EARN – Effects on Availability of Road Network

EARN background data

Sachgebiet Bau und Erhaltung von Verkehrswe gen
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Presented by Dr Cliff Nicholls (TRL)
Service lifetime and availability of road materials and structures

- **LCA study conducted during Re-Road:**
  - Durability has same effect as high recycling rate
  - Benefits of recycling can be reverted in case of reduced durability

- **Objectives and promised results: Empirical evaluation of effects on pavements durability**
  - Effect of high proportions of reclaimed road materials
  - Road works conditions (weather, season, day/night)
  - Materials with high contents of reclaimed and secondary materials
  - Warm-mix asphalt
  - Working time and availability effects of road maintenance
Methodology

1. Synthesis of relevant parameters affecting pavements durability
2. Review of existing service lifetime estimations
3. Identification and analysis of databases for empirical assessment of durability effects of:
   - RA use and
   - Construction work conditions
1. Parameters with relevance for durability

- Traffic loading
- Sub-base characteristics
- Pavement type and structure
- Environmental effects
- Asphalt layers
- Bitumen stabilised base layers (cold recycling)
- Unbound base layer
- Hydraulically bound base layers

Durability
1. Parameters with relevance for durability

Sub-base characteristics
- Bearing capacity
- Sub-base moisture/drainage

Traffic loading
- Tyre/axle load
- Axle number
- Traffic speed
- Axle configuration

Environmental effects
- Temperature
- Sun exposure
- Humidity
- Frost-thaw cycles
- High-depth frosting

Asphalt layers
- Type of mixture
- Aggregate grading
- Binder type
- Binder content
- Volumetric properties
- Additives
- RA quality and content
- Construction conditions
- Performance properties

Pavement type and structure
- Flexible or rigid
- Number of layers
- Layer thicknesses
- Interlayer bonding

Unbound base layer
- Composition (grading, type of aggregates)
- Degree of compaction
- Moisture
- Bearing capacity

Hydraulically bound base layers
- Grading of aggregates
- Binder type
- Binder content
- Void content
- Stiffness
- Strength
- Construction conditions

Bitumen stabilised base layers (cold recycling)
- ... (see CoRePaSol project)

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Additives, e.g. for warm mix asphalt

- **Zeolite additives**
- **Organic (wax) additives**
- **Fatty acid derivatives**
- **Chemical additives**
- **Other specified additives**
- **Emulsions**
- **Foamed bitumen technologies**
- **Other processes**

In total, 35 WMA variations with distinct approaches... how to generalise their effect on durability?
1. Parameters with relevance for durability

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1. Parameters with relevance for durability

Interim result: Pavement durability is affected by a high number of parameters. A detailed analysis of general material-specific service lifetime from laboratory and modelling assessment is not possible.
2. Review of existing service lifetime estimations

- Who else needs to know about the durability of pavements?

- Pavement Management Systems
  - Require service life estimations
  - Apply performance prediction models
  - Widely applied data available
  - Standardised approaches

- Network databases
## Life cycle assumptions in PMS

<table>
<thead>
<tr>
<th>Road layer</th>
<th>Pavement material</th>
<th>Germany (FGSV, 2001)</th>
<th>Netherlands (IVON, 2012)</th>
<th>UK (SWEEP Pavements, 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>≥ 300 ESAL/day</td>
<td>&lt; 300 ESAL/day</td>
<td>Right hand lane</td>
</tr>
<tr>
<td>Surface asphalt layers</td>
<td>Asphalt concrete (AC)</td>
<td>12</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Very thin layer asphalt concrete (BBTM)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Hot rolled asphalt (HRA)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Stone mastic asphalt (SMA)</td>
<td>16</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Mastic asphalt (MA)</td>
<td>19</td>
<td>26</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Porous asphalt (PA)</td>
<td>–</td>
<td>–</td>
<td>10</td>
</tr>
<tr>
<td>Asphalt base layers</td>
<td>Asphalt concrete (binder layer)</td>
<td>26</td>
<td>30</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Asphalt concrete (base layer)</td>
<td>55</td>
<td>75</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Other base layers</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Hydraulically bound base layer</td>
<td>60</td>
<td>80</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Unbound base layer</td>
<td>55</td>
<td>75</td>
<td>*</td>
</tr>
<tr>
<td>Rigid pavement</td>
<td>Concrete surface layer</td>
<td>26</td>
<td>30</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Hydraulically bound base layer</td>
<td>55</td>
<td>70</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Asphalt concrete base layer</td>
<td>50</td>
<td>65</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Unbound base layer</td>
<td>45</td>
<td>60</td>
<td>*</td>
</tr>
<tr>
<td>Maintenance materials</td>
<td>Slurry surfacing</td>
<td>6</td>
<td>8</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Micro-surfacing</td>
<td>5</td>
<td>8</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Thin hot-mix asphalt layer on sealing</td>
<td>8</td>
<td>10</td>
<td>–</td>
</tr>
</tbody>
</table>
PMS background data

- High scatter in model trimming data
  - Result of high number of parameters affecting the pavement performance & life
  - High risk for mistakes for individual road structures
  - Applicable only on network level
Available data on durability effect of RA

- **Direct-Mat project:**
  - Majority of laboratory and full-scale studies result in same or better performance when RA is applied
- **West *et al.* (2011):**
  - Cracking risk is higher for mixtures with RA

<table>
<thead>
<tr>
<th>Mixture type</th>
<th>HMA with x % RA has the same or better properties than comparable mix without RA</th>
<th>HMA with x % RA has worse properties than comparable mix without RA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory study</td>
<td>Full-Scale study</td>
</tr>
<tr>
<td>Surface course asphalt</td>
<td>AC</td>
<td>20%(DRF4.2) 40%(DRF4.6) 50%(DRF4.1)</td>
</tr>
<tr>
<td></td>
<td>SMA</td>
<td>20%(DRF4.162) 30%(DRF4.14) 30%(DRF4.51)</td>
</tr>
<tr>
<td></td>
<td>ACTL</td>
<td>30%(DRF4.229)</td>
</tr>
<tr>
<td>Binder course asphalt</td>
<td>AC</td>
<td>25%(DRF4.2); 30%(DRF4.15); 30%(DRF4.155);</td>
</tr>
<tr>
<td></td>
<td>Base course asphalt</td>
<td>AC</td>
</tr>
<tr>
<td></td>
<td>HRA</td>
<td>30%(DRF4.222); 30%(DRF4.224); 35%(DRF4.160); 40%(DRF4.158); 45%(DRF4.159); 40%(DRF4.163); 50%(DRF4.225); 50%(DRF4.51); 70%(DRF4.181); 70%(DRF4.223); 100%(DRF4.228);</td>
</tr>
</tbody>
</table>

### Analysis ofdurability effects
- Virgin better than RA
- Same
- RA better than virgin

1. higher moisture sensitivity
2. more cracking
3. reduced fatigue resistance
4. reduced rutting resistance
HAPMS database

Service lifetime [a] (Mean, Min Max)

- 28.5, 24.4, 10.0, 8.4, 8.9
- 22.5, 19.1, 27.9, 5.8, 7.1
- 32.1, 21.6, 7.1
- 29.2, 20.8
- 33.9
- 25.3, 7.6, 8.5, 4.1

Structure

- PQ Concrete
- Porous Asphalt
- Hot Rolled Asphalt
- Low Modulus Roadbase
- High Modulus Roadbase
- Dense Bituminous Macadam
- Recycled (Dense Bituminous Macadam)
- Recycled (Thin Surfaced)
- Thin Surfaced (Fibre)
Interim result: PMS data is too fuzzy for assessment of durability effects of single material parameters.
Asphalt mix database in Lower Saxony

- 80,000 asphalt mixture data from contractual compliance tests
- Accurate binder properties, mix composition, binder content, type of aggregates, use of RA, …
- Data implemented by test laboratories
- Less accuracy regarding site location
  (manual localisation necessary for each dataset)

Surface performance data

- Input for PMS models
- Regular assessment of surface properties
- Directly linked to actual pavement location
Majority of base layer asphalt contains RA
Minority of surface layer asphalt contains RA
For quantitative assessment of RA effect on performance, binder courses seems to be best for evaluation
Effect of RA in binder course on cracking

- Age of asphalt binder course [a]
- Cumulated traffic loading [No. 10-t-ESALs]

Area with surface cracking [%]

With RA in binder course
Without RA in binder course
Effect of RA in binder course on evenness

- With RA in binder course
- Without RA in binder course

Longitudinal evenness [cm²]

Asphalt binder course age [a]

Cumulated traffic loading [No. 10-t-ESALs]
Effect of RA in binder course on evenness

Interim result: No clear effect of RA in AC binder layers on surface performance
Durability effects of construction site conditions

- **Weather effects**
  - Constraints for pavement works according to national specifications

- **Paving season effect**
  - Consequence of insufficient compaction and missing interlayer bonding
  - Proportion of insufficient compacted asphalt layers versus construction date
  - Proportion of insufficient interlayer bonding versus construction date
### Allowed weather conditions for pavement works

<table>
<thead>
<tr>
<th>Country</th>
<th>Minimum allowed air temperature for paving of</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC base layer</td>
<td>AC binder layer</td>
</tr>
<tr>
<td>Germany</td>
<td>-3 °C</td>
<td>0 °C</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>UK and Ireland</td>
<td>Combination of wind and rainfall for layers less than 50 mm to Figure 14</td>
<td>0 °C</td>
</tr>
</tbody>
</table>

* Paving of PA is restricted at high wind velocities (not further defined)

** There are no specific requirements for other types of asphalt pavements than PA. However, the contractor is obliged to monitor and report on the conditions during construction and indicate how the quality of the paving work was ensured.

*** PA pavements can only be constructed when the air temperature is above 5°C plus the wind velocity (T is the air temperature in °C; W is the wind velocity in m/s).
Allowed weather conditions for pavement works

![Graph showing the relationship between air temperature and average wind speed for pavement lay. The graph indicates that it may not lay when the wind speed is high at 2 m height and the temperature is low, and it may lay when the wind speed is low at 10 m height regardless of temperature.](image)
Effect of compaction quality on calculated lifetime

Based on lifetime calculations by applying German mechanistic-empirical pavement design guide

![Graph]

- Compaction degree:
  \[ y = 16,173x - 1518,5 \]
  \[ R^2 = 0,9853 \]

- Void content difference:
  \[ y = -17,498x + 97,896 \]
  \[ R^2 = 0,9833 \]
Data base analysis: Seasonal effect on compaction degree

- AC 32
- AC 22
- AC 16

Compaction

Samples not reaching degree [%]

Proportion of the requirement of 97 %
**Mean risk of insufficient compaction in winter (Oct - Jan):** 14.1%

**Mean risk of insufficient compaction in summer (Apr - Sep):** 10.7% (without PA)
Data base analysis: Seasonal effect on interlayer bonding

(Wellner et al. 2012):
Reduction of calculated service life by insufficient interlayer bonding:
- 33% between surface and binder
- 75% between binder and base layer

Increased rutting of surface layer:
- 70% of service life
Results summerised in EARN D3

Deliverable D3: Effects of constituent materials, recycled and secondary sources materials and construction conditions on pavements durability derived from literature and site data review

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General

- **Pavement durability is affected by high number of parameters**
  - Detailed analysis of general material-specific service lifetime from laboratory and modelling assessment not possible
- **Reliable databases combining detailed on pavement structure and materials and long-term performance data not available**
  - Empirical data sources are limited in number and accuracy

**However…**

Regarding the application of RA in hot-mix asphalt

- **Empirical data identifies negative effect but with a large scatter**
- **Most international literature shows adequate material durability performance**
- **Some studies identified reduced durability**
  - Additional procedures (mix design, mix production) increases risk of reduced durability
  - Increased demand for high-quality approach in all productions stages
Conclusions from background data analysis (2)

Regarding new additives and mix designs (e.g. WMA)

• Additional additives will increase demand for quality by additional risks (e.g. incompatibilities to specific binders)
• Feasible laboratory conditioning procedures are required in order to allow the estimation of long-term properties during the mix design
• Laboratory test results with site-adapted laboratory tests will enable LCA and LCCA for single projects

Regarding construction conditions

• Construction season effect by adverse weather conditions
  – Slightly increase the risk for insufficient compaction and interlayering bonding
  – Significant reductions of pavement and/or road material service lifetime.
  – Service lifetime decrease of -2.2% for pavements constructed in autumn/winter months (October to January)
    > -1.7% by non-sufficient compaction
    > -0.5% by insufficient interlayer bonding
References


