French Experiences on Noise Reducing Thin Layers

Danish Road Institute
Technical note 28
2005
### Road Directorate

Guldalderen 12  
P.O. Box 235  
DK-2640 Hedehusene  
Denmark  

<table>
<thead>
<tr>
<th>Title</th>
<th>French Experiences on Noise Reducing Thin Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authors</td>
<td>Hans Bendtsen, Jørn Raaberg</td>
</tr>
<tr>
<td>Published by</td>
<td>Road Directorate, Danish Road Institute</td>
</tr>
<tr>
<td>Copyright</td>
<td>Road Directorate, All rights reserved</td>
</tr>
<tr>
<td>Photo</td>
<td>Hans Bendtsen</td>
</tr>
<tr>
<td>Print</td>
<td>Electronic</td>
</tr>
<tr>
<td>ISSN electronic</td>
<td>1395-5530</td>
</tr>
<tr>
<td>ISBN electronic</td>
<td>87-91177-73-1</td>
</tr>
</tbody>
</table>

Reports published by the Danish Road Directorate can be requested from the bookshop:  

<table>
<thead>
<tr>
<th>Telephone</th>
<th>+45 4322 7300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telefax</td>
<td>+45 4363 1969</td>
</tr>
<tr>
<td>e-mail</td>
<td><a href="mailto:schultz@schultz.dk">schultz@schultz.dk</a></td>
</tr>
</tbody>
</table>
French Experiences on Noise Reducing Thin Layers

Hans Bendtsen
Jørn Raaberg

Danish Road Institute
Technical note 28
2005
Contents

1. Preface .......................................................................................................................... 5
1. Forord .......................................................................................................................... 7
2. Introduction to LCPC ................................................................................................... 8
3. Technical properties of thin layers ........................................................................ 11
4. Acoustical performance of thin layers ................................................................... 17
5. Practical experiences .................................................................................................. 22
   5.1 Contracting company ......................................................................................... 22
   5.2 Road administration ........................................................................................... 22
6. Conclusion ................................................................................................................... 24
7. References ................................................................................................................... 26

Appendix A
Report from meeting at Colas France ................................................................. 27
1. Preface

The Danish Road Institute and the Road and Hydraulic Engineering Institute in the Netherlands (DWW) carry out a co-operation called the DRI-DWW noise abatement programme [1] which is a part of the Dutch Noise Innovation Program on Road Traffic (the IPG programme) [2]. One of the projects in the DRI-DWW noise abatement programme is dedicated to development and testing of noise reducing thin pavements. In order to collect the latest international knowledge in this field a literature study has been carried out by DRI [3]. As it became clear that there were many interesting experiences in France, staff from DRI and DWW in September 2005 performed a study tour to the French road research institute (Laboratories des Pont et Chausses (LCPC)) situated in Nantes.

The expectations at DWW for thin layers are noise reductions of 4 dB on highways and a price cut of 30 % compared to the price of porous pavement. In the Netherlands thin layers have so far mainly been developed and used on urban roads with speeds of 50-60 km/h. Around 20 contracting companies are supplying these pavements. The IPG program is now focussing on the development of thin layers for highway applications. The focus is on:

- Noise reduction and durability of noise reduction.
- Structural durability.
- Traffic safety (skid resistance and splash/spray).
- Other properties.

In 2006 DWW will establish 6 large test sections with thin layers on highways. The research program for these test sections are being developed in autumn 2005.

The following staff of DRI and DWW attended the study tour:

- Arjan Visser, DWW
- Jørn Raaberg, DRI
- Hans Bendtsen, DRI

During the one day meeting at LCPC presentations were given by the following specialists:

- Michel Boulet, Technical director of the Pavement Division, LCPC
- Yves Brosseauaud, Pavement Technology Researcher, LCPC
- Fabienne Anfosso-Lédée, Acoustical Researcher, LCPC
- Joël Conan, Technical Director, Enrovia Pavement Contractors.
- Caroline Boband, Region Nantes, Department of Public Works
- Sylvain Charlicart, Region Nantes, Department of Public Works
On the third of November 2005 Hans Bendtsen from DRI attended a supplementary meeting with the French Colas Company in Paris. Highlights from this meeting are reported in Appendix A. The group from DRI and DWW will like to express their warm thanks to our French colleagues for their high level technical presentations and the interesting discussions we had. This technical report produced by Hans Bendtsen and Jørn Råberg form DRI presents the findings from the study tour to France.
1. Forord

Vejdirektoratet/Vejteknisk Institut og Hydraulic Engineering Institute (DWW) i Holland gennemfører i perioden 2004 til 2007 et forskningssamarbejde kaldet “the DRI-DWW noise abatement programme” [1] som er en del af ”the Dutch Noise Innovation Program on Road Traffic” (IPG programmet) [2]. Et af de 7 samarbejdsprojekter omhandler udvikling og test af støjreducerende tyndlagsbelægninger. For at indsamle den nyeste viden har Vejdirektoratet/Vejteknisk Institut gennemført et internationalt litteraturstudie [3]. Da det stod klart at der fandtes mange interessante erfaringer i Frankrig, blev det besluttet at gennemføre en studietur til det franske vejlaboratorium (Laboratories des Pont et Chausses (LCPC)) i Nantes i september 2005.

I Holland anvendes støjreducerende tyndlagsbelægninger allerede på bygader. I IPG programmet fokuseres der på udvikling af tyndlagsbelægninger, som kan anvendes på motorveje. Følgende temaer er i fokus:

- Støjdæmpning og den støjmæssige langtidseffekt.
- Belægningernes strukturelle levetid.
- Trafiksikkerhed (fraktion og opsprøjt).
- Andre forhold.

I Holland vil der i 2006 blive anlagt 6 nye forsøgsstrækninger med tyndlagsbelægninger på motorveje og det planlægges at udlægge en forsøgsstrækning på en dansk motortrafikvej, ligeledes i 2006.

Følgende deltog i studieturen til Frankrig:

- Arjan Visser, DWW i Holland.
- Jørn Raaberg, Vejdirektoratet/Vejteknisk Institut.
- Hans Bendtsen, Vejdirektoratet/Vejteknisk Institut.

På møderne hos LCPC holdt følgende specialister oplæg:

- Michel Boulet, teknisk direktør for belægningsdivisionen, LCPC.
- Yves Brosseau, belægningsspecialist, LCPC.
- Fabienne Anfosso-Lédée, støjspecialist, LCPC.
- Joël Conan, teknisk direktør, Enrovia asfalt firma.
- Caroline Boband, Region Nantes, Ministeriet for offentlige arbejder.
- Sylvain Charlicart, Region Nantes, Ministeriet for offentlige arbejder.

2. Introduction to LCPC

LCPC has a total staff of around 500 people working in two main branches one in Paris and one in Nantes. All the pavement related research and development activities are situated in Nantes. The development and the practical use of thin layers started in France in the 1980’s. Some early results were presented at the PIARC conference in Marocco in 1991. Thin layers are a road material that offers a noise reduction and at the same time has a good skid resistance and durability.

Figure 1. The test track at LCPC with different pavement types. The facility is used to test and calibrate different measurement equipment as well as pavements.

Figure 2. A water system makes it possibly to make the test pavements artificially wet.
Figure 3. The surface of a new thin layer open pavement with a maximum aggregate size of 6 mm.

Figure 4. The surface of a new thin layer open pavement with a maximum aggregate size of 6 mm which has been diamond ground in order to get a more even surface texture.
Figure 5. The surface of a porous cement concrete pavement with a maximum aggregate size of 14 mm and a built in air void of 28 %. The black line is a joint between two concrete slaps.
3. Technical properties of thin layers

French asphalt companies started the development of the thin layer in the 1980’s. In 1989 the concept won a famous French price for new technologies. The development over time of surface layers in France is roughly the following:

1. In 1960’s 60-100 mm of asphalt concrete (called BBSG) was used to give structural reinforcement to roads.
2. In the 1970’s thinner asphalt concrete (thickness 40-50 mm) was used (called BBM).
3. From around 1985 thin layers of 20 to 30 mm (called BBTM) and ultra thin mixes with a thickness 10 to 15 mm (called BBUM) were used in order to improve visual performance under wet conditions (reduce splash and spray). For this purpose also porous pavements were used (called BBDr). Thin layers with aggregate size down to 6 mm (called BBTM 0/6)) were used. These pavement types were also developed for noise reduction.

The evolution of thin layers are characterised by:

- Reduction of thickness down to 10-20 mm. Ultra thin mixes with a thickness down to 10 mm are not used very often.
- Mix design by use of gap graded mixes.
- The porosity has been increased and therefore the use of special bitumen became more important.

Table 1 gives a translation of the French and the English terms for these pavement types.

Table 1. Translation of the used Terminology.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness mm</th>
<th>France</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfacing</td>
<td>50 – 80</td>
<td>BBSG (Beton bitumineux semi grenus)</td>
<td>Gap graded hot mix asphalt</td>
</tr>
<tr>
<td></td>
<td>30 – 40</td>
<td>BBM (Beton bitumineux minces)</td>
<td>TS (Thin Surfacing)</td>
</tr>
<tr>
<td></td>
<td>20 – 30</td>
<td>BBTM (Beton bitumineux tres minces)</td>
<td>VTS [VTAC] (Very thin surfacing)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>BBUM (Beton bitumineux ultra minces)</td>
<td>UTS [UTAC] (Ultra thin surfacing)</td>
</tr>
</tbody>
</table>
The typical “steep” grading curves for thin open mixes can be seen in Figure 6.

The mix is based on the components available on the market (aggregates, filler, binder and additives). The properties of the components have to be checked according to performance standards. The minimum binder content is defined according to the geometric properties of the material. The compatibility is tested in the laboratory by the Gyratory method. The water sensitivity is tested by the Duriez method. Rutting test is sometimes performed; this is also used to test the texture of the pavement. Only in special cases the stiffness is tested. For base courses, also a fatigue test is normally performed.

There is a relation between the thickness of the pavements and the bitumen content. For thin layers 6 % of bitumen is used and for the ultra thin layers of only 10 mm 7 % of bitumen is used. Normally modifiers are added to the bitumen together with fibres in order to improve the durability. The pure binder has to be 50/70 or 35/50 if no modifiers is used.

In France there is a standard for thin layers published in May 2001. For porous pavements the current standard was published in June 2000.

The thin layers can be used both for maintenance of wearing courses as well as for new surfacing. Thin layers are used for all types of traffic, low speed as well as high speed, low and high volumes of traffic as well as a high percentage of heavy vehicles. The ultra thin layers of 15 to 20 mm are applied with a weight of 25-40 kg/m². The thin layers with a thickness of 20-30 mm are applied at a weight of 40 to 65 kg/m².

Thin layers must not be laid manually and they can only be used where the layer below has a good bearing capacity and no structural problems. If there are problems with
the layer below it has to be improved or another type of wearing course than thin layers has to be used.

Normally high quality aggregate from crushed massive rock are used due to the rather good mechanical properties of the material.

The typical material composition of the different types of thin layers can be seen in Table 2.

Table 2. Typical material composition of thin layers.

<table>
<thead>
<tr>
<th>Material</th>
<th>Very Thin layer</th>
<th>Very Thin layer</th>
<th>Ultra Thin layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class 1</td>
<td>Class 2</td>
<td></td>
</tr>
<tr>
<td>Aggregate 6/10 mm or 4/6 mm</td>
<td>65 - 78 %</td>
<td>79 – 85 %</td>
<td>75 - 88 %</td>
</tr>
<tr>
<td>Sand (0/2 mm)</td>
<td>22 - 35 %</td>
<td>17 – 22 %</td>
<td>15 - 22 %</td>
</tr>
<tr>
<td>Total filler</td>
<td>7 - 9 %</td>
<td>4 – 7 %</td>
<td>4 - 8 %</td>
</tr>
<tr>
<td>Binder content: Type 0/6 mm</td>
<td>6.2 – 6.7 %</td>
<td>5.0 – 5.5 %</td>
<td>5.8 – 6.4 %</td>
</tr>
<tr>
<td>Binder content: Type 0/10 mm</td>
<td>5.7 – 6.2%</td>
<td>4.5 – 5.5 %</td>
<td>5.0 – 5.8 %</td>
</tr>
<tr>
<td>Thickness</td>
<td>20 - 30 mm</td>
<td>20 - 30 mm</td>
<td>15 - 20 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>25 - 40 kg/m²</td>
<td>25 - 40 kg/m²</td>
<td>40 - 65 kg/m²</td>
</tr>
</tbody>
</table>

The requirements in relation to the build in air void in specimens prepared by the gyrator compactor after 25 gyrations are seen in Table 3. As showed in this table two classes are defined. There is no relation between the measured porosity in the laboratory on the specimens produced by the gyrator compactor and the porosity in the pavements when they are applied on site. It is generally very difficult/impossibly to measure porosity on drilled cores of the very thin pavements. Seen from a Danish/Dutch point of view the Class one pavements must be considered semi dense and very open in the surface texture but having a dense structure with no porous in the pavement structure. The Class two pavements must be considered porous. According to Yves Brosseauad this is not quite the case and there are several uncertainties on the real build in air voids of these thin pavements.

Table 3. Build in air void measured on laboratory test samples of thin layers produced by the gyrator compactor in class one as well as in class two.

<table>
<thead>
<tr>
<th>Max. aggregate size</th>
<th>Class 1</th>
<th>Class 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>6 mm</td>
<td>12 %</td>
<td>20 %</td>
</tr>
<tr>
<td>10 mm</td>
<td>10 %</td>
<td>18 %</td>
</tr>
</tbody>
</table>

Usually no structural problems can are expected in France if a modified binder is used. In order to secure a good adhesion to the layer below and to seal this layer so that no water penetrates to this layer, a sealing of pure bitumen emulsion is applied before laying the thin layer. Modified bitumen is used at locations with high shearing
stresses. For thin layers and porous pavements 300 to 500 g/m² of residual bitumen are used. For ultra thin layers 400 to 600 g/m² are used.

Thin layers can normally be laid on a road by ordinary laying machines. The ultra thin pavements have to be laid by special machines where the bitumen emulsion is sprayed out by the laying machine just before the laying of the thin pavement. Some meteorological conditions were highlighted for the laying of thin layers in order to avoid too fast cooling before a sufficient compaction has been performed:

- Temperature over 5 degrees Celsius.
- Wind speed less than 8 m/s for temperatures below 10 degrees Celsius.

The compaction shall be carried out with a steel roller without vibrations. There are some problems with durability in relation to sheering forces for thin layers in roundabouts and intersections. These problems can also occur at situations where parked cars are turning the tyres when they are not driving. This might damage the pavement.

Common characteristics of thin layers:

- Waterproof because of the use of a bitumen seal on the bearing layer.
- Excellent rutting resistance.
- Excellent skid resistance. The pavements with 6 mm aggregate have a better skid resistance than the pavements with 10 mm aggregate. The pavements have a good stone polishing value because of the use of a high quality aggregate.
- Improved evenness for short texture wavelengths.
- Quick reappearance of active cracking (as for any other thin pavement).
- Comparable acoustic performance between thin and ultra thin according to max. aggregate size.

Every year around 27 mil. square meters of thin layers and 1.5 mil. square meters of ultra thin layers are applied in France. Around 39 % of the pavements applied on toll motorways in France are thin layers. On the national highways it is around 15 %.
Figure 7. Medium Profile Depth (MPD) measured by the sand patch test for different pavement types all with 10 mm maximum aggregate size.

Ordinary asphalt concrete normally has a Medium Profile Depth (MPD) of around 0.5 mm. The thin layers with 6 mm aggregate the MPD is around 0.7 to 0.9 mm (for ultra thin layers 1.1 to 1.3 mm). Figure 7 show the Medium Profile Depth (MPD) measured by the sand patch test for different pavement types all with 10 mm maximum aggregate size when the pavements are new and 2-3 years old. A slight decrease in the measured values can be observed over the 2-3 years period. The required minimum for these measurements is 0.4 mm.

The skid resistance is better for the thin pavements than for the ordinary dense asphalt concrete. This is due to the macro texture of the pavement. The skid resistance is increased as the maximum aggregate size is reduced. The reason is that the size of contact point between pavement and tyre is increased. The skid resistance can be improved on the newly laid thin layers by applying sand during the compaction. The durability of the skid resistance is very good.

The splash and spray reduction by using 10 mm aggregate is better than by using 6 mm aggregate. LCPC are not performing measurements of splash and spray.

The rutting resistance is the same for the two max aggregate sizes. The structural durability of the thin pavements are the same or better than for thick pavements.

According to the French road building tradition, where there is no noise problems like on highways in the open country, here 10 mm max aggregate size are usually used for thin layers. In urban conditions where noise reduction is needed 6 mm aggregate are used.
It is not possible accurately to measure the build in air void of the thin layers. It is evaluated that the air void is around 15 % which is less than the porous pavements where the build in air void is over 20 %. Problems with frost damages on the thin layers have generally not been observed, but this might be due to the meteorological conditions in the part of France with very little frost during the winter period.

The thin layers are used both on urban roads and on highways, also with a very high volume of traffic.
4. Acoustical performance of thin layers

The SPB method has been used to measure noise from pavements for a long period in France. 10 laboratories in France are performing SPB measurements. All SPB measurements performed in France have been collected in a database (Tyre-Road Noise National Data Base). The results of the noise database can be seen below in Figure 8. For passenger cars at a speed of 90 km/h and adjusted to an air temperature of 20 °C. The temperature correction used is +0.1 dB pr. degree Celsius reduction of temperature. The same correction is used for passenger cars as well as for trucks. The temperature correction generally used is valid for dense asphalt but it might be too big for open and porous pavements.

![Figure 8. Results from SPB noise measurements on different pavement types in France for passenger cars at a speed of 90 km/h and a temperature of 20 degrees Celsius [4]. (Copied by the permission of Fabienne Anfosso-Lédée, LCPC).](image)

PCA is Porous Asphalt Concrete  
UTAC is Ultra Thin Asphalt Concrete  
VTAC is Very Thin Asphalt Concrete  
DAC is Asphalt Concrete

It can be seen that the spread of noise emission is quite big for the same type of pavement. These differences are now a subject for new research. The spread in noise level for a given type of pavement is typically 6 to 8 dB. This can be due to the special pavement produced for each different section in the database. It can be due to different ages of the included pavements or due to other factors. If the average noise level for each pavement type is used as an indicator some interesting tendencies can be observed. The pavements can be divided in 3 main groups according to noise, the quiet, the intermediate and the noisy types.
A dense asphalt concrete with 10 mm aggregate has a noise level of 77.8 dB. This pavement might be quite similar the 11 mm dense asphalt concrete normally used as a reference pavement in Denmark (see Table 4). Where as a dense asphalt concrete with 14 mm aggregate has a noise level of 79.3 dB. This increase in noise level of 1.5 dB corresponds to a 4 mm increase in the maximum aggregate size. This pavement might be quite similar the 16 mm dense asphalt concrete which I sometimes used as a reference pavement (see Table 5).

The thin layers has as an average 74.1 dB (type 2) to 75.1 (type 1) dB for 6 mm aggregate and for 10 mm the noise level is 75.6 dB for type 2 and 78.0 dB for type 1. The lowest noise level is reached by a single layer porous pavement with 6 mm aggregate at 71.8 dB. In France two-layer porous pavements are not so common.

The same tendencies are seen for trucks (Figure 9). A reference pavement with dense asphalt concrete with 10 mm aggregate has a noise level of 85.6 dB which again might be compared to the typical Danish reference pavement (see Table 4). Where as a dense asphalt concrete with 14 mm aggregate has a noise level of 86.7 dB. This increase in noise level of 1.1 dB for multi axle trucks corresponds to a 4 mm increase in the maximum aggregate size. This pavement might be quite similar the 16 mm dense asphalt concrete sometimes used as a reference pavement (see Table 5).

The thin layers with 6 mm aggregate has an average noise level of 82.5 (type 2) to 83.7 dB (type 1). For thin layers with 10 mm aggregate the average noise level is 82.6 dB for type 2 and 85.4 dB for type 1. The lowest noise level is reached by a single layer porous pavement with 6 mm aggregate of 81.3 dB. There are more data for passenger cars than for trucks and therefore the database is most accurate for passenger cars.
Table 4. Average noise levels for passenger cars and trucks with more than two axles on porous pavements and thin layers measured by the SPB method. A relative noise reduction in relation to a dense asphalt concrete with 10 mm aggregate is also indicated. These noise reductions might be compared with reductions typically achieved in Denmark.

<table>
<thead>
<tr>
<th>Pavement type</th>
<th>Maximum aggregate size</th>
<th>Passenger cars 90 km/h</th>
<th>Noise reduction relative to a dense asphalt concrete with 10 mm aggregate for passenger cars</th>
<th>Trucks multi axles (more than two axles) 80 km/h</th>
<th>Noise reduction relative to a dense asphalt concrete with 10 mm aggregate for Trucks with more than two axles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Dense asphalt concrete</td>
<td>10 mm</td>
<td>77.8 dB</td>
<td>-</td>
<td>85.6 dB</td>
<td>-</td>
</tr>
<tr>
<td>Porous pavement</td>
<td>6 mm</td>
<td>71.8 dB</td>
<td>6.0 dB</td>
<td>81.3 dB</td>
<td>4.3 dB</td>
</tr>
<tr>
<td>Porous pavement</td>
<td>10 mm</td>
<td>74.3 dB</td>
<td>3.5 dB</td>
<td>82.1 dB</td>
<td>3.5 dB</td>
</tr>
<tr>
<td>Thin layer type 1</td>
<td>6 mm</td>
<td>75.1 dB</td>
<td>2.7 dB</td>
<td>83.7 dB</td>
<td>1.9 dB</td>
</tr>
<tr>
<td>Thin layer type 2</td>
<td>6 mm</td>
<td>74.1 dB</td>
<td>3.7 dB</td>
<td>82.5 dB</td>
<td>3.1 dB</td>
</tr>
<tr>
<td>Thin layer type 1</td>
<td>10 mm</td>
<td>78.0 dB</td>
<td>-0.2 dB</td>
<td>85.4 dB</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>Thin layer type 2</td>
<td>10 mm</td>
<td>75.6 dB</td>
<td>2.2 dB</td>
<td>82.6 dB</td>
<td>3.0 dB</td>
</tr>
</tbody>
</table>

The average noise levels for the thin layers as well as the porous pavements can be seen in Table 4. The relative noise levels for a dense asphalt concrete with 10 mm aggregate is also shown (close to Danish standard reference pavement). In Table 5 the same data are shown but for dense asphalt concrete with 14 mm aggregate as a reference. The noise reductions are generally a little higher for passenger cars than for trucks.
Table 5. Average noise levels for passenger cars and trucks with more than two axles on porous pavements and thin layers measured by the SPB method. A relative noise reduction in relation to a dense asphalt concrete with 14 mm aggregate is also indicated.

<table>
<thead>
<tr>
<th>Pavement type</th>
<th>Maximum aggregate size</th>
<th>Passenger cars 90 km/h</th>
<th>Noise reduction relative to a dense asphalt concrete with 14 mm aggregate for passenger cars</th>
<th>Trucks multi axles (more than two axles) 80 km/h</th>
<th>Noise reduction relative to a dense asphalt concrete with 14 mm aggregate for Trucks with more than two axles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Dense asphalt concrete</td>
<td>14 mm</td>
<td>79.3 dB</td>
<td>-</td>
<td>86.7 dB</td>
<td>-</td>
</tr>
<tr>
<td>Porous pavement</td>
<td>6 mm</td>
<td>71.8 dB</td>
<td>7.5 dB</td>
<td>81.3 dB</td>
<td>5.4 dB</td>
</tr>
<tr>
<td>Porous pavement</td>
<td>10 mm</td>
<td>74.3 dB</td>
<td>5.0 dB</td>
<td>82.1 dB</td>
<td>4.6 dB</td>
</tr>
<tr>
<td>Thin layer type 1</td>
<td>6 mm</td>
<td>75.1 dB</td>
<td>4.2 dB</td>
<td>83.7 dB</td>
<td>3.0 dB</td>
</tr>
<tr>
<td>Thin layer type 2</td>
<td>6 mm</td>
<td>74.1 dB</td>
<td>5.2 dB</td>
<td>82.5 dB</td>
<td>4.2 dB</td>
</tr>
<tr>
<td>Thin layer type 1</td>
<td>10 mm</td>
<td>78.0 dB</td>
<td>1.3 dB</td>
<td>85.4 dB</td>
<td>1.3 dB</td>
</tr>
<tr>
<td>Thin layer type 2</td>
<td>10 mm</td>
<td>75.6 dB</td>
<td>3.7 dB</td>
<td>82.6 dB</td>
<td>4.1 dB</td>
</tr>
</tbody>
</table>

Statistical analyses have been performed on the SPB data in the database in order to study the effect of aging on the noise emission [5]. Many road sections have been measured when the pavements were new but there are no time histories of measurements. At LCPC they selected 5 test sections with long time measurement series and made some statistical analyses by using averages and standard deviation for the noise levels for passenger cars. For thin layers with 6 mm aggregate they found a statistical increase in noise levels of 0.5 dB for the first 2 years and an added increase form year 3 to 5 of 2.5 dB. No data on texture has been measured in relation to the SPB measurements. There were no observations of ravelling on the 5 selected road sections that could explain the increase of noise. The increase is quite significant and no explanations have been found.

An explanation could be that the openness of the thin layer is so large that they are porous or semi porous and therefore the pores are filled up by sand and dirt during the years. This process is also seen on some types of porous pavements which turns the
open and porous thin layers into dense pavements over time and by this increasing the noise.

The tendency was that with the highest initial noise levels the lowest increase can be expected and for the lowest initial noise levels the biggest increase has been observed.

The same statistical analyses have been performed for porous pavements (10 mm max. aggregate) in the database and an increase in noise level of 5.5 dB over a 10 year period has been seen. This increase can be explained by clogging. These results have not been correlated with measurements of clogging related properties but that is a subject for future research. In this coming research SPB, CPX and absorption measurements will be performed. Also the texture spectrum will be measured together with traffic measurements.

So far the same type of statistical analyses has not been performed on dense reference pavements. This will be done in future research programmes.
5. Practical experiences

5.1 Contracting company
Enrovia is a French pavement contractor. Enrovia started the use of thin layers in 1990. The products have been developed over the years. The company has a pavement called “Viaphone” with 6 mm max. aggregate size, modified bitumen (SBS modification) and fibres added. The pavement is applied at a thickness of 20-30 mm. The noise level measured for passenger cars at 90 km/h is less than 72 dB. The skid resistance is over 0.5, measured by a French method, and this is considered a very good skid resistance. Viaphone is used both on urban roads as well as on highways with high speeds and high volume of traffic. The pavement is not resistant to sheering forces due to turning of vehicles like on roundabouts and intersections. The company has produced over 7.8 mill. square meter of this pavement type.

In Appendix A experiences on thin layers from the French Colas contracting company are presented.

5.2 Road administration
Noise protection is required by the French legislation in the case of construction of new roads and in case of a significant modification of an existing infrastructure. A significant modification is in relation to noise defined as a situation where the noise level will be increased by more than 2 dB.

There have been noise problems around the 77 km long ring road system around Nantes where the average traffic volume is 58,000 vehicles pr. day. The speed limit on the road varies between 80 to 110 km/h. It has been decided to use a common speed limit of 90 km/h as a tool for noise abatement. It has also been decided to apply noise reducing thin layers with 6 mm maximum aggregate instead of the former traditional dense pavement. A noise reduction of 3 to 5 dB has been expected because of the use of thin layers. It has been planned to apply these layers over a period of 6 years as a part of the ongoing road maintenance program. At the same time many of the connecting aces roads will also be applied with thin layer pavements. At some sections there were existing noise barriers. Some of these barriers have been build and financed by the people living near the ring road.

In order to evaluate the effect of the pavements a noise measurement campaign (L_{Age} measurements) has been carried out with a total of 27 measurement sites at the façade of dwellings along the ring road. It is planned to repeat the measurements in 2006 in order to evaluate the effect of aging on the pavements (in combination with the increase in traffic).

It is the general strategy to use thin layers with 6 mm aggregate size on urban roads and highways with a speed limit up to 90 km/h and to use thin layers with 10 mm maximum aggregate size on highways with a speed limit of 110 km/h. The reason for using thin layers is their good noise reducing effect and the good skid resistance and
structural durability combined with the fact that these pavement types are easy to apply on existing roads.

A reason for the use of 10 mm aggregate might be that this type is slightly less expensive than the 6 mm type. According to LCPC the 6 mm type has a good structural durability so the type can be used on high speed highways. The 6 mm type has a better skid resistance than the 10 mm type. But the 10 mm type has a better effect on reducing splash and spray than the 6 mm type.

The price of the thin layers used in Nantes is 5-6 € pr. square meter. The price for traditional dense layers is around 4 €. The extra cost is due to the use of high quality aggregate and the use of modifier in the bitumen.

They have nearly no frost periods in the region so damages due to freezing water in the pavement structure can not be expected.

The air void seems rather high. But LCPC has the point of view that these pavements are only open in the top layer and that they are not open down in the pavement structure, so the pavements are not like porous pavements. Measurements of water permeability have not been carried out on the thin layers. Such measurements are only performed on real porous pavements.

Acoustical absorption has been measured on some thin layers. There is an absorption peek at around 2000 Hz which is much higher than on porous pavements. But this was on a type 2 pavement which has the highest build in air void. They do not expect very much absorption on type 1 thin layers because the build in air void is not that high.

As there are thin layers with ages from 1 to 6 years on the ring road in Nantes it could be an idea to perform CPX measurements in order to establish a time dependency of the noise emission.
6. Conclusion

From around 1985’s thin layers and ultra thin mixes have been developed and used in France, in order to improve visual performance under wet conditions (reduce splash and spray) and in order to achieve noise reduction. Thin layers with a maximum aggregate size down to 6 mm were used. The typical thickness of these pavements is 20 to 30 mm even though ultra thin pavements with a thickness down to 10 to 15 mm are also used sometimes.

The thin pavements have an open surface structure in order to reduce noise. To achieve this, the pavements have a rather high built in air void. It is generally very difficult/impossibly to measure porosity on drilled cores of the very thin pavements. The French requirements in relation to the build in air void are therefore defined for specimens prepared by the gyrator compactor after 25 gyrations. Two classes of thin layers are defined. Class one has an air void of 12 – 20 % and Class two has 20 – 25 %.

There is no relation between the measured porosity in the laboratory on the specimens produced by the gyrator compactor and the porosity in the pavements when they are applied on a road. Seen from a Danish/Dutch point of view the Class one pavements must be considered semi dense and very open in the surface texture but having a dense structure with no porous down in the pavement structure. The Class two pavements must be considered porous. This is underlined by the fact that time series of noise measurements has shown a high increase of noise levels from the Class two pavements like what is seen on some porous pavements.

Common characteristics of thin layers used in France:

- Waterproof because of the use of a bitumen seal on the bearing layer.
- Excellent rutting resistance.
- Excellent skid resistance. The pavements with 6 mm aggregate have a better skid resistance than the pavements with 10 mm aggregate. The pavements have a good stone polishing value because of the use of a high quality aggregate.
- Quick reappearance of active cracking (as for any other thin pavement).
- Comparable acoustic performance between thin and ultra thin according to max. aggregate size.
- The structural durability of the thin pavements are the same or better than for thick pavements.
Table 6. Average noise effect in France by the use of thin layers with 6 mm maximum aggregate size. Relative noise reduction for passenger cars and trucks in relation to a dense asphalt concrete with 10 mm aggregate is also indicated. These noise reductions might be compared with reductions typically achieved in Denmark.

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Passenger car</th>
<th>Multi axle trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>90 km/h</td>
<td>80 km/h</td>
</tr>
<tr>
<td>Type 1</td>
<td>2.7 dB</td>
<td>1.9 dB</td>
</tr>
<tr>
<td>Type 2</td>
<td>3.7 dB</td>
<td>3.1 dB</td>
</tr>
</tbody>
</table>

Table 6 and 7 shows the average noise reductions measured on thin layers with a maximum aggregate size of 6 mm in relation to dense asphalt concrete with 10 mm aggregate (comparable to the typical Danish reference pavement). Table 7 shows the average noise reductions measured on thin layers with a maximum aggregate size of 6 mm in relation to dense asphalt concrete with 14 mm aggregate which is also sometimes used as a reference pavement.

Table 7. Average noise effect in France by the use of thin layers with 6 mm maximum aggregate size. Relative noise reduction for passenger cars and trucks in relation to a dense asphalt concrete with 14 mm aggregate is also indicated.

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Passenger car</th>
<th>Multi axle trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>90 km/h</td>
<td>80 km/h</td>
</tr>
<tr>
<td>Type 1</td>
<td>4.2 dB</td>
<td>3.0 dB</td>
</tr>
<tr>
<td>Type 2</td>
<td>5.2 dB</td>
<td>4.2 dB</td>
</tr>
</tbody>
</table>
7. References


Appendix A

Report from meeting at Colas France

A Danish group of road specialists from the municipalities of Copenhagen and Aalborg, the Road Directorate (construction division and the Danish Road Institute) and Colas Denmark visited the Colas Research Campus on the 3rd of November 2005 in order to study the development of noise reducing pavements carried out by the Colas Company. Presentations were given by:

- Jacques Samanos, technical director Colas North Europe.
- Jean-Eric Poirier, Scientific Director
- Jean-Luc Gautier.
- Jean-Paul Michaut.

Introduction

75 people are employed at the Colas Research Campus, the scientific and technical centre of Colas situated near Versailles outside Paris. 50 of these employees are working at the laboratories testing of materials. 50% of the work is used for job assistance and control and 40% for research and testing of new products. The goal is to work with:

- Job site assistance.
- Norms and standards.
- Development of new products.
- Expertise centre. Assessment of troubles on pavements.

Figure A1. The Colas version of the CPX measurement system.
Ecoliant is a technical Colas company that performs different types of measurement on the roads. They perform noise measurements using their version of a CPX measurement system where 3 microphones are applied to a passenger car. See Figure A1. The technical centre does not perform measurements of splash and spray!

Two microphones are placed 20 cm from the tyre and 20 cm over the road surface (see Figure A2). The third microphone is placed behind the tyre according to an older French standard (see Figure A3). This microphone to some extend also reflects the effect of the road surface on the noise propagation. The measurement data are collected on a PC. The system is operated by one person driving the car and operating the measurement system. The system can be used at speeds up to 110 km/h. At higher speeds unevenness of the road surface might cause vibrations and variance in the distance between the microphones, and therefore measurements at very high speeds are not recommended. This measurement setup has been used for 5 years.

Figure A2. The two microphones 20 cm from the tyre and 20 cm over the road surface.

Figure A3. The microphone is placed behind the tyre.
In 2005 Colas participated in a French round robin test with different CPX systems with microphones mounted on passenger cars. A report will be available in the spring of 2006 with a national French suggestion for the definition of a version of the CPX measurement system. These CPX systems applied to passenger cars are easier to manure and use at 50 km/h on urban roads than the trailer based CPX systems which usually are quite wide. Colas are only using one tyre, it is a French Michelin tyre and not any of the tyres demanded in the CPX draft standard. We were informed that Michelin might propose to produce tyres for a revised version of the CPX method and that the company might guarantee that these tyres will be produced for a long time period.

They are also performing SPB measurements. In relation to this they measure wind direction and speed at a height of around 1 m.

**Development of noise reducing pavements**

Colas have been working with noise reducing pavements for more than 15 years. The Colas noise reducing pavements are called Rugosoft which is the latest development. Microville, also developed by Colas, has also been applied on the M10 highway in Denmark and Miniphone that uses lightweight expanded clay.

Colas have been working on the influence of the surface texture where they use the formula developed by Sandberg and Descornet from 1980. According to which the fine texture around 5 mm frequency shall be increased and the texture around 80 mm frequency shall be reduced in order to reduce the noise emission. The type of the surface is important it can have a “positive shape” with stones on a flat ground level or it can be a “negative shape” a flat top surface with holes down in the structure.

![Figure A4. Principal sketches of pavements with “positive” and “negative” shape of surface structure.](image)

A model developed by LCPC has been used to evaluate the effect of acoustical absorption. The important parameters in this model are:

- The thickness of pavements
- The efficient porosity
- The specific resistance to air flow
- The shape factor of voids

At the moment Colas is working with theoretical models developed by F. Hamet from INRETS about the influence of the stiffness of a pavement on the noise emission. The noise emission might be reduced if the stiffness of the road is not lower than a third of
the stiffness of the pavement. This point towards development of new noise reducing pavements with “soft” surfaces produced by the use of different kinds of rubber materials.

The French database on SPB measurements that was presented at the meeting at LCPC was also highlighted by Colas. From this database it can be seen that noise reduction can be achieved by reducing the maximum aggregate size as much as possible. 6 mm gives the lowest noise levels. Pavements with 4 mm aggregate are not included.

It was stated that porous pavements clog and that this results in a noise increase of up to 1 dB pr year (for urban roads). On this background it was stated that porous pavements are mainly used on high speed roads in France where there is a self cleaning effect.

The background for development of second generation of noise reducing pavements (thin layers) the goals have been to reduce:

- The impact on noise by reducing unevenness of the surfaces.
- Reduce air pumping noise.
- Reduce the slip stick noise.

**New thin noise reducing pavements**

New thin noise reducing products have been developed by many French companies. These products are characterised by:

- Use of 4, 6 or 10 mm maximum aggregate size.
- Thickness 15 to 30 mm.
- Build in air void 10-25 %.
- Elastomer modified binders or bitumen with fibre added.
- Additives (Rubber powder, etc.)

This type of pavements is used for urban roads as well as for highways. They are used on highways with a very high volume of traffic (80.000 vehicles a day was mentioned).

*Table A1. The material distribution of Microville with 4 and 6 mm maximum aggregate size.*

<table>
<thead>
<tr>
<th>Max aggregate size</th>
<th>4 mm</th>
<th>6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate 4/6</td>
<td></td>
<td>75-90 %</td>
</tr>
<tr>
<td>Aggregate 2/4</td>
<td>75-90 %</td>
<td></td>
</tr>
<tr>
<td>Sand 0/2</td>
<td>6-20 %</td>
<td>6-20 %</td>
</tr>
<tr>
<td>Filler and fibre</td>
<td>1-5 %</td>
<td>1-5 %</td>
</tr>
<tr>
<td>Total fibre content</td>
<td>3-8 %</td>
<td>3-8 %</td>
</tr>
<tr>
<td>Binder content</td>
<td>5-6.5 %</td>
<td>5-6.5 %</td>
</tr>
<tr>
<td>Normal thickness</td>
<td>20-25 mm</td>
<td>20-30 mm</td>
</tr>
</tbody>
</table>
Microville is a thin noise reducing pavement developed by Colas. A layer of bitumen emulsion or modified bitumen is first applied on the base course (500 to 800 g/m²). The maximum aggregate size is 4 or 6 mm (see Table A1). The aggregate is natural hard rock or a porous artificial rock product. The binder can be pure bitumen (50/70 or 35/50) with artificial or organic fibres added or the binder can be SBS modified bitumen. The special modification of the binder should make it possibly to use these pavements on roads with heavy and aggressive traffic and also at zones where the traffic is turning and creating high shear forces. The compaction is performed with rollers not using vibrations.

It is difficult to determine the build in air void of these thin pavements. The air void measured on specimens produced in the laboratory by the gyro compactor system after 25 revolutions can be around 17%. It is expected that the air void will also be around 17% when the pavement is applied on the road. Measured by the sand patch method the result varies between 0.8 and 2.0 mm with most results ranging from 1.2 to 1.8 mm. These values indicate that the pavements have an open surface structure.

Noise reductions of 1-4 dB have been measured for this type of pavement.

Longitudinal Braking Force Coefficient (skid resistance) measured by the French standard is higher than 0.45 at 60 km/h, higher than 0.30 at 90 km/h and higher than 0.22 at 120 km/h.

The skid resistance seems to be kept over the years in France also for the 6 mm aggregate pavements. Even on roads with dense traffic, polishing of the aggregate are normally not seen. But it is necessary to use polymer modified binders in order to secure the good texture as the pavements gets older.

The technical lifetime of these thin noise reducing pavements is the same as for other normal thin pavements with a thickness of 25 to 30 mm.

Microvill will be used a new highway around Herning in Denmark. It is discussed if it shall be 8 mm aggregate or 6 mm. In Denmark there is a fear that the skid resistance will be reduced too much due to tear and wear of the pavements by using 6 mm aggregate. In France 6 mm normal aggregate are used also on highways resulting in a good skid resistance.
Site visits

Figure A5. A four years old Microville pavement applied on Avenue Villeneuve L’Etang in Versailles.

Figure A6. Parts of a 4 years old Microville pavement on Avenue Villeneuve L’Etang seemed to have a very open surface texture.
Figure A7. Parts of a 4 years old Microville pavement on Avenue Villeneuve L’Etang seemed to have a more dense surface texture.

Two urban roads paved with Microville thin layers were visited during the meeting. Red collared aggregate was used for these pavements for architectural reasons in the historic city of Versailles. The maximum aggregate size of these pavements was 6 mm and the thickness was 25 mm. The build in air void was evaluated to be 15-17%.

One pavement on Avenue Villeneuve L’Etang in Versailles was 4 years old. It was applied on an urban road with a speed limit of 50 km/h and some traffic (see Figure A5). Most of the pavement seemed to have a very open surface structure (see Figure A6) but some parts of the pavement seemed to have a more dense structure (see Figure A7). This pavement was reddish because of the red aggregate used.

Another pavement on Rue Coste in Versailles was only two weeks old (see Figure A8). It was applied on an urban road with very little traffic and a speed around 40 km/h. The pavement was black because bitumen film was still on the aggregate. Some sections of this pavement seemed to be very open and other parts seemed denser (see Figure A9 and A10). The pavement had a very even surface structure with open cavities.
Figure A8. Two weeks old Microville pavement applied on Rue Coste in Versailles.

Figure A9. Parts of the two weeks old Microville pavement on Rue Coste seemed to have a very open surface texture.
Figure A10. Parts of the two weeks old Microville pavement on Rue Coste seemed to have a more dense surface texture.
<table>
<thead>
<tr>
<th>Nr. No.</th>
<th>Titel/Title/Shortcut</th>
<th>Forfatter/Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/98</td>
<td>Fællesafprøvning af diverse asfalttyper i forbindelse med revision af vejregel for varmblændet asfalt</td>
<td>Jørn Raaberg, Ole Grann Andersson, Jan-Ole Nielsen, Asfaltindustrien</td>
</tr>
<tr>
<td>9/99</td>
<td>Måling af asfaltbelægningers tekstur i relation til friktion</td>
<td>Bjarne Schmidt</td>
</tr>
<tr>
<td>10/00</td>
<td>Tilstandsvurdering af udvalgte kunststofbelægninger</td>
<td>Jeanne Rosenberg</td>
</tr>
<tr>
<td>11/00</td>
<td>Temperaturer i vejbefæstelser</td>
<td>Susanne Baltzer, Brian Henrik森, Ole Fog</td>
</tr>
<tr>
<td>12/01</td>
<td>Vejens egenskaber - fra måleure og regnemærke til sensorer og pc'ere (ikke i elektronisk udgave)</td>
<td>Jørgen Banke</td>
</tr>
<tr>
<td>13/02</td>
<td>The Danish Road Testing Machine 1995 - 2000</td>
<td>Wei Zhang, Robin Macdonald</td>
</tr>
<tr>
<td>14/02</td>
<td>Sammenligning mellem Viagra og viagrafællesvirkning beregnet ud fra profilografmålinger</td>
<td>Bjarne Schmidt</td>
</tr>
<tr>
<td>15/02</td>
<td>Rensning af overfladevand og husholdningsvand</td>
<td>Gitte Falstrup, Knud A. Pihl</td>
</tr>
<tr>
<td>16/03</td>
<td>Statisk pladebelastning, faldlod og minifaldlod Resultater af sammenlignende målinger</td>
<td>Gregers Hildebrand, Susanne Baltzer</td>
</tr>
<tr>
<td>17/03</td>
<td>Stenfyldte fuger</td>
<td>Vibeke Wegan</td>
</tr>
<tr>
<td>18/03</td>
<td>Veje, jævnhet og bilers hastighed - er oplevelsen af en vej jævnhed afhængig af bilens hastighed?</td>
<td>Bjarne Schmidt</td>
</tr>
<tr>
<td>19/04</td>
<td>Støjdæmpende vejbelægninger på Motoring 3 Teknisk og samfundsøkonomisk analyse</td>
<td>Carsten Bredahl Nielsen</td>
</tr>
<tr>
<td>20/04</td>
<td>Vejsøj på Inter-Noise konferencen i Prag - rejserapport august 2004</td>
<td>Hans Bendtsen, Bent Andersen</td>
</tr>
<tr>
<td>21/04</td>
<td>Måling af trafikstøj fra vejbelægninger på M10 ved Solrød</td>
<td>Bent Andersen, Hans Bendtsen, Bjarne Schmidt, Carsten Bredahl Nielsen</td>
</tr>
<tr>
<td>22/04</td>
<td>Tilstødning mellem vejbelægningers tekstruktur og trafikstøj - et litteraturstudium</td>
<td>Bent Andersen</td>
</tr>
<tr>
<td>23/04</td>
<td>Rolling resistance, fuel consumption - a literature review</td>
<td>Hans Bendtsen</td>
</tr>
<tr>
<td>24/05</td>
<td>The DRI - DWW Noise Abatement Program - Project description</td>
<td>Hans Bendtsen, H.J. Ertman Larsen, Bent Andersen, Carsten Bredahl Nielsen, Jørn Raaberg, Vibeke Wegan, Bjarne Schmidt, Karin Kool Ammitsøe</td>
</tr>
<tr>
<td>25/05</td>
<td>Holdbarhed af Drænasfalt – asfaltprøvning</td>
<td>Carsten Bredahl Nielsen</td>
</tr>
<tr>
<td>26/05</td>
<td>Thin layer Test Pavements in Denmark - Project description</td>
<td>Hans Bendtsen</td>
</tr>
<tr>
<td>27/05</td>
<td>Notes from Forum Acusticum in Budapest 2005</td>
<td>Hans Bendtsen, Bent Andersen, Lars Ellebjerg Larsen</td>
</tr>
<tr>
<td>28/05</td>
<td>French Experiences on Noise Reducing Thin Layers</td>
<td>Hans Bendtsen, Jørn Raaberg</td>
</tr>
<tr>
<td>Road Directorate</td>
<td>Road Directorate</td>
<td>Road Directorate</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Niels Juels Gade 13</td>
<td>Guldalderen 12</td>
<td>Thomas Helsteds Vej 11</td>
</tr>
<tr>
<td>P.O. Box 9018</td>
<td>P.O. Box 235</td>
<td>P.O. Box 529</td>
</tr>
<tr>
<td>DK-1022 Copenhagen K</td>
<td>DK-2640 Hedehusene</td>
<td>DK-8660 Skanderborg</td>
</tr>
<tr>
<td>Denmark</td>
<td>Denmark</td>
<td>Denmark</td>
</tr>
<tr>
<td>Telephone +45 3341 3333</td>
<td>Telephone +45 4630 7000</td>
<td>Telephone +45 8993 2200</td>
</tr>
<tr>
<td>Telefax +45 3315 6335</td>
<td>Telefax +45 4630 7105</td>
<td>Telefax +45 8652 2013</td>
</tr>
<tr>
<td><a href="mailto:vd@vd.dk">vd@vd.dk</a></td>
<td></td>
<td>Vejdirektoratet.dk</td>
</tr>
</tbody>
</table>