Two-layer porous asphalt for urban roads

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An experiment with two layer porous asphalt pavements was started on an urban road in Copenhagen, Denmark in 1999. The noise reduction was optimised by the use of small aggregate size in the top-layer and rather great thickness of the porous layers. Three different two-layer porous pavements as well as a dense asphalt concrete as a reference pavement were laid on a road. The goal of the project was to follow the pavements in their structural lifetime. Noise and permeability has been measured every year. When the pavements were new the noise reduction was 4 to 6 dB compared to the reference pavement of dense asphalt concrete with 8 mm max. aggregate. Both the noise reduction and the permeability have decreased over the years, probably due to clogging of the pores of the open pavement. The results over a 6 years period are presented in this paper. In 2004 a new research project was started as a co-operation between the Danish Road Institute / Road Directorate (DRI) and Road and Hydraulic Engineering Institute in the Netherlands (DWW) called the DRI-DWW noise abatement programme. The project is focussing on investigation in the clogging process, and the goal is to develop concepts and methods that can reduce the clogging of porous pavements.

1 Introduction

Porous pavements are used in different European countries as a tool for noise abatement. Such pavements generally prove to have a good noise reducing effect when they are new but this may change as the pavements get older. There are not many lifetime studies of the noise emission from road pavements at all, and especially not from traffic on porous pavements. In the 1990s a Danish experiment showed that a single-layer porous pavement with a rather small maximum aggregate size of 8 mm maintained a noise reduction of 3-4 dB during the whole lifetime of the pavement. The reduction was measured by the SPB method relative to a dense asphalt concrete with a maximum aggregate size of 12 mm. This experiment was carried out on a highway where the speed limit was 80 km/h. The same type of porous pavement was tested on an urban road with a speed limit of 50 km/h. Here an initial noise reduction of 3 dB disappeared after only 2 years due to clogging of the pores of the pavement. There seems to be a tendency that porous pavements on highways keep the porous structures open during their lifetime. This is explained by a self cleaning mechanism where the tires in rainy periods press water down in the pores of the pavement under high pressure. Whereas on low speed roads the water pressure is not high enough to ensure a continuous cleaning effect of the pavements, and therefore they tend to clog and by that loose their noise reduction.

2 DRI-DWW programme

There is a big need to understand the clogging process as well as the process of self cleaning of porous pavements. In 2004 a co-operation between the Dutch (DWW) and the Danish (DRI) road institutes was started. The cooperation is called “The DRI-DWW noise abatement program”, [1]. A total of 7 projects are carried out in the framework of the program which is a part of the Dutch Innovation Program on Noise from road traffic also called the IPG research program, [2]. Three of these projects are focussing on the acoustical as well as the structural lifetime of porous pavements and one of these is especially dedicated to the clogging phenomenon of two-layer porous pavements. In order to understand and be able to describe the clogging process an intensive measurement program has been established with the goal to make it possible over the lifetime of the pavements to describe:

1. The acoustical properties of the pavements.
2. The structural properties of the pavements.
3. The clogging of the pavements.

Two-layer porous pavements applied on two different types of roads are included:

1. Urban roads with a low average speed of around 50 km/h.
2. Highways with high average speed around 110 km/h.
3 Hypotheses of DRI-DWW programme

The following hypotheses drawn up at the beginning of the clogging cooperation project are used as a background to design the measurement programs as well as the analytical work in the clogging project:

1. The pavements get more clogged as they get older!
2. The tendency of clogging is reduced when larger aggregates are used!
3. The tendency of clogging is reduced when the initial air voids are increased!
4. The tendency of clogging is reduced when the average speed of the traffic is increased!
5. The clogging starts at the interface between the top and the bottom layer of two-layered porous asphalt!
6. As long as the upper 20 mm of the porous pavement is open a good noise reduction will be achieved!
7. There is less clogging in the wheel tracks than between the wheel tracks!
8. Clogging is initiated at the bottom of the lower porous layer!
9. The first lane that clogs is the emergency lane!

4 Urban test field

The urban “test field” is Øster Søgade in Copenhagen, [3]. It is a two-lane urban road with a traffic volume of around 7000 vehicles pr. day and a speed limit of 50 km/h. The test fields for high speed roads are highways and motorways in the Netherlands. This paper describes the layout of the urban clogging project in Copenhagen and reports the first results.

Noise and permeability measurements were made at test sections of a two-lane urban road with various twin-lay porous asphalt pavements [3] with a high built-in air void of 22 to 26 %. As a reference a dense asphalt concrete with a maximum aggregate size of 8 mm was constructed at the test site at the same time as the porous pavements. See Table 1.

A comprehensive measurement program was established. Measurements were made in 1999 just after the test sections had been built, and have been repeated each year to investigate the effect of ageing, wear, and clogging of air voids in the porous asphalt. Three positions were chosen at each section to ensure spatial averaging, although in some years measurements have not been carried out in every position. Twice a year the porous asphalt has been cleaned by high-pressure water / air suction. In this paper the results from the SPB noise measurements as well as the permeability results are presented in order to quantify the clogging phenomenon.

Table 1: Test sections.

<table>
<thead>
<tr>
<th>No.</th>
<th>Designation</th>
<th>Type</th>
<th>Top-layer</th>
<th>Bottom-layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Thickness [mm]</td>
<td>Aggregate size [mm]</td>
<td>Thickness [mm]</td>
</tr>
<tr>
<td>I</td>
<td>DA8-70</td>
<td>Porous asphalt</td>
<td>25</td>
<td>5/8</td>
</tr>
<tr>
<td>II</td>
<td>DA5-55</td>
<td>Porous asphalt</td>
<td>20</td>
<td>2/5</td>
</tr>
<tr>
<td>III</td>
<td>DA5-90</td>
<td>Porous asphalt</td>
<td>25</td>
<td>2/5</td>
</tr>
<tr>
<td>IV</td>
<td>AB8t (ref.)</td>
<td>Dense asphalt</td>
<td>30</td>
<td>0/8</td>
</tr>
</tbody>
</table>
5 Permeability

Figure 1: Out-flow time (s/10 cm) in the wheel-track as a function of pavement age in months. b: before, a: after cleaning. Top figure represents the lane towards south and the bottom figure the lane towards north.

From Figure 1 it can be seen, that there is a strong tendency for clogging in the lane towards south where the two porous pavements with 5 mm aggregate were clogged after 15 to 20 months years whereas the pavement with 8 mm aggregate stays in a much better condition. The out-flow time has increased rapidly in the lane towards south at Section II and III. The reason for this clogging is believed to be dirt and fine material from the adjacent dense asphalt concrete pavement having been dragged onto the porous pavements by vehicle tires, since clogging first appeared at position nearest to the reference section. In the lane towards north a much lower tendency for clogging can be seen for all the pavements. Also here the lowest level of clogging is found – at the porous pavement with 8 mm aggregate. It is generally not possible to see significant reductions in the level of clogging from before (b) to after (a) the cleaning of the pavements.

6 Noise measurements

<table>
<thead>
<tr>
<th>Category</th>
<th>Light Passenger</th>
<th>Van</th>
<th>Heavy Two-axle</th>
<th>Multi-axle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed [km/h]</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>W&lt;sub&gt;x&lt;/sub&gt;, This paper, [-]</td>
<td>0.8</td>
<td>0.1</td>
<td>0.075</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Microphones were placed at horizontal distances d of 9 m and 11 m from the centre-line of the near and far lane (towards North and South), respectively, 1.2 m above the road surface. Results have been corrected to d = 7.5 m by +20 log (d/7.5). Pass-by noise from vehicles in the normal traffic was analysed. The specifications of the Statistical Pass-By Method, [5], were followed as far as possible. Maximum A-weighted noise levels with time constant “F”, L<sub>AFmax</sub>, in 1/3-octave bands were measured as well as the speed of each vehicle, separately in four categories, x: passenger cars, delivery vans, trucks having two axles, and trucks having more than two axles. For each category the ”Vehicle Noise Level”, L<sub>veh</sub>, was determined by linear regression analysis of the noise level on the logarithm of the speed. L<sub>veh</sub>-values were determined for the speeds given in Table 2, which differ from the reference speeds given in [5] in order to increase accuracy and relevance in comparison between test sections.

Based on the L<sub>veh</sub>-values a modified ”Statistical Pass-By Index”, SPBI’, was calculated by means of (1).

\[
SPBI' = 10 \times \log \left( \sum W_x \times 10^{L_{veh,x}/10} \right)
\]

L<sub>veh,x</sub> is the vehicle noise level for category x, and W<sub>x</sub> is the weight for that category shown in Table 2, [5] specifies 90% passenger cars, 7.5% dual-axle trucks, and 2.5% multi-axle trucks. Instead of 90% passenger cars a distribution of 80% passenger cars and 10% vans have been assumed.

The results in Figure 2 and Table 2 supplements the data presented in [6] with data from 2003 and 2004 [7].
Figure 2: Results of the noise measurements (top figure) and the reduction of the Statistical Pass-By Index, SPBI’, for a mixed traffic (relative to the DAC 8 pavement) measured year 0 to year 5 (bottom figure).

Table 3. Noise reduction for mixed traffic (SPBI’) and for passenger cars ($L_{veh,p}$) relatively to the reference pavement (DAC8) of the same age.

<table>
<thead>
<tr>
<th>Noise reduction [dB]</th>
<th>I (DA8-70)</th>
<th>II (DA5-55)</th>
<th>III (DA5-90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPBI’</td>
<td>$L_{veh,p}$</td>
<td>SPBI’</td>
<td>$L_{veh,p}$</td>
</tr>
<tr>
<td>Year 5 (2004)</td>
<td>1.7</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Year 4 (2003)</td>
<td>2.8</td>
<td>3.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Year 3 (2002)</td>
<td>2.4</td>
<td>4.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Year 2 (2001)</td>
<td>2.7</td>
<td>3.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Year 1 (2000)</td>
<td>4.6</td>
<td>5.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Year 0 (1999)</td>
<td>4.5</td>
<td>4.6</td>
<td>4.9</td>
</tr>
</tbody>
</table>

7 Thin and plane section analyses

The Danish Road Institute has developed a technique where thin and plane sections are cut out of drill cores and analysed in a microscope, [9]. When the test sections were new and every second year since then cores have been drilled and analysed using this technique. Figure 3 shows an example of an image of a plane section of a new (upper picture) and a four year old porous pavement (lower picture). The blue and the dark green areas of these cores are the stones of the pavements. The white areas are the open space (air void) which is the porosity of the pavements. In the new porous pavement (upper picture) the very open structure of the pavement can be seen as large white areas. In the 4 years old pavement some dirt can be seen as a light grey-green substance between the stones of the pavement. It can be seen that it is especially in the fine graded top layer that the dirt is clogging the porous. The bottom layer with larger stones and larger air voids is not clogged as very little dirt is seen in the porous after 4 years. When the upper layer of a two layer porous pavement gets clogged the effect of reducing the air pumping noise is reduced. The noise absorption effect of the pavement is also reduced.
Conclusion and perspective

When new, the thickest porous pavement with the smallest aggregate in the top-layer (5 mm) had the best noise reduction. As time has passed the porous pavement with the larger aggregate (8 mm) in the top-layer seems to better maintain the noise reduction. This is highlighted by the measurements of permeability where the pavement with 8 mm aggregate in the top-layer gets significantly less clogged than the pavements with smaller aggregate. On the background of these preliminary results it is not possible to give a final evaluation of the validity of the hypotheses of the DRI-DWW project (see section 3). Further measurements and analyses are needed and will be carried out. Analyses of thin and plane sections as well as the use of CT-scanning of drill cores will be used to evaluate the clogging process of the porous pavements.

Acknowledgements

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