Experiences with thin noise reducing pavements

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Like porous pavements, thin layer pavements have a noise reducing potential on urban roads as well as on highways. In Denmark a project on urban roads was started in 2003. The goal was to develop and test thin layers as noise reducing pavements under Nordic conditions. This project is a part of the European SILVIA project started in September 2002. Another Danish project with test sections of thin layer pavements on a highway was started in the summer of 2004. 13 test sections have been constructed on urban roads and 5 on the highway. Different pavement types are included: 1. Open graded asphalt concrete. 2. Stone Mastics Asphalt. 3. A thin layer constructed as a combination pavement. Dense asphalt concrete pavements with maximum 8 or 11 mm aggregate size are included as reference pavements. Comprehensive measurement programs have started. Noise is measured by the SPB method. The pavements will be described together with the results of the first series of noise measurements. In 2004 a new research project on optimization of thin layers started as a co-operation between the Danish Road Institute / Road Directorate (DRI) and the Road and Hydraulic Engineering Institute in the Netherlands (DWW) called the DRI-DWW noise abatement program. This new project is focusing on optimising the noise reduction and to find the long-term noise reducing effects of thin layers. The project plan for this new project will also be presented.

1 Introduction

Thin layer pavements have been used for 10 to 15 years in different European countries as wearing courses on roads. Only in the last years there has also been a focus on this type of pavements as noise reducing pavements. The reasons for this is a wish to develop noise reducing pavements that are not porous and therefore will not have clogging and lifetime problems as porous pavements have, and at the same time to develop noise reducing pavements that are not very costly. The noise reducing effect of thin layers is related to the structure of the pavement surface. The goal is to create as smooth a pavement as possible in order to reduce the generation of vibration noise from the tires, and at the same time to create as open a pavement surface as possible in order to reduce the noise generated from air pumping. [4, 5].

In Denmark a project started in 2003 with the goal to develop and test noise reducing thin layers for urban roads. The project is called SILVIA.DK and is part of the EU project SILVIA [6]. Test sections have been constructed in 3 Danish cities (Copenhagen, Aarhus and Randers) [4]. The first measurement results are presented in this article. In 2004 the Danish Road Directorate established a test site on a highway (M10 near Solrød) [3]. The first results from this site are also presented and discussed in this paper.

In 2004 co-operation between the Dutch (DWW) and the Danish (DRI) road institutes was started. The co-operation is called “The DRI-DWW noise abatement program” [1]. A total of 7 projects are carried out inside the framework of the program, which is a part of the large Dutch Innovation Program on Noise from Road Traffic, also called the IPG research program [2]. One of these projects is focussing on the acoustical as well as the structural lifetime of noise reducing thin layers. In order to get as long measurement series as possible measurements will be continued for some years on the SILVIA.DK and the Solrød test sites as a part of the DRI-DWW noise abatement program. New test sections with noise reducing thin layers will also be constructed in Denmark on highways with a speed limit of around 80 km/h and in the Netherlands on highways with speed limits around 110 km/h.

2 Test on urban road

2.1 Pavement types

The municipalities of Copenhagen, Randers and Aarhus participate in the SILVIA.DK project. They have agreed to provide test roads for the project and to finance the construction of the test pavements. The three urban test roads have a traffic flow of 6700 to 12500 vehicles pr. day, around 8 % of heavy vehicles and an average speed of 50-60 km/h [4]. The development and design of the recipes for the pavements to be tested in the project were based on a combination of the best available knowledge and technology in Denmark combined with a study of the latest experiences in the Netherlands, [7], and other European countries.
The goal is to develop pavements fulfilling the following functional requirements:

- Pavements with as smooth a top surface as possible in order to minimize the noise generated by vibrations in the tires. In order to achieve this, pavements with a maximum aggregate size of 6 mm have been selected.
- Pavements with as open a surface as possible in order to minimize the noise generated by the air pumping effect. In order to achieve this, pavements with a very open top structure have been selected. The pavements are open - but not porous (with an open structure in the whole layer thickness of the pavement). In one of the test pavements a certain amount of larger aggregate (size 5-8 mm) has been added, in order to increase the openness of the top surface.

Three different types of thin open pavements are included in the project:

1. Open graded asphalt concrete (AC-open) with a (built-in) Marshall air void of approx. 8 - 14 %.
2. Stone Mastics Asphalt (SMA) with a (built-in) Marshall air void of approx. 4 - 8 %.
3. A thin layer constructed as a combination pavement (TP c). On the existing road surface a thick layer of polymer modified bitumen emulsion (including water) is laid out. On the top of this a very open pavement (like porous asphalt) with a (built-in) Marshall air void of approx. 14 % or even more is applied. The bitumen layer “boils up” in the air voids of the pavement, leaving only the upper part of the structure open. This reduces the built-in air void of the pavement because the pores of the pavement are filled with bitumen.

Reference pavements constructed as dense asphalt concrete with 8 and 11 mm maximum aggregate size are used. The bitumen will be in the soft end of the spectrum, in order to achieve a good lifetime for the pavements. Cement will be added to the bitumen in order to improve the adhesion of the bitumen. In some of the pavements elastomer modified bitumen will be used in order to improve flexibility and durability. On the test sections in Aarhus and in Randers the same pavement types have been tested even though small modifications in the recipes have been made.

### Table 1: Pavements tested on the Copenhagen test road [4]. Specified data.

<table>
<thead>
<tr>
<th>Type</th>
<th>Max. aggregate size</th>
<th>Built-in air void</th>
<th>Thickness approx.</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC11d (reference)</td>
<td>11 mm</td>
<td>-</td>
<td>30 mm</td>
<td>70 kg/m²</td>
</tr>
<tr>
<td>AC8d (reference)</td>
<td>8 mm</td>
<td>-</td>
<td>25 mm</td>
<td>55 kg/m²</td>
</tr>
<tr>
<td>AC6o</td>
<td>6 mm</td>
<td>8 – 14 %</td>
<td>20 mm</td>
<td>45 kg/m²</td>
</tr>
<tr>
<td>SMA6+</td>
<td>6 mm + 5/8 mm</td>
<td>4 – 8 %</td>
<td>20 mm</td>
<td>45 kg/m²</td>
</tr>
<tr>
<td>TP6c</td>
<td>6 mm</td>
<td>14 %</td>
<td>17 mm</td>
<td>35 kg/m²</td>
</tr>
</tbody>
</table>

### 2.2 Noise measurements

The noise has been measured when the pavements were new by the use of the Statistical Pass-By method [8].

Table 2: Noise for passenger cars as $L_{PA,fast,max,7,5m}$ at 60 km/h, and noise reduction relative to the reference pavement (AC11d) for each pavement type at the test sections in Copenhagen (in dB re 20 µPa).

<table>
<thead>
<tr>
<th></th>
<th>AC11d</th>
<th>AC8d</th>
<th>AC6o</th>
<th>SMA6+</th>
<th>TP6c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>72.6</td>
<td>71.6</td>
<td>70.3</td>
<td>70.6</td>
<td>69.5</td>
</tr>
<tr>
<td>Noise reduction</td>
<td>Ref.</td>
<td>1.0</td>
<td>2.3</td>
<td>2.0</td>
<td>3.1</td>
</tr>
</tbody>
</table>
Figure 1 shows an overview of the noise reductions for passenger cars relative to the reference pavement (AC11d) for each pavement type at the test road at 60 km/h. On the background of these early results from the first measurement campaign when the pavements were around 6 month old, it seems that the combination pavements (TP6c) offers the best noise reducing potential of 3 dB followed by the open asphalt concrete (AC6o) and the SMA pavements with a noise reducing potential of 2 dB. As the differences are small no strong conclusions shall be drawn at this early stage on which pavement family that offers the best noise reductions. The measurements will be continued in the coming years.

In Figure 2 the noise level ($L_{pA, \text{fast, max, } 7.5m}$) for passenger cars is shown for the test sections included at 60 km/h. The noise from the reference pavements (AC11d) are around 72.6 dB. The dense asphalt concrete with 8 mm maximum aggregate size has a noise level which is 1 dB lower. This illustrates the importance of which reference pavement that are selected for an experiment with noise reducing pavements.

3 Test on Highway

3.1 Pavement types

In the summer of 2004 four test sections with thin layer pavements as well as a dense asphalt concrete reference surface with maximum 11 mm aggregate size were constructed on the M10 highway near Solrd. The traffic volume is around 80,000 vehicles per day and the speed limit is 110 km/h. Generally the thin layers have an open surface structure and a small maximum aggregate size. The thin layers used on the highway are the following:

- SMA8: Stone Mastics Asphalt (SMA) with a (built-in) Marshall air void of approx. 12 %. The pavement is constructed like a porous pavement with a stone skeleton. The voids are filled with bitumen and filler, leaving only the surface structure open.
- AC8o: A dense, but very open graded asphalt concrete (AC-open) with a (built-in) Marshall air void of approx. 15 %.
- TP8c: A thin layer constructed as a combination pavement (TP c). On the existing road surface a thick layer of polymer modified bitumen emulsion (including water) is laid out. On the top of this a very open pavement (like porous asphalt) with a (built-in) Marshall air void of approx. 14 % is applied. The bitumen layer “boils up” in the air voids of the pavement, leaving only the upper part of the structure open.
- SMA6+: Stone Mastics Asphalt (SMA) with maximum 6 mm aggregate size, but with a small amount of 5/8 mm aggregate added.

<table>
<thead>
<tr>
<th>Type</th>
<th>Max. aggregate size</th>
<th>Built-in air void</th>
<th>Thickness approx.</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC11d</td>
<td>11 mm</td>
<td>3 %</td>
<td>33 mm</td>
<td>80 kg/m²</td>
</tr>
<tr>
<td>SMA8</td>
<td>8 mm</td>
<td>12 %</td>
<td>29 mm</td>
<td>60 kg/m³</td>
</tr>
<tr>
<td>AC8o</td>
<td>8 mm</td>
<td>15 %</td>
<td>28 mm</td>
<td>60 kg/m³</td>
</tr>
<tr>
<td>TP8c</td>
<td>8 mm</td>
<td>14 %</td>
<td>22 mm</td>
<td>45 kg/m²</td>
</tr>
<tr>
<td>SMA6+</td>
<td>6 mm + 5/8 mm</td>
<td>3 %</td>
<td>26 mm</td>
<td>60 kg/m²</td>
</tr>
</tbody>
</table>

Table 4: Pavements tested on the M10 highway [3].

Specified data.

### 3.2 Noise measurements

Also here the noise has been measured when the pavements were 4-5 month old by the use of the Statistical Pass-By method [8]. In the following the noise reduction is given relative to a dense asphalt concrete reference surface with maximum 11 mm aggregate size.

<table>
<thead>
<tr>
<th>Type</th>
<th>Noise reduction (dB re 20 µPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>0.5 3.0 2.3 1.6</td>
</tr>
<tr>
<td>Dual-axle trucks</td>
<td>1.7 2.6 2.8 1.0</td>
</tr>
<tr>
<td>Multi-axle trucks</td>
<td>1.2 2.3 1.8 1.2</td>
</tr>
<tr>
<td>SPBI</td>
<td>86.3 85.3 83.8 84.3 85.1</td>
</tr>
</tbody>
</table>

It can be seen that the very open graded asphalt concrete (AC8o) has the best noise reduction of 2.5 dB. The noise reduction for trucks is generally only a little smaller than for passenger cars, indicating that thin layers also has a good noise reducing effect on truck noise at highways with high speeds.

### 4 Conclusion and discussion

The noise reducing potential of different types of thin pavements has been measured on an urban test road (speed 60 km/h) and on a highway (speed 110 km/h). The measurements have been performed when the pavements were only about 6 month old. Three types of thin pavements have been included in the experiments. Stone Mastics Asphalt (SMA), open graded asphalt concrete (ACo) and combination pavement (TPc). Reference pavements constructed as
dense asphalt concrete with 11 mm maximum aggregate size is used (AC11d).

On the background of these early results from the first measurement campaign when the pavements were around 6 month old the following tendencies can be highlighted:

- Thin layer pavements with a small aggregate size offer a noise reducing potential in relation to dense asphalt concrete (aggregate size 11 mm).
- It seems that for passenger cars on the urban roads at 60 km/h the combination pavements (TP6c) offers the best noise reducing potential of 3 dB followed by the open asphalt concrete (AC6o) and the SMA pavements with a noise reducing potential of 2 dB.
- For the highway experiment the open graded asphalt concrete (AC8o) has the best noise reduction of 2.5 dB for mixed traffic followed by the combination pavement with a noise reduction of 2 dB.
- The noise reduction for trucks on the highway is generally only a little smaller than for passenger cars, indicating that thin layers also has a good noise reducing effect on truck noise at highways with high speeds.

As the differences are small no strong conclusions shall be drawn at this early stage on which pavement family that offers the best noise reductions. The measurements will be continued in the coming years.

5 Acknowledgements

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References