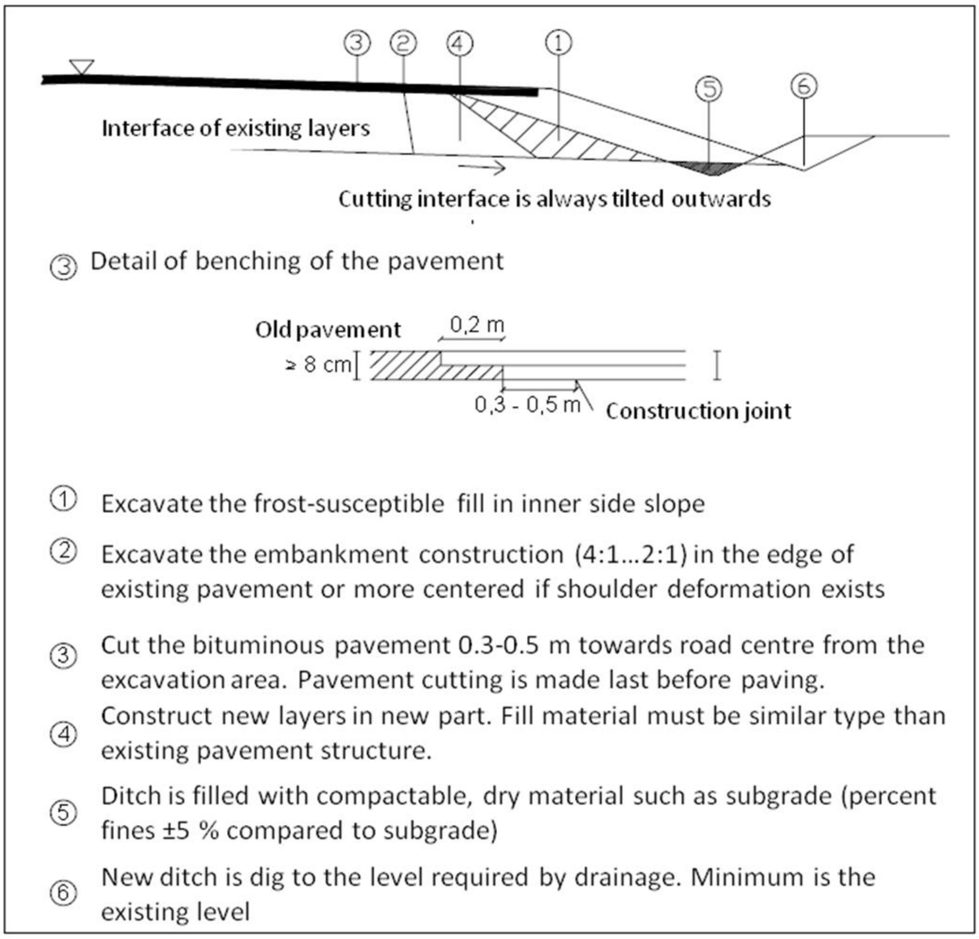

Figure 4.9.2. Treatment card for a basic paved road widening [Modified from the Finnish Road Administration 2005]

Figure 4.9.3 presents a similar drawing for a paved road widening on relatively high embankment that includes the use of reinforcement.

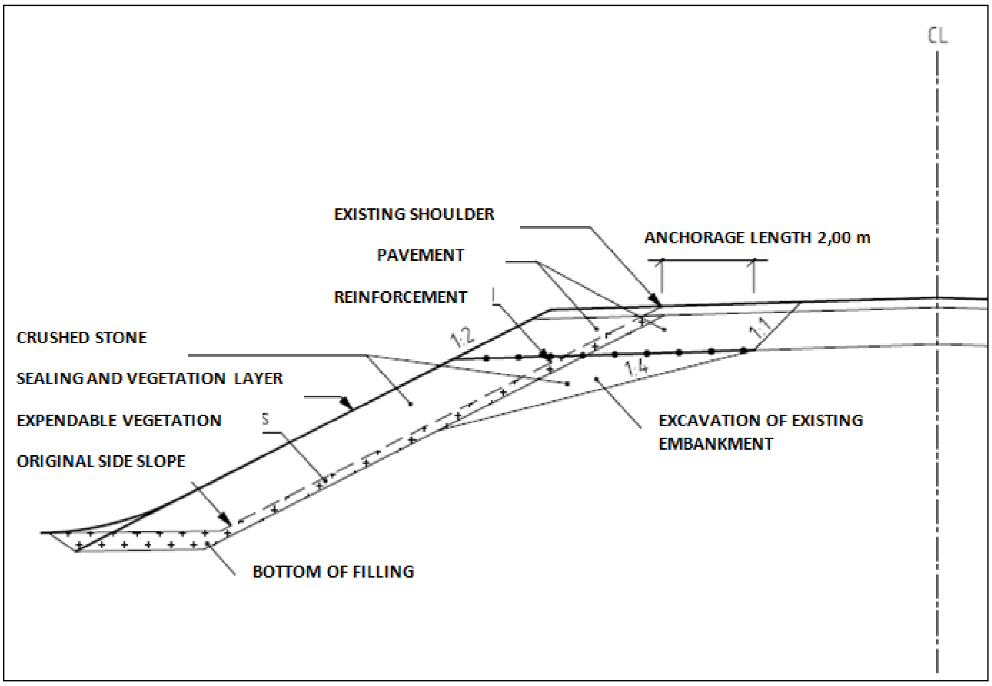

Figure 4.9.3. Schematic drawing of a paved road widening with reinforcement [Modified from Norwegian Public Road Administration 2007]

It should also be kept in mind that the widening structure should not be built to be too strong. Figure 4.9.4 shows an example of such a case from Iceland. The top window presents the rainbow map of the road section from 3D laser scanning. The two figures below that give the digital video (left) and laser scanner cross section (right). It can be observed from these that the strong widened road shoulders are behaving totally differently from the rest of the road.

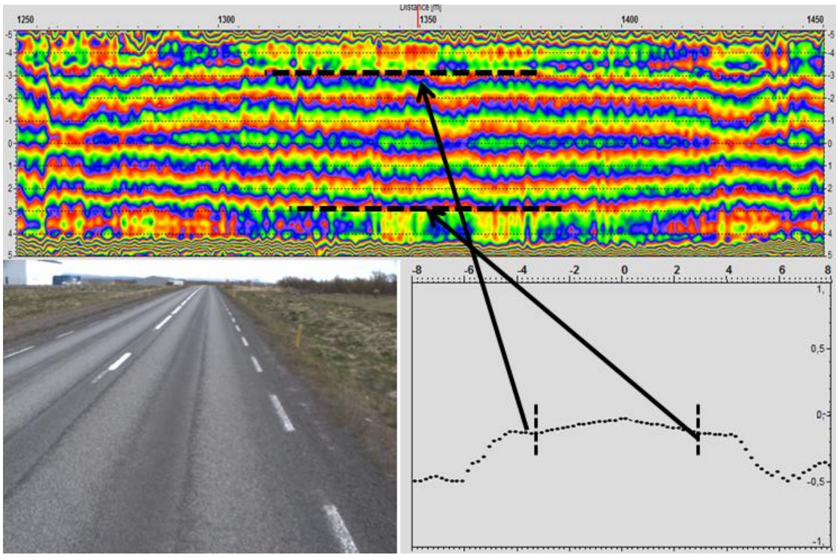

Figure 4.9.4. A widening structure should not be too strong. An example from Iceland shows that the strong widened road shoulders are behaving totally differently from the rest of the road.

It is recommended that construction joints should not be permitted under the wheel path, or reflection cracking is likely to take place very rapidly (Figure 4.9.5). Methods for minimizing reflection cracking over a joint include constructing an equal structure in the widened portion, allowing sufficient time for settlement before overlaying, the use of a stepped joint between the pavement layers, and ensuring sufficient lateral transverse support, e.g. by using geogrids or steel reinforcement.

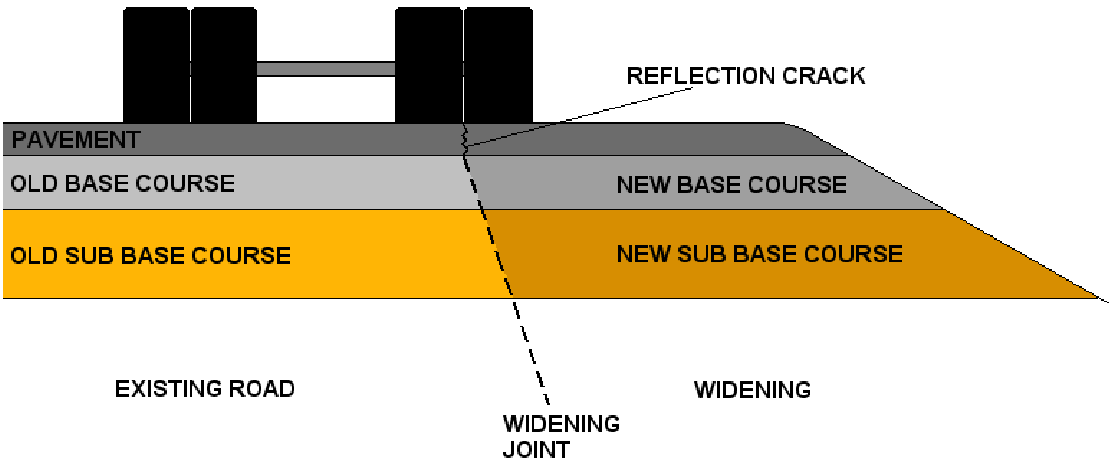

Figure 4.9.5. A reflection crack is likely to take place if the *construction joint is located under the wheel path*

Another very important issue to keep in mind when constructing a road widening is that all layers should be adequately compacted. Good compaction of the widened structure is essential to achieve adequate strength and uniform settlement. If the widening is not compacted adequately, post-compaction can happen as a consequence of traffic loading. This in turn can cause rutting, pavement cracking and non-uniform settlements. Adequate compaction can be ensured by using good quality materials and by constructing the structure in several layers and using a roller between each layer. For this reason it is important that the widening structure should be designed wide enough for the planned compaction equipment otherwise it will not be possible to ensure adequate compaction during the widening works.

4.10. ROAD FURNITURE AND UTILITIES

Road furniture and utilities such as road signs, guardrails, cables and pipelines should be mapped before starting the widening works. This is especially important when road widening in urban areas where underground utilities should be carefully mapped. It is possible that on some occasions that pipelines or underground cables will need to be moved. There is also a possibility that new guardrails will be necessary as a consequence of road widening due to the steepening of side slopes.

4.11. DESIGN OF TRAFFIC ARRANGEMENTS AND CONSTRUCTION PRACTICE

The level of traffic management during the road widening works will usually depend on the traffic volume of the road. On some low traffic volume forest roads it will not be a problem to close the whole road during widening works. On higher traffic volume roads traffic arrangements will require to be planned more carefully and it is recommended that they should be contracted to specialist contractors. Usually at least one of the lanes should be kept open for traffic at all times during construction (Figure 4.11.1). The use of bypass roads or temporary widenings is also recommended.

Widening works and working order must be planned carefully and adequate resources must be put on the project to make the working period as short as possible. Appropriate timing of the elements of the works will also be necessary to minimize inconvenience during rush hours. Well carried out pre-design surveys and investigations can prevent delays and save money as the probability of unexpected surprises during construction will be reduced. Excavations should be small and filled as soon as possible, and closed sections should be clearly separated from open sections for traffic safety.

Figure 4.11.1. The important thing in road widening project is to ensure that traffic can use the road during the construction. An example from a road widening project in Norway.

5. QUALITY CONTROL

It is important to verify that the construction of the structures has been made in accordance with the planned design. Various survey techniques can be utilized for quality control purposes to check if the widening or repair has been carried out correctly. Properties such as structural thicknesses, bearing capacity, road width and ditch depth can all be monitored.

Ground Penetrating Radar (GPR) is a very useful survey technique for quality control after the widening works have been completed, because it is an NDT technique and provides a continuous record of the structure (Figure 5.1). The final structural layer thicknesses can be verified with GPR and then compared to the designed thicknesses.

The Falling Weight Deflectometer (FWD) can be used to monitor the strength and compaction of the structural layers during construction, as well as the final bearing capacity of the completed structure. FWD measurements can be used to backcalculate the E-modulus values achieved for the layers, and these moduli can then be used for calculating the final bearing capacity of the widening portion.

Digital photographs and video records can also provide very useful tools for quality control. They can help in comparing the road condition and surroundings before and after rehabilitation. Video recording gives a continuous record of the road. With digital video the final documentation of the road and its surroundings can be recorded for future use. Video can also be utilized for continuous monitoring of the drainage and for detecting the possible first pavement damages showing up after the first freezing-thawing cycles after construction. Video recording can be carried out simultaneously with other surveys, e.g. GPR measurements, and all data files can be linked together.

Laser scanners can be used in many applications in road widening quality control. Laser scanning can provide a continuous cross section profile of the road which can then be compared to the initial situation and the design documents. The angle of the side slopes can be obtained which can help in evaluating the steepening of slopes. Other important parameters obtained from laser scanner data are the final road width and ditch depth.

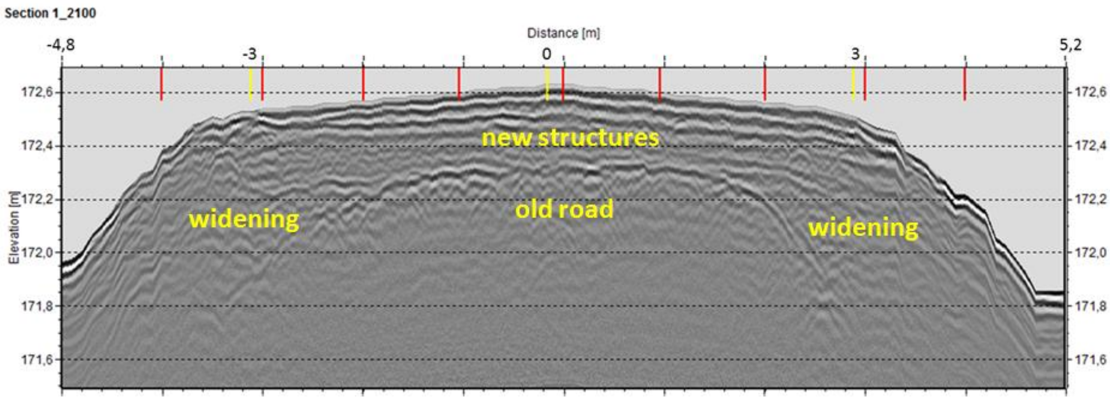

Figure 5.1. A GPR cross section integrated with laser scanner data and level control information is a good method to ensure that the road widening has been constructed satisfactorily.

6. SUMMARY AND CONCLUSIONS

A successful road widening project is a function of many factors and considerations, and the weakest link will define the life time of the structure. If just one consideration is neglected; it can lead to significant failures. Normally defects are not generally apparent immediately after construction however and usually the effectiveness of the widening only becomes clear after a period of time.

Carefully performed surveys and diagnostics are essential therefore before starting the design for road widening. It is very important to find out the conditions on the site, such as the thickness of the old road structural layers, material properties of the subgrade, the layer materials used in the old embankment, the road shape and its surroundings, any problem areas and damages on the existing road, drainage condition, etc. For this ROADEX recommends that certain measurements should always be performed as they give exact and objective information on the road's condition.

It is especially important to find out the reasons for failures when designing the repair of a widened road. Usually at least GPR measurement, video recording, laser scanner measurement and drainage analysis are recommended. The aim of all studies should be to ensure that the widened portion is similar in character and structure to the existing road and if the existing road is too weak or frost-susceptible, or if it is showing non-uniform settlement, it is recommended that the old part should also be repaired during widening. In this case the reasons for the failure should be identified before the repair is carried out.

It is generally agreed that the widening structure should be as similar to the original structure as possible, both in structural thickness and materials used. This will help achieve a uniform behaviour between the old and new parts of the road. Some of the most important parameters for selecting materials are water absorption properties and frost properties, and the degree of compaction is also very important. Good drainage structures and their proper maintenance are highly critical to the long term sustainability of a road, and good drainage measures can even “forgive” some deficiencies in the road widening construction.

The construction joint between the old and new part of the embankment can be made in many ways. A stepped joint and an angled joint are both recommended options, but a vertical joint should only be used where it is strictly necessary. A stepped joint can be made with various step sizes, and angled joints with different angles. Such joint details are case-specific and will depend on the embankment structure and subgrade. In the ideal case a road widening should not fail. In many cases with paved roads however a longitudinal reflection crack has developed between the original embankment and the widened part. This is a result of differential movement between the old and new side of the structure, and shear problems. This crack can be avoided by achieving uniform movement in both sides of the road body. The construction of a durable pavement joint can help in the short term; however the underlying vertical interface at the widening can still cause reflective cracking to come through to the surface. The correct location of the joint is essential. It is strongly recommended that construction joints should not be located under the wheel path, otherwise reflection cracking is likely to take place. This type of crack can cause surface water to infiltrate into the embankment, which can further weaken the embankment and cause frost problems.

There are many ways to improve the performance of a road widening. Whether or not a particular method can be used will depend on the circumstances and properties of the site. For example in some cases the subgrade soil may be so firm that reinforcement will not be needed, and on some softer soils it will be necessary to use a range of reinforcements. However, generally the use of reinforcement can be recommended whenever there is any reason to consider that failures will occur. This can include steel grids, geogrids and geotextiles. It is also important to remember that reinforcement must always be firmly tied into the old embankment.

Old structures below or inside the existing road structure can cause discontinuities and have the potential to cause problem sections. These old structures may include an old gravel road below the existing structural layers, old reinforcement, old pavement layers inside the structure, etc.

Good compaction of the widened structure is essential to achieve adequate strength. If the widening is not compacted adequately, post-compaction can happen as a consequence of traffic loading, which in turn can cause rutting and pavement cracking. Adequate compaction can be ensured by using good quality materials, constructing the structure in several layers and by using a roller between each layer. Inappropriate compaction machinery is a main cause of unequal compaction. For this reason it is important to design the widening structure to be wide enough for the compaction equipment available, otherwise it might be very difficult to ensure adequate compaction during the widening works. Compaction should also be carefully monitored during construction.

Designing a well working drainage system is a very effective method, and the cheapest, to improve the bearing capacity of a road and prevent cracking, deformations and frost problems. Road widening cases are not an exception to this. For this reason road widening design should always include a careful drainage design as well. Generally, drainage should always be improved to a good condition, no matter if the design is for a new widening structure or the repair of an old one. The drainage system from the old construction to the new widening should be continuous, and work equally well in the new and old parts of the road. It is therefore recommended that the widened portion should have a similar structure to that of the existing embankment. Another very important rule is that the bottom of the drainage system should always be at lower level than the bottom of the road structures (usually at least 25 - 30 cm is recommended).

Road widening on soft soils is a highly challenging operation and to be effective the settlement of the old embankment and the widening part has to be equal. Usually the old embankment will have already partially settled into the soft soil before the widening is added. Adding the widening portion, and possibly upgrading the road, can increase or restart the settlement of the existing embankment again and this has to be kept in mind. The basic idea is to construct similar structures, but before that preloading is usually required. The widened parts of roads on soft soils can be tied to the existing embankment with steel grids or geogrids. Settlement in soft soils can sometimes be decreased with soil replacement or stabilization.

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.