Continuous road traffic noise monitoring and aging of asphalt surfaces

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ABSTRACT
A highway in Switzerland has been paved with two different types of asphalt surfaces one after the other. Next to each of the road sections two acoustic recording stations were permanently registering traffic noise levels over a time period of two years. In parallel, meteorological parameters had been monitored and road traffic had been counted automatically in terms of vehicle classes. The noise levels at both monitoring stations display significant and slightly different increases over the observation period. This indicates differences in the aging behavior between the two asphalt surfaces. Since the noise level variances due to dependencies on meteorological conditions and traffic distributions are larger than the anticipated changes due to the aging of the surfaces, a stratified sampling strategy has been successfully applied in the statistical analysis of the traffic noise data. The consideration of temperature effects on tire-road noise has been of particular relevance. Periodical measurement surveys of noise levels by means of a CPX-trailer and the statistical pass-by method and of in situ measurements of acoustically relevant road surface characteristics show significant temporal changes on both pavement sections that go along with the results from the permanent noise monitoring stations and offer some insight into the physical changes of the surface.

Keywords: Road traffic noise, road surface, noise monitoring, CPX, SPB 1-INCE Classification of Subjects Numbers: 76.1.1, 75.1, 72.1.

1. INTRODUCTION
Road traffic noise emissions depend on the physical mechanisms within the tire-road contact as the rolling tire and its components deform, vibrate and cause air flow within the tire-road contact patch. Noise level and spectral properties of the tire-road noise are controlled by bulk mechanical tire vibrations, deformation of tire treads, air flow between the tread blocks and the road surface grains and transport of air into the voids of the pavement and out again (1). The overall tire-road noise recorded along a road is a function of the number of passing vehicles per time unit, their vehicle class distribution, their driving speeds, the types of tires mounted, meteorological conditions and physical road surface properties. Most important among the latter are surface texture, air flow resistance and sound absorption (1). These properties can be steered towards acoustically desirable ranges if the grain size distribution of an asphalt mixture and the layer thickness is chosen accordingly. On the other hand road pavements are optimized to withstand the anticipated traffic loads as long as possible, often with reverse requirements.

An ideal pavement would preserve its structural substance for a long time while it would maintain desirable acoustic properties. Reality, however, looks different: Asphalt roads that are particularly silent immediately after construction tend to lose this advantage in particularly short time intervals and their mechanical aging is proceeding particularly fast. Road construction is an expensive long-term investment. Therefore, it appears to be advisable to investigate time functions of mechanical behavior and road traffic noise first on small-scale road test sites after new asphalt surface mixtures have been developed and prior to paviing at large scales.

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The average road traffic noise excitation may increase little over time periods of few years compared to noise level fluctuations due to other relevant parameters like traffic composition, tire temperature or wind direction. Therefore, traffic has to be counted and meteorological conditions must be logged in parallel to the noise recording. A multi-parameter statistical analysis may be able to isolate the effect of noise level change that can be attributed to road surface alterations. To better understand which changes in physical surface properties cause the anticipated increase in noise levels over time the surface properties itself must be monitored as well.

The outlined strategy has been followed in a recent project financed by the Federal Road Administration (ASTRA) of Switzerland and executed by Müller-BBM Schweiz AG. In this paper the project site and the accompanying measurement program is presented. The applied stratified sampling statistical analysis method for permanent noise level recordings that allowed to isolate the effect of “gradual acoustic surface aging” from noise level fluctuations due to other causes will be discussed. It is also shown that CPX- and SPB-noise levels gradually increase over the observation time. A comparison with the temporal changes of surface texture parameters, air flow resistance and in situ sound absorption shows that a gradual deterioration of surface texture and reduction of the void content is responsible for the noise level increase as function of time.

2. MEASUREMENT PARAMETERS

2.1 Asphalt Mixtures

The majority of low-noise road surfaces are built from asphalt. Asphalt consists of a grain matrix embedded in a binding material. The matrix material may come from a quarry close to the road construction site and may have been broken into grains. These pass different sieves for sorting and subsequently to recombine the grains to yield a specified grain size distribution within the matrix. Binders have the task to glue the grains together and are usually based on viscous hydrocarbons with a percentage of chemical additives. The selection of the grain size distribution and the binder determines the physical and chemical properties of the road pavement and their performance that is also influenced by traffic loads and meteorological conditions. The noise reduction potential of a road surface increases with void content while its ability to resist wear and fracturing, i.e. the mechanical life expectancy, decreases with increasing porosity. Low-noise asphalts are a compromise to reduce tire vibrations (which calls for small grains and smooth surfaces) and to optimize sound absorption and air flow (which calls for high void contents) while at the same time granting the stability of the structural substance of the road over its scheduled life expectancy.

In Switzerland a standard road pavement for highways is called SDA 8-12. The name indicates a maximum grain size of 8 mm and typical void content of 12 percent (2). Its acoustical performance is mainly based on an optimized surface texture. In a more recent development the SDA 8-12 has been modified to allow for a higher void content of 14 % to 18 % with the expectation that a better acoustical performance can be achieved. The mass percentage of grains with diameters up to 4 mm has been decreased from about 35 % to 40 % for the SDA 8-12 to about 20 % for the modified mixture called SDA 8-16 while the percentage of larger grains increased accordingly.

2.2 Project Site and Measurement Program

In the summer 2011 200 m sections of SDA 8-12 and of SDA 8-16 have been paved consecutively along a highway east of Aarau, Switzerland on 4 lanes, two eastbound and two westbound (Figure 1). On the western half of the test area the SDA 8-12 is paved on all lanes, the SDA 8-16 on the eastern half. This resulted in eight pavement sections to be monitored. The surrounding area is flat and rural without reflecting obstacles. The construction of both surface types for one direction took place at the same day and had been built by the same crew and in the same manner to ensure that any difference in mechanical or acoustical behavior can be attributed to differences in the asphalt mixtures. South of the road two acoustic monitoring stations have been installed (positions marked with red dots and “M” in Figure 1). They were placed in order to minimize the impact of the noise emissions from the older neighboring stone mastic asphalt sections at distances of about 140 m and that of the neighboring new pavements with much more similar acoustic properties at distances of about 60 m such that emissions from either the western SDA 8-12 or the eastern SDA 8-16 were recorded at the two stations essentially.
In a large-scale investigation program the pavements were monitored over a time period of two years and in a reduced effort the investigations still continue today. The two-year phase at the beginning of the investigation program comprised:

- Permanent noise level recordings at each pavement type via stations close to the southern lane together with
  - Traffic monitoring and
  - Logging of local meteorological conditions
- CPX-measurements on all lanes
- SPB measurements at each pavement type and driving direction (right lanes only)
- In situ measurements at selected points on each pavement type and lane:
  - Measurement of surface texture
  - Sound absorption in situ
  - Air flow resistance
- Extraction of drill cores and material testing

In the following the measurement results are presented, discussed and interpreted.

3. CONTINUOUS MONITORING

3.1 Data Acquisition

The automatic stations of type Müller-BBM Inomos measured sound levels with outdoor microphones 5 m above the center of the road and 7.5 m away from the center of the rightmost lane. A-weighted sound levels recorded with time constant FAST were averaged over one-second time intervals ($L_{A,eq}$) and stored. Various local weather parameters were measured close to the microphone of one station: air temperature, wind speed, wind direction and rain fall. The meteorological data were stored at one minute intervals. Once a day sound and weather data were transferred to a server at Müller-BBM via UMTS modem for quality control and further processing. The passing traffic was automatically counted by a nearby traffic monitoring station of the Swiss Federal Road Administration with no exits between the microphones and the counters. The counting station delivered hourly vehicle counts per driving direction (i.e. the sum of two lanes) for each of ten vehicle classes according to the Swiss10-standard (3). The average total daily traffic passing in both driving directions was about 40,000 vehicles a day.

3.2 Noise Data

In a first step the sound and weather data are averaged to obtain 1 h values. Certain data hours have to be excluded from the further analysis because they do contain invalid data (see Table 1). In order to restrict the data to dry surface conditions only all data from up to five hours after the last rain fall are eliminated.
Average monthly noise levels taken at both microphones for all valid hours are combined in Figure 2, left. Note that the new mixture yields noise levels more than 2 dB(A) below that of the more traditional paving but both pavements lose in performance during the two years, the SDA 8-12 by 2 dB(A), the SDA 8-16 by 2.4 dB(A). Both time series display similar quasi-periodic seasonal fluctuations around their respective regression lines. This may be caused by a temperature-dependence of the tire-road noise emissions. Therefore the average sound levels have been plotted versus the average temperatures and regression lines are computed for each monitoring station. The slope of this line defines an empirical linear correction factor in dB/°C that allows for the correction of all noise levels with respect to a reference temperature of 20 °C (see also standards for SPB and CPX measurements, 4 and 5). After applying the temperature corrections to the average noise levels the fluctuations get smaller and appear less periodic (Figure 2, right). The noise levels after temperature correction increase by 2.2 dB(A) for the SDA 8-12 and by 2.7 dB(A) for the SDA 8-16 over the two year period such that the gap between both coverings decreases from about 2.9 dB(A) at the beginning to about 2.4 dB(A). The sound level fluctuations that remain after temperature correction are still clearly correlated between the two records. This indicates that some deterministic component other than temperature or surface alteration is still not accounted for by the analysis. The seasonal use of winter tires that have different temperature-dependent elasticity than summer tires may be one of these components.

**Table 1 – Meteorological conditions for valid sound levels**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>No rain</td>
<td>Exclude the sound of rain</td>
</tr>
<tr>
<td>Dry road surface</td>
<td>Wet affects noise emission</td>
</tr>
<tr>
<td>Wind strength &lt; 8 m/s</td>
<td>Avoid wind noise at microphones</td>
</tr>
</tbody>
</table>

**Figure 2** – Average monthly sound levels at both microphones and for all statistical strata combined. Shown are raw levels (left) and levels after temperature correction (right).

### 3.3 Stratified Sampling Strategy

Long-term noise level observations of road traffic noise display short-term fluctuations that reflect quasi-periodic changes in the amount of traffic with typical maxima during rush hours and minima at night or sinusoidal daily changes due to air temperature that may impact the emissions from the tire-road contact. Noise level fluctuations need to be interpreted and ask for a statistical evaluation method. The guideline 3723 of the society of German engineers (6) describes a stratified sampling method that is applied here. The idea is to separate data into ensembles with similar noise emission and propagation conditions and to evaluate each of these ensembles individually.

The valid data underwent a stratified sampling strategy, i.e. the overall data population has been divided into more or less homogeneous subpopulations (strata) that are sampled independently. The division into strata should improve the representativeness of the samples by reducing sample error and should lead to weighted means with less variability than the arithmetic mean of a random sample. Here strata are built based on meteorological and traffic conditions.

Since sound propagation depends on wind speed and wind direction the data is stratified according to Table 2. Note that the permanent stations were mounted south of the road such that wind from south blows against the sound propagation direction and away from the microphones which on an average may lead to lower levels, whereas wind from north tends to support higher noise levels. The west-east...
and east-west winds may be included in the same stratum because they have the same impact on the measured data.

Table 2 – Stratified sampling according to wind speed and -direction

<table>
<thead>
<tr>
<th>Wind layer</th>
<th>Wind speed in m/s</th>
<th>Wind direction in degrees clockwise against North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calm</td>
<td>0 – 1.5</td>
<td>0 – 360</td>
</tr>
<tr>
<td>North</td>
<td>1.5 – 8</td>
<td>0 – 45; 315 – 360</td>
</tr>
<tr>
<td>South</td>
<td>1.5 – 8</td>
<td>135 – 225</td>
</tr>
<tr>
<td>West-East</td>
<td>1.5 – 8</td>
<td>45 – 135; 225 – 315</td>
</tr>
</tbody>
</table>

Noise emissions from roads increase directly with the number of passing vehicles. The number of vehicles passing east or west differs, in particular during rush hours. The emissions from the northern lanes reach the microphones in the south at lower magnitudes than traffic noise from the adjacent southern lanes. To be able to separate these effects strata are built for variations in the direction of traffic flow. The ratio of traffic moving towards Aarau (westbound) and towards Hunzenschwil (eastbound) is computed and determines the traffic grouping into six strata, see Table 3.

Table 3 – Traffic flow strata

<table>
<thead>
<tr>
<th>n_Aarau</th>
<th>n_Hunzenschwil</th>
</tr>
</thead>
<tbody>
<tr>
<td>stratum</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2/3</td>
</tr>
<tr>
<td>2</td>
<td>2/3</td>
</tr>
<tr>
<td>3</td>
<td>1/3</td>
</tr>
<tr>
<td>4</td>
<td>1/3</td>
</tr>
<tr>
<td>5</td>
<td>2/3</td>
</tr>
<tr>
<td>6</td>
<td>∞</td>
</tr>
</tbody>
</table>

The traffic class 1 contains at least 1.59 times the number of vehicles driving east than west. In stratum 6 it is just the opposite. In the center strata 3 and 4 the traffic ratio varies from 0.79 to 1.26.

The acoustic pavement properties affect different vehicle categories differently. For example, the SDA 8-16 pavement reduces motor noise of trucks more effectively than the SDA 8-12 because of its higher void content. Given the Swiss10 categorization of traffic it is in principle possible to isolate such effects. But the number of hours without any trucks was too small in the two year observation period to allow for a statistically robust distinction of these effects. Therefore, in this paper only mixed traffic as sum of the swiss10 counts is discussed.

The stratified sampling according to the four wind layers and six layers for the predominant traffic direction yields 24 statistical layers as presented in Table 4.

Table 4 – Naming convention of statistical layers

<table>
<thead>
<tr>
<th>Layer Wind</th>
<th>Traffic Directivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>West-East</td>
<td>WE1 WE2 WE3 WE4 WE5 WE6</td>
</tr>
<tr>
<td>Calm</td>
<td>wh1 wh2 wh3 wh4 wh5 wh6</td>
</tr>
<tr>
<td>North</td>
<td>north1 north2 north3 north4 north5 north6</td>
</tr>
<tr>
<td>South</td>
<td>south1 south2 south3 south4 south5 south6</td>
</tr>
</tbody>
</table>

The data samples in each stratum are statistically analyzed. The data are interpreted as random samples representing a much larger subpopulation. Uncertainty is characterized by a confidence interval. The confidence interval describes the range where the expected value of a quantity has a certain probability of occurrence. It depends on the number of sample values, their variance and a correction factor for the t-distribution. The latter corrects for the deviation from an assumed normal distribution due to the limited size of the sample. Here a sample probability of 0.8 is chosen which means that the wanted value of the overall population has a probability of 0.9 to lie within the confidence interval. Upper and lower limits of the confidence interval are given by upper and lower deviations from an ensemble average of the L_AFeq values within the stratum.
If the standard deviation of the data ensemble is unknown (as with most measured data) confidence intervals with the upper limit \( L_u \) and the lower limit \( L_l \) follow the equation:

\[
L_u, L_l = \overline{L_{\text{AFeq}}} + 10 \log \left( 1 \pm \frac{Z\' t_{n-1}}{\sqrt{n}} \right) \text{ dB}
\]

(1)

where

- \( L_u \) upper limit of the confidence interval in dB
- \( L_l \) lower limit of the confidence interval in dB
- \( \overline{L_{\text{AFeq}}} \) energy equivalent sound pressure level in dB(A)
- \( n \) number of measured data values
- \( Z' \) standard deviation of the ensemble of delogarithmized long-term noise level values
- \( t_{n-1} \) Student t-factor as function of the number of data values (see for example Table 3 in (6))

If one computes equivalent sound pressure levels for each of the 24 data strata and each month and subtracts the average levels for the SDA 8-12 from that for the SDA 8-16 one obtains the results shown in Figure 3. Note that the level differences stretch over ranges up to 3 dB(A) for a given month. Northern wind mostly tends to result in smaller difference values than west-eastern wind and southern wind yields usually largest difference values. A clearer picture of the sound level differences between the two pavements results if single statistical strata are investigated.

![Figure 3 – Monthly noise level differences between the pavements for all weather and traffic strata.](image)

Figure 4 shows this difference for the weather class with east-west and west-east wind and the most populated traffic class 3. Displayed are the sound level differences prior to temperature correction (upper curve in red), after temperature correction (lower curve in green) and the average monthly temperature in blue (see right ordinate axis). Note that prior to the temperature correction the differences between the pavements are smallest in cold months and largest when the temperature is at its highest. The relative advantage in the acoustic performance of the SDA 8-16 mixture is highest in summer when the overall noise level for both asphalt mixtures is lower because tires are softer and therefore emit less noise. During winter when the rubber is stiffer and winter tires are mounted this advantage gets smaller. After the temperature correction all monthly values lie in a narrow band of...
0.6 dB(A). A systematic decrease of the difference values with time is still observable.

Figure 4 – Monthly sound level differences at the two microphones for weather stratum WE and traffic stratum 3. Displayed are differences prior to (red) and after temperature correction (green) and average temperature in degrees Celsius (blue).

4. ACCOMPANYING MEASUREMENTS

The permanent sound recordings at the test fields were accompanied by periodic investigations of sound emission by means of CPX- and SPB measurements (4, 5). Alterations of physical surface properties were monitored periodically by visiting identical locations on the eight pavement sections and determining surface texture, air-flow resistance and sound absorption (Figure 5).

Figure 5 – CPX measurement system in action (left) and in situ measurements on the test fields (right) determining sound absorption (foreground), texture (center) and air flow resistance (center, background).

4.1 CPX

Close-proximity measurements (CPX) record tire-road noise about 0.2 m away from the tire-road contact in a trailer with acoustic insulation to keep exterior noise away from the microphones (Figure 5, left). The ISO standard requires repetition of the passes with two different reference tires P and H and
Noise level recordings as $L_{AF}$ (4). The P-tire represents passenger cars and is more susceptible to texture properties whereas the H-tire is meant to represent truck tires and more sensitive to absorption. Six surveys of close-proximity measurements on all four lanes and on all eight pavement sections were carried out between autumn 2011 and autumn 2015. Figure 6, top displays the average nearfield noise levels for each section and the P-reference tire ($CPX_P$ index). Note that the SDA 8-16 pavements start at sound levels that are typically slightly below that of the SDA 8-12. All lanes get at least 1 dB(A) per year louder. The right lanes that carry more traffic (and in particular the trucks) show a significantly higher acoustic degradation for the SDA 8-16 (about 1.5 dB(A) per year versus 1 dB(A) per year on the left lanes and all SDA 8-12 lanes). A stronger loss in acoustic performance on the right SDA 8-16 lanes is also visible for the H-tire (Figure 6, bottom). H-tire gradients are about 0.1 dB(A) per year for most surface sections but around 0.5 dB(A) per year for the SDA 8-16 on the right lanes.

Figure 6 – $CPX_P$ sound level for the P-tire (top) and the H-tire (bottom) at the eight test site sections from 2011 to 2015. The grey boxes indicate the average gradient of the sound level increase per year.

4.2 SPB

The statistical pass-by method requires the measurement of isolated vehicle passes by microphones next to the the road (5). In Switzerland the $L_{Aeq}$ is recorded 5 m away from the center of the rightmost
lane at a relative height of 1.5 m and the $L_{A_{\text{max}}}$ at a horizontal distance of 7.5 m and 1.2 m above the center of the lane (7). Five surveys of statistical pass-by measurements (5) on the right lanes on all four pavement sections were carried out in autumn 2011 and spring and autumn 2012 and 2013. Figure 7 displays the differences $K_b$ of the measured $L_{A_{\text{eq}}}$ levels from the Swiss reference curve $S_{\text{TL86+}}$ (see 3). Large bars as for the new SDA 8-16 pavements indicate that the noise levels are considerably below the reference curve. But noise levels increase systematically over time with largest gradients at the SDA 8-16 observation points for both passenger cars (N1) and trucks (N2). The SDA 8-12 results show that noise starts at higher levels but the performance loss over time is smaller than for the SDA 8-16 mixture. For trucks the performance loss is generally smaller than for passenger cars on both types of pavements.

![Figure 7](image)

Figure 7 – Deviations of SPB sound levels from the Swiss reference model $S_{\text{TL86+}}$ determined for the sections on right lanes for the vehicle classes N1 (passenger cars) and N2 (trucks) from 2011 to 2013.

### 4.3 In Situ

In situ investigation surveys were carried out four times after the construction of the test pavements. In each yearly survey at least two measuring points were defined on each lane and type of pavement. At each of the in situ points surface texture was determined, the sound absorption spectrum was measured as well as the air-flow resistivity (see Figure 5, right).

Several 2 m long parallel texture profiles were measured with a laser at each of the in situ points in the rolling tracks in compliance with the ISO standard (8). Analysis of the laser data resulted in roughness spectra, mean profile depth values and other statistical parameters. Among them was the shape factor (1) of the texture which is a statistical measure that describes the shape of a surface and is given as a percentage value. High percentages indicate concave shapes (“a lot of contact points at hills”), low percentages convex shapes. Acoustically desirable road surfaces are concave with shape values clearly above 60 % (1). Figure 8 displays shape factors determined from laser texture profiles taken at all eight pavement sections for in situ points that have been visited repeatedly from 2011 to 2014. Note that all sections start at high factors above 90 %. In the following years the shape gradually degrades. The SDA 8-12 reaches factors around 84 % two years later when the SDA 8-16 is already typically below 80 %, however with considerable local variations. Texture roughness depths decrease in a way similar to that of the shape factor, while the frequently used parameter of mean profile depth MPD experiences little systematic change (not shown).
Sound absorption is determined in situ when a loudspeaker radiates a sound wave towards the road surface where air pressures and particle velocities of both the incident and reflected sound waves are measured such that the absorption spectrum can be computed (9). Figure 9 shows the average absorption spectra for the SDA 8-12 and the SDA 8-16 in 2011 and 2014. Note that the absorption is higher for the more porous SDA 8-16 surfaces compared to the denser SDA 8-12. All surfaces lose considerably in ability to absorb sound during the three years of observation. The absorption spectra for the SDA 8-16 pavement heading Hunzenschwil stand out. There portions of the pavement had been suddenly cooled by a rain storm during construction which prevented a regular roller compaction and resulted in a higher porosity than had been intended originally.

Air-flow resistance is measured by pressing air all across the area between the rough road surface and an elastic ring which is pressed onto the road surface. Constant air flows are adjusted and the difference between the pressure needed to maintain a certain air flow velocity and the atmospheric pressure is recorded. The specific air-flow resistance is derived from several data pairs of pressure differences and air flow velocities. The Müller-BBM measuring system m|ars works on the basis of the EN 29053 for laboratory systems (10). The SDA 8-12 as the denser pavement displays higher resistance than the more porous SDA 8-16. From 2011 to 2012 a small increase is observed before the air flow resistance went down again in 2013 on most positions investigated. This may indicate that the new surface has been compacted in the first year before the surface gets rougher again thus decreasing the air flow resistance.
Close to the in situ measurement points drill cores were extracted and analyzed. Standard material testing showed that the mixtures were in accordance with the intended properties, i.e. that the SDA 8-16 sample cores had higher void content than the SDA 8-12 and that this void content reduces over time which is in line with the sound absorption measurements. The elasticity of the asphalts went down by several ten percent for both pavements between 2011 and 2014. But this is more significant for the mechanical aging.

5. CONCLUSIONS

The test site near Aarau in Switzerland allows the comparison of the acoustic performance of two pavements as a function of time with several investigation methods. The two year installation of monitoring stations at both types of pavements demonstrated differences in acoustic performance. The SDA 8-16 pavement starts with a performance advantage of nearly 3 dB(A) compared to the SDA 8-12. After two years of traffic the advantage of the SDA 8-16 was still about 2.4 dB(A) after a performance decrease of 2.7 dB(A). Two measures are required in order to obtain robust estimates of the acoustic performance and its gradual loss with time (resp. traffic load): (i) a stratified sampling strategy to differentiate strata with different traffic flow and weather conditions, and (ii) a temperature correction of sound levels. Repeated periodic CPX and SPB measurements verify the results of the permanent monitoring and illustrate the continuing loss in acoustic performance for both pavements. SPB and CPX\(_P\) levels display similar differences between the two pavement types and also similar time gradients. CPX\(_H\) shows considerably smaller differences and gradients. After four years of traffic only little differences remain in the CPX levels of both types of pavement. The texture’s shape factor and spectral roughness depth indicate an acoustically high-quality texture immediately after pavement construction and a gradual loss of texture quality along with the measured acoustic performance. The shape factor degrades much faster for the SDA 8-16. Both surfaces show the ability to absorb sound in the beginning, but also both quickly lose in absorption capacity. For the SDA 8-16 which started on a much higher absorption level this loss is more pronounced.

Permanent monitoring of road traffic noise is in general a viable tool to monitor the acoustic performance of road pavements provided continuous information on weather and traffic conditions are available and are used properly in the statistical data evaluation. In order to shed light on the physical causes for the increase in traffic noise both CPX and SPB measurements can be helpful. Here both measurements indicated that a deterioration of surface texture was the primary cause because (i) the texture-sensitive CPX\(_P\) index increased much more than the absorption sensitive CPX\(_H\) index and (ii) SPB levels for passenger cars increased more than those measured for trucks. The acoustic observations fit very well with the non-destructive direct measurement of surface properties that proved to be very helpful to bridge the gap between acoustic measurements and destructive road building materials testing.

The aging of asphalt as discussed here refers only to the change in acoustic performance due to changes in surface properties. This “acoustic aging” is loosely related to the mechanical aging of...
asphalt roads. Asphalt surfaces that display fast acoustic performance losses tend to have a high void content and therefore also tend to have a shorter mechanical life expectancy. Acoustic aging displays the largest gradients for new pavements and then slowly approaches a steady state. For this phase a time-dependent exponential behavior of sound level increase has been suggested (11). Further along the time line noise levels increase again when the surface gets major cracks and loses material and a poor texture causes enhanced tire vibrations. At that stage micro cracks that have been developing over the years in the road structure connect to larger visible cracks and point to the oncoming complete mechanical failure of the road pavement.

ACKNOWLEDGEMENTS

Müller-BBM Schweiz AG thanks for the support of the Federal Road Administration of Switzerland (ASTRA) and the permission to publish this paper.

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