ROADEX Research and eLearning Package: Drainage

Timo Saarenketo, PhD
Roadscanners
Contents:

1. History of Drainage Research in ROADEX project
2. Introduction to Drainage eLearning
3. Economic Importance of a Well Performing Drainage
4. Drainage Demonstration Projects
5. Drainage Maintenance Follow Up in Finland
6. Conclusions and New Ideas
History of Drainage Research in ROADEX Projects 1998 - 2012

• Benchmarking: Drainage was of the biggest road condition management problems shared by all partners

• Drainage research: Identifying critical drainage sections, modelling drainage and pavement life time

• Development and testing drainage field survey techniques, drainage classification, drainage procurement documents in maintenance contracts

• Implementation: Drainage demonstration projects in partner areas, testing new techniques, drainage maintenance follow up, Drainage eLearning packages
Drainage eLearning Package

Lesson 1
Permanent Deformation

Lesson 2
Roads on Peat

Lesson 3
Drainage of Roads
To be issued in 2012

Ready by 05/2012

Lesson 4
Environmental Considerations
Drainage eLearning Package - Contents

1. Introduction, why drainage is important
Drainage eLearning Package - Contents

2. Water in Road Materials and Subgrade Soils

Phase properties and relations

1. Surface water
2. Intermediate vadose zone
3. Sat. zone

Vadose zone
Capillary water
Ground water

Ground water table
Lower ground water table

Matric suction
$\Delta h = Z$

Pressures, $u$ (kPa)

Temperature, $t$ (°C)

Solid
Liquid
Vapor
Sublimation curve
Fusion curve
Triple point
Vaporization curve
Drainage eLearning Package - Contents

3. Water and Mechanical Properties of Roads
Drainage eLearning Package - Contents

4. Components of Road Drainage Systems
5. Drainage Problems and How to Avoid them
Drainage eLearning Package - Contents

6. Drainage Analysis and Classification
7. Examples of Drainage Deficiencies in ROADEX Area
Economic Importance of a Good Drainage System

What is Pavement Life Time?

- rehabilitation measures needs to be taken when more than 10% of the rutting or roughness values are higher than the trigger value

What is Common for these critical sections?
Critical Parameters in Pavement Life Time Evaluation are Rut and IRI Growth Speed

<table>
<thead>
<tr>
<th>Rut increase (mm/year)</th>
<th>Initial rut (mm)</th>
<th>Life time (years)</th>
<th>Rut depth max (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>2</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>0.5</td>
<td>2</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>0.6</td>
<td>2</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>0.7</td>
<td>2</td>
<td>25.7</td>
<td>20</td>
</tr>
<tr>
<td>0.8</td>
<td>2</td>
<td>22.5</td>
<td>20</td>
</tr>
<tr>
<td>0.9</td>
<td>2</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>1.1</td>
<td>2</td>
<td>16.4</td>
<td>20</td>
</tr>
<tr>
<td>1.2</td>
<td>2</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>1.3</td>
<td>2</td>
<td>13.8</td>
<td>20</td>
</tr>
<tr>
<td>1.4</td>
<td>2</td>
<td>12.8</td>
<td>20</td>
</tr>
<tr>
<td>1.5</td>
<td>2</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>1.6</td>
<td>2</td>
<td>11.3</td>
<td>20</td>
</tr>
<tr>
<td>1.7</td>
<td>2</td>
<td>10.6</td>
<td>20</td>
</tr>
<tr>
<td>1.85</td>
<td>2</td>
<td>9.8</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>9</td>
<td>20</td>
</tr>
</tbody>
</table>

Pavement life time (years)

Rut increase (mm/year)

But pavement life time can be also calculated using linear elastic theory.
PMS Objekt Pavement Life Time Calculations – Good Drainage

Bound: 80
Unbound base old: 250 mm
Unbound sub base old: 150 mm
Filter course: 220 mm
Structures: total: 700 mm
Subgrade: moraine
Drainage: Ok

Rut Increase: 0,9 mm/year

Bound: 100
Unbound base old: 250 mm
Unbound sub base old: 150 mm
Filter course: 220 mm
Structures: total: 720 mm
Subgrade: moraine
Drainage: Ok

Rut Increase: 0,7 mm/year

Bound: 120
Unbound base old: 250 mm
Unbound sub base old: 150 mm
Filter course: 220 mm
Structures: total: 740 mm
Subgrade: moraine
Drainage: Ok

Rut Increase: 0,4 mm/year

Traffic volume: 500, heavy traffic 5 %
Drainage and Linear Elastic Behaviour of Pavement Structure

Case: Drainage in Good Condition

- 120 mm: 2300 €/year/km
- 100 mm: 2900 €/year/km
- 80 mm: 3400 €/year/km
PMS Objekt Pavement Life Time Calculations – Poor Drainage

Bound: 80
Unbound base old: 250 mm
Unbound sub base old: 150 mm
Filter course: 220 mm
**Structures: total: 700 mm**
Subgrade: moraine
Drainage: class 3

Rut Increase: 1,85 mm/year

Bound: 100
Unbound base old: 250 mm
Unbound sub base old: 150 mm
Filter course: 220 mm
**Structures: total: 720 mm**
Subgrade: moraine
Drainage: class 3

Rut Increase: 1,1 mm/year

Bound: 120
Unbound base old: 250 mm
Unbound sub base old: 150 mm
Filter course: 220 mm
**Structures: total: 740 mm**
Subgrade: moraine
Drainage: class 3

Rut Increase: 0,7 mm/year

Traffic volume: 500, heavy traffic 5 %

Frost heave: 160 mm
Drainage and Linear Elastic Behaviour of Pavement Structure

Case: Drainage in Poor Condition

- 120 mm: 2900 €/year/km, 3700 €/year/km
- 100 mm: 2300 €/year/km, 2900 €/year/km
- 80 mm: 3400 €/year/km, 5200 €/year/km

Pavement life time (years) vs. Rut increase (mm/year)
But, in addition to linear elastic fatigue, poor drainage is causing permanent deformation!

Road 78 Section 219 Pavement Life Time
Investment to Better Drainage is Win-Win for Everyone

Rovaniemi area:
First year investments:  
100 k€ =>
Potential savings:  
250 – 330 k€/year

Further use of savings:  
1. 50 k€: for drainage maintenance  
2. 200- 330 k€: for thicker pavements
Drainage, Frost and Rutting: Case Road 81

- Rutting
- Rut increase /year
- Side sloping ground (from right to left)
- Drainage left
- Drainage right
- Frost line left lane
- Frost line right lane
The ROADEX demonstration projects - Drainage
DRAINAGE IMPLEMENTATION PROJECTS

WESTERN ISLES

NORWAY

ICELAND

SISIMIUT, GREENLAND
Drainage Condition in Western Isles
ROADEX Demonstration project: Umeå Södra, Region Norr, Sweden:

- Testing tools to improve drainage analysis in Umeå Södra maintenance area
  - Laser Scanner and GPR; combining road structure and ditch bottom depths
  - Drainage analysis – seasonal tests
  - Tools for outlet ditch inventory
  - Thermal camera development
Results:
Drainage analysis can be done both in spring and in fall.
Road Doctor Cam Link for Outlet Ditches

Video camera pointing 90°

Outlet ditch observing comparison

Still image
Ditch Depths with Laser Scanner and GPR

Proportion of ditches with acceptable depths
(ditch bottoms are 20cm lower than road structure)

<table>
<thead>
<tr>
<th>Road</th>
<th>Left ditch</th>
<th>Right ditch</th>
</tr>
</thead>
<tbody>
<tr>
<td>353</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>515</td>
<td>19%</td>
<td>28%</td>
</tr>
<tr>
<td>520</td>
<td>36%</td>
<td>48%</td>
</tr>
<tr>
<td>523</td>
<td>30%</td>
<td>50%</td>
</tr>
</tbody>
</table>
Problems with Shallow Ditch Depths are Reflected also in IRI and Rut Depth Values

IRI medians. Road 353. Thickness 0,6-1,0. DRA >= 2

RUT medians. Road 353. Thickness 0,6-1,0. DRA >= 2

Thicknes weighted average
Drainage Examples from Norway
Ditch Bottom Level Analysis Rd 73 Norway
Ditch Bottom Level Map: E6, section 12
Demonstration project:
Lapland Region, Finland:

- Follow up, how the new drainage policy works in practise in Rovaniemi and Kittilä maintenance contracts
  - Monitoring the condition of special drainage sections
    - How well contractors have done their job,
    - What is the reason for the failures?
- Has road deterioration rate (rut increase, roughness, pavement distress) really decreased?
  - And if not, what is the reason
- Problems with Drainage Analysis
Kittilä Follow Up: Rd 80_10, 3000-4000 m
Kittilä Follow Up: Rd 80_10, 7000-8000 m

2005 Rut depths

2010

IRI

Rut depths

2005

2010
Condition of Kittilä Special Drainage Maintenance Sections

Increased Rut and IRI and the Reason for that.

Ditch depth was not analysed
Condition of Rovaniemi Special Drainage Maintenance Sections

Drainage Class

- Drainage Class 1 (%)
- Drainage Class 2 (%)
- Drainage Class 3 (%)

Increased Rut and IRI and Reason for that.

Road 78
- 95%
- 1%
- 1%
- 3%

Road 926
- 78%
- 1%
- 3%
- 18%

Road 934
- 84%
- 1%
- 11%
- 4%

Ditch depth was not analysed
Rovaniemi follow Up: Rd 934 / 3-4

Special problem: Clogged Private Acces Road Culverts
Special problem: Clogged Private Access Road Culverts
Special Problem: Private Access Road Culverts
Special Problem: Private Access Road Culverts
Problems Caused by Private Access Road Culverts
Problems Caused by Private Access Road Culverts

Culvert freezes during winter

Height (m)

A. snow
   ice
   water

B. snow

Frozen culvert

A. Frozen culvert

B.
Problems Caused by Private Access Road Culverts
Special Problem also on Gravel Roads:
Private Access Road Culverts
Formation of Ice Lenses Under Road at the End Point of Flooded Ditch
Special Problems Unstable Ditch Slopes
Road 934 section 3, 1740 right
The Role of Private Access Road Drainage Condition and Pavement Life Time

Section 3

Section 4

Sandy subgrade
Special Drainage Problem – Sheet Ice
Special Drainage Problem – Ditches too High
## Special Drainage Problem – Ditches too High

<table>
<thead>
<tr>
<th>Condition</th>
<th>Section 3</th>
<th>Section 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ditch bottom level is &gt; 0,3m deeper than bottom level of road structure</td>
<td>46,9</td>
<td>46,9</td>
</tr>
<tr>
<td></td>
<td>45,9</td>
<td>58,7</td>
</tr>
<tr>
<td>Ditch bottom level is 0-0,3 m deeper than bottom level of road structure</td>
<td>21,1</td>
<td>30,6</td>
</tr>
<tr>
<td></td>
<td>29,9</td>
<td>23,7</td>
</tr>
<tr>
<td>Ditch bottom level is &gt; 0 m higher than bottom level of road structure</td>
<td>32,1</td>
<td>22,6</td>
</tr>
<tr>
<td></td>
<td>24,2</td>
<td>17,7</td>
</tr>
</tbody>
</table>

The images on the right show profiles and data readings over time, indicating variations in road elevation and drainage conditions, with markers for frost heaves and road profile changes.
Ditch Condition is a Problem also on Main Roads - Example of HW4

Surface height

IRI

Rut depth right
Rut depth left

Structure thickness vs. ditch bottom

Cross section

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Roadscanne

ROADEX Network Implementing Accessibility
ROADEX Drainage Analysis in general showed problem sections, but more sections could have been selected, special problems were roads with recently improved drainage.
Conclusions (1):

- Poor drainage is causing MAJOR problems in all ROADEX countries and better maintenance is even more important than earlier were evaluated.
- New mobile laser scanner results really show the importance of good drainage maintenance.
- In test road 934 > 50% of the frost heave problem can be related to private road exit and their poorly working culverts.
- Poor access road culverts cause also collapse of ditch slopes and further problems with roads.
Conclusions (2):

- Verges are causing problems in all ROADEX areas and should be always removed.
- Even small ponding in ditches may cause problems.
- Narrow (sharp) ditches cause problems.
- Sheet Ice is causing major frost heave and deformation problems in road shoulders => traffic safety issue.
- Visual drainage evaluation is not enough accurate and too subjective to enforce maintenance contractors for actions.
New Ideas:

- **From visual inspection to objective drainage condition surveys:**
  - 1. Phase GPR + Laser Scanner => target ditch bottom level
  - 2. Phase: Improvement
  - 3. Phase: Monitoring Ditch Bottom Level with Laser Scanner

- **Monitoring Systems for Verges**

- **Focus on Private Access Road Culverts:**
  - Road owner need to take responsibility

- **Preventing Formation of Sheet Ice:**
  - Locating sheet ice sections
  - Installation of heating cables and solar panels
  - Focusing on the ditch form (wider ditch bottoms)
And Poor Drainage is Also a Traffic Safety Issue!!

Thank You!