Low Rolling Resistance pavements in Denmark

MIRIAM workshop
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Rolling Resistance in Road Infrastructure
Asset Management

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OUTLINE

1) COOEE Project Introduction

2) Stensved (2012) – test section
   - Mix design
   - MPD & Friction
   - RR data analysis

3) Conclusions and recommendations
INTRODUCTION
COOEE project

Cooee project focused on **development of novel pavements types** and **asset management solutions** that minimize the rolling resistance for cars and trucks.

Two SMAs, with a maximum nominal size respectively of 8mm (SMA8 COOEE) and 6mm (SMA6 COOEE), were appropriately developed by NCC aiming an optimized texture capable of introducing a reduction in Rolling Resistance.

TEST SECTIONS
1) Stensved in 2012
2) Langeskov in 2013
3) Sorøvej in 2014
INTRODUCTION

TUG trailer for RR measurements

TUG trailer, developed by the Technical University of Gdansk (TUG) was adopted to measure the Rolling Resistance (RR)

\[ RR = \frac{P_f}{F_Z} \]

Direction of travel

\[ \theta \]

\[ F_z \]
Phase 1: Mortar Optimization

<table>
<thead>
<tr>
<th>Fillers type</th>
<th>Portland Cement [%]</th>
<th>Limestone filler A [%]</th>
<th>Limestone filler F [%]</th>
<th>Aggregates Filler [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>20</td>
<td>45</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>F2</td>
<td>20</td>
<td>0</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td>F3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

*by mass of total filler

Phase 2: Gradation Optimization

[Graph showing passing percentage vs. sieve size for SMA8 and SMA6 COOEE]
STENSVED 2012
TEST SECTION DESCRIPTION

SMA6 Cooee (0m-500m)  SMA8 Cooee (500m-1000m)

Rolling Resistance, Long. Profile

MPD_L, Friction_L  MPD_R, Friction_R  vibrations

SMA8 Ref. (0m-1000m)

MPD & Friction  Rolling Resistance
STENSVED
MPD and Friction
STENSVED
MPD and Friction

SMA6 Coee (0m-500m)  SMA8 Coee (500m-1000m)

MPD \_L, Friction \_L  MPD \_R, Friction \_R

Rolling Resistance, Long. Profile

SMA8 Ref. (0m-1000m)

<table>
<thead>
<tr>
<th>Year</th>
<th>MPD</th>
<th>Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>0.74</td>
<td>0.67</td>
</tr>
<tr>
<td>2013</td>
<td>0.67</td>
<td>0.73</td>
</tr>
<tr>
<td>2014</td>
<td>0.75</td>
<td>0.61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>MPD</th>
<th>Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>0.67</td>
<td>0.72</td>
</tr>
<tr>
<td>2013</td>
<td>0.54</td>
<td>0.60</td>
</tr>
<tr>
<td>2014</td>
<td>0.71</td>
<td>0.62</td>
</tr>
</tbody>
</table>
STENSVED
Initial Raveling (picture from June 2015)

SMA8 COOEE

SMA6 COOEE
Tire type (Stiffness) has the strongest effect on RR
Gradation of the mixtures can be optimized to reduce texture depth

**IMPORTANT**

- Temperature Correction Factor
- Influence of the Longitudinal profile height
Example of RR measurements at 50 and 80 km/h
STENSVED

RR measurements at 80 km/h

Influence of the Longitudinal profile

Linear regression between RR and Longitudinal Profile height
**STENSVED**

**RR measurements**

RR data and height of the longitudinal profile have been measured by different equipment and consequently both data sets may not come from the same pavement path;
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RR measurements

RR Ratio [%] = \( \frac{RR_{\text{Cooee}}}{RR_{\text{Ref}}} \times 100 \)
STENSVED
RR measurements

RR Ratio [%] = \( \frac{RR_{\text{Cooee}}}{RR_{\text{Ref}}} \times 100 \)
STENSVED
RR measurements

- Both **MPD and LP profile should be investigated combined**
- An average of 5% reduction in 2012 measured on the SMA6 COOEE while 3% in the SMA8 COOEE
STENSVED

RR measurements

The section has been divided in segments of 250m
- Average RR ratio is described in the Table

<table>
<thead>
<tr>
<th>Year</th>
<th>Tire</th>
<th>SMA6 COOEE</th>
<th>SMA8 COOEE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0m-250m</td>
<td>250m-500m</td>
</tr>
<tr>
<td></td>
<td>RR Ratio* [%]</td>
<td>RR Ratio* [%]</td>
<td>RR Ratio* [%]</td>
</tr>
<tr>
<td>2012</td>
<td>SRTT</td>
<td>97.59</td>
<td>97.82</td>
</tr>
<tr>
<td></td>
<td>MCEN</td>
<td>94.23</td>
<td>95.62</td>
</tr>
<tr>
<td></td>
<td>AAV4</td>
<td>95.78</td>
<td>96.84</td>
</tr>
<tr>
<td>2013</td>
<td>SRTT</td>
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<td>96.91</td>
</tr>
<tr>
<td></td>
<td>MCPR</td>
<td>96.65</td>
<td>97.44</td>
</tr>
<tr>
<td></td>
<td>AAV4</td>
<td>97.72</td>
<td>99.01</td>
</tr>
<tr>
<td>2014</td>
<td>SRTT</td>
<td>98.18</td>
<td>99.80</td>
</tr>
<tr>
<td></td>
<td>MCPR</td>
<td>90.79</td>
<td>97.03</td>
</tr>
<tr>
<td></td>
<td>AAV4</td>
<td>97.30</td>
<td>100.00</td>
</tr>
</tbody>
</table>

RR Ratio [%] = RR<sub>Cooee</sub> / RR<sub>Ref</sub> * 100
STENSVED
RR measurements

Wavelength vs Slope of the Power Spectral density (PSD) function
CONCLUSIONS

1. Rolling Resistance;
2. Performance;
3. Test Section construction;
CONCLUSIONS

Rolling Resistance

1) SMA6 & SMA8 COOEE (average MPD 0.65 mm) might contribute on reducing rolling resistance by **5%** and **3%**, respectively, if compared to the Reference SMA8;

2) compared to the average RR properties measured on 100km of Danish state roads (average MPD 0.98 mm) the **reduction of RR** increases up to **20%**;

3) From 2012 to 2014, the **difference on the RR properties** is reduced approximately by **60%** on the SMA6 COOEE

4) In 2014, SMA8 COOEE and SMA8 Ref. have similar RR properties

5) The textural contribution on RR might be also affected by the longitudinal profile properties;

6) **Temperature correction factor** should be reconsidered;
CONCLUSIONS

Performance

1) Performances of the COOEE mixtures must be improved;

2) poor texture stability which compromises the lifetime of the mixture Sorøvej paved in 2014
CONCLUSIONS

Performance

1) Durability of the COOEE mixtures must be improved;

2) poor texture stability which compromises the lifetime of the mixture

3) moisture susceptibility might represent a critical distress and might induce to premature failure reducing adhesion and cohesion properties of the mortar

Stensved paved in 2012
CONCLUSIONS

Test Section construction

1) Quality of the asphalt mixture production and paving operations could be increased when homogeneous surface and texture are required.

2) **Recommendation**: reference mixture and a LRR mixture must be paved on the same pavement structure on two parallel lanes.
RECOMMENDATIONS

- wave length distribution and PSD functions of pavements with big difference in MPD to understand for each texture depth which wave number hides the texture contribution on the RR.
- Investigation of Temperature correction factor will improve the evaluation of the evolution RR properties with time;

- Tire
- Speed
- Pressure
- Load