大阪 inter.noise 2011
Osaka Japan September 4-7

aging of low noise road surfaces and procedure to implement them in a classification system

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ABSTRACT

Low noise road surfaces are known to deteriorate and partially lose their noise reducing abilities over their life time. Most classification procedure are based on the evaluation of their properties in new state, since monitoring over their life time is impracticable and affected by specific circumstances of usage. M+P has investigated the aging effect of several types of low noise surfaces and this information has been processed by a Dutch working group guided by the CROW, into a proposal for implementation of this effect in the Dutch classification scheme.
Keywords: Noise, Vibration, Measurement

1. INTRODUCTION

The effectiveness of low noise road surfaces for reducing traffic noise is undisputed and on several locations road traffic noise problems are solved by applying noise reducing road surfaces. Road surfaces are therefore an essential part in the determination of the noise production of road vehicles. For this reason the road surface effects are implemented in the calculation schemes for the determination of the noise exposure in the vicinity of roads. In the present Dutch scheme for noise calculations the effect, referred to as *Croad*, is added to the noise production level of the road vehicles.

The value of *Croad* is basically established on base of a measured difference between the pass-by sound levels observed for vehicles on the specified surface and the pass-by sound levels observed for vehicles on a reference road surface. The simplicity of this scheme is jeopardized by the fact that due to aging the properties of both the reference surface and the specified surface deteriorate. A classification scheme based on the surface properties in newly laid conditions will therefore not be representative for the effect of the surface over its life time. In Figure 1 the relation between the surface properties in new condition and during its life time are presented in a schematic way.

The graph demonstrates the relation between the surface effect in new condition, the surface effect at the end of its life time and the average effect over its life time. The aging of the low noise surfacing is related to the aging of the reference surface. We have taken into account the more frequent renewal of low noise surfaces. The graph illustrates the fact that although the effect of the low noise surface may drop to close to zero when compared to the initial effect, the average effect, taking into account several lifecycles and the aging of the reference surface, is still close to 3 dB.

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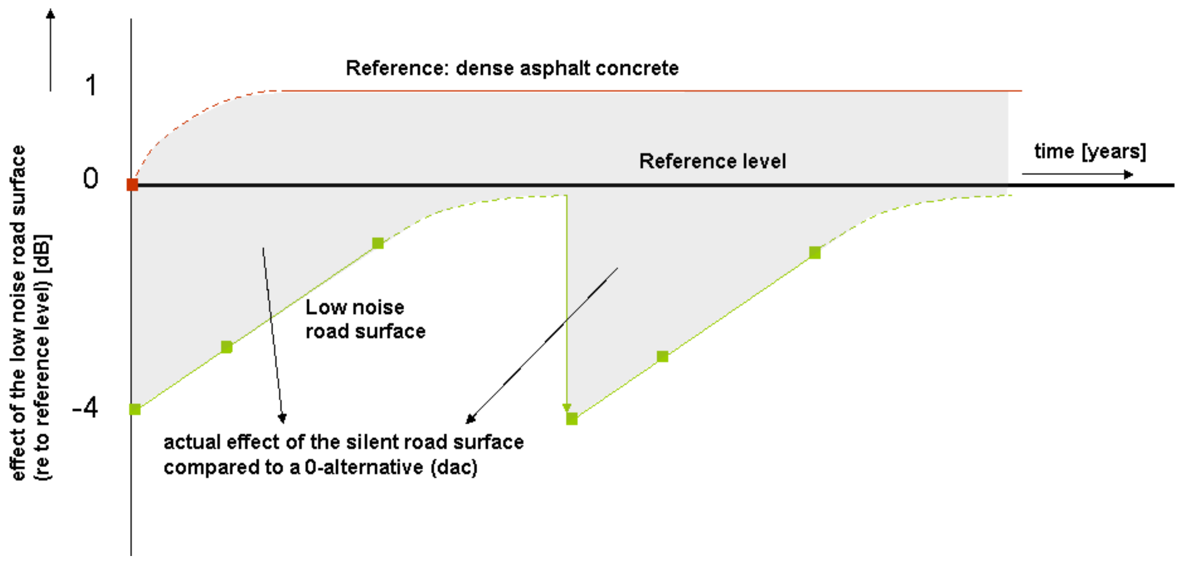

Figure 1 – a schematic presentation of the aging of both the reference surface and a specific low noise road surface. It illustrates the way aging affects the effective noise reducing capabilities of the low noise surface over its lifetime. The average reduction, presented by the grey area however is still close to 3 dB.

2. PROPOSED CLASSIFICATION SCHEME

2.1 implementation of a road surface effect in a noise calculation scheme.

The relevance of the determination of an acoustic road surface effect lies in the assessment of environmental noise levels in the vicinity of roads. The general calculation scheme leading to an immission level is based on the subtraction of propagation damping from the source strength (see (1)).

$$L_{reception} = L_{production} - D_{propagation} \quad (1)$$

$$L_{production} = L_{emission} - C_{road} \quad (2)$$

The source strength is composed of the source strength as determined on a reference surface type (frequently a general dense asphalt concrete with 0/11 or 0/16 mm grading) and a correction value that takes into account the effect of the road surface type on the sound power of a vehicle stream, either determined for an individual case or based on a road surface type classification scheme.

This paper addresses the development of an updated *Croad* classification scheme. This scheme is designed to represent an optimal balance between simplicity and practical applicability at one side and a fair representation of the lifetime related effect at the other side. Simplicity and straightforwardness prevents defining the effect of a low noise surface as a function of its age but generalizes the effect as an average over its life time. This implies that in case of a gradual degrading surface in the first half of its lifetime the surface effect will be underestimated and in the second half it will be overestimated (see Figure 1).

We have chosen to distinguish in the term *Croad* the following two components:

1. *Croad-initial:* a component representing the reducing effect of the specific surface type in newly laid condition relative to a (virtual) life time averaged reference surface type.
2. *Croad-time:* a component representing the degradation of the reducing effect of the surface averaged over its life time.

2.1.1 Initial value: Croad-initial

The initial value is defined as the difference between the pass-by levels of a certain class of vehicles on the specified road surface type relative to the levels on the reference surface type. The reference surface is defined as an Dense Asphalt Concrete of 0/8-to 0/16 grading of average age. The spread in the properties of the reference surface is covered by averaging over about 10 different sites and in varying speed ranges. The source strength of road vehicles ($L_{emission}$) is directly coupled to the *Croad* reference value by using the same pass-by data sets for the determination of both values. The source strength is based on the *SEL* levels, while the reference value is based on the L_{max} values of the same pass-by events.

2.1.2 Degradation effect: Croad-time

Comparing the pass-by levels on a newly laid surface with those on a reference surface of average age does of course greatly overestimates the effect. This overestimation is taken care of in the term *Croad-time* that represents the average degradation over the life time of surface type. For reasons of simplicity is this value defined as the difference between the initial value and the end-of-life value divided by 2.

2.2 Composition of the total *Croad*

The total value of *Croad* is now composed as the sum of the initial value and the time effect:

$$C_{road} = C_{road-initial} + C_{road-time} \tag{3}$$

This approach exhibits the following advantage over an integral determination of *Croad*. The value of *Croad-initial* and *Croad-time* can be determined in different ways. For instance can *Croad-initial* be based on pass-by measurements on series of newly laid surfaces while the *Croad-time* is based on the age behavior of a comparable mixture. It also emphasizes the relative importance of an improvement of the aging of low noise surfaces.

2.3 Differentiation within *Croad*

The Netherlands classification scheme and its related European SILVIA and proposed CNOSSOS schemes differentiate between light and heavy vehicles, between the different octave bands and includes speed effects.

$$C_{road-initial} = \alpha_{i,m} + \beta_m \cdot \lg\left(\frac{v}{v_{ref}}\right) \tag{4}$$

With:
i: octave band number (1:63 Hz,…, 8: 8 kHz), *m:* vehicle class (1: light vehicles, 3: heavy vehicles)

For newly laid surfaces such detailed data is often available, for end of its life time surfaces data is more limited and due to higher spread in the data also less accurate to determine within a limited measurement program. Therefore *Croad-time* may be defined in much more simpler terms with only frequency and vehicle class as parameters.

3. DATA ANALYSIS

3.1 Data base

Within the frame work of several projects for both governmental organizations and private enterprises we have accumulated a data base of measurements data on newly laid surfaces combined with repeated measurements on these surfaces up to 10 years of age. In total the results of over 3000 CPX measurements and over 1000 SPB measurements are stored in the data base. With this data set we have investigated the effect of aging on the performance of low noise road surfaces and we have proposed a procedure to incorporate the aging effect in the evaluation and classification system.

A few examples of graphs of available data sets are given in the figures below.

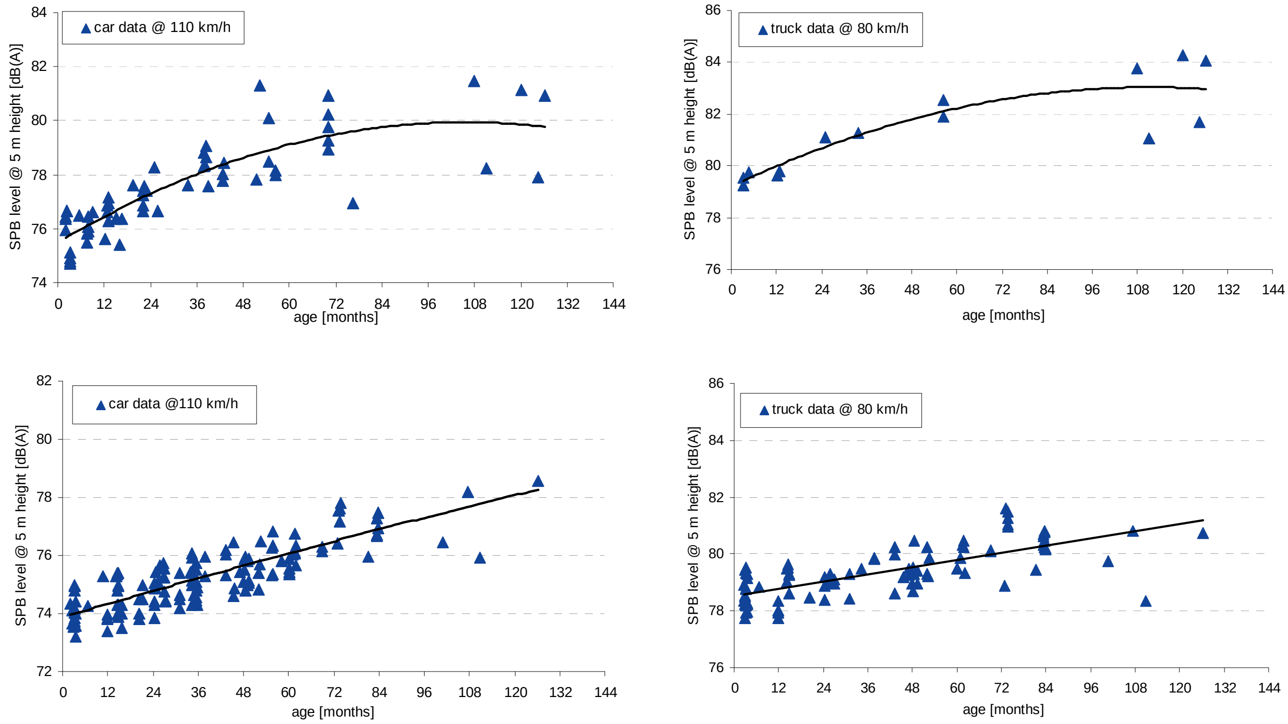

Figure 2 – examples of SPB levels on porous surfaces applied on highways as a function of age. Top: single layer porous asphalt, bottom: double layer porous asphalt. Left light vehicles, right: heavy vehicles. (SPB data at 7,5 m distance, 5 m height). The line represents a second order fit.

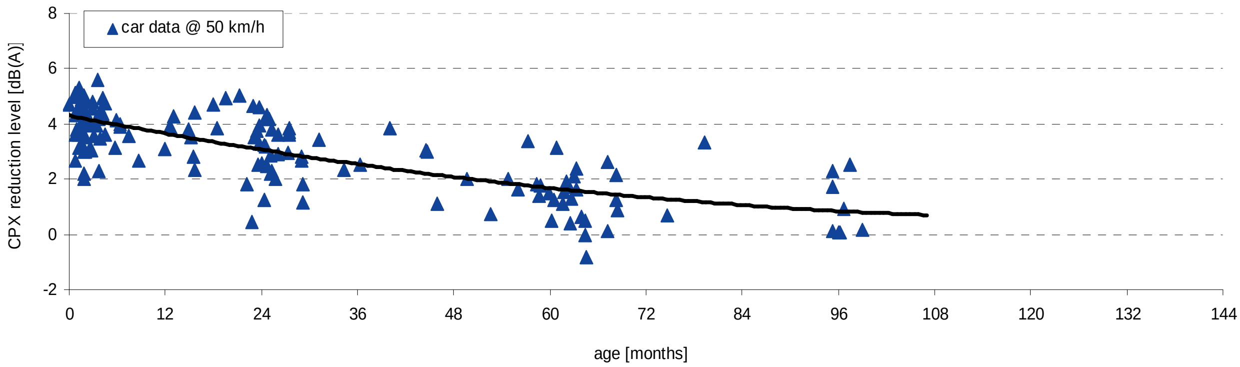

Figure 3 – Reduction values of noise reducing thin-layers as a function of age. Data from CPX measurements and values relative to a newly laid reference surface.

3.2 Analysis

The analysis in this stage of the development has been focused on single and double layer porous asphalt and noise reducing thin layers, since these three surface types are most commonly applied as noise mitigation measure. Single and double layer porous asphalt mainly on the highway network, thin layers on urban and regional roads. Although there are many propriety types of thin layers, in a first approximation the *Croad-time* for thin layers was regarded as a type independent value, as is allowed within the formulation (3). In a later stage differentiation between types is possible, even desirable, since it invites developers to enhance the life time related performance of their products.

For sake of simplicity three approximations were made:

1. The loss of noise reducing performance with time is a linear function
2. The performance at the end of life time can be found by averaging over 5 surfaces with age of >75% of its nominal life time
3. After an initial increase in noise level, aging of the reference surface can be neglected.

Taking these assumptions into account, the *Croad-time* was determined for a single and a double layer porous asphalt concrete and for the group of thin noise reducing asphalt surfaces.

3.3 Results

3.3.1 Results overall values

The determination of the values of *Croad-time* resulted in the following results (see Table 1).

Table 1 – noise reduction values *Croad-total* and its components *Croad-initial* and *Croad-time* for cars and trucks.

Vehicle class	Road surface type	*Croad-initial*	*Croad-time*	*Croad-total*
1-layer porous asphalt	Cars @ 110 km/h	-3,7 dB	1,8 dB	-1,8 dB
0/16 mm	Trucks @ 90 km/h	-4,5 dB	1,4 dB	-3,1 dB
2-layer porous asphalt	Cars @ 110 km/h	-6,2 dB	1,6 dB	-4,6 dB
4/8 mm-11/16 mm	Trucks @ 90 km/h	-6,5 dB	1,2 dB	-5,3 dB
0/6 mm thin layer	Cars @ 80 km/h	-6,2 dB	2,2 dB	-4,0 dB

3.3.2 Results spectral values

The effect of aging can exhibit strong spectral differences. Especially when clogging is the main cause of degradation, loss of performance is mainly seen at frequencies above 1 kHz. In the figures below SPB spectra of the surfaces in new condition are compared with those at the end of lifetime. Especially for single layer porous asphalt and for noise reducing thin layers there exist a srong frequency dependent aging effect, almost zero at low frequencies and a maximum around 1 kHz. For double layer porous asphalt the aging shows less spectral variation.

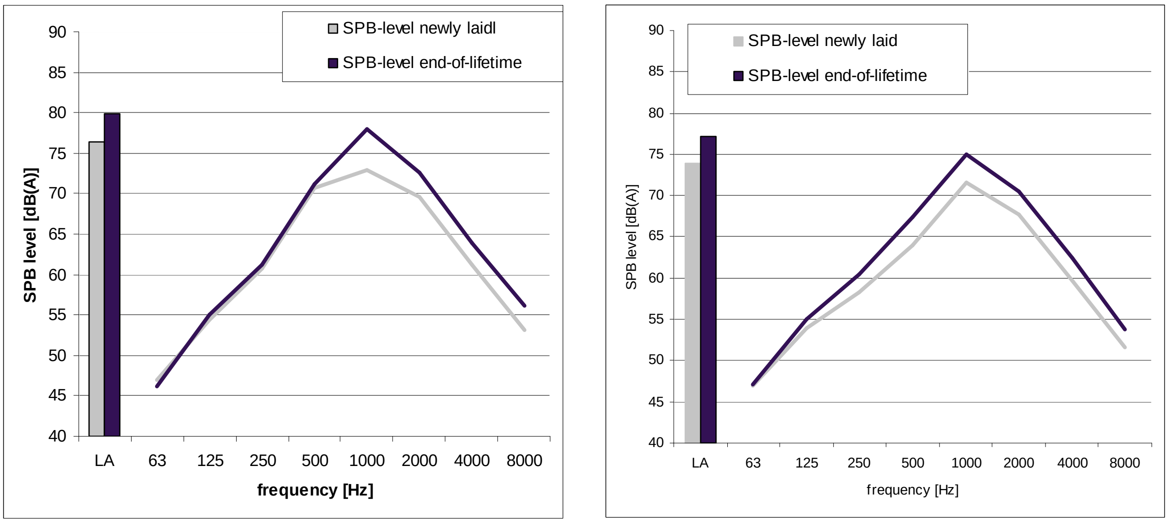

Figure 4 – SPB level for cars at 110 km/h in newly laid conditions and in and in end-of-lifetime condition. Left: single layer porous asphalt, right: double layer porous asphalt.

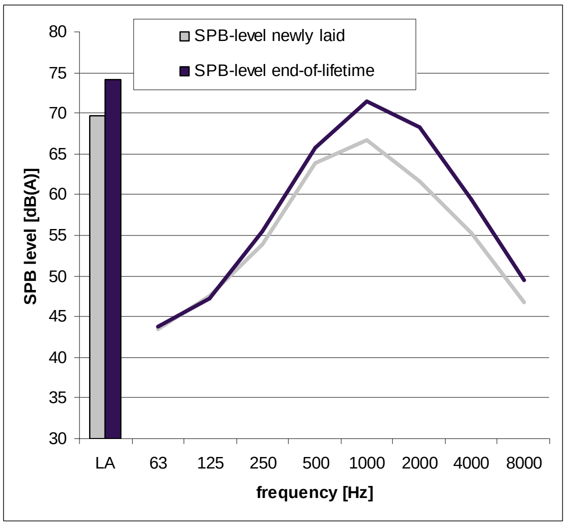

Figure 5 – SPB level for cars at 80 km/h . Noise reducing thin layer in newly laid conditions and in end-of-lifetime condition

The presented spectral variation in aging affects the spectral distribution of the noise emission of traffic. It is important to take this effect into account in relation with noise mitigation measures. The propagation of noise from the road to the receiver is subjected to strong spectral variability such as the effect of noise barriers or the effect of façade insulation. For more detailed calculation of the noise exposure in combination with low noise surfaces and mitigation measures, it is necessary to not only have *Croad-initial* defined in octave bands, but also *Croad-time*.

4. CONCLUSIONS

This paper presents results of an updated scheme that now includes the life time averaged effect of low noise road surfaces. Distinguishing between an initial value component and a component representing the aging effect allows separate approaches for the determination of these two and emphasizes the relevance of improving aging effect of low noise road surfaces. Including the age effect also improves the reliability and the credibility of applying low noise surfaces as a noise mitigation measure. Additional improvement of the accuracy can be obtained by spectral differentiation of both the initial and the aging effect.

ACKNOWLEDGEMENTS

The authors acknowledge the intellectual and financial support from the Dutch Ministry of Infrastructure and Environment and the improvements proposed through the discussions within the *Croad* working group of the CROW.