Ageing of low noise road surfaces
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ABSTRACT
Low noise road surfaces are a well known and effective measure to reduce tire-road noise and thus overall traffic noise. However, it is observed that all kinds of low noise road surfaces lose their noise reducing properties to some extent over time - which could be described as an “acoustic ageing”. For porous road surfaces, the acoustic ageing is mainly caused by clogging of the open pores which reduces the sound absorption and thus the noise reduction capacity. The parameters relevant for the acoustic ageing seem to be time and traffic volume. For dense low noise road surfaces, the acoustic ageing is mainly caused by an acoustically unfavorable change of the surface texture, which is mainly influenced by the traffic volume.

Recent results for the acoustic ageing of porous and dense low noise road surfaces will be shown. The results allow for estimating the acoustic lifetime of different types of road surfaces. Different approaches to extend the acoustic lifetime will be discussed.

Keywords: low noise road surfaces, tire-road noise, acoustic ageing.
I-INCE Classification of Subjects Number(s): 11.7.1, 52.3.

1. INTRODUCTION
Low noise road surfaces can either substitute other noise reducing measures like noise barriers or they can be combined with them, if the necessary noise reduction cannot be achieved with one single measure. A big advantage of low noise road surfaces is, that the noise reduction is included in a construction element which is needed anyway for a road – the road surface itself. In addition, the noise is directly reduced at the source which provides lower noise levels for the whole surrounding and not only a shielded area.

A big disadvantage of low-noise road surfaces is, however, that all practically applied construction types lose their noise reducing properties to some extent over time - which could be described as “acoustic ageing”. Most other measures retain a constant noise reduction over the lifetime.

For the further development of noise reducing road surfaces it is important to understand the relevant mechanisms for acoustic ageing, which would also allow to develop countermeasures for the acoustic ageing of existing road surfaces.

It is shown in (1) that low noise road surfaces can be „robustly efficient“ from an economic point of view, if properly planned. Understanding the acoustic ageing supports the building authorities to plan construction works on a large time scale and allows for economic planning and economic analyses.

The results presented in this paper add new aspects to the findings given in (2), while possible countermeasures and new data are presented in particular.
2. DENSE LOW NOISE ROAD SURFACES

2.1 Ageing mechanisms

The acoustic properties of dense road surfaces are mainly influenced by the road surface texture. The acoustically relevant texture wavelengths $\lambda$ range from $\lambda = 0.50$ mm to $\lambda = 50$ mm. This wavelength region is defined as the macrotexture of a road surface (3) and all relevant ageing mechanisms can be observed within this wavelength region.

There are different concepts for dense low noise road surfaces such as hot rolled dense asphalt, dressed asphalt and different types of cement concrete surfaces. The experience has shown, that the noise reduction potential of dressed surfaces seems to be limited, so that these surfaces were not further developed within the last years. For cement concrete surfaces a number of new production methods were established in the past years (4). This means that there is probably a great potential for dense low noise road surfaces made of cement concrete, but up to now no long term experience and thus no experience with acoustic ageing of these road surfaces are available. Therefore this section is focused on the hot rolled dense low noise road surfaces.

For hot rolled dense low noise road surfaces, the results given in (5) show, that the acoustic ageing is mainly a function of traffic load, especially of the number of heavy vehicles. The traffic load leads to a disaggregation of the filler component in the surface texture. This results in a decrease of the air-flow-resistance in the tire-road contact und thus an increase of the aerodynamic sound sources. The subsequent figure shows pass-by levels of passenger cars obtained with statistical pass-by measurements according to (6) on a dense low noise road surface at the same measurement position for different years after construction.

![Figure 1 – Spectra of SPB-measurements for 120 km/h measured different years after construction on a dense low noise road surface.](image)

It can be seen, that the sound pressure level does not change at low frequencies (below 1000 Hz), where tire vibrations are the predominant sound source. In the high frequency range, however, the sound pressure level increases with the age of the road surface. In this frequency region the aerodynamic sound sources are most relevant.

2.2 Change of the acoustic properties over time

In figure 2, the $CPX_p$-Indices according to (7) for 16 different hot rolled dense low noise road surfaces are shown as a function of the age of the road surface. The measurements were performed on highways that are regularly CPX-monitored. The left diagram shows the data for the right lane, the right diagram shows the data for the left lane. All measurements were performed with a nominal speed of 80 kmph using the Müller-BBM/M+P CPX-trailers. Additionally to the data also the linear
regression line and its equation are given. Most of the tracks show a CPXp-Index of approximately 94 dB(A) after construction on both the left and the right driving lanes. The slopes of the regression lines, however, differ clearly for the two driving lanes: On the right driving lane the slope is approximately 0.5 dB/year and on the left driving lane it is approximately 0.3 dB/year. This means that the acoustic ageing is slower on the left driving lane. The reason for the difference in the acoustic ageing is the different traffic volume on the driving lanes – especially the much smaller number of heavy vehicles on the left lane.

![Figure 2 – CPXp-Indices (80 kmph) on low noise dense hot rolled road surfaces on highways as a function of the age of the road surface. Left diagram: right driving lane; right diagram: left driving lane.](image)

This strong impact of the heavy vehicles on the acoustic ageing and the fact, that dense low noise road surfaces have a relatively small noise reduction potential for heavy traffic anyway, make it possible to allocate dense low noise road surfaces to those traffic situations where the major traffic load is given by passenger cars. In that case dense low noise road surfaces are supposed to be the best choice.

3. POROUS ROAD SURFACES

3.1 Ageing mechanisms

The acoustic properties of porous road surfaces are influenced by the acoustic impedance and the surface texture. The sound absorption is influenced by the void content of the surface, the airflow resistance, the layer thickness and the tortuosity (8).

The main difference comparing dense road surfaces with porous road surfaces is, that not only the traffic load influences the acoustic ageing but also clogging of the open pores is relevant. The clogging of the pores influences all above mentioned parameters like void content, airflow resistance etc. Furthermore, changes in the road surface texture may be relevant. Thus, the ageing mechanisms are much more versatile for porous road surfaces compared to dense surfaces and can be divided into the following categories:

- Clogging:
  - Clogging of the top level of a porous road surface. This effect prevails on road surfaces and sections, respectively, where traffic volume or driving speeds are low (inner city roads or hard shoulder). Clogging of the top layer actually “seals” the road surface. Possibly available voids below the top layer cannot be reached by the sound wave any more. This results in a total loss of the sound absorbing capacities.
  - Clogging of the bottom layer of the porous road surfaces. This occurs on road surfaces with high traffic load and on surfaces, where bigger quantities of dirt are spread on the surface, e.g. when there are construction sites nearby. Clogging of the bottom layer reduces the acoustically relevant layer thickness. The sound absorption is shifted to higher frequency ranges.
  - Homogenous clogging of the porous layer. This can be observed frequently at
porous road surfaces. Depending on the amount of dirt spread on the surface and on the initial void content, small particles accumulate in small voids in the layer. This causes only marginal losses in the (initial) void content, but changes the tortuosity of the layer and thus shifts the sound absorption to lower frequencies.

- Aggregate loss: The most relevant texture change for porous road surfaces is the aggregate loss. Isolated aggregate loss is not relevant for the acoustic properties, but it frequently acts as a starting point for the extensive degradation of the surface top layer. Open porous asphalts consist of a single-size mixture. Thus, the contact points between neighboring grains are very small as there is no filler added to the mixture. This makes the road surface texture much more fragile than a dense road surface.

The clogging of a road surface commonly is assessed by means of sound absorption measurements. Notably, these measurements should not be performed in the impedance tube using drill cores, as the drilling dust already changes the void distribution significantly. A more accurate way to perform sound absorption measurements is to do them in-situ using either the extended surface method or – even better – determine the surface impedance directly using a p-p-, p-p-p- or p-u-probe. For more detailed investigations computer tomography (CT) has proven to be useful. In the following figure horizontal intersections of CT measurements are shown for a “clean” and a clogged sample of porous asphalt.

Figure 3 – Horizontal CT-intersections for a “clean” and a clogged porous asphalt (9).

Accumulated small dirt particles are visible in the right picture between the single grains. These dirt particles close smaller channels in the porous matrix and thus increase the tortuosity of the road surface. Figure 4 shows the sound absorption coefficient calculated as a function of the tortuosity using the model described in (8).

Figure 4 – Sound absorption coefficient of porous asphalt, calculated as a function of tortuosity for porous asphalt.
3.2 Change of the acoustic properties over time

According to the different ageing mechanisms described in the section above, it can be observed, that the ageing of porous road surfaces usually does not follow a linear trend over time. To evaluate the acoustic ageing of porous road surfaces, it is helpful to divide the overall lifetime in at least 3 sections as shown in figure 5. After some initial level increase the sound pressure level consolidates for a long time. In this period the road surface remains in a metastable equilibrium between clogging and self cleaning. The self cleaning of porous road surfaces is described in section 3.3.1.

Figure 5 – Scheme for the acoustic ageing of porous asphalt.

3.3 Countermeasures

3.3.1 Cleaning

A lot of porous road surfaces are getting cleaned to prevent the clogging of open pores. Several reports like (9) and (10) show, however, that neither dry cleaning (like vacuuming) nor wet cleaning (pouring or spraying water on the surface and suction cleaning) have a significant impact. On a porous road surface in Ingolstadt, Germany the effect of wet cleaning was investigated in detail. One section of the road surface was wet cleaned twice a year and another section was not cleaned. After a period of 8 years, no significant difference in the acoustic performance of the two sections was detected. To reveal the underlying mechanisms, detailed investigations were performed together with the Technical University of Munich (11): The speed of the water poured in or sucked out of the porous layer decreases very quickly in lower areas of the porous matrix as a result of the flow resistance. Slow water-flows, however, are not able to carry solid material, which therefore remains in the porous layer. The following figure 6 shows the results of the CFD-calculation (11) leading to these results.
(11) also shows that porous road surfaces have a self cleaning effect, when fast traffic is rolling over the water saturated porous surface, e.g. during rain. In this case, the rolling tire produces a pressure pulse in the porous matrix, resulting in flow speeds being much higher compared to those generated by cleaning machines. Small dust particles are then thrown out of the surface together with the water and the porous matrix is getting cleaned. This effect can be observed especially well on a road surface with the shoulder being constructed of porous asphalt as well: the shoulder normally has no relevant traffic load and thus the void content and sound absorption coefficient, respectively, are reduced significantly.

3.3.2 Adding bitumen or changing the top layer

One common problem for porous road surfaces is the embrittlement of the bitumen, reducing its elasticity and ending up in aggregate loss, being a problem for both, the mechanical stability of the surface and the acoustic ageing. Applying an extra bitumen film to the surface could help to counteract the embrittlement. Nevertheless, this method must be handled with care: the film, which is normally sprayed onto the surface, must not close the top layer pores. Measurements on a porous road surface before and after application of the bitumen film show the acoustic effect (see figure 7).

![Graph showing sound pressure level before and after bitumen application](image)

Figure 7 – Near field sound pressure levels of the tire-road noise measured with the tire P1 acc. to (7).

The figure shows that the sound pressure level of the tire-road noise increases slightly in the high
frequency range after the application of the bitumen film. This means that some of the open pores are closed by the bitumen application which results in a reduction of the sound absorption capacity of the road surface.

Later monitoring measurements on the track with the bitumen application show a tendency to lower sound pressure levels in the high frequency range, again. This could mean, that some of the closed pores are opened again, but this tendency is not significant compared to the standard deviation of the tire-road noise levels measured along the track.

Considering the long term stability of the porous asphalt, the application of an extra bitumen film is very positive while costs are relatively low. So, the cost/benefit ratio is good.

If it is not possible to apply a bitumen film on the surface before extensive degradation takes place it could be possible to maintain the bottom layer of the porous asphalt while removing the top layer. Relevant experience with this method is described in detail in (12), showing that this kind of partial reconstruction works well.

### 3.3.3 Nanotechnological coating

Another attempt to counteract the clogging of the porous matrix is to add a nanotechnological polymer coating with hydrophobic properties to the bitumen. A special nanotechnological polymer which stratifies to the bitumen surface was investigated together with the University of Stuttgart. A scheme of the stratifying process is shown in figure 8.

![Figure 8](image_url)

To assess the effectiveness of the polymer coating, a laboratory test was performed. In this test samples of approximately 1 m² of porous asphalt were “polluted” with a specially designed artificial dust. The composition of this artificial dust was the result of a chemical analysis of dust samples from real roads under traffic. It consisted of fine graded sands, rubber and ground organic material. The tests were made with the following asphalt samples:

- Single layered porous asphalt with a maximum grain size of 8 mm PA8
- Single layered porous asphalt with a maximum grain size of 11 mm PA11
- Double layered porous asphalt with a maximum grain size of 8 mm in the upper layer and 16 mm in the bottom layer.

From each type of asphalt 2 samples were produced – one with standard polymer refined bitumen and the other with nanotechnological polymer refined bitumen.

Each sample was charged with 960 g/m² dust, which was spread in several turns. After each turn, the dust was washed in and the plates were dried with ultraviolet lamps. The whole process was fully automated to ensure comparable pollution for all samples. Details about the process setup are given in (9).

Before and after polluting the sound absorption coefficient was measured using a p-u-probe. In figure 9 the results are shown.
The data shows, that, after spreading the same amount of artificial dust on the surface, the sound absorption coefficient is significantly higher for the samples with nanotechnological refined bitumen. Also, the frequency shift is much smaller for the samples with the nanotechnological coating. The smallest effect was observed for the PA11. This might be due to the fact, that the pores in PA11 are somewhat larger compared to those in PA8 and so the tendency for clogging is smaller for PA11 anyway. First demonstrators on highways are installed and show promising results.

4. CONCLUSIONS

Low noise road surfaces are nowadays an important noise mitigation measure. It can be shown that they provide an efficient cost/benefit ratio. There is a number of construction types available being optimized for different traffic conditions.

A major disadvantage of low noise road surfaces is acoustic ageing. All road surfaces show acoustic ageing to some extend and there is a high demand for more durable low noise road surfaces and innovative countermeasures for acoustic ageing. For construction types being used for a relatively long time up to now (such as porous road surfaces) several countermeasures for acoustic ageing are available. For younger construction types these countermeasures are not yet available.
REFERENCES