PRACTICAL USE OF NOISE REDUCING PAVEMENTS AND IMPLEMENTING RESEARCH: THE DANISH EXPERIENCE

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2. Noise policy and actions
3. Tendering noise reducing pavements
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ROAD NOISE PROBLEM IN EUROPE IS HUGE

Case Denmark:

- 30 % of households exposed to over 58 dB ($L_{den}$) Environmental Protection Agency guideline
- Urban problem
- Effects:
  - Annoys people => Real estate prices
  - Impacts sleep => Health
  - Society economy
- Large focus on noise annoyance in the population
- Often main issue in public hearing on new road and infrastructure projects
THE COST OF THE NOISE PROBLEM

Noise reduces house prices:
- 1.2 % per dB urban roads => less tax
- 1.6 % per dB highways

Increased risk of cardio-vascular diseases:
- Annually 800-2200 at hospital
- Annually 200-500 early deaths in Denmark due to noise

- Socio-economic costs of noise 0.8–1.2 billion € pr. year annually in Denmark (house and health)

- Small country 5 mill. inhabitants
THE BIGGEST PROBLEM
EXISTING ROADS AND DWELLINGS

Danish Road Directorate policy for noise management – 2009 Objectives:

- As many dwellings as possible below 58 dB ($L_{den}$)
- To reduce the noise on as many dwellings as possible
- Ensure the best cost effectiveness in noise abatement
- Research in cost effective solutions
THE STATE ROAD NOISE ACTION PLAN

State road EU noise mapping

<table>
<thead>
<tr>
<th>$L_{den}$</th>
<th>&lt; 58 dB</th>
<th>58-63 dB</th>
<th>63-68 dB</th>
<th>&gt; 68 dB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number dwellings</td>
<td>77.000</td>
<td>31.000</td>
<td>11.000</td>
<td>119.000</td>
<td></td>
</tr>
</tbody>
</table>

Goal to reduce the noise annoyance for as many dwellings as possible along the highway sections with the highest noise levels:

- New highways < 58 dB
- Noise barriers
- Noise reducing windows
- 55 mill. € over last 6 years
- Noise reducing pavements when pavements are renewed over 58 dB
APPLICATION OF NOISE REDUCING PAVEMENTS

- Pavement renewal on highways
- Noise reducing pavements are used:
  - Highways near residential areas noise over 58 dB
  - Highways near recreational urban areas over 58 dB
- The same for construction of new highways
- Research on integration of noise in Pavement Management Systems
**SRS SYSTEM FOR TENDERING NOISE REDUCING PAVEMENTS**

Noise labeling of pavements by CPX trailer noise measurements

<table>
<thead>
<tr>
<th>Noise class</th>
<th>Description</th>
<th>Noise reduction in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRS standard</td>
<td>Good noise reduction</td>
<td>$4.0 &lt; x &lt; 7.0$</td>
</tr>
<tr>
<td>SRS special</td>
<td>Very good noise reduction</td>
<td>$x &gt; 7.0$</td>
</tr>
</tbody>
</table>

Reference Nordic noise prediction method NORD2000
NCC Roads A/S - Asfaltprodukter
SMA 6P tyndlagsskærvemastiks

Produktbeskrivelse:
SMA 6P er en tyndlagsbelægning af skærvemastiks-typen med en 

hvis støjreducerende effekt. SMA 6P fremstilles ved tilsætning af en

Gode resultater med SRS - støjreducerende asfalt
AB 6å Stålfalt B (50 km/t) A (80 km/t)
AB 6å Stålfalt med polymérmungeret bitumen er Munck Asfalts flagskib ind 

for asfalt. Selv i små lagtykkler opnås en helt ekstraordinær støjreduktion.

SMA 6 plus 8/11 B (50 km/t) B (80 km/t)
SMA 6 plus 8/11 er et godt eksempel på en all-round belægning, som kan an 
stes steder. SMA 6 plus 8/11 har en mere åben struktur end almindelig SMA.

ARKIL A/S

PANKAS AB SRS
PANgrip SRS
PANKAS SMA SRS

Asfalslidlag
• Asfaltbeton og Pulverasfalt
• Skærvemastik
• Tyndlagsbelægning
• Støjreducerende asfalt

Asfalt binde- og bærelag

Colas Danmark A/S, Fal

∑ > 25 SRS-products on market
COPENHAGEN MUNICIPALITY POLICY

- Pavement renewal process
- Roads with more than 2000 vehicles/day
- Noise reducing pavements are used
- Tendered with the SRS system
Components of noise

- Road
- Propulsion
- Tyres
Propulsion

$L_{AF\max}$ [dB] vs Speed [km/h]

- $L_{AF\max}$ [dB] increases linearly with speed.
- The graph shows a clear upward trend.
- The line represents the relationship between $L_{AF\max}$ and speed.

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**Key Points**

- $L_{AF\max}$ [dB]
- Speed [km/h]
- Linear relationship
- Propulsion

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**Notes**

- Additional analysis or commentary could be included here.
The graph shows the relationship between speed (km/h) and noise level (L\textsubscript{AFmax} [dB]). The graph includes a line labeled 'P_Roll' which represents the rolling noise level and a line labeled 'P_Prop' which represents the propulsive noise level.

- **P_Roll** indicates the noise level increases with speed, showing a linear relationship.
- **P_Prop** also shows an increase with speed but at a different rate compared to P_Roll.

The graph suggests that both the rolling and propulsive noise levels increase with increasing speed, which is important for understanding the noise impact at different speeds.
VIBRATION GENERATED NOISE

- The texture of the surface makes tyre vibrate
- Low frequency under 1500 Hz
AIR PUMPING NOISE

- Air is pressed out and in between the rubber blocks of the tyre
- High frequency over 1000 Hz
OPTIMISATION OF NOISE REDUCTION:

- The highest points of the surface same height. Reduce X
- Cubic aggregate and good compaction
- Distance between high points short. Reduce H
- Small aggregate size
- Holes in the surface as big as possible. Increase MPD
  Large built in air void

Vibrations generated noise

Air pumping noise

X

H

MPD
POROUS ASPHALT

- One layer
EXPERIMENT WITH SINGLE LAYER POROUS ASPHALT

<table>
<thead>
<tr>
<th>Pavement</th>
<th>Aggregate size</th>
<th>Air void</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAC8 type A</td>
<td>8 mm</td>
<td>18-22 %</td>
</tr>
<tr>
<td>PAC8 type B</td>
<td>8 mm</td>
<td>&gt; 22 %</td>
</tr>
<tr>
<td>PAC12</td>
<td>12 mm</td>
<td>&gt; 22 %</td>
</tr>
<tr>
<td>OGAC12</td>
<td>12 mm</td>
<td>6 %</td>
</tr>
<tr>
<td>DGAC12</td>
<td>12 mm</td>
<td>3 %</td>
</tr>
</tbody>
</table>
DGAC12 - Passenger cars

\[ y = 0.40x + 75.94 \]
\[ R^2 = 0.92 \]

0.4 dB/year

PAC8 Type A - Passenger cars

\[ y = 0.87x + 70.45 \]
\[ R^2 = 0.93 \]

0.9 dB/year
RESULT POROUS ASPHALT AVERAGE NOISE REDUCTION

<table>
<thead>
<tr>
<th>Asphalt Pavement</th>
<th>Passenger Cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Graded</td>
<td>- 1.7 dB</td>
</tr>
<tr>
<td>Porous 8 - A</td>
<td>3.3 dB</td>
</tr>
<tr>
<td>Porous 8 - B</td>
<td>3.3 dB</td>
</tr>
<tr>
<td>Porous 12</td>
<td>1.2 dB</td>
</tr>
</tbody>
</table>
NOISE REDUCING THIN LAYERS - SRS

- Open surface
- Not porous
- Small aggregate size
# First Danish Test of Noise Reducing SRS Pavements on Highway

<table>
<thead>
<tr>
<th>Pavement</th>
<th>Aggregate size</th>
<th>Air void</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA8</td>
<td>8 mm</td>
<td>12.4 %</td>
</tr>
<tr>
<td>OGAC8</td>
<td>8 mm</td>
<td>15.3 %</td>
</tr>
<tr>
<td>UTLAC8</td>
<td>8 mm</td>
<td>14 %</td>
</tr>
<tr>
<td>SMA6+</td>
<td>6+8 mm</td>
<td>3 %</td>
</tr>
<tr>
<td>SMA8+</td>
<td>6+11</td>
<td>5.7 %</td>
</tr>
<tr>
<td>DGAC11</td>
<td>11 mm</td>
<td>2.8 %</td>
</tr>
</tbody>
</table>
**PASSENGER CARS**

**M10 110 KM/H**

Passenger car

110 km/h

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**LAmax [dB]**

- DGAC11
- OGAC8
- SMA6+
- SMA8
- SMA8+
- UTLAC8

**Age [years]**

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
DENSE GRADED ASPHALT CONCRETE

Passenger cars 110 km/h

0.50 dB/year
OPEN GRADED ASPHALT CONCRETE

Passenger cars 110 km/h

LAmax [dB]

Age [year]

0.70 dB/year

SPB [dB]
# AVERAGE NOISE REDUCTION
# FIRST GENERATION SRS

<table>
<thead>
<tr>
<th>Pavement</th>
<th>Passenger car</th>
<th>Heavy multi axle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average noise reduction [dB]</td>
<td></td>
</tr>
<tr>
<td>OGAC8</td>
<td>2.0</td>
<td>2.7</td>
</tr>
<tr>
<td>SMA6+</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td>SMA8</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>SMA8+</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>UTLAC8</td>
<td>0.9</td>
<td>1.6</td>
</tr>
</tbody>
</table>
CONCLUSION

- Politics for noise reducing pavements in place and active
- Noise reducing pavements are now used on state roads and in municipalities
- Because:
  - There is a need for "low cost" noise reduction
  - Noise reducing pavement solutions are on the marked ready for use
  - Road engineers and politicians know the concept
  - The SRS system facilitates noise as a functional request in tendering process
- Cheap solution to be implemented in noise action plans
- Research ongoing for improvements
POROELASTIC PAVEMENT
FULL SCALE
TEST SECTION

Constructed in Denmark August 27th 2013