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ROAD WIDENING

Literature review and questionnaire responses

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LITERATURE REVIEW AND QUESTIONNAIRE RESPONSES

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PREFACE

This report is a part output of ROADEX IV project task D 2 “Widening of Roads”. The project aims to provide information on the reasons why road widenings fail, the critical parameters that the road engineer needs to know when designing a road widening, and the information on how to deal with a widened road that is showing problems. The cost effective widening of roads is a major issue facing the ROADEX Partners and new design guidelines specifically tailored to the harsh conditions of the Northern Periphery are required to meet the demands of modern traffic.

The research had three phases. The first part is this literature review on current practices and guidelines for road widening in the ROADEX countries. The second part will deal with field surveys on selected widening test sites. The third part will deliver the final report and the new guidelines for the road widening of low volume roads.

This literature review also consists of three parts. The first part considers the national road widening guidelines of the ROADEX countries. These are reviewed and compared with each other. The second part reviews test roads and research reports. For this, a road widening questionnaire was produced and circulated to experts in the Partner countries to get their knowledge of local practices in road widening. The third part deals with the questionnaire responses.

The report 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.

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ABSTRACT

This report is the first part of the ROADEX IV research project “Widening of Roads” and provides information on the techniques and practices currently being used on road widening projects in the ROADEX countries.

The report has three main parts. The first part introduces the national road widening guidelines and practices of the ROADEX countries based on responses received from interviews and literature reviews. Some countries publish extensive guidelines for road widening, others do not. In these latter countries guidance for road widening projects has to be abstracted from general road design manuals. Some countries do not produce any guidance on road widening.

The second part of the report focuses on the results of a literature review of research reports on road widening tests. This deals with published reports on road embankment widening and how to repair problems in widened road sections.

The third part of the report consists of a summary of responses received from a web based road widening questionnaire. The questionnaire was designed to collect the personal experiences and opinions of road widening experts in the ROADEX countries. It focuses on the problems raised by road widening projects and how they can be dealt with. The results showed that the biggest problems reported were how to ensure that the old and widened sections of road behaved similarly. A further problem reported was that of widening roads resting on peat. Overall the questionnaire showed that respondents had a wide range of views and opinions on how roads should be widened to suit local conditions.

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1. INTRODUCTION

Road widening is normally carried out when the road width is inadequate for the traffic using it, or when extra lanes are needed. Road widening can improve traffic safety and capacity.

There are a number of special issues that need to be considered in road widening. If widening is carried out poorly several problems can occur. These can include construction joint cracking (reflection cracking) between the old and new parts of the road, non-uniform settlements between the old and new parts of the embankment, and stability problems. Significant problems can also be caused by frost action in cold countries. Such harmful effects can however be avoided by good survey and design. Damages can be repaired by using techniques such as geo-reinforcement, steel grids, stabilization and soil replacement. These methods usually increase construction costs, but can significantly decrease life cycle costs. It is therefore important that the correct widening method and structure is chosen to avoid extra costs.

There are a number of differences given in the guidance on road widening across the ROADEX partner countries. Some of the countries have national guidelines and some have not. The guidance given for road widening is generally similar but there are some differences reflecting the fact that widening design and construction can be carried out in many ways.

This report starts by considering the existing national guidelines in the ROADEX countries and discussing their differences and similarities. The second part reviews road widening tests and research. A road widening related questionnaire was created and sent to experts in the ROADEX countries in order to collect experience and knowledge of road widening. Their responses to the questionnaire are examined and discussed in the third part of the report.



Figure 1: Frost action on a widened road

2. NATIONAL GUIDELINES

Road widening design is generally carried out in accordance with the standard national road design guides of each country and is not normally a separate field of design. There are a number of special circumstances to consider in road widening however. For example drainage design can be more challenging, as the drainage must work continuously across the widened and existing parts of the road, and it must also work of course during the widening works.

This part of the report will focus on the specific national guides for road widening. Other road design manuals will not be considered.

2.1. FINLAND

The National road widening guidelines for Finland are given in the publication “Rakenteen parantamisen suunnittelu” [Finnish Road Administration, 2005]. One chapter of the publication discusses road widening and includes guidance on recommended surveys for the existing structure, drainage design, minimising frost action and widening on soft soils.

Four of the preliminary drawing options for road widening are given below. The actual widening method will depend on the existing road. The first picture shows a preliminary drawing for a paved road widening (figure 2). The second picture shows a strengthened road widening (figure 3). The third and fourth drawings are widening methods for a slightly frost-susceptible gravel road (figures 4 and 5).

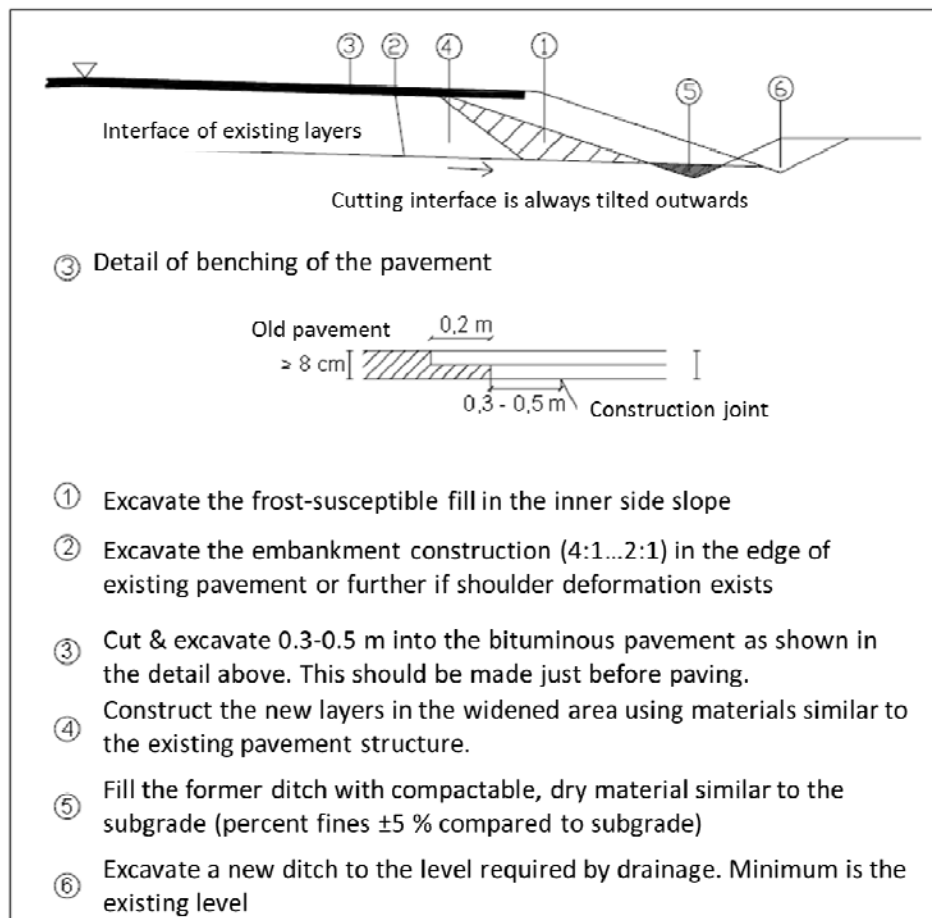


Figure 2: Preliminary drawing for a paved road widening [Modified from Finnish Road Administration 2005]

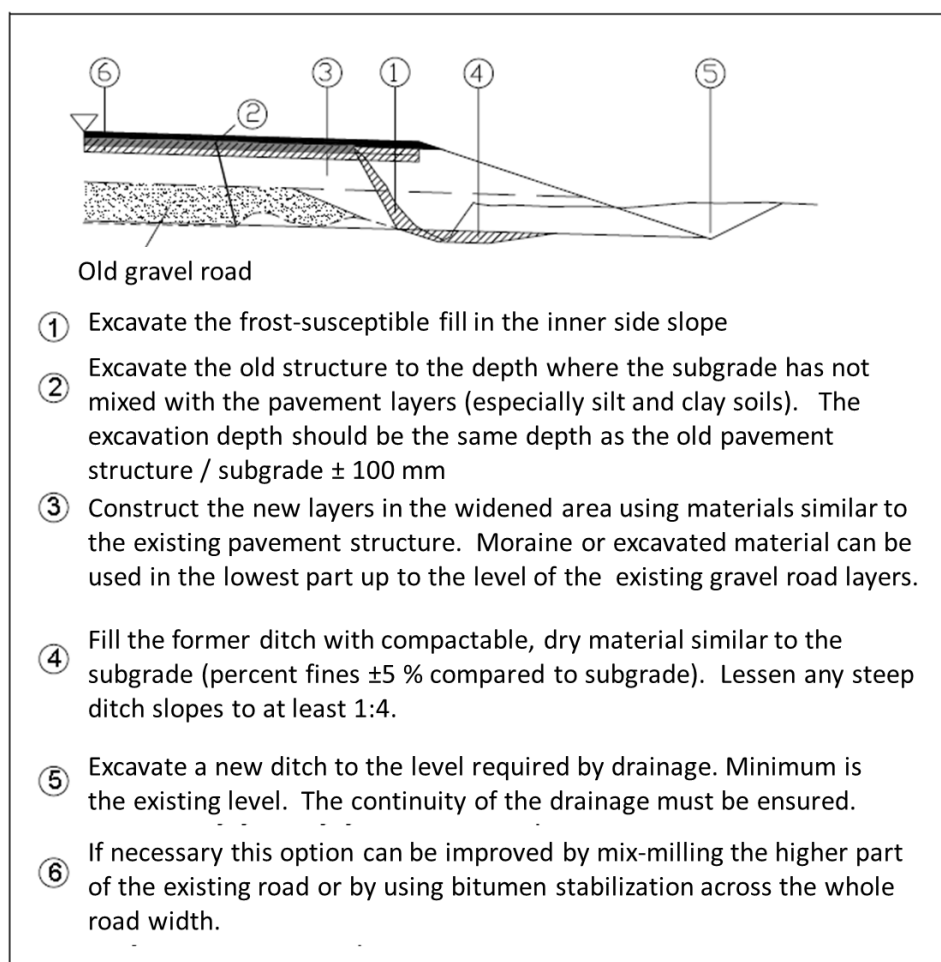


Figure 3: Preliminary drawing for a strengthened road widening [Modified from Finnish Road Administration 2005]

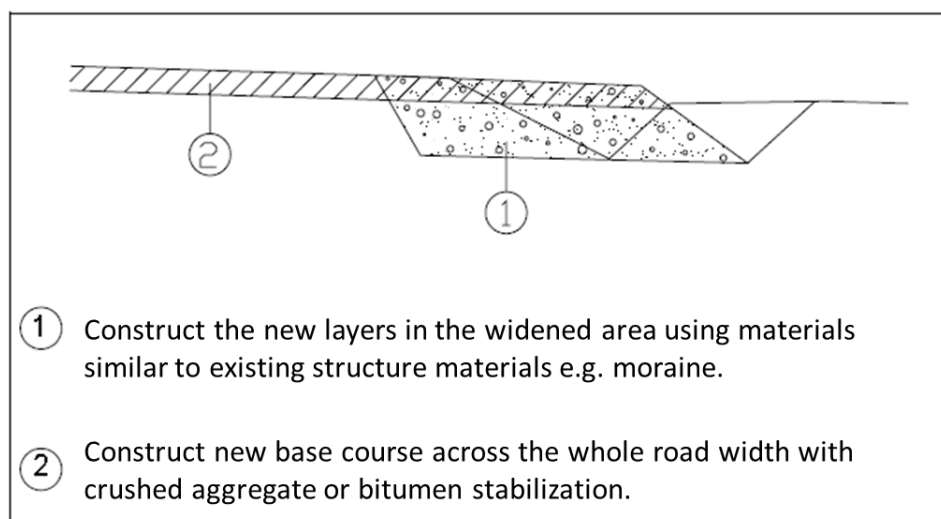


Figure 4: Preliminary drawing for a gravel road widening, alternative 1 [Modified from Finnish Road Administration 2005]

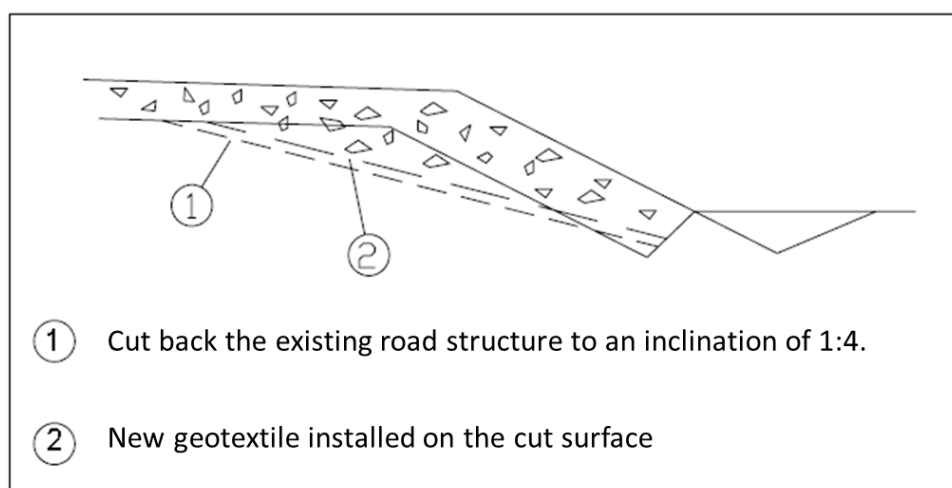


Figure 5: Preliminary drawing for a gravel road widening, alternative 2 [Modified from Finnish Road Administration 2005]

2.2. GREENLAND

National guidelines on road widening in Greenland were not found.

2.3. ICELAND

The Icelandic road widening guideline, “Hönnun breikkana” [Icelandic Road Administration, 2010] is a publication that deals mainly with road widening. Parts of the guideline are based on the Norwegian publication “Håndbok 018” [Norwegian Public Road Administration 2005]. According to the guideline, the design of road widening should be based on the general road design principles of Håndbok 018. Good information is given on surveying the existing road ahead of road widening, widening on soft soils and the compaction of the widened areas.

The following three pictures are taken from the handbooks. The first picture shows the recommended sampling strategy for an existing road before road widening. Sampling of materials from the existing road will help to identify similar materials for the widened structure to ensure that it behaves in a similar way to the existing structure. The second figure is a general drawing of a widening to one side. The third figure outlines the use of an overload embankment on a low volume road widening on a compressible soil. When using an overload embankment it is essential to design the settlement time. This is essential to ensure that the old and new part move similarly after the overloading is removed.

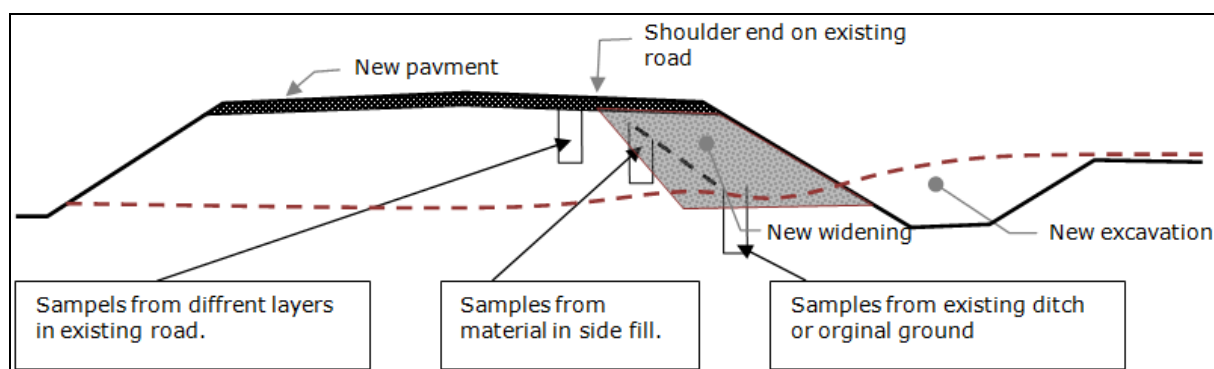


Figure 6: Recommended sampling in road widening cases [Modified from Icelandic Road Administration 2010]

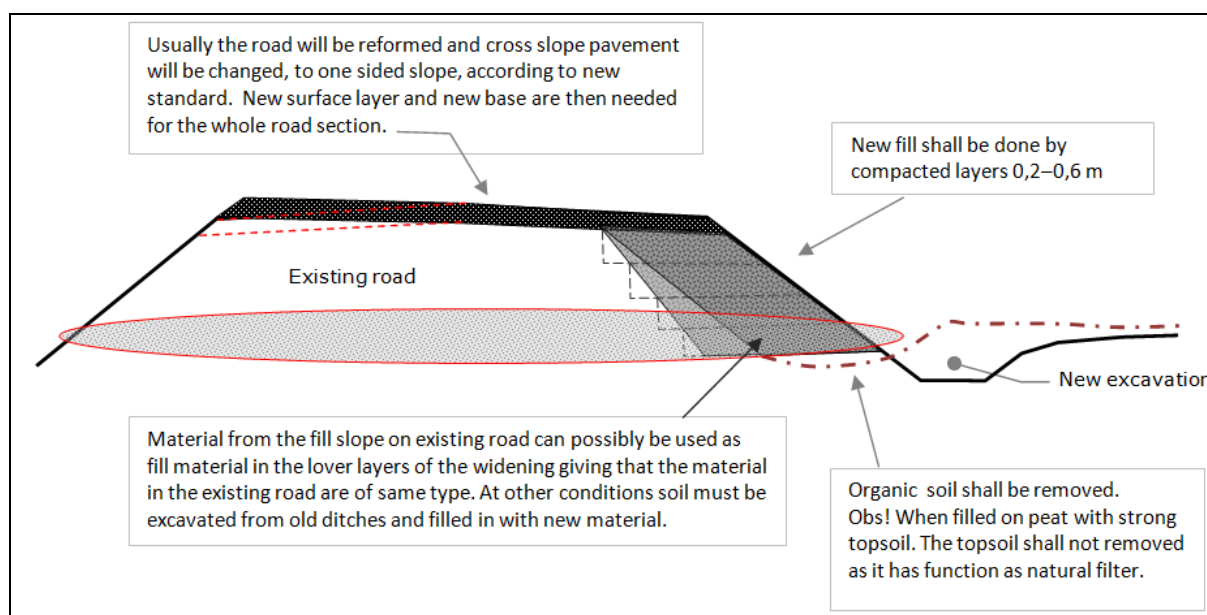


Figure 7: Widening method [Modified from Icelandic Road Administration 2010]

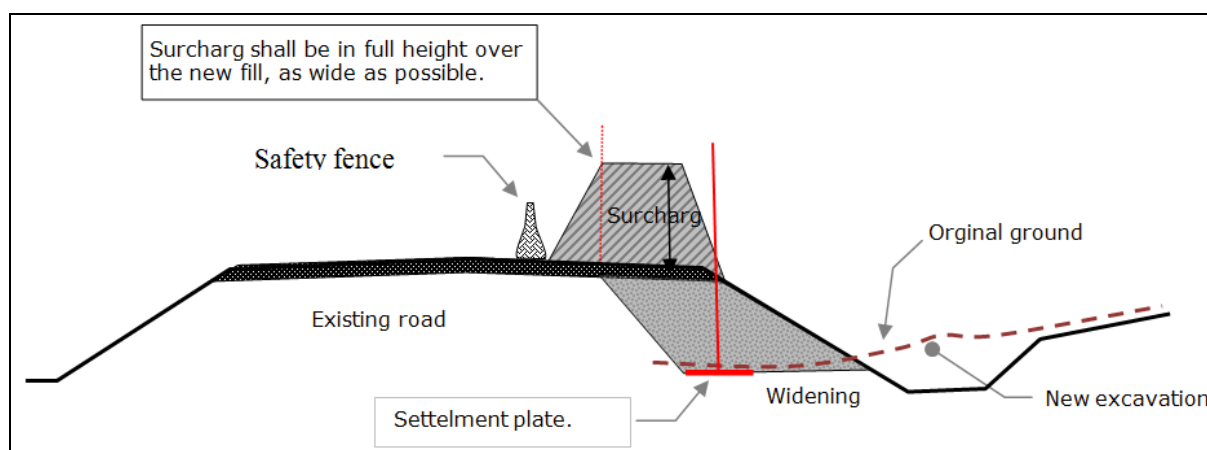


Figure 8: Using an overload embankment in road widening [Modified from Icelandic Road Administration 2010]

2.4. IRELAND

The research team carrying out this study were not given a road widening guideline from Ireland but according to the ROADEX Partners in Ireland road widening is usually carried out using local practices.

A typical road widening method is to excavate out the widened area, backfill with fill material and roadstone and surcharge the widened area with 300 mm of roadstone. This is left to settle for a period before removing the surcharge and laying the pavement layers. After that the road is open for traffic for a year and then the full road width is surfaced. This method has incurred cracking in the joints in some schemes. Roadmesh has been used as an anti-cracking reinforcement occasionally.

The Partners also mentioned that the road design should not only consider the structural elements and cost. It should be accepted that traffic would probably travel faster on the widened road, and any adverse cambers could become more dangerous. Designers should also consider the safety of the widened road.

2.5. NORWAY

A number of guidelines on road widening are published by the Norwegian Public Road Administration and reviewed in this report. These are: "Håndbok 018, Vegbygging" (Road Building) [Norwegian Public Road Administration 2005], "Håndbok 139, Tegningsgrunnlag" (Design Basis) [Norwegian Public Road

Administration 2007] and “Håndbok 274, Grunnforsterkning, fyllinger og skråninger” (Soil Reinforcement, Fillings and Slopes) [Norwegian Public Road Administration 2008]. The guidance on road widening in these manuals is generally similar, and general in nature. Norwegian guidelines recommend widening only to one side of the road wherever possible, as shown in the 3 figures below.

The first picture is a common general drawing for road widening to one side. The second picture is a more detailed drawing of a widening. The third picture is an example of a widening using lightweight fill material.

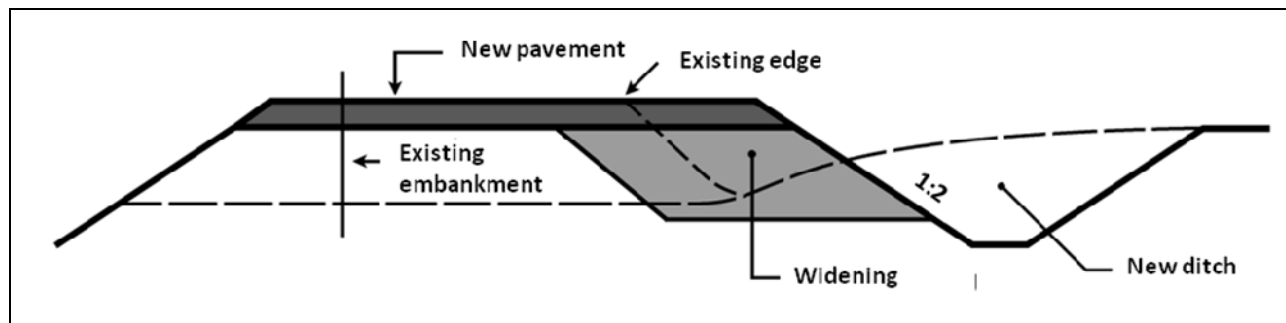


Figure 9: Example of a road widening to one side [Modified from Norwegian Public Road Administration 2005]

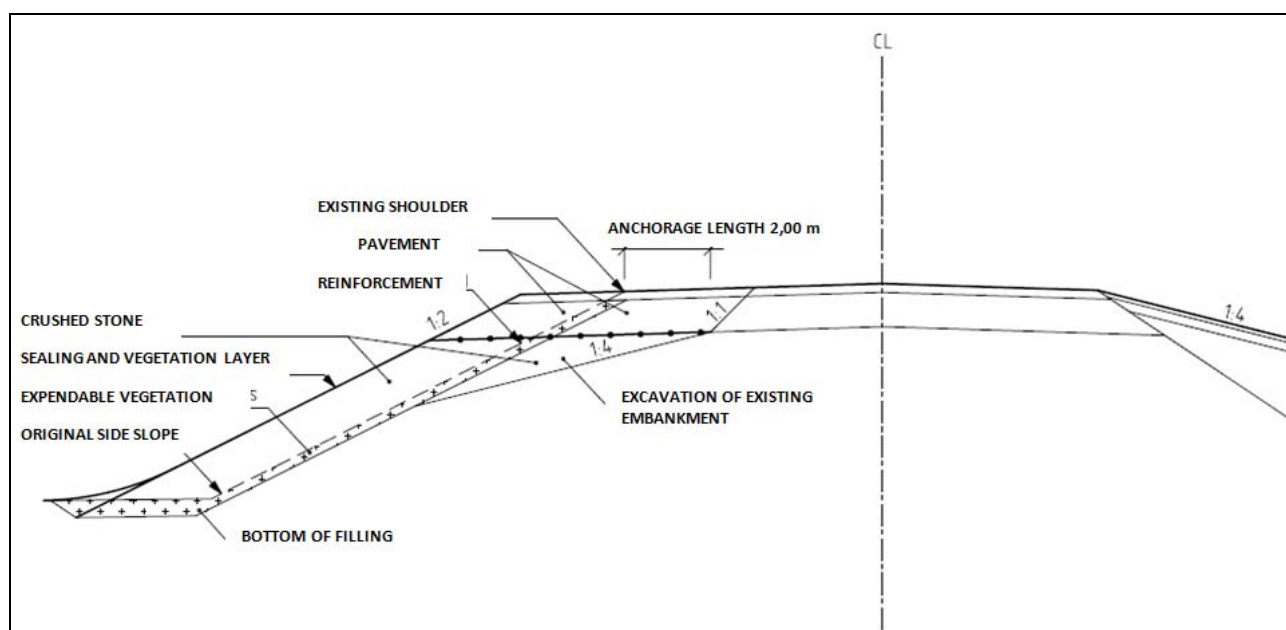


Figure 10: Preliminary drawing of a paved road widening [Modified from Norwegian Public Road Administration 2007]

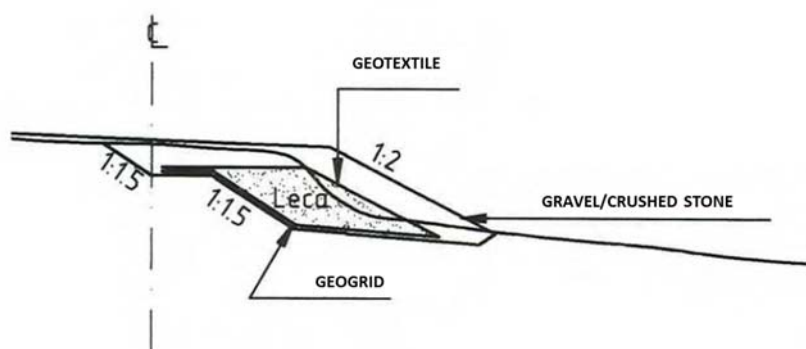


Figure 11: Example of a lightweight road widening (Modified from Norwegian Public Road Administration 2008)

2.6. SCOTLAND

Guidance for road construction in the UK is set out in the “Design Manual for Roads and Bridges” (DMRB). The DMRB was first introduced in 1992 in England and Wales, and subsequently in Scotland and Northern Ireland. The overseeing organizations are Highways Agency, Transport Scotland, Transport Wales and Department for Regional Development (Northern Ireland).

The Manual is a large publication that includes guides on highway structures, geotechnics, drainage, road geometry, environmental design and economical assessment. The guidance on road widening is contained in the chapter on “Widening of Pavements”. This gives a broad guidance on the pavement design and construction issues that should be considered where the widening of an existing road is proposed. There are instructions on the evaluation of the existing pavement, pavement design, pavement materials and construction. The chapter also includes instructions on concrete pavement construction and repair. The chapter refers to other chapters within the DMRB. Instructions for road widening are not so detailed as they are, for example, in the Finnish Road Administration guideline. The recommended construction method for a pavement joint is shown in figure 12. The Manual does not give guidance for widening methods for different types of asphalt and gravel roads.

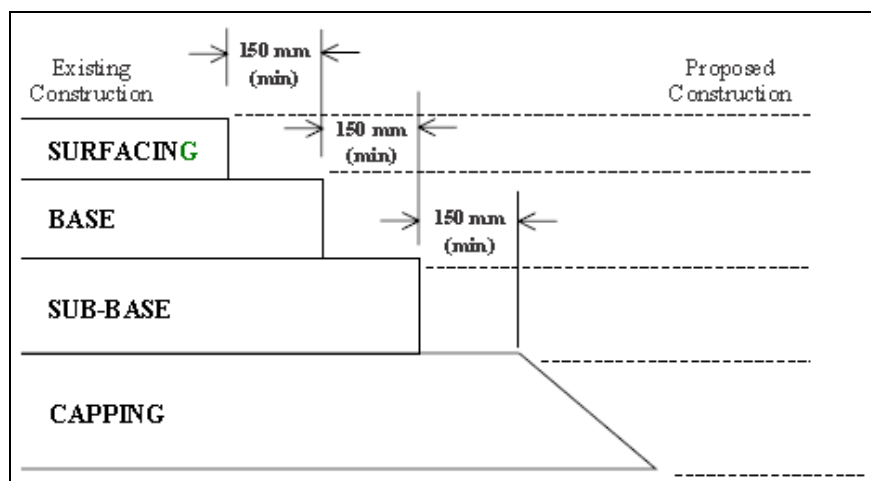


Figure 12: Preliminary drawing of benching at joint (Design Manual for Roads and Bridges)

2.7. SWEDEN

There are no nationally agreed guidelines for road widening in Sweden. Some occasional pieces of advice are given in the general documentation.

2.8. COMPARISON BETWEEN GUIDELINES

The main difference in road widening guidelines across the ROADEx countries is in the scope of information provided. Some guidelines include detailed drawings and phased instructions for road widening for various circumstances. Other guidelines merely offer general advice on possible alternatives, for example using a geogrid or steel grid. Some countries do not publish widening instructions. In some, road widening guidelines are given in one separate publication, while in other countries the guidelines are parts of many different manuals. There are also references to other countries' manuals in some guidelines. A more detailed comparison between the guidelines reviewed is given below.

2.8.1. Scope

The Finnish Road Administration's guideline provides extensive guidance for road widening in different circumstances. The widening guidance is given in one dedicated chapter in a design guideline. The road widening guideline of the Iceland Road Administration provides a good general knowledge of road widening.

The Design Manual for Roads and Bridges (UK) is an extensive publication, but the guidance on road widening is slight. In Norway, guidance on road widening is given in a range of handbooks. A dedicated guideline was not identified. Guidelines were not identified for Greenland, Ireland and Sweden.

2.8.2. Required Surveys

Road widening guidance in Finland recommends using information from the national database on road structure, old design documents and interviews. Any information from these sources should however be verified for example by excavation, test pits and drill cores. It is essential that the thickness of structure layers and subgrade reinforcement are surveyed. It is also important to find out frost susceptible areas, large shoulder deformation areas, stiff and thick bound layers and the need for reinforcement. If the road has been previously strengthened or widened it is also important to survey the types of structures within the existing road. The Finnish guidance states that sometimes it will be necessary to carry out the road reconstruction without a survey of the existing road if the costs of the survey are very high. This could arise when the repairing method has already decided and is not dependant on the underlying reasons for the existing failures. In these cases one should be prepared to review work practices during the reconstruction in the light of conditions found. **In practice however a GPR survey is carried out on most road widening schemes in Finland to determine the conditions in the existing road.**

The road widening guide in Scotland (DMRB) recommends carrying out a full assessment of the condition of the existing pavement ahead of the widening work. 'As-constructed' records are also recommended as providing a useful source of information. It is however important to verify the accuracy of any historic records with exploratory excavation. The guidelines contain separate guidance on the analyses of pavement surveys, the interpretation of results, and the design of appropriate strengthening measures.

The road widening guides in Norway do not provide detailed advice on the types of surveys to be carried out before widening. The Icelandic guideline includes advice on surveys. It recommends that the condition and materials of the existing road should be surveyed. Survey methods recommended include sampling, grading analysis and CBR measuring using DCP. It is considered that careful surveys will make it easier to ensure the similarity of widening portion and evaluate the need for reinforcement.

2.8.3. Construction Joint

One difference between the instructions of the ROADEX countries is the shape of the construction joint. The guidance in Finland, Iceland and Norway recommends excavating the embankment using an angled cut while the DMRB of Scotland advises the use of a stepped joint (figure 12). The Finnish guideline recommends an angle from 4:1 to 2:1. The Icelandic rule is that if the sideslope of the ground is steeper than 1:6 the excavation should be cut at an angle of 1:1.25 or steeper. The Norwegian guide additionally recommends that the shoulder of the existing embankment should be cut at angle of 1:2 (figure 13).

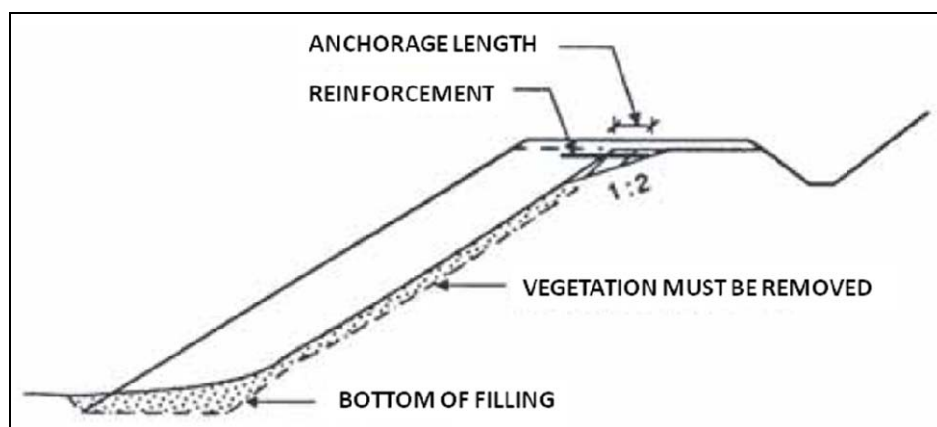


Figure 13: Cutting the shoulder of an existing embankment [Modified from Norwegian Public Road Administration 2005]

2.8.4. Joint location and widening on both sides

The Finnish guideline states that the joint between the new and old construction should not be located under the wheel path and that the joint of the bound layers should not be located in the same place as other joints. The guidance also recommends that the existing pavement should be cut 0.3 m – 0.5 m in from the embankment joint (figure 2). The corresponding advice from the Scottish DMRB is that the joint should be placed mid lane, or near the lane dividing line, in order to avoid wheel tracks. Short lengths of joint crossing a lane diagonally, such as in a realignment, may be acceptable. The Icelandic guide also recommends that placing the construction joint under wheel path should be avoided if possible. The Norwegian handbooks do not give guidance on this issue.

Usually the guidelines recommended that widening should be carried out only to one side of the road as this reduced costs. The Finnish guideline also gives some advantages to widening both sides of a road. When widening 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. Similarly, the need for soil reinforcement or additional land can be lessened and deformation can be expected to be smaller. The Icelandic guideline also permits widening on both sides in some situations. Norwegian guidelines recommend that widening should only be carried out on one side of a road. The DMRB mentions both widening methods.

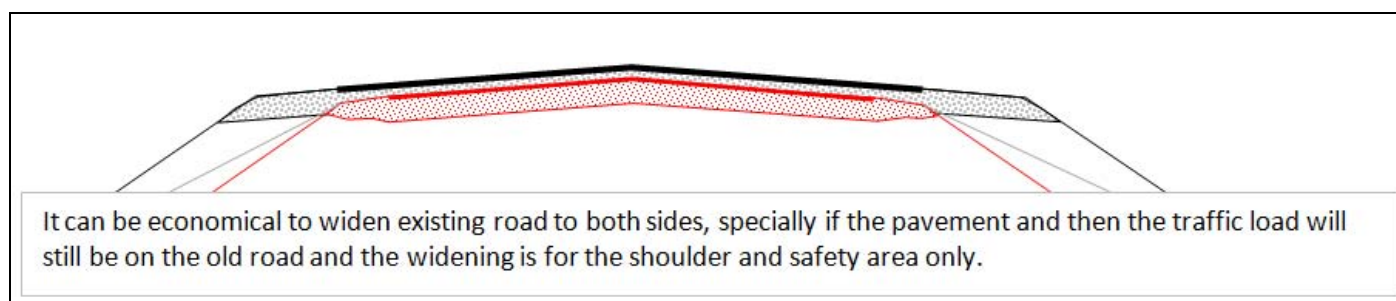


Figure 14: Road widening on both sides of an existing road [Modified from Icelandic road administration 2010]

2.8.5. Old drainage structures

It is normally acceptable to leave the old drainage structures in widened carriageways in Finland although paved channels are required to be removed in motorways or other high traffic volume roads. Drainage channels should not be located in wheel tracks. In the DMRB it is normally unacceptable for manholes and channels to be located on high speed carriageways. The Norwegian and Icelandic guidelines did not offer any recommendations on old drainage structures.

2.8.6. Costs

The Finnish guide did not include much information on the estimation of costs, only general comments on the need to avoid excess costs. The Finnish Road Administration publication dealing with the use of steel grids [Kanerva-Lehto, 2009] states that investment costs should be an essential consideration in estimating the profitability of a road project. It recommends that life cycle costs should be considered during the project planning stage. This can be difficult however where the initial data is poor and can result in the analysis being unreliable. It is useful however to consider the whole life costs of widening measures as some, such as using steel grids, can clearly prolong the period of operation and decrease the need for maintenance.

The UK DMRB recommends that all options for carrying out the works should be assessed on the basis of minimising whole life costs over a 40-year analysis period. The Manual also recommends that consideration should be given to the principles of sustainable development and the future maintenance costs of the existing and widened elements of the pavement. Where site constraints or operational procedures require a solution other than that which would give the lowest whole life cost, approval must be sought from the Overseeing Organization, supported by evidence to demonstrate that the proposed solution will provide acceptable value for money.

Norwegian and Icelandic guidelines do not contain much information on the estimation of cost. The main point mentioned is that cost estimating is difficult and case-specific.

2.9. WIDENING STRUCTURES IN OTHER COUNTRIES

A brief review of road widening manuals in North America revealed that there are a number of road widening manuals but most deal with concrete roads. An example of road widening guidance from the USA is taken from the Pavement Design Guide from Texas. [Texas Department of Transportation, 2008] The guidance in this manual is similar to those of the ROADDEX countries. Figure 15 shows an example of widening a structure with an unbound base. Like the guidelines in the ROADDEX countries, this guide recommends that similar materials and structures to the existing embankment should be used in the widened portion. Using a different structure in the widened portion is considered to incur drainage problems. The use of a different structure can however be a possible option in some cases where there is a low rainfall and a deep water table. The Guide recommends placing the construction joint far from the wheel path to improve performance. It also recommends applying a final overlay across the entire section with the overlay joint offset from the underlying vertical interface. This is expected to improve the structure in the short term. In the longer term the construction joint is normally expected to cause reflective cracking through to the surface over the course of time. The use of a geotextile is considered to help avoid reflection cracking in some cases.

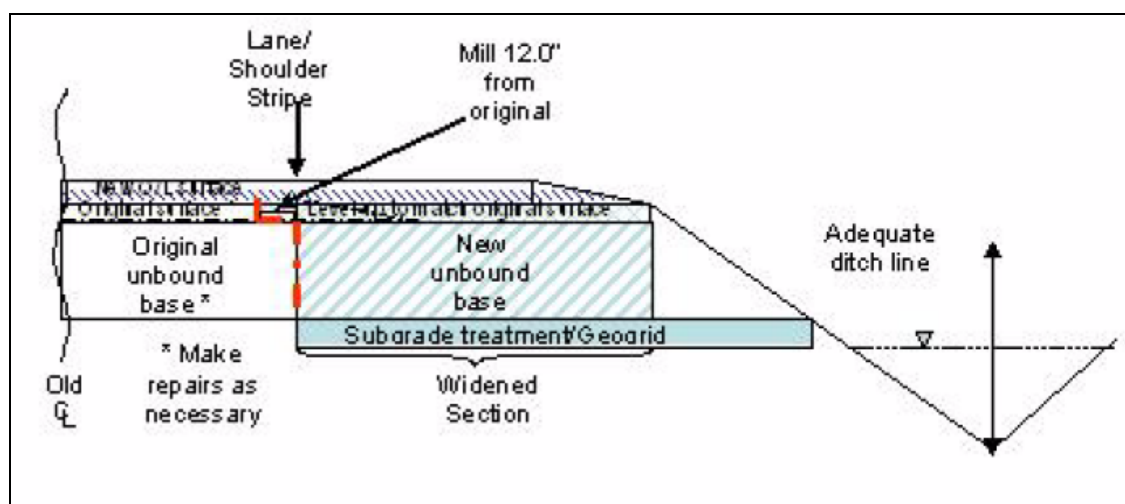


Figure 15: Recommended widening of Texas Department of Transportation [Texas Department of Transportation, 2008]

The Highway Design Manual of California Department of Transportation [California Department of Transportation, 2009] further recommends that the adjacent existing pavement condition should also be examined to check if the existing pavement should be rehabilitated at the same time as the widening. Usually it is not cost-effective to widen a road without dealing the problems of the existing road. The pavement design life for the widening should at least match the remaining pavement service life of the adjacent roadway. This will involve considering factors such as the remaining service life of the adjacent pavement, any planned future projects and any future corridor plans for additional lane widening and shoulders.

3. RESEARCH REPORTS AND TEST ROADS

This chapter reviews a number of road widening test reports and case studies from the ROADDEX, and other, countries.

3.1. FINLAND

The Finnish Road Administration published a research report on the use of geo-reinforcement in road widening on soft soils ("Geosynthetic reinforcement in the widening of a road embankment on soft ground"). This looked into the experiences and research on reinforced widening in Finland and in other countries. It also modelled reinforced road widening structures using finite element method (FEM).

According to the research, geosynthetic reinforcement is suitable in the following situations:

1. Where there is no separate "dry crust" in the subgrade or where it is thin or weak. Where the side slopes will become steeper as a result of widening.
2. In expanded clay. Geo-reinforcement can decrease lateral movement by 20-30 per cent compared to an unreinforced embankment widening.

Geo-reinforcement is not considered useful in the following situations:

1. Where the dry crust is thick and significantly firmer than the subgrade above
2. Where the widening is narrow, less than 2 – 3 m. In these cases depressions in the part to be widened are not usually caused by deformation of the subgrade
3. Where the safety factor to failure is greater than 2.0. Here lateral movement of the subgrade and embankment can be expected to be minor.
4. Where the change of the side slope in the widened part will be greater than 1.5 - 2.0 % of the unreinforced structure. In these cases the widened part is likely to depress significantly more than old embankment. Geo-reinforcement cannot restrain non-uniform settlements and lateral movement.

When using geo-reinforcement the biggest advantage is said to be achieved by installing the reinforcement both in the upper part of the embankment and on the subgrade. The anchorage length of the reinforcement should be as long as possible (>1-2 m). [Uotinen, 1996]

The Finnish Road Administration also carried out a research project called "Geo-reinforcement-project" in 1996-2001. One part of this research involved the testing of geo-reinforced road widening. The subgrade of the test site was a slightly over-consolidated clay. Traffic flow was 5600 vehicles/day. No subgrade treatment or soil replacement was carried out on the site.

Five types of test structures were trialled in the research. These were: 1. A structure without reinforcement, the reference structure (Figure 16), 2. Using a geogrid as a separating structure (Figure 17), 3. A geosynthetic grid between the base course and the "distributive" layer (Figure 18), 4. A steel grid between the base course and the sub-base (Figure 18), 5. A geosynthetic grid between the pavement layers (Figure 19).

Note: The old pavement was not excavated during the widening and upgrading of the road. As a result there were two bituminous pavement layers in the pavement structure after the widening. This kind of sandwich structure has proven to be problematic in earlier ROADDEX demonstrations.

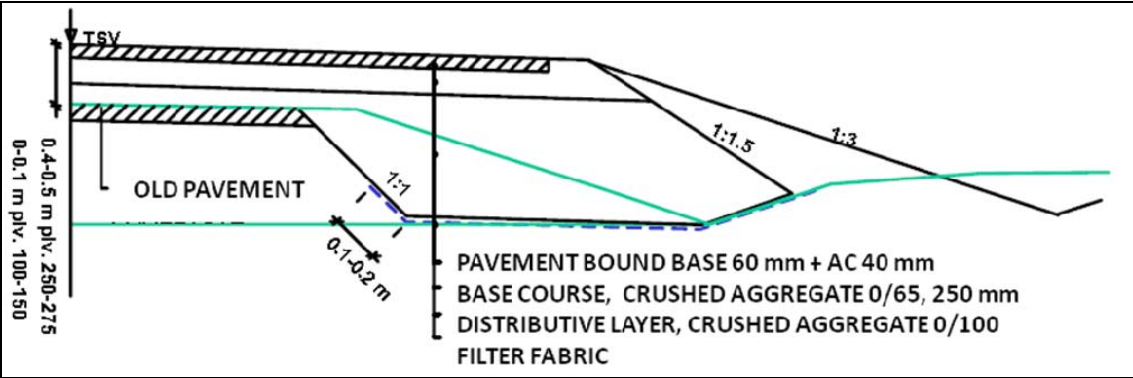


Figure 16: Reference structure [Based on Finnish Road Administration 2001]

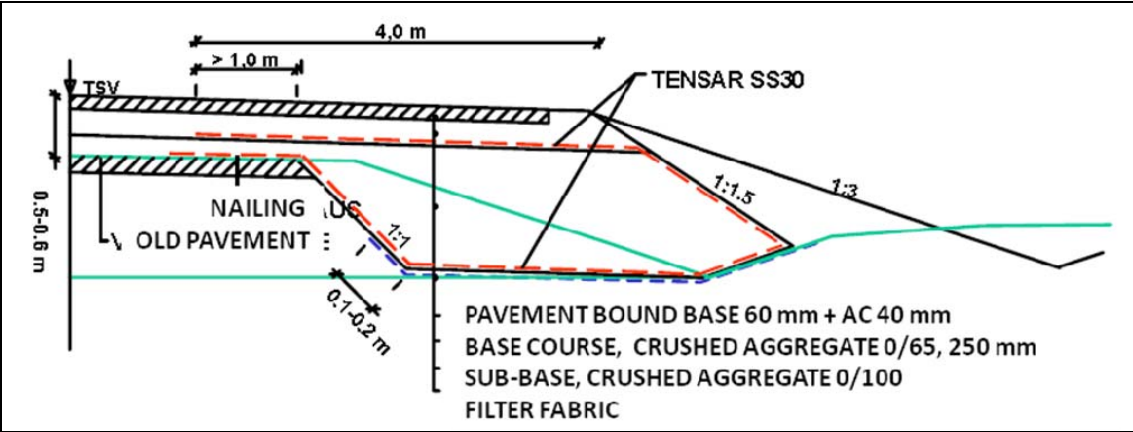


Figure 17: Geogrid as a separating structure [Based on Finnish Road Administration 2001]

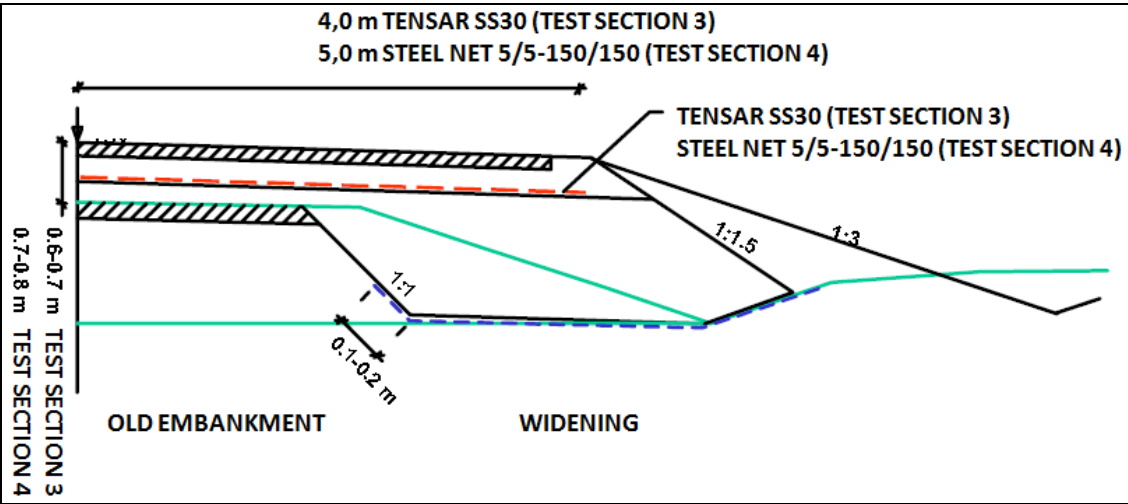


Figure 18: Reinforcement between base course and sub-base [Based on Finnish Road Administration 2001]

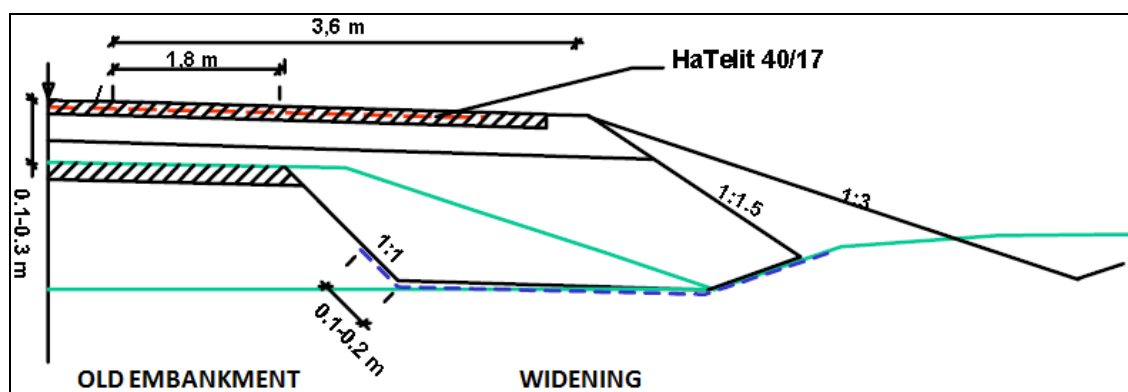


Figure 19: Geogrid between bituminous pavement layers [Based on Finnish Road Administration 2001]

Conditions for the tests were not optimal for the widening test due to the over-consolidation of the subgrade. Settlements were fairly minor and uniform, with the result that the reinforcements were not strictly necessary. According to the report, reinforcements can probably decrease harmful effects of dynamic traffic loads in the long term.

The settlements, deformation and bearing capacity of the embankment and reinforcement force were measured over the test period 1996-2001. The test structures were also visually assessed. Deformation in wheel path was found to be greatest in the structure without reinforcement, and the slightest in the steel reinforced structure. Settlements in the geo-reinforced structures were of the same magnitude. Using reinforcement proved to equalize settlements and decrease lateral movement.

The steel reinforced structure had the highest bearing capacity when measured by static plate load test and falling weight deflectometer. In those places where the original bearing capacity was high, and the structure was stiff, installing the geosynthetic reinforcement initially decreased the bearing capacity. Later this capacity increased.

No cracking, settlement or other unusual occurrences were noticed in the test structures. The least costly construction was the reference structure. The most expensive structure was the structure with the separating geogrid (Figure 17), which was 45 % more expensive than the reference structure. The steel reinforcement structure was 10 % more expensive and the structure with the geogrid below the base course (figure 18) was 14 % more expensive. [Finnish Road Administration, 2001]

A further widening test in Finland was carried out on Highway 4 in Leivonmäki. The daily traffic at the site in 1996 was 3600 vehicles per day and a widening of 0.75 m was carried out. Two types of reinforcement, both plastic and fibreglass, were installed on the crushed gravel sub base and on top of the base course and anchored 0.5 m over the joint. Test structures were constructed on both soft and stiff subgrades, and a further structure was constructed that omitted the lower reinforcement

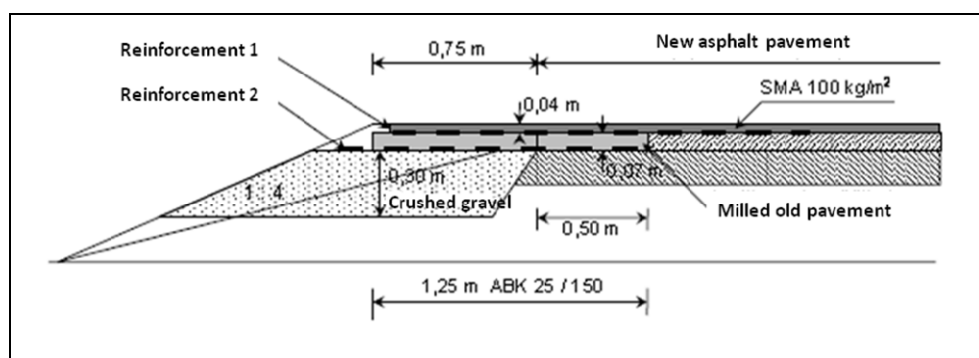


Figure 20: Highway 4 Test structure [Alkio, Pihlajamäki, 2001]

The bearing capacity was measured twice in 1996 together with one measurement of the road condition after construction. This latter measurement proved difficult to repeat due to the difficulty in driving exactly on the same lines in successive measurements and was abandoned after the first measurement. The road was

visually assessed four times during the test. This found only one longitudinal joint crack between old and new structure in the test sections. The researchers could not find any reasons for this crack using bearing capacity measurement and subgrade analysis. Many transverse cracks were detected due to reflection cracking from the old pavement. The geogrids did not decrease transverse cracking.

The construction joint without the lower reinforcement performed as well as the twin reinforced joint. The area without reinforcement did not have any joint cracking. This test was considered to be too short-term however to show how the widening would perform over the longer term. [Alkio, Pihlajamäki, 2001]

3.2. SWEDEN

Two examples of road widening repair were reviewed from Sweden. Both examples used steel grids.

Tylosand road near Halmstad was an old paved road constructed on sand. It was widened approximately twenty years ago. Since then, there had been a series of problems with longitudinal joint cracking such that every year, or every other year, the cracks had to be sealed with bitumen emulsion. This was expensive and did not solve the problem. In 1993 the whole road was reinforced by installing steel grids between the old and new pavement. No longitudinal cracking has appeared since this work. [Sandberg, Björnfot, 2004]

Road 600 near Luleå is an old road which was last improved in 1970. The top subgrade soil comprised approximately 2 metres of clay and below that moraine. The road had been widened and had had subsequent roughness, frost damages and bearing capacity problems. Daily traffic was 480 vehicles per day. For the research project the road was reinforced with different types of steel grids at different depths. The diameter of the steel bars was 5 mm and the depth of the grids varied between 40 mm and 300 mm. There were also comparison sections without any reinforcement. The performance of the new structures was observed for two years.

Unfortunately the construction of the road structures above the steel grids was not constructed in accordance with the plan and as a result it was not possible to evaluate the significance of the steel grid position on the strength of the structure.



Figure 21: Road 600 before repairing

The test sections were monitored over the period 1999-2001. It was found that the steel grids significantly reduced longitudinal cracking, but some transverse cracking was observed in the reinforced sections, especially above culverts. It was found that the steel grid moved the longitudinal cracking to the edge of the pavement. In those sections where the steel grid was installed in the bituminous top layers the pavement also cracked slightly. The reinforced sections were found to have slightly better bearing capacity than the unreinforced reference sections. No significant differences were observed between the steel grids used. [Said, Sundberg, Johansso, Jansson, Svensson, 2003]



Figure 22: Road 600 after repairing

The Luleå University of Technology published a master's thesis on "shoulder excavation" in 2010. Shoulder excavation is a repair method where the damaged part of the road is replaced with new material (see figure 23). The research project dealt with roads with damage to one side only. These were reinforced in place but not widened. There are however some parallels with road widening projects.

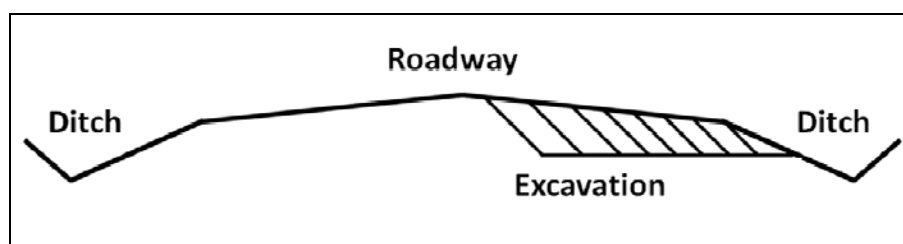


Figure 23: Shoulder replacement area [Modified from Hjelm 2010]

Six strengthening cases with different reinforcement structures were observed in the research. According to the research, the greatest problem was in the compaction of the replacement structure. If the compaction was unequal to the existing road, several problems appeared. These included rutting post-compaction and deformation of the shoulders. The construction joint was also found susceptible to cracking as the replacement structure was usually constructed slightly different to the existing road and moved in a different way. A main recommendation of the research was that the reasons for the damages should be carefully found out before attempting the repair. [Hjelm, 2010]

3.3. STUDIES ELSEWHERE

3.3.1. Embankment widening

A research group in Purdue University in Indiana published a report on "Embankment widening design guidelines and construction procedures" in 1999. This considered embankment widening and steepening projects in Indiana, and the reasons for any failures. Five widening projects, both successful and unsuccessful, were investigated post construction.

According to the report, the main reasons for the failures were the sub-standard compaction of fill and inadequate benching into the original embankment. Surface water infiltration contributed problems, possibly saturating and softening the soils. There was also a significant lack of design documents in some of the failed sites. The successful projects had construction plans that indicated that benching, compaction and control of surface water had been carried out correctly.

The research concluded that there were a number of factors that influenced the ultimate stability of the widened embankment slopes. These include the removal of vegetation and the construction of the benches in the existing embankment, achieving adequate compaction and shear strength in the fill soils, achieving compatibility in the permeability of fill materials, controlling surface water runoff, considering the ultimate ground water flow regime and considering the required final inclination of the embankment slope. The biggest problem identified was however a lack of appreciation of the potential for failure by the personnel involved.

The research made the following recommendations to avoid widening problems,:

1. Remove the existing vegetation and organic topsoil to obtain an adequate construction joint. Construct benches in the existing slopes to provide a good construction joint between the old and new fill and to provide a horizontal surface upon which adequate compaction of the lifts can be achieved.
2. Compact the fill material at a minimum dry density equal to or greater than 95 percent of the maximum dry density achieved in the standard Proctor test, with a range of water content from -2% to +1% of the optimum for this test.
3. Where the embankment widening is relatively minor, ensure that the construction lifts are wide enough to accommodate the compaction equipment. The embankment slopes can be subsequently graded to the desired slope after compaction.
4. Consider the permeability of the fill materials used. If the new fill soil has substantially greater permeability than the original embankment soil, water can infiltrate into it which could lead to a reduction in shear strength of the material. If the permeability of the new fill soil is less than that of the existing material, then water may become trapped within the embankment.
5. Control the surface water runoff. If the surface water runoff is uncontrolled, it can cause erosion and increase the water content of the embankment. [Deschamps, Hynes, Bourdeau, 1999]

A research group from Tongji University in Shanghai, China investigated highway widening in "Failure Mechanism and Design Criterion for Low-Volume Roads Subgrade Widening" and found four main types of distress. Those were: sliding of the subgrade, failure of the retaining structure, pavement damage and the decrease in pavement performance. Road widening was analysed through a combination of finite element method, laboratory tests, and in situ observation. Three main kinds of failure modes were determined: shear cracking, bottom-up cracking and top-down cracking. Shear cracking was found to relate to the slippage of the newly built subgrade along the interface. Bottom-up cracking was caused by differential deformation of the widening and was started as a result of the build up of tensile stresses. This type of crack moved towards the surface of the pavement. Top-down cracking was caused by convex and non-uniform deformation at the top of the widened subgrade. The top-down cracking moved downwards in the road structure. According to the research, the distresses in highway widening were mainly caused by differential deformation at the top of the subgrade and the widened part. It was considered that this could be prevented by replacing the old subgrade or by reinforcement. Differential deformation was considered to be the main source of pavement cracking due to additional bending stress. Restraining non-uniform deformation was one way to avoid cracking. [Ling, Qian, Huang, 2007]

The Southeast University in Nanjing, China, used centrifuge model testing and finite element modelling (FEM) to research road widening in the report "Comparison between responses of reinforced and unreinforced embankments due to road widening". The purpose of the research was to find out how reinforcement can affect embankment widening. Differences in settlements between reinforced and unreinforced embankments were found. These differences were not great but clearly observable. Geosynthetic reinforcements slightly reduced the non-uniform settlements, the coefficient of pore water pressure and horizontal displacement. [Huang, Wang, 2009]

The University of Kansas, USA and Istanbul University, Turkey collaborated in the research project "Numerical analysis of foundation columns to support widening of embankments". This numerical study showed that consolidated soil with improved properties under the existing embankment could reduce the maximum settlement, the horizontal displacement, and the transverse gradient change, but had little influence on the vertical and shear stress distributions. In the case of columns installed only under the widened portion, the maximum displacements moved to the connecting side slope of the existing embankment. Further installation of columns under the existing embankment controlled these displacements. The best performance obtained was through optimizing the column spacing under the connection side slope of both the existing embankment and the widened portion. The project concluded that changes in transverse gradient should be controlled to avoid possible failures, widening the embankment increased shear stresses in the existing

embankment towards the widened portion, and foundation columns could provide shear resistance to the shear stresses induced by widening the existing embankment. [Han, Oztoprak, Parsons, Huang, 2007]

3.3.2. Pavement Joint

Several studies have been carried out into the construction of the longitudinal pavement joint and have concluded that it is critical to avoid low density in the area of the joint. If a low density area is created in the joint, water can percolate to the joint and break it in cold weather. A solid asphalt joint can give a high density area but reflective cracking due to the joint can sometimes break through the pavement.

The research project “Density Evaluation of the Longitudinal Construction Joint of Hot-Mix Asphalt Pavements” looked at longitudinal joint density in Texas to find out if a problem existed. The researchers found that there was often an area of low density at the edge of the first paved lane. [Estakhri, Freeman, Spiegelman, 2001] A typical low density area in asphalt joint is shown in figure 24. The National Pavement Association (NAPA) has suggested a tapered joint technique (Figure 25) to avoid creating a low density area in a joint.

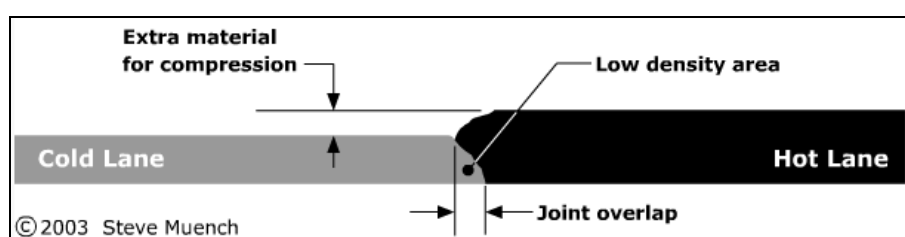


Figure 24: Low density area in joint [Pavement Interactive]

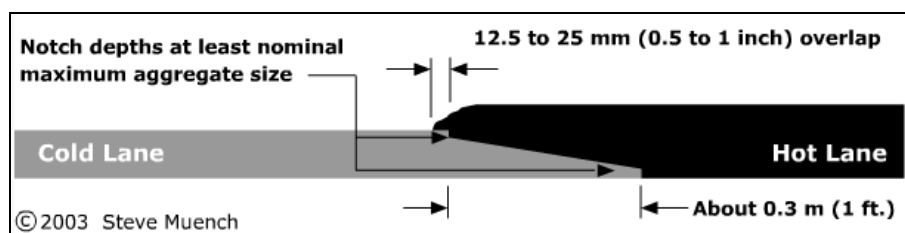


Figure 25: Notched wedge joint [Pavement Interactive]

Pavement joint construction in New Jersey is reported in “Construction of Durable Longitudinal Joints”. According to the research, four steps on jointing are essential. These are:

1. The unsupported edge of the “cold” lane should be compacted by placing the drum of a steel wheel roller 150 mm over the top of the unsupported edge
2. The amount of mix placed over the top of the cold lane when laying the new lane should be limited to a distance of 25 mm to 40 mm.
3. The new mix placed at the joint should not be moved with a rake but should remain as placed by the edge plate of the screed of the paver.
4. The mix at the longitudinal joint should be compacted from the hot side of the joint with the outside tire of a rubber tire roller directly over the joint, or with the drum of a steel wheel roller extending 150 mm over the top of the joint.

This research stated that durable longitudinal joints are a workmanship issue and that proper construction techniques should give a long life longitudinal joint without ravelling or deterioration. [Benson, Scherocman, 2006]

4. THE ROADDEX QUESTIONNAIRE ON ROAD WIDENING

In view of the limited number of road widening reports available it was decided to create a questionnaire on road widening to provide greater information and knowledge of road widening. Questions listed covered a range of typical problems likely to be encountered in road widening. Respondents were asked to indicate their view on the problems and any methods they knew on how to deal with the problems. The questionnaire was launched July 2010 as a web-questionnaire and closed in August 2010. Information on the questionnaire was sent to road widening experts in the ROADDEX countries by email. Seventeen responses were received and these are summarised in the following sections.

4.1. TOPOGRAPHY AND GEOMETRY

The existing road topography and geometry were considered to pose occasional problems for road widening projects but respondents had a range of views on this. The lack of space was cited as a problem by some, depending on their areas. For example, creating more space by felling trees adjacent to low-volume forest roads was not a problem. Respondents reported that local landowners were normally helpful in allowing road works to proceed as long as land encroachment was kept to a minimum. Where space was limited, respondents had used steeper side slopes with reinforcement and/or retaining walls. The choice of the most suitable type of drainage system was a consideration for sites with space problems.

Diagonal construction joints between the new and old structures were reported as presenting problems, especially where the new road involved improvements to sharp curves on existing roads.

4.2. CONSTRUCTION AND REPAIRING TECHNIQUES

When making a construction joint between the existing road and the new widening, the commonly recommended method is to construct equal structures in the old and new parts of embankment. The joint construction type will depend on the formation type and the subgrade soil. A stepped joint and an angled joint are both commonly in use in the ROADDEX areas, and a vertical joint is also sometimes recommended. Many of the respondents did not recommend any particular angle, but some suggested angles between 45° to 80° were proposed. Many recommended that the pavement layers should be cut or staggered in some way. The use of geotextile or steel grids was recommended under new paving, under the base course and under the sub-base. The wrapping of unbound materials in a geogrid was also recommended. These types of reinforcement must however be tied into the old embankment. Gabions and reinforced earth were also reported as being used. One solution used the existing embankment as a uniform base layer for the new road.

Lack of compaction of filling materials was considered to result in lateral movement in the widened area. This was a commonly observed phenomenon. On low-volume roads it may be possible to allow the widened part to settle for a number of months before finishing the works and site transport can be used as compaction equipment. The surface of the existing embankment must be excavated however before the widening. One 'rule of thumb' recommended was that at least 0.5 m of the embankment should be excavated to achieve a satisfactory key for the widened area.

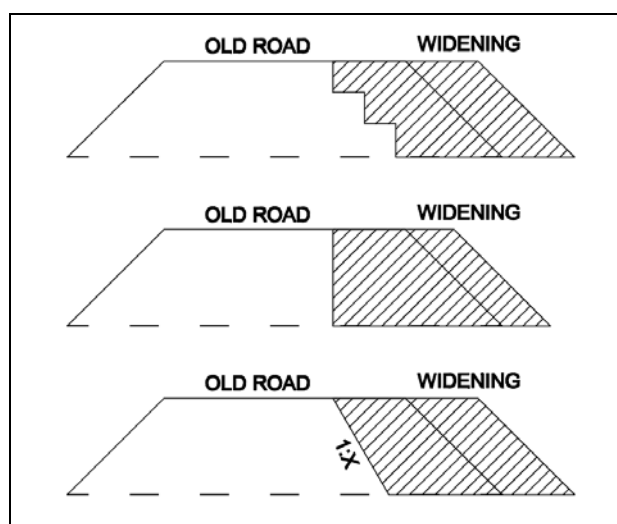


Figure 26: Construction joint types

Most of the respondents recommended that construction joints should not be located under the wheel path. This is not always possible however and one respondent said that sometimes it can even be useful to have the joint near or under wheel track in order to maximize settlement prior to completion of top layers. In some Partner areas the joint location is determined just by the width of existing embankment and the widening. Methods for minimising reflection cracking over the joint included constructing an equal structure in the widened portion, allowing sufficient time for settlement before overbanding, the use of a stepped joint between the pavement layers, and ensuring sufficient lateral transverse support.

When asked about the repair of widened roads fewer replies were received. Some of the respondents did not have experience of repairing widened roads. One advised that they carried out repairs by trial and improvement. Most of the respondents recommended that it was necessary to find out the reasons for the failures before carrying out a repair. This involved understanding the initial situation and analysing the reasons underlying the failure. In some cases the widening had had to be reconstructed. Sometimes the use of a steel grid has been enough.

4.3. SURVEYS

The structural layers of the existing road and embankment must be carefully researched before widening is carried out. The most common way of doing this according to the replies received were by excavating test pits, ground penetrating radar, referring to old design documents and taking drill cores. Some of the respondents stated that they only excavated test pits. It was considered that any existing reinforcement in the road should be identified before widening and that the road should be monitored and topped up during the settlement period. Some of the reported failed sites had happened as a result of a poor evaluation of the original embankment and subgrade. The actual thickness of layers and materials were sometimes only discovered during the excavation of the existing embankment.

4.4. SETTLEMENT AND PEAT SOILS

Respondents generally considered settlement to be a minor problem, but some thought that it was a major problem. It was considered that the old embankment and new structure should settle similarly. When asked about how to prevent cracking between the old and new part of embankment due to uneven traffic loading respondents gave a number of replies including the use of preloading and reinforced structures. The use of site transport to compact the widening was also mentioned. It was felt that the final paving should be laid after the traffic had loaded and compacted the widening. This was stated to reduce lateral settlement. A temporary pavement was recommended during settlement period. Some respondents reported that projects had not been given adequate time for settlement before paving. These had consequently had failures in the new pavement. It was said that differential settlement may not be so noticeable in wet bound macadam roads, or as much of a problem, as it is in roads with paved surfaces.

Road widening on peat soils was regarded as a major problem. Many respondents stated it was a significant or major problem. Some of the respondents said they did not want to widen roads over peat soils. It was again considered essential that a uniform settlement was achieved across the old and new part of the embankment. Assessing the settlement of the existing embankment was reported to be difficult as it usually had already settled due to the weight of the structure and the traffic load. Settlement in the existing embankment could be restarted or increased after adding the widening section, or during upgrading the road. It was also considered difficult to evaluate settlement of the new part of the road. Both parts should settle equally. It was not considered good practice to have the widened area significantly better than the existing road.

The most common methods of dealing with widening on peat soils were using overload embankments, geogrids, steel reinforcement, and soil replacement down to a hard base. Piles, stabilization, lightweight structures, timber stumps and logs had also been used. The most commonly agreed method was to construct the layers of the widening equal to those of the existing embankment, and to have them tied to it with reinforcement such as geogrids or steel grids. In areas of deep soft ground it was considered important to separate the new construction layers from the subgrade. This was commonly carried out by using a separating fabric to prevent the migration of materials, leading to settlement.



Figure 27: Settlement on peat soil

4.5. DRAINAGE

Drainage was generally considered to be a minor problem in road widening as the new drainage system was usually better after the widening works, particularly if enough space was available. A range of steel and plastic culverts, pipes and open channels had been used in drainage systems. One respondent recommended all the subdrains should be replaced during road widening as the joints between the old and new pipes could loosen. All agreed that the drainage system should be continuous from the old to the new, and that 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. Poor drainage systems were reported as causing edge failures and weakening the road structure. The surface shape of the ground had to be considered in the design of the drainage system as it could restrict its efficiency. It was felt that a good drainage system was dependant on the subgrade and formation of the road. The available space at the side of the road had a great affect on the type of drainage system that could be chosen. Difficult drainage problems had sometimes been overcome by pumping.

4.6. FROST ACTION

A range of replies were received on the questions regarding frost action. Some replied that frost was not a problem to them, others regarded it as a major consideration. Of these, the recommended methods to minimise frost action included insulation, good consistent drainage, geotextiles and maximum compatibility. It was also recommended that the frost properties of the widening materials should be equal to those of the existing embankment, and that the layer thicknesses should be the same as the old structure. Often the old road was improved at the same time as the widening, e.g. by adding aggregate. This practice was considered to decrease the impact of frost thaw and the risk of failures. Voids in pavement joints were considered to induce tearing of the joint in winter and it was recommended that the entire road should be sealed on completion to prevent this. Where pavements were broken, surface water had entered and had been absorbed into the embankment. Possible repair solutions for frost thaw included installing geogrids and steel grids. A possible way of minimising damage to low volume roads during frost susceptible periods was to control the traffic loading.

4.7. SLOPE STABILITY

When asked about the steepening of side slopes on road widenings due to lack of space, respondents reported some slippages. These had happened in the spring when the moraine slopes had flowed. A number of methods were given to improve slope stability; using a geotextile, heavy rip-rap to support the slope, retaining walls and stepped batters were considered to be feasible alternatives. Vegetation on the slopes was usually the most economical way to reduce local erosion on the slopes. A workable drainage was also considered necessary to assure stability. On low-volume forest roads it was often easier to create space for gentle slopes by felling more trees. One problem that was reported was that of lorries cutting corner and going off the road because of the steep slopes.

4.8. BEDROCK

The cost of widening of roads constructed close to bedrock was considered to be a significant issue. Some respondents mentioned that they had had problems estimating the costs and rock masses involved. If there were no other constraints, the bedrock was usually blasted and excavated, with the resulting rock material used for construction depending on the quality of aggregate produced. Transition wedges were considered necessary where the bedrock was below the road. The variable surface of bedrock was stated to pose non-uniform settlements and frost effects if not dealt with. Surface water runoff had to be monitored to ensure that it worked and this could require surface reshaping. Drainage arrangements in shallow construction were a particular problem that had to be planned in order to keep the low water table low within the road. Sometimes the width of side drain had been reduced to ease the cutting of bedrock. Rock netting was recommended for unstable cliffs.



Figure 28: Bedrock close to road

4.9. TRAFFIC MANAGEMENT

All respondents reported that their arrangements for traffic management depended on the speed and traffic volume of the road. Some forest roads had been closed during widening works. On high traffic volume roads traffic management had to be planned more carefully and it was recommended that this should be part of the contract. Normally at least one lane was kept open for traffic during construction. Respondents stated that the widening works, and the order that the works were carried out, had to be carefully planned, and adequate resources given, to ensure that the working period could be minimised. The timing of works was also considered critical in order to avoid rush hours. Well carried out ground investigations could prevent delays, as could the use of bypasses and temporary widenings. It was considered that any excavations should be small as possible and filled quickly. Closed sections of road had to be clearly separated from open sections for traffic safety.



Figure 29: Widening works require traffic management

4.10. OTHER ISSUES

When asked about other issues that should be considered in road widening a number of matters were suggested. Road Widening on deep peat soils was commonly thought to be a significant problem. Other problems mentioned were the lack of space and obtaining a compatible formation and behaviour between the existing and widened sections. Often design and construction had been based on poor ground surveys and this had resulted in a failure to adequately identify the properties of the existing embankment and subgrade. A further criticism was that designers did not have enough knowledge of local contractors working methods and it was felt that this could pose problems in executing the work on site. Hasty construction practices were thought to result in problems. It was important that roads were allowed to settle before the final paving was laid.

5. CONCLUSIONS

There are a number of differences in road widening practices across the ROADEX partner countries, the main one being in the scope of guidance given. Some guidelines are extensive, other are fairly minor. Guidelines for road widening were not found for Greenland, Ireland and Sweden. The national guidelines reviewed were generally broad and did not include much detailed advice. Most are similar, with similar drawings, although some are more detailed than others. The manuals reviewed in this report were the nationally agreed guidelines. Other road widening manuals and guides issued by private organizations are also available in some ROADEX countries. These have not however been reviewed in this report.

Successful road widening project is the sum of many considerations. If one consideration is neglected, it can lead to significant failures. Usually the effectiveness of the widening only becomes clear after a period of time. Defects are not generally apparent immediately after construction.

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 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. These can include steel grids, geogrids and geotextiles. Stabilization, soil replacement and piling may also help but these are likely to increase overall costs. For this reason it is important that a careful evaluation of the original embankment and subgrade is carried out, together with an assessment of the need for reinforcement. The life-cycle cost should be considered in this, not just the construction costs. For example the use of steel grids will increase construction costs, but it can also decrease the need for maintenance. So in the long term the use of reinforcement can be more economical. The assessment of whole life costs can be difficult however.

In all road widening projects is essential to understand the condition of the existing structure before attempting the design of the widened area. There are a number of ways that this can be done. This review reports methods such as the excavation of test pits, ground penetrating radar and drilling cores. Old design and construction records can also provide very useful information, but these should be confirmed with other studies before being accepted. The aim of all studies should be ensure that the widened portion is similar in character and structure to the existing road. If the existing road is frost-susceptible, or if it is showing non-uniform settlement, it is recommended that the road should be repaired before widening. In this case the reasons for the failure should be identified before the repair is carried out. It may be that, as shown in the questionnaire, that the structure of some roads can only be verified during the construction phase, but this should not be taken as the standard.

It was generally agreed that the widening portion should be as similar to the original embankment as possible, both in structure and materials used. This will help to achieve a uniform behaviour between the old and new parts of the embankment. Some of the most important parameters for selecting materials are water absorption properties, frost properties and compaction. The construction joint between the old and new part of the embankment can be made in many way. Stepped joints, angular joints and vertical joints are all in use in the ROADEX partner countries. A stepped joint can be made with various step sizes, and angular joints with different angles. Such joint details are case-specific and will depend on the embankment structure and subgrade.

Good compaction of the widened portion is essential to achieve uniform settlement. This can be difficult in places, and many cases of inadequate compaction have been found during the study. 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. Inappropriate compaction machinery is a main cause of unequal compaction and designers should make themselves aware of the compaction plant available in the local area and the local working practices. It is recommended that the design of the road widening should determined by the compaction equipment available. For example the minimum width of widening should determine by the width of conventional compaction equipment and compaction should be carefully observed during construction.

The drainage from the old construction to the new widening should be carefully planned. It should be continuous, and work equally well in the new and old parts of the embankment. If the new materials in the widened portion have greater water absorption properties than those of the existing embankment, surface water can be led to the existing embankment and create problems there. Conversely if the water absorption

properties of the widened portion are less than those of the existing embankment, water can be trapped the existing embankment. It is therefore recommended that the widened portion should have a similar structure to that of the existing embankment. Where this is not possible, the resulting drainage must be carefully considered.

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 borne in mind. Often, the widened portions of roads on peat are tied to the existing embankment with steel grids or geogrids. Settlement in soft soils can sometimes be decreased with soil replacement or earth reinforcement.

An ideal road widening project should not fail. In many cases with paved roads however a longitudinal reflection crack has developed between the original embankment and the widened portion. This is a result of differential movement between the old and new portion. This crack can be avoided by achieving uniform movement in both portions of the embankment. Practical methods to avoid reflection cracking include subgrade treatment or embankment reinforcement. 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 through to the surface. This type of crack can cause surface water to infiltrate into the embankment. This can weaken the embankment and cause frost problems. It is important therefore to seal any cracks in order to limit water absorption into the embankment.

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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
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