ROADEX Drainage Research:

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Roadscanners, Finland
ROADEX PROJECTS 1998 - 2007

Image © 2006 TerraMetrics
Image © 2006 NASA

Implementing Accessibility

ROADEX

Northern Periphery
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?
ROADEX Projects have so far shown:

Drainage is a **Major Problem** in NP Area Roads!
Special Drainage Problem in NP Area: Roads on side sloping ground
Cumulative distribution of the ratio for rut depth in the drained and the undrained lane
Effect of Poor Drainage on Pavement Performance: Theoretical Calculations:

Test Calculations Based on Swedish Design Guide

Structure
110 mm bituminous wearing course
120 mm bituminous macadam
800 mm old sub-base gravel material
Subgrade: silt

Improving drainage from class 3 to class 1

Increase the lifetime by a factor of nearly 2,2.
### Drainage condition

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Drainage classes</th>
<th>Factor - change in lifetime by improving the drainage system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1</strong></td>
<td>Drainage system does not work at all (or drainage system does not exist). Water susceptible soil in road structure and subgrade. Very high ground water table. Low ground and rocks blocking the ground water flow. Often local spots.</td>
<td>&gt;3</td>
<td>&gt; 2,5</td>
</tr>
<tr>
<td><strong>Group 2</strong></td>
<td>Drainage system does not work at all and the soil in road structure and subgrade are less water susceptible then in group 1. Drainage system is working badly because of lack of maintenance (ditches and culverts not cleared) and water susceptible soil in road structure and subgrade.</td>
<td>3</td>
<td>2-2,5</td>
</tr>
<tr>
<td><strong>Group 3</strong></td>
<td>Drainage system is working badly because of lack of maintenance. (Ditches and culvert not cleared.) The soil in road structure and subgrade are less water susceptible.</td>
<td>2</td>
<td>1,5-2</td>
</tr>
<tr>
<td><strong>Group 4</strong></td>
<td>Drainage system is working unsatisfactory because of lack of maintenance or the maintenance guidelines are not sufficient.</td>
<td>1-2</td>
<td>1-1,5</td>
</tr>
</tbody>
</table>

1) Comparison to the drainage classes in the Swedish design guide.
Roadex III Report
Developing Drainage Guidelines for Maintenance Contracts
Results of a ROADEX III Pilot project in the Rovaniemi Maintenance Area in Finland
Drainage Guidelines – Project Goals:

*Implementing New Drainage Policies and Techniques*

• new drainage management model for maintenance contracts
• new techniques for drainage analysis in paved roads and gravel roads
• analysing drainage condition in Rovaniemi road network
• standards for the maintenance contract
• calculate the effect of poor drainage for life cycle costs on paved and gravel roads
• how much investments can be used to improve drainage – and still be profitable
• test the new guidelines in the procurement process of Rovaniemi maintenance contracts 2007 - 2012
New RD CamLink system for drainage and distress surveys
New tests: drainage analysis and thermal cameras
VISUAL DRAINAGE CONDITION CLASSIFICATION OF PAVED ROADS

Class 1: Good Drainage Condition

Description:
Faultless drainage. Road cross section shape has preserved its form well and water flow from the pavement to ditch has no obstacles. Unrestricted water flow in ditches.
VISUAL DRAINAGE CONDITION CLASSIFICATION OF PAVED ROADS

Class 2: Adequate Drainage Condition

**Description:**
Small changes in the road cross section form can appear. Road shoulder has small verges or vegetation that prevents good water flow to ditch. Vegetation in ditch restrains water flow and causes dams. Small amount of soil flows from road slopes into ditches and raises the bottom of the ditch, slows the water flow and raises the ground water table.
Class 3: Poor Drainage Condition

**Description:**
Deformations and damages in the road cross section. Road shoulder can have a high verge and/or dense vegetation that causes ponding on the traffic lane or on the shoulder. Vegetation in ditch restrains water flow and causes dams in the ditch. Unstable soil flows from ditch slopes into ditches and blocks the water flow. Clocked culvert or outlet dict prevent the water flow in the ditch.
VISUAL DRAINAGE CONDITION CLASSIFICATION OF GRAVEL ROADS

Class 1: Good Drainage Condition

**Description:**
Faultless drainage. Road cross section shape has preserved its form well and water flow from the pavement to ditch has no obstacles. Unrestricted water flow in ditches.
Class 3: Poor Drainage Condition

**Description:**
Deformations and damages in the road cross section. Road shoulder can have a high verge and/or dense vegetation that causes ponding on the traffic lane or on the shoulder. Vegetation in ditch restrains water flow and causes dams in the ditch. Unstable soil flows from ditch slopes into ditches and blocks the water flow. Clocked culvert or outlet dict prevent the water flow in the ditch.
ROAD CROSS SECTION PROFILE IN DRAINAGE CLASSIFICATION

- Road cut
- Road on side sloping ground
- Road at 0-level
- Road built on embankment
Drainage Analysis Data for Paved Roads

Project: 14_934_1 Line: 934_2

Drainage left
Drainage right

Rut increase mm/year
Statistical analysis, example: Rd 79_19

IRI

Roughness: IRI mean value

<table>
<thead>
<tr>
<th>Drainage class</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epätasaisuus</td>
<td>1,63</td>
<td>1,86</td>
<td>2,35</td>
</tr>
</tbody>
</table>

Rutting

Rutting: Rut depth mean value

<table>
<thead>
<tr>
<th>Drainage class</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uraisuus</td>
<td>11,01</td>
<td>13,34</td>
<td>15,54</td>
</tr>
</tbody>
</table>

Drainage Class Distribution:

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>63,5 %</td>
<td>26,3 %</td>
<td>10,2 %</td>
</tr>
<tr>
<td>3806</td>
<td>1576</td>
<td>610</td>
</tr>
</tbody>
</table>
Drainage Analysis: GIS-maps, road 79_19
Statistical analysis, example: 79_20

**IRI**

![IRI Graph](image)

**Rutting**

![Rutting Graph](image)

**Drainage Class Distribution:**

<table>
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<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>65.0%</td>
<td>32.3%</td>
<td>2.7%</td>
</tr>
<tr>
<td></td>
<td>4755</td>
<td>2360</td>
<td>200</td>
</tr>
</tbody>
</table>
Drainage Analysis: GIS-maps, road 79_20
Selecting special drainage maintenance class areas:

a) Good correlation between rutting and drainage problems

b) Good correlation between pavement distress and poor drainage
Network level drainage analysis in Finland and Sweden:

Lapland
• Rovaniemi
• Kittilä
• Kemi
• + several others

Central- Finland District

Häme District

Sweden
• Skellefteå
• Haparanda – Överkalix
• Kramfors
Drainage Analysis in Rovaniemi, Kittilä and Kemin maintenance areas

Kittilä

- Kuivatusluokka 2: 27.4, 19.2, 37.5
- Kuivatusluokka 3: 5.5, 5.9, 8.5

Rovaniemi

- Kuivatusluokka 2: 31.2, 1.4, 4.0
- Kuivatusluokka 3: 46.7

Kemi

- Kuivatusluokka 2: 51.7, 44.9, 35.6
- Kuivatusluokka 3: 9.8, 9.8, 7.6
Case Rovaniemi results:

Relative Amount of Class 2 and Class 3 Drainage Problem Sections in Main Roads in Rovaniemi Area

Rovaniemi maintenance area
Examples of Drainage Condition in Road 19733

Filled ditch

Clockked outlet ditch
Average Rut Depths in Each Road Class and Drainage Class
Pavement Life Time Factor and Average Condition of 10 % Worst Drainage Sections on Main Roads in Rovaniemi Area

Average for 10 % worst rut depth values (Pavement lifetime factor)
- < 1,05
- 1,05 - 1,19
- 1,20 - 1,29
- 1,30 - 1,50
- > 1,50

Average for 10 % worst drainage class values
- > 2,50
- 2,00 - 2,50
- < 2,00

Rovaniemi maintenance area
Case Rovaniemi results:

**Average Rut depth in Each Road Profile and in Each Road Class**

- and rut depth ratio compared with average rut depth in embankments

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Embankment</th>
<th>0-level</th>
<th>Side sloping ground</th>
<th>Road cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main roads</td>
<td>1.35</td>
<td>0.97</td>
<td>1.02</td>
<td>1.10</td>
</tr>
<tr>
<td>Regional roads</td>
<td>1.05</td>
<td>0.99</td>
<td>0.99</td>
<td>1.22</td>
</tr>
<tr>
<td>Local roads</td>
<td>1.35</td>
<td>0.97</td>
<td>1.02</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Average Rut depth in Each Road Profile and in Each Road Class:

- Embankment 6.71
- 0-level 7.04
- Side sloping ground 6.83
- Road cut 7.39
Case Rovaniemi results:

Average IRI Values in Each Road Class and Drainage Class
Case Rovaniemi results:

Pavement Life Time Factor (IRI) and Average Condition of 10 % Worst Drainage Sections on Regional and Local Roads in Rovaniemi Area
Example of Poor Drainage on Roughness and Pavement Distress Growth, Road 934, section 4
Benefits of the Improved Drainage on Paved Roads –
Life Cycle Cost Analysis Results from Rovaniemi Area

<table>
<thead>
<tr>
<th></th>
<th>Main roads (m)</th>
<th>Regional roads (m)</th>
<th>Local roads (m)</th>
<th>Total (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>382 361</td>
<td>146 719</td>
<td>115 930</td>
<td>645 010</td>
</tr>
<tr>
<td>Width (m)</td>
<td>7.2</td>
<td>6.2</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>Paving cost €/m</td>
<td>36</td>
<td>31</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>Average lifetime (years)</td>
<td>10</td>
<td>13</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Drainage lifetime factor</td>
<td>1.16</td>
<td>1.19</td>
<td>1.24</td>
<td></td>
</tr>
<tr>
<td>Increased lifetime (years)</td>
<td>11.6</td>
<td>15.5</td>
<td>13.6</td>
<td></td>
</tr>
</tbody>
</table>

Discount rate: 4 %
Paving cost: 5 €/m2

<table>
<thead>
<tr>
<th></th>
<th>Main roads</th>
<th>Regional roads</th>
<th>Local roads</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual paving costs (€)</td>
<td>1 917 000</td>
<td>517 000</td>
<td>415 000</td>
<td>2 849 000</td>
</tr>
<tr>
<td>Costs if drainage improved(€)</td>
<td>1 698 000</td>
<td>461 000</td>
<td>355 000</td>
<td>2 514 000</td>
</tr>
<tr>
<td>Savings (€)</td>
<td>219 000</td>
<td>56 000</td>
<td>60 000</td>
<td>335 000</td>
</tr>
<tr>
<td>Savings (%)</td>
<td>11.4</td>
<td>10.8</td>
<td>14.5</td>
<td>11.8</td>
</tr>
</tbody>
</table>

If, in the LCC analysis, 1,5 longer pavement life time would have been used, the annual paving costs would have dropped in Rovaniemi about 36 % from 312.000 euro down to 199.000 euro (from 11% down to 7 %)
Potential Savings in 3 Maintenance Areas

Kemi
- Annual paving costs (€)
- Annual paving cost if drainage improved (€)
- Savings (€)
- Savings (%)

Kittilä
- Annual paving costs (€)
- Annual paving cost if drainage improved (€)
- Savings (€)
- Savings (%)

Rovaniemi
- Annual paving costs (€)
- Annual paving cost if drainage improved (€)
- Savings (€)
- Savings (%)

<table>
<thead>
<tr>
<th></th>
<th>Main roads</th>
<th>Regional roads</th>
<th>Local roads</th>
<th>All roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kemi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual paving</td>
<td>2044000</td>
<td>1106000</td>
<td>915000</td>
<td>4065000</td>
</tr>
<tr>
<td>costs (€)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual paving</td>
<td>1956000</td>
<td>1013000</td>
<td>710000</td>
<td>3679000</td>
</tr>
<tr>
<td>cost if drainage improved (€)</td>
<td>88000</td>
<td>93000</td>
<td>205000</td>
<td>386000</td>
</tr>
<tr>
<td>Savings (€)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings (%)</td>
<td>4,3</td>
<td>8,4</td>
<td>22,4</td>
<td>9,5</td>
</tr>
</tbody>
</table>

| Kittilä        |                  |                |             |           |
| Annual paving  | 2022000          | 527000         | 512000      | 3061000   |
| costs (€)      |                  |                |             |           |
| Annual paving  | 1663000          | 381000         | 400000      | 2444000   |
| cost if drainage improved (€) | 359000 | 146000 | 112000 | 617000 |
| Savings (€)    |                  |                |             |           |
| Savings (%)    | 17,8             | 27,7           | 21,9        | 20,2      |

| Rovaniemi      |                  |                |             |           |
| Annual paving  | 1695000          | 530000         | 370000      | 2595000   |
| costs (€)      |                  |                |             |           |
| Annual paving  | 1505000          | 464000         | 314000      | 2283000   |
| cost if drainage improved (€) | 190000 | 66000 | 56000 | 312000 |
| Savings (€)    |                  |                |             |           |
| Savings (%)    | 11,2             | 12,5           | 15,1        | 12,0      |
DRAINAGE IMPLEMENTATION PROJECTS

WESTERN ISLES

NORWAY

ICELAND

SISIMIUT, GREENLAND
Demonstration project:
Region Norr, Sweden:

- Testing tools to improve drainage analysis in Umeå Södra maintenance area
  - Tools for outlet ditch inventory
  - Thermal camera development
  - Laser Scanner and GPR; combining road structure and ditch bottom depths
  - Drainage analysis – seasonal tests
Road Doctor Laser Scanner

RD Cam Link (video cameras + GPS + inventory)
Laser Scanner (+ 3d Inclinometers)
Thermal Cameras
Road Doctor Laser Scanner
EFFECT OF DITCH DEPTH VS. ROAD STRUCTURE THICKNESS TO ROAD CONDITION

RUT medians. Road 353. Thickness 0.6-1.0. DRA $>= 2$

RUT values

Thickness weighted average

N=          115
<0.3          2.94

N=          291
0.3-0         2.72

N=          305
0-0.3        3.08

N=          248
$>=0.3$      3.96
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

Sections: 78 / 219, 222, 926 / 17, 19, 934 / 3, 4
Kittilä Follow Up: Rd 80_10, 3000-4000 m
Kittilä Follow Up: Rd 80_10, 7000-8000 m
Road 934 Section 3 Special Drainage Maintenance Sections

RUT Depth values and IRI Values 2004 and 2010
Thank You!