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Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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ACOUSTICAL AGEING OF LOW NOISE PAVEMENTS EXPRESSED BY DIFFERENT MEASURING TECHNIQUES

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Abstract

Low noise asphalt pavements are being implemented more often in colder climate regions. However, main disadvantage of low noise pavements is sensitivity to severe climate conditions (freeze-thaw, large temperature fluctuations) resulting in shorter acoustical and structural lifetime. This paper presents research study which main focus was to analyse acoustical and structural properties ageing/degradation of optimized low noise asphalt mixtures (SMA 5 TM, SMA 8 TM and TMOA 5) and porous asphalt (PA 8) on the real trafficked road sections. In depth analysis of CPX noise levels, SPB noise levels and sound absorption measurements, performed multiple times in a 2 years' period (after construction), is given and explained in the paper. Paper concludes with the acoustical and structural ageing trends for selected asphalt mixtures and recommendations for low noise asphalt pavements maintenance actions in order to extend their lifetime.

Keywords: Low noise asphalt, CPX, SPB, sound absorption, ageing

1 Introduction

Environmental noise is associated with different social, transportation and industrial activities, but the major part of overall noise is generated by road, rail and air transport. Increasing globalisation and mobility results in higher traffic volumes that are responsible for increased road transport noise emissions. Because of harmful effects on human health and living quality, noise is considered to be one of the major environmental protection problems. It is known that in the longer term, exposure to permanent high noise levels consequence serious health and living problems related to hearing, mental state, central nervous system, sleep, nuisance and cardiovascular system [1]. It should be mentioned that some animal species are also negatively affected by noise resulting problems at individual and population levels mostly related with reproduction and migration. According to EC calculations [2] annual socio-economic costs (healthcare costs, reduced work/learning proficiency, real estate depreciation, abatement costs, etc.) due to transport related noise pollution are approx. 40 billion EUR and expected to increase 50 % by the 2050.
Road transport noise is caused by a complex of vehicle related noise sources. Three main vehicle noise sources can be distinguished: noise from vehicle propulsion; noise caused by rolling tyre and pavement interaction; noise because of vehicle aerodynamics. Different noise sources dominate at different speeds. Propulsion noise dominates at low speeds (less than 40 km/h), tyre/road noise dominates at the speed range from 40 to 100 km/h and noise due to vehicle aerodynamics dominates at very high speeds (higher than 120 km/h) [3]. Recent technology advancements in the automotive sector had led to the noise reduction associated with quieter vehicle components, better aerodynamics and tyre improvements. Despite those

improvements, in the middle-high speed driving range tyre-road noise generation mechanisms are the dominant noise sources [4, 5].
National Road Administrations are facing increasing road transport noise challenge and looking for cost-effective and cost-efficient solutions for noise abatement and mitigation. Traditional noise mitigation solutions such as noise barriers are effective however their cost for exploitation and implementation are relatively high as well as there are many restrictions for their implementation. One of the most cost-efficient alternatives is use of low noise pavements. A big advantage of low noise pavements is that noise reduction is included as a road construction element (road surface) which is needed anyway for the road [6]. However, all practically applied low noise pavements loose their initial acoustic properties over the time. This phenomenon can be described as an acoustic ageing process – decrease of sound absorption and increase of aerodynamically related tyre/road noise generation mechanisms due to clogging and traffic compaction, increase of tyre vibration related tyre/road noise generation mechanism due to changes in surface texture induced by the impact of traffic and environmental conditions. In order to extend the acoustical lifetime, acoustically aged pavements require external intervention in the pavement to restore their initial noise reduction properties.

2 Acoustic ageing of asphalt pavements

Acoustic ageing of low noise asphalt pavements depends on many factors such as wearing course mix design, including aggregate quality and grading, binder and binder modification, laying conditions and pavement degradation [4]. There are numerous low noise asphalt mixtures and each of them differs with its composite materials and their composition itself. The most commonly used are porous asphalt (PA) mixes due to decent absorption properties, can reduce noise by 3-5 dBA compared with the traditional stone mastic asphalt (SMA) or dense asphalt concrete (AC) pavements [4, 7]. However, due to shorter lifetime and specific maintenance, porous asphalt pavements might have 50 % higher life-cycle costs than traditional dense asphalt concrete pavements [8]. The research in Japan indicates that clogging of porous pavements on urban roads occurs after 3-4 years and initial noise reduction of PA surfaces drops from 5 dB to 1 dBA after 6 years of exploitation [9]. To extend the lifetime and increase noise reduction properties of PA pavements double layer porous asphalt layer was developed where the upper layer consists of smaller maximum aggregate size to protect surface texture from clogging while the bottom layer is constructed using larger size of maximum aggregate to ensure good acoustical absorption [10, 11].
Acoustic properties of dense road surfaces are mainly influenced by the road surface texture. For dense asphalt road surfaces, acoustic ageing is mainly a function of traffic load (especially of the number of heavy vehicles) leading to a disaggregation of the filler component in the surface texture. This was confirmed by comparing noise level measurement results on different traffic lanes showing that on the right traffic lane the noise regression slope is approximately 0.5 dB/year and on the left traffic lane it is approximately 0.3 dB/year meaning that the acoustic ageing is slower on the left driving lane [6]. 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. Another research shows the noise levels in traditional asphalt pavements increase linearly and it is usually two times higher for cars than for heavy vehicles [14]. Typically, smooth and medium-textured dense asphalt surfaces such as SMA and AC have increased noise levels for the first 1–2 years of exploitation, then stabilize until the end of the lifetime [12, 13].
Semi-porous asphalt mixtures suffer different acoustical ageing. Belgian research [14] on the acoustical ageing of thin asphalt layers revealed a linear relationship of the acoustic ageing effect on the noise reduction: noise increase of 0.02–0.14 dBA per month (based on SPB measurements) and 0.05–0.2 dBA per month (based on CPX measurements). Strong relationship between the acoustic ageing and raveling was found out for thin asphalt layers [15],

which can be explained by the composition of the mixtures (aggregate grading and bitumen content) and the higher void content.
Literature analysis showed that acoustical ageing of asphalt mixtures can be associated with many different factors which impact ageing speed differently. Additionally, different acoustical properties' measurement methods characterise ageing trends from a slight different perspectives. Idea of this paper is to analyse acoustical ageing using 3 different measurement techniques.

3 Test site and methods

3.1 Test road of low noise pavements

Acoustical properties measurements were carried out in the Test Road of Low Noise Pavements. Test Road of Low Noise Pavements was constructed in September 2015 as a follow-up of successful national research project "Laboratory development of Low Noise Asphalt Mixtures for Lithuanian climate conditions" results [16]. Test Road was constructed on one of the main Lithuanian dual-carriageway highways A2 Vilnius-Panevėžys, where average annual daily traffic (AADT) in different parts of this highway varies from 7000 to 10000 vehicles per day. Speed limit is 110 km/h. Test Road is 1.5 km in length and consists of 9 short sections where asphalt wearing course was constructed of different asphalt mixtures. Those mixtures include 3 optimized low noise asphalt mixtures (TMOA 5, SMA 5 TM, SMA 8 TM) developed by Road Research Institute of Vilnius Gediminas Technical University (VGTU RRI) for Lithuanian and regional climate conditions, 1 porous asphalt mixture (PA 8), 1 special pavement and 4 traditional asphalt mixtures (SMA 8 S, SMA 11 S, AC 11 VS, AC 8 PAS-H) [17]. Further analysis of acoustical ageing of low noise asphalt mixtures includes only sections, that were constructed of low noise asphalt mixtures SMA 5 TM, SMA 8 TM, TMOA 5 and PA 8.

3.2 Methods

This paper presents results of 4 low noise surfaces compared by different methods – Statistical Pass-By (SPB) (ISO 11819-1), Close-ProXimity (CPX) (ISO 11819-2) and acoustical absorption using impedance tube in laboratory (ISO 10534-1). Measurements were performed annually: twice in spring (when average daily temperature is higher than 5 °C and when average daily temperature is 10-15 °C) and once in autumn (before the winter season). The same 80 km/h driving speed was used for CPX and SPB methods.

Figure 1 Fragment from CPX (left), SPB (middle), Standing wave tube (right) noise level measurement

CPX method (ISO 11819-2) is based on measuring tyre/road generated noise at the source location – rolling tyre and road surface contact patch. Measurements are performed using CPX trailer (Figure 1) towed by a light vehicle. Trailer has two measurement wheels which are covered with the trailer case to isolate microphones from unwanted outside sound sources, wind or traffic influence. Parallel to the CPX measurements, driving speed, road section length, GPS coordinates, air and road surface temperature are measured too. Two sets of mea-

surement tyres to represent passenger cars and heavy duty vehicles were used: For passenger car representation standard reference test tyres (SRTT) for passenger car representation and Avon Supervan AV4 tyres (AAV4) for heavy vehicle representation.
Unlike the CPX, SPB method (ISO 11819-1) (Figure 1) is based on near-road measurement for passing vehicles emitting noise. The microphone is placed 7,5 m away from the center of the measured driving lane. Generated sound pressure levels and speed of traveling vehicles are recorded during the measurement. The method makes it possible to compare different road surfaces for different vehicles at different speeds. For that purpose, the SPBI indicator is calculated.
Acoustical absorption measurements in the laboratory were performed by impedance tube using The Standing Wave Tube method (ISO 10534-1) (Figure 1) which allows to perform measurements of the normally incident sound absorption coefficients. The sound absorption coefficient of a material is by definition the ratio of the sound power entering the surface of the test object to the incident sound power. The impedance tube requires only small, carefully erected samples of the tested materials without any differences concerning applicable sound measuring technique. For this purpose, samples were formed by drilling cores in the Test Road of Low Noise Pavements.

4 Research results

After 2 years of exploitation, CPX noise level results showed that acoustic ageing impacts all low noise asphalt mixtures. Lowest initial noise level values on the first traffic lane were determined for PA 8 and SMA 8 TM asphalt mixtures, 93.4 dBA and 94.5 dBA respectively (Figure 2). On the second lane, lowest initial noise levels were determined for PA 8 and SMA 5 TM asphalt mixtures, 94.9 dBA and 95.3 dBA respectively (Figure 3). Noise level increase after two years was highest for mixtures with higher air void content (PA 8, SMA 8 TM). It can be explained that mixtures with higher air void content tend to clog and be compacted by traffic more than other asphalt mixtures.
Significant CPX noise level differences between the traffic lanes were determined: PA8 – 1.5 dBA, SMA 8 TM – 2.4 dBA, SMA 5 TM – 2.0 dBA, TMOA 5 – 1.9 dBA. For the PA 8 and SMA 8 TM mixtures, larger noise levels were measured on the second traffic lane while for SMA 5 TM and TMOA 5 – on the first lane. Differences can be linked only with the construction quality and inhomogeneity. It should be noted; that differences were changing over the exploitation time. Difference between the traffic lanes for PA 8 and SMA 8 TM mixtures were decreasing, while for SMA 5 TM was increasing. These trends can be linked with the higher traffic volumes and loads on the first traffic lane.

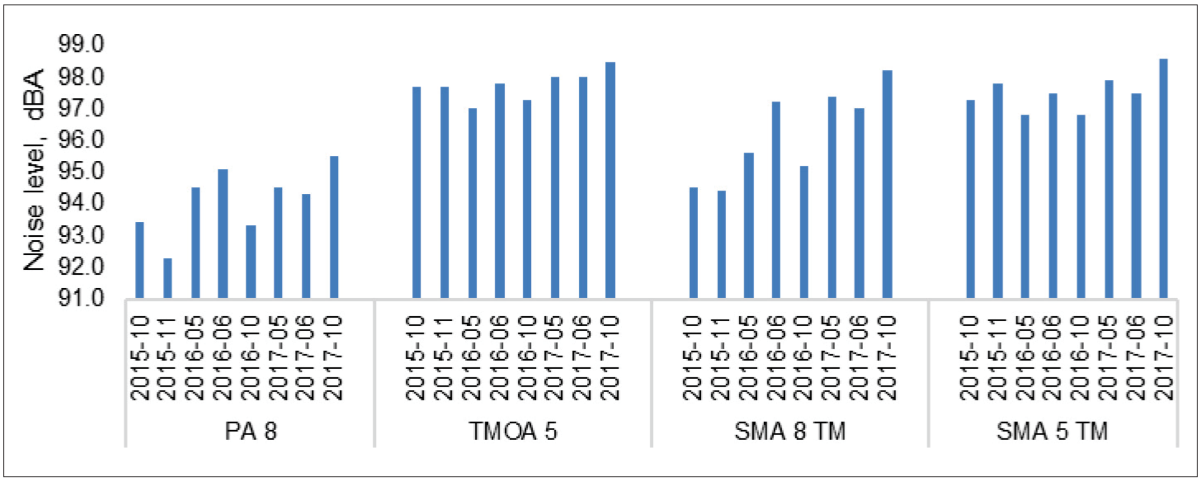

Figure 2 Results of CPX noise level measurements on the first traffic lane

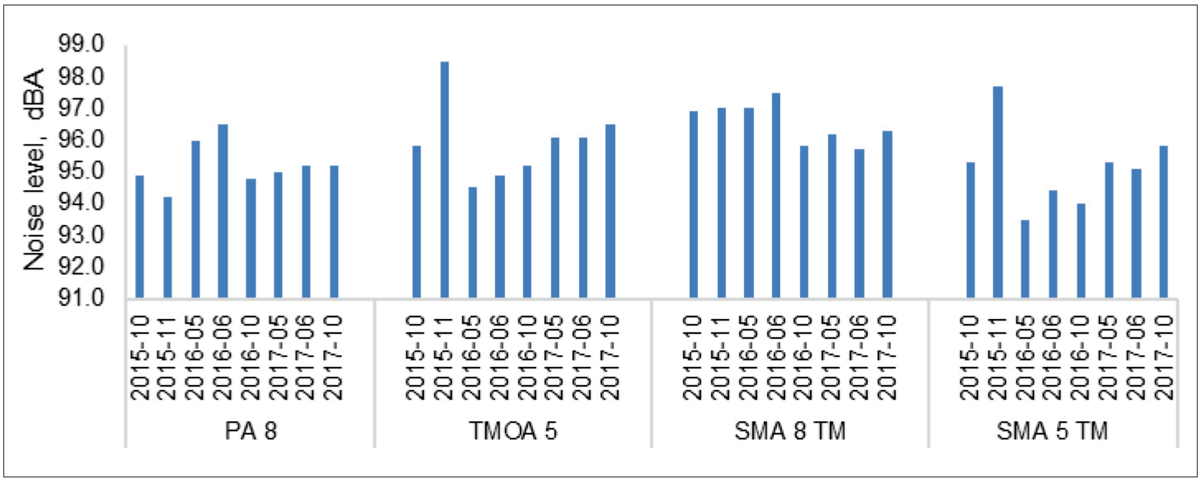

Figure 3 Results of CPX noise level measurements on the second traffic lane

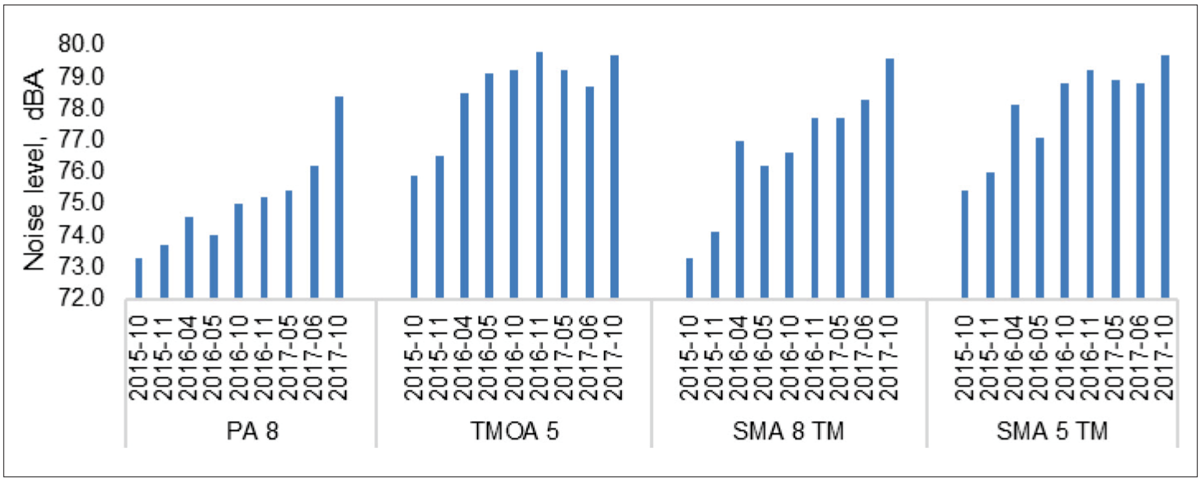

Figure 4 Results of SPB noise level in the first traffic lane

SPB measurement (Figure 4) results were very similar to CPX results as all mixtures can be sorted similarly according their noise level. The PA mixture is the most silent pavement of investigated mixtures, however the difference decreases every year and noise values can converge with other mixtures. The second best acoustic mixture is SMA 8 TM which shows slightly higher noise level than PA pavement but has better acoustic properties than SMA 5 TM and TMOA 5 mixtures. Pavement with TMOA 5 asphalt surface is the loudest of investigated mixtures, but looking at the last measurement results the difference from other mixtures are not significantly high.

Sound absorption measurement results are presented only for PA 8 and SMA 8 TM asphalt mixtures as their sound absorption coefficient was high enough to take into consideration as a noise reduction feature comparing with traditional asphalt mixtures (Figure 5-6). The highest absorption for PA 8 was measured at high frequency range (800–1250 Hz) with the maximum absorption coefficient 0.93, for SMA 8 TM – 0.51. Better absorption can be related with the larger air void content in the mixture. After the 2 years' period, sound absorption coefficient for PA8 reduced to 0.5 (comparing to 0.8-0.9 in the beginning) and for SMA 8 TM to 0.2 (comparing to 0.4-0.5 in the beginning) what can also be partly related with clogging and compaction due to traffic processes.

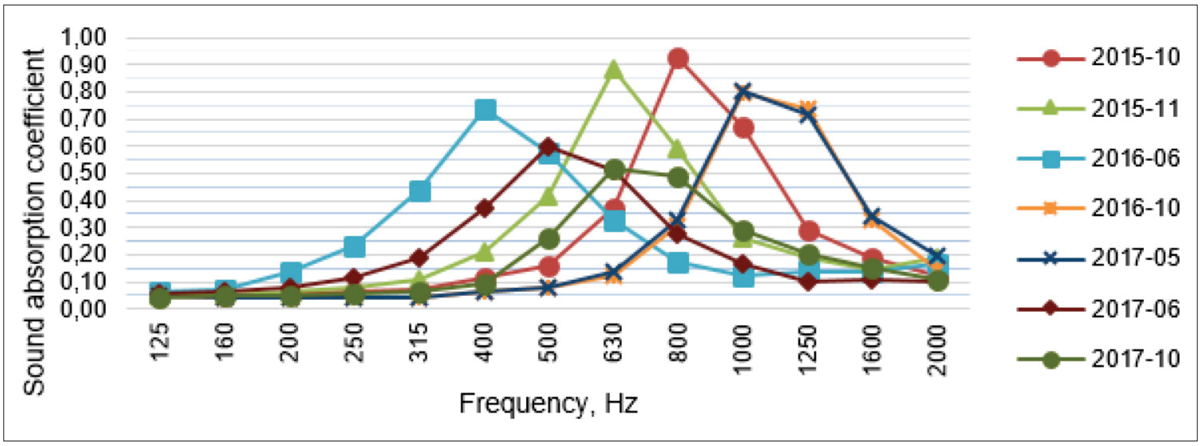

Figure 5 Sound absorption coefficient for PA8 asphalt mixture

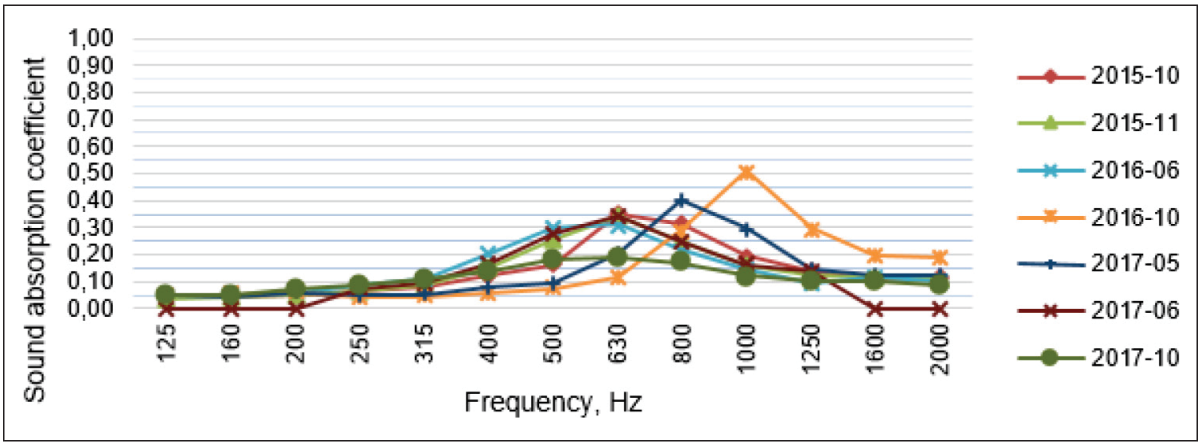

Figure 6 Sound absorption coefficient for SMA 8 TM asphalt mixture

5 Conclusions

Low noise pavements are an important noise mitigation measure. There are many different mixtures available which can be optimized for different traffic conditions. However, acoustical ageing occurs and all low noise asphalt mixtures lose their initial acoustic properties over time which raise a need for more frequent and specific road maintenance.

In order to ensure adequate horizontal and vertical water drainage to protect road surface from negative winter climate effects for low noise asphalt pavements it is recommended timely to remove snow and ice from all driving lanes and emergency lane by applying higher amounts of ice melting materials.

Comparison of low noise asphalt mixtures acoustical ageing expressed by different measurement techniques showed similar trends that noise levels were increasing the most for asphalt mixtures with higher air void content (PA 8 and SMA 8 TM) (respectively 2.1 and 3.7 dBA on the first traffic lane) what can be linked with the clogging effect and post-construction compaction due to traffic impacts. This was also confirmed by sound absorption tests that showed decreased sound absorption coefficient for PA 8 mixture to 0.5 and for SMA 8 TM to 0.2 after 2 years of exploitation.

However, other low noise asphalt mixtures SMA 5 TM and TMOA 5 lost their initial noise reduction properties too (respectively 1.3 and 0.8 dBA on the first traffic lane). Since these mixtures don't have high air void content, their main noise reduction properties are related with the reduction of tyre vibrations due to optimised ("negative") road surface texture and small maximum aggregate size. Thus, can be concluded, that acoustical ageing of non-porous

asphalt mixtures is mostly related with changes in road surface texture (texture degradation). To investigate changes in road surface texture, further analysis on road surface texture parameters is needed.
SPB noise level measurements allowed to evaluate not only the tyre/road noise generation, but also the noise propagation further from the road. Overall noise level trends showed that lowest initial noise levels were measured for PA 8 and SMA 8 TM mixtures (both 73.3 dBA) comparing to SMA 5 TM and TMOA 5 (75.4 and 75.9 dBA respectively), but after two years of exploitation, difference from SMA 5 TM and TMOA 5 mixtures was only around 1 dBA. It can be stated that, in order to ensure longer absorption effect of low noise asphalt mixtures, it is necessary to protect surface texture and open air voids from clogging and to ensure adequate surface maintenance on both traffic lanes including emergency lane too.

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