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Road wearing layer type and age effect on pavement acoustic degradation

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Abstract

Long-term positive acoustic behavior as well as sufficient strength and durability is required for low noise road surfaces. However, combination of these properties in many cases is a challenging task, especially at the severe climate conditions. In such regions, optimized asphalt layers (SMA and AC) seem to be promising solution as they have similar structural conditions to traditional AC and SMA pavements but at the same time modified distribution of aggregates, increased air void content and optimized surface texture for noise reduction. Development of optimized surface layer asphalts in most cases relies on the good experience from different climate regions, however, acoustic degradation is different, faster than in milder regions. To analyze these effects, large number of road sections constructed of different asphalt mixtures (incl. low noise asphalt mixtures, traditional asphalt mixtures) and with different exploitation age were measured by Close Proximity (CPX) trailer. Collected noise level data was compared and linked with the pavement age, resulting acoustic degradation trends. After analyzing interrelations and similarities between traditional and optimized low noise asphalt surfaces and summarizing the results, recommendations for optimized low noise asphalt mixtures development are presented in the paper.

Keywords: Acoustic degradation; low noise asphalt; asphalt mixture; CPX.

1. Introduction

Traffic noise is one of the most underestimated major environmental problems in the recent decades. According to EC calculations (European Commission, 2011), annual socio-economic costs of traffic noise are exceeding 40 billion EUR and are expected to increase 50% by 2050. It must be highlighted that heavy and light vehicle traffic is responsible for most of these socio-economic costs. Exposure to excessive noise levels result a high risk medium-long term risks to human health, negatively affects specific animal species (impacts on migration, reproduction) and economies (e.g. decreased real estate prices). To mitigate with the environmental noise problem, EU member states implementing *Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to assessment and management of environmental noise*.

Low noise pavements are being widely used as a successful noise mitigation measure and as an alternative to high costs and maintenance required noise barriers. For example, porous asphalt surfaces are the most common low noise pavement solution used in Europe, especially in the countries with mild climate. However, due to mixtures sensitivity to severe climate conditions (Vaitkus et al. 2017), it is not always feasible to use such pavements in different climate regions. Therefore, colder region climate countries are more using modified traditional dense

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asphalt concrete (AC) and stone mastic asphalt (SMA) mixtures with an optimized road surface texture and increased porosity.

Low noise pavements, depending on their mixture composition, lose their initial noise reducing properties over the time. Acoustic degradation process can be linked with the clogging of surface texture (mostly affects porous asphalt mixtures), climate and traffic impact. Understanding of how different road surfaces with different asphalt mixture properties perform in terms of noise reduction properties, it is valuable to develop long-term and region adapted low noise pavement solutions.

In recent years, Road Research Institute of Vilnius Gediminas Technical University was working on the development of low noise asphalt mixtures for Lithuanian and regional climate conditions (e.g. annual number of frost-thaw cycles in Lithuania is 60–80, and the temperature fluctuation range can be from –35 to 50 °C (Ratkevičius et al. 2013), what is considered as severe climate conditions for road infrastructure).

Developed and optimized in laboratory (Vaitkus et al. 2014) low noise asphalt mixtures (SMA 5 TM, SMA 8 TM and TMOA 5) were successfully implemented in practice (Andriejauskas et al. 2016) for further testing under real traffic and climate conditions. Further development and optimization of low noise pavement requires region based knowledge on pavement acoustic degradation. This research study address this issue and is aiming to analyze road surface ageing trends in terms of tyre-road noise levels for different types of asphalt mixtures. Study covered mostly traditional asphalt surfaces in order to analyze their ageing surface properties and texture impact on tyre-road noise levels.

2. Pavement acoustic degradation

National Road Authorities are getting more pressure and complaints from the society due to increasing traffic noise problem and asking to construct noise mitigation solutions. Low noise pavements are being constructed more often but at the same time it is challenging to provide good durability of these pavements from both acoustic and strength point of views. Pavement acoustic degradation is one of the most important problems that negatively affects the performance of low noise asphalt mixtures. Low noise asphalt pavements should not only have good initial noise reduction but also need to retain high noise reduction performance for a long term.

Porous asphalt surfaces are the most common low noise pavement solutions with a 4–6 dBA higher noise level reduction compared with the SMA and AC pavements (Yu et al. 2014). However, the shorter lifetime leading to 50% higher life-cycle costs than traditional dense asphalt concrete wearing courses (Ongel, Harvey 2012) is the main disadvantage when selecting porous asphalt (PA) as a low noise pavement solution. Dutch research shows that acoustic degradation of porous asphalt mixtures is 0.2-0.4 dBA per year (Kragh et al. 2013). Similar research done in Japan showed PA mixtures acoustic degradation from 5 dBA to 1 dBA after 6 years of exploitation (Takahashi 2013). Acoustical degradation for porous asphalt mixtures is mostly linked with clogging and raveling effects. It should also be noted that in cases where traffic volumes and speeds are not high enough, regular surface texture cleaning is required for porous surfaces in order to increase pavement acoustic lifetime. Studded tyres has also a huge impact on the noise acoustic degradation, especially for the pavements with a small aggregate size. Norwegian research showed that the noise level on a newly laid pavement increased 2-4 dB after the first winter with exposure to studded tires (Berge et al. 2009).

For dense asphalt surfaces, acoustical degradation is mostly linked with the structural changes and wear of road surface texture. Texture change 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 also confirmed in the HOSANNA project (Schmerbek 2013) where CPX (close proximity method) measurements on different dense asphalt surfaces on highways driving 80 km/h showed that on the right driving lane acoustical regression is 0.5 dB/year comparing with 0.3 dB/year on the left driving lane it is, meaning that the acoustic ageing is slower on the left driving lanes which has much smaller number of heavy vehicles.

Several research studies show that acoustic ageing is a non-linear process (Sandberg, Ejsmont 2002, Wehr et al. 2015, Irali et al. 2015), showing that surfaces have increased noise levels for the first 1–2 years of exploitation, then stabilize until the end of the lifetime or significant pavement distress occurs (Fig. 1). Increase is mostly 1-2 dBA and generally occurs at frequencies typical of air-displacement mechanisms (Sandberg, Ejsmont 2002). It should also be mentioned that raveling processes occur on optimized thin asphalt layers too (Bergiers et al. 2014), which can be explained by the composition of the mixtures (aggregate grading and bitumen content) and the higher void content.

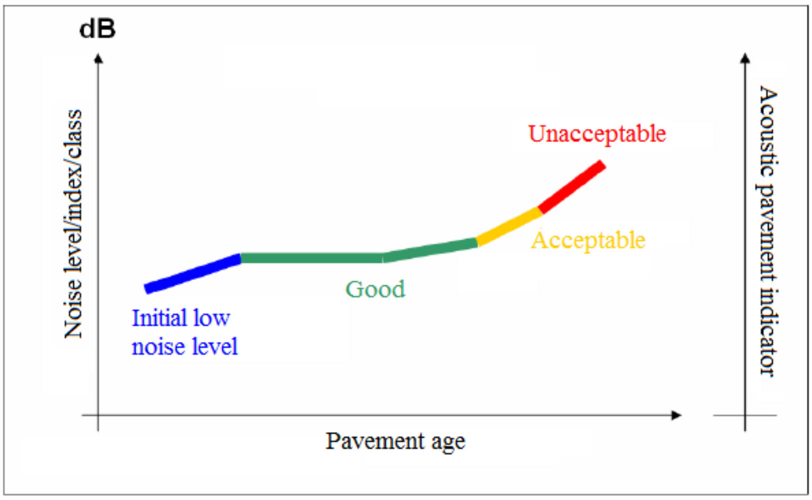

Fig. 1 Acoustic ageing of road surfaces (Sandberg, Ejsmont 2002).

Acoustic degradation is a continuous process caused by the impacts of traffic, environment related phenomenon, regular and winter maintenance actions. The speed of acoustic ageing process also depends on the asphalt mixtures itself (asphalt mixture type, surface texture, porosity, properties and quality of the materials, resistance to wear). Before a visual pavement wear and significant pavement distresses (polishing of aggregate, raveling, cracks, potholes, bitumen bleeding) occur, the following processes might influence the acoustic ageing (Bendtsen et al. 2009):

- Additional continuous pavement compaction because of traffic loads.
- Aggregate pressed further down in mortar and the openness of the surface structure is reduced.
- Change in the orientation of the aggregate because of traffic load.
- Clogging where the open structure with communicating pores in the upper part of a porous pavement layer is more or less clogged.
- The average driving speed might have an influence on the clogging process as the high speed and traffic volumes are causing self-cleaning effect.
- Ordinary pavement maintenance and cleaning.
- Winter maintenance procedures (snow and ice removal, salting, plowing).
- Impact of studded tyres and snow chains.
- Weather conditions (rain water, sun, snow, freeze-thaw, oxidation, etc.).
- Ultraviolet radiation from the sun.

Analyzed literature gave an overview of the main acoustic degradation influencing factors and different process for different surface types. Knowledge on the acoustic ageing (either linear or non-linear regression curves) is important for mixtures application (conditions, locations, lifetime, etc.) and further development directions. Regional and country variables need to be included in the mixtures construction procedures. Therefore, paper presents research which aims to analyze regional peculiarities in terms of acoustical degradation.

3. Experimental research

3.1. Methodology

Experimental research on the acoustic degradation of asphalt mixtures was performed by measuring CPX noise levels on selected road section on Lithuanian national significance roads with different AADT (annual average daily traffic) – main, national and regional roads. The tested surfaces include dense surfaces, thin layers, porous asphalt and others. Table 1 gives an overview of the analyzed road surfaces. TMOA 5, SMA 5 TM and SMA 8 TM are optimized thin asphalt layers specifically developed for noise reduction. Mixtures have optimized surface texture, gradation, optimal binder content and increased air void content in order to reduce both tyre vibrations and air pumping related noise generation mechanisms (Vaitkus et al. 2014). AC 11, AC 16, SMA 8 and SMA 11 are traditional dense asphalt concrete and stone and mastic asphalt mixtures widely used in Lithuania.

Road sections were selected also taking into account pavement age, which was grouped to:1-2 years, 4-6 and 8-10 years. A total of 191.45 km of different roads were selected for testing in this research project.

Table 1. Surface layer types used in the research study.

Surface type	**Surface layer**	**Surface type**	**Surface layer**
PA 8	Porous asphalt	SMA 8	Dense stone mastic asphalt
TMOA 5	Optimized AC thin layer	SMA 11	Dense stone mastic asphalt
SMA 5 TM	Optimized SMA thin layer	VPA	Single layer surface dressing
SMA 8 TM	Optimized SMA thin layer	DPA	Double layer surface dressing
AC 11	Dense asphalt concrete	Concrete	Concrete pavement
AC 16	Dense asphalt concrete	Slurry seal	Slurry seal pavement
AC 8 PAS-H	Dense asphalt concrete	Cobblestone	Cobblestone pavement

To analyze different low noise asphalt mixtures' acoustic ageing, road sections were measured using CPX method (ISO 11819-2:2017). This method is based on test tyre rolling on the road or the test track surface with measuring microphones located close to the tyre surface. CPX trailer (Fig. 2) is 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, road surface texture, driving speed, road section length, GPS coordinates, air and road surface temperature were measured too.

Fig. 2 CPX noise level measurement trailer.

CPX noise level measurements were performed at two different speeds: 50 and 80 km/h. Such measurement speeds were selected with a purpose to accurately determine road surface influence on noise generation mechanisms depending on the driving speed and road category (low speed roads/urban streets and high speed roads).

Two sets of measurement tyres to represent passenger cars and heavy duty vehicles were used. For passenger car representation standard reference test tyres (SRTT) are used and for heavy duty vehicle representation – Avon Supervan AV4 tyres (AAV4).

3.2. Research results and interpretation

After performing statistical analysis of the measured CPX noise levels it is clearly seen that porous asphalt pavement PA 8 has the lowest noise level comparing with all other pavements at both speeds (at 50 km/h - 88.62 ± 0.98 dBA; at 80 km/h – 94.00± 1.14 dBA) and independent on the surface age. The highest noise levels were measured for cobblestone pavement (only measured at 50 km/h due to driving speed limit at the road section) following by traditional asphalt surfaces AC 11, SMA 11 and slurry seal (Fig. 3-6).

Concrete pavement has second lowest noise level at low speed (50 km/h) – 89.52±1.02dBA, but at the higher speed noise increase much more than for other pavement types – 97.9±0.90 dBA. This phenomenon can be associated with the air pumping related noise generation mechanisms as the measured concrete pavement has a smooth texture.

The opposite behavior was seen for SMA 8 TM pavement which has optimized surface texture and increased air void content leading to slower increase of noise levels at higher speeds, respectively noise levels are 89.76±0.52 dBA and 95.6±0.48 dBA.

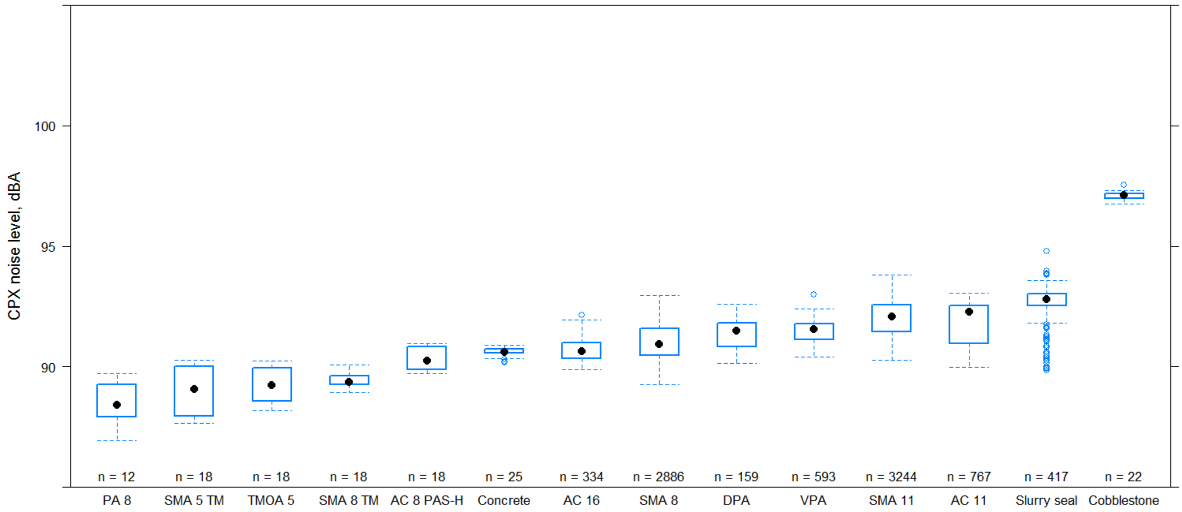

Fig. 3 CPX noise levels for different pavement types measured at 50 km/h speed with AAV4 tyres.

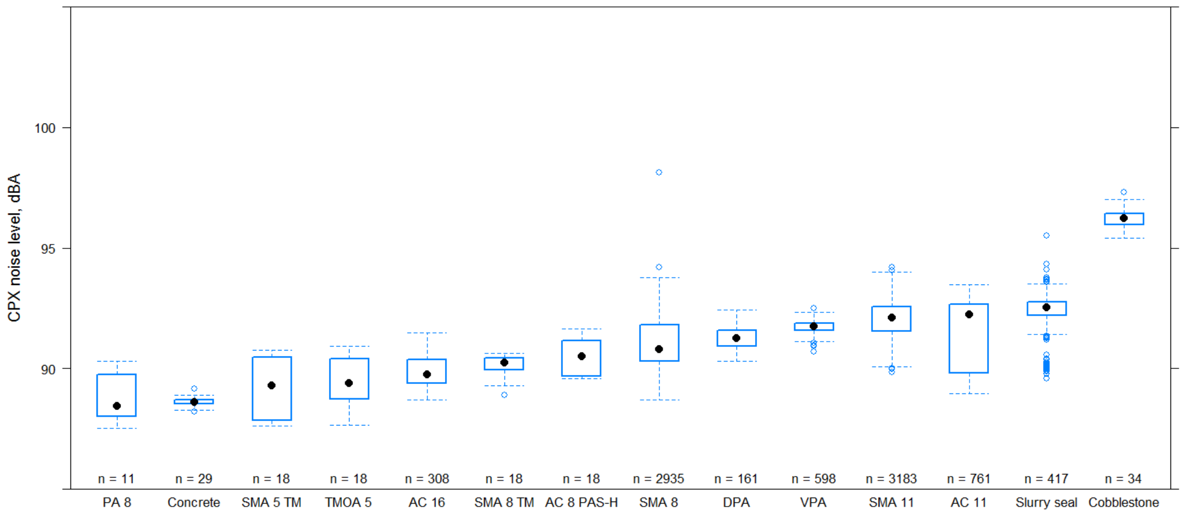

Fig. 4 CPX noise levels for different pavement types measured at 50 km/h speed with SRTT tyres.

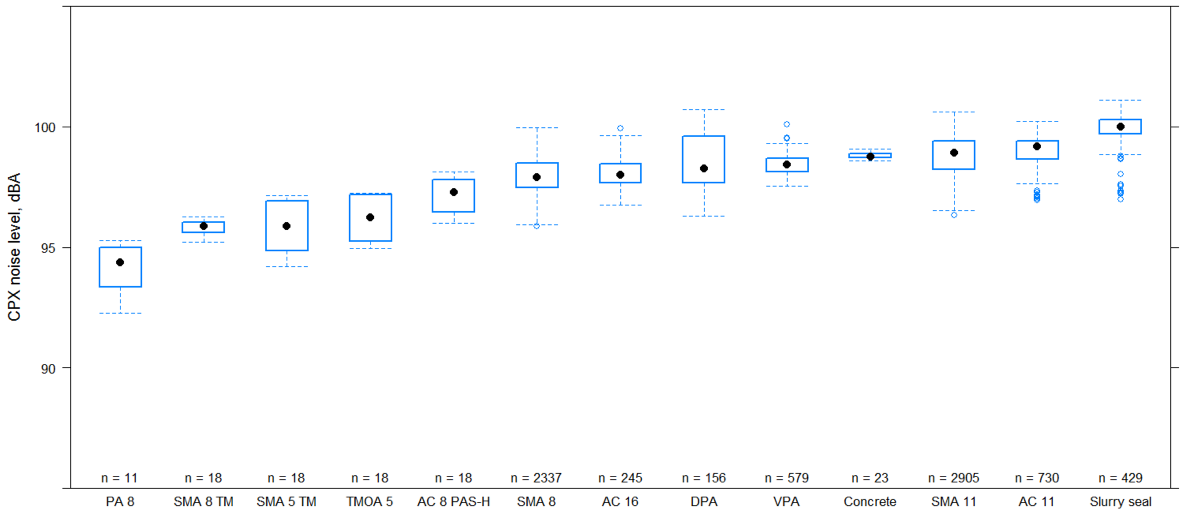

Fig. 5 CPX noise levels for different pavement types measured at 80 km/h speed with AAV4 tyres.

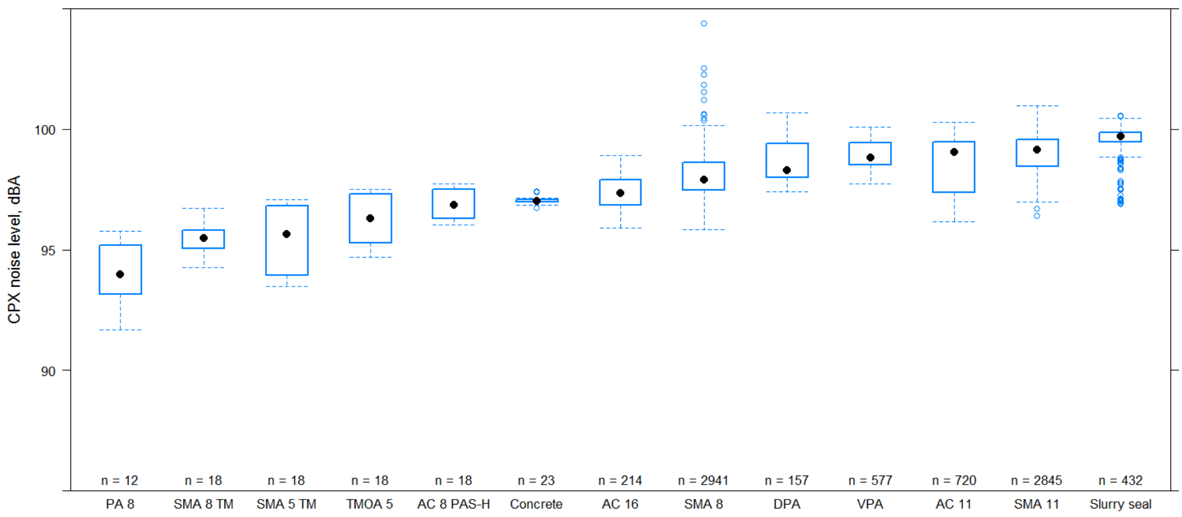

Fig. 6 CPX noise levels for different pavement types measured at 80 km/h speed with SRTT tyres.

Comparison between the noise levels between the tyre types for different pavement age groups gave the result that noise levels for both SRTT and AAV4 tyres at 50 km/h aren't very different for 4-6 and 8-10 pavement age groups, but is higher than comparing with the 1-2 years old SMA 8, SMA 11 and AC 11 pavement groups (Fig. 7). This tendency justifies the non-linear pavement degradation trend. In overall, 1-2 years old pavement group has lowest noise levels while 4-6 has the highest. Depending on the pavement type, it was seen that opposite behavior was determined for AC 16 pavements, 1-2 years old pavements have higher noise (93.98 ±3.06 dBA) comparing with 4-6 years old pavements (92.86 ± 2.95 dBA). Since AC 16 has very rough texture with the large aggregate size, such behavior can be associated with the positive impact of traffic – smoothening texture.

Noise levels measured with SRTT tyres (91.50±1.1 dBA) are a bit lower than noise levels (91.58±0.9 dBA) for AAV4 tyres at low speed (50 km/h) but at the higher speed (80 km/h) is more or less similar, 98.55±0.97 dBA and 98.55±0.92 dBA respectively.

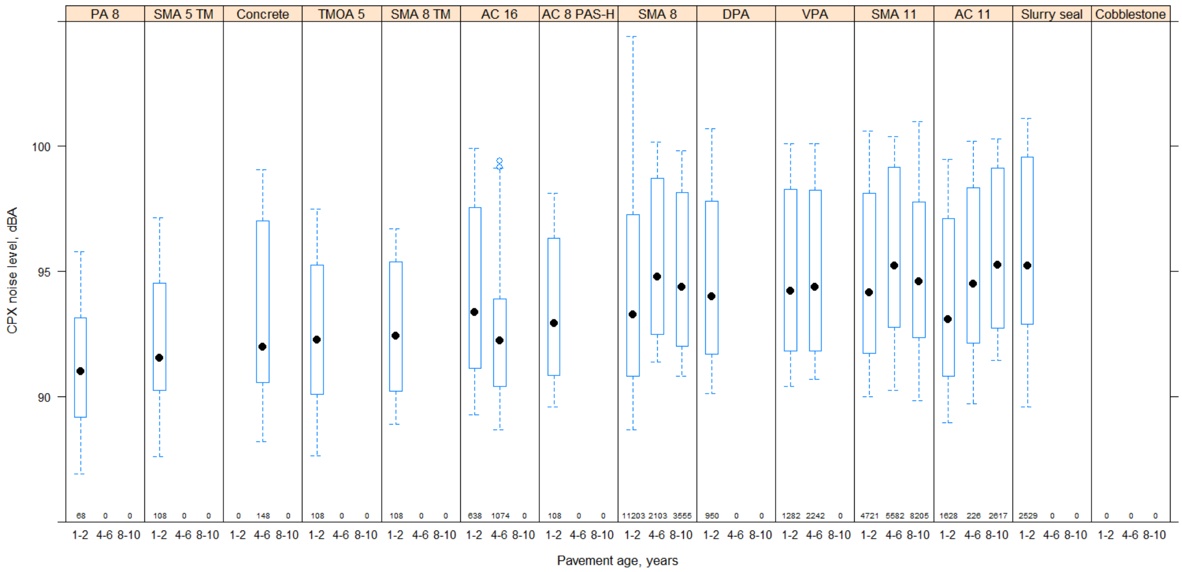

Fig. 7 CPX noise level change for different surface types depending on the pavement age.

4. Conclusions

Acoustic degradation is a dynamic process influenced by a various environmental, traffic and road surface factors. Different regions have different acoustic ageing phenomenon, therefore regional and country variables need to be included in the pavement wearing layer mixtures design and construction procedures related to acoustic characteristics.

Tyre-road noise level measurements were performed at 191.45 km of road sections, which wearing courses are constructed of different wearing layer types and exploitation age (1-2, 4-6 and 8-10 years). Such high number of tested road section allowed to represent most of the country's road network.

Analysis showed that noise reduction properties of the tested traditional pavements decrease in a non-linear manner. This was also confirmed by a comparison analysis of acoustical ageing trends for specific pavement types but different age groups that showed that for most of the pavement types, 1-2 years old pavements have lowest noise levels while 4-6 has the highest. Considerable noise level increase after first 1-2 years of exploitation likely to be a consequence of the Lithuanian climate conditions, especially at winter when snow/ice removal, salting and ploughing actions are performed. Additionally, allowable operation of studded tyres in winter also contributes to the rapid road surface texture change.

It was determined that traditional pavements have significantly higher initial noise levels comparing with low noise asphalt pavements (PA 8, SMA 5 TM, SMA 8 TM and TMOA 5). Since low noise pavements started to use only 3 year ago, there is lack of such pavements CPX noise level data to make sufficient comparison with traditional ones. Additional measurements should be performed in the future to supplement the research results by low noise pavements acoustical degradation.

Assessment of the noise degradation trends for different types of pavements gave general indication about the overall noise level increase/decrease. It is planned to continue research by analysing noise spectra for different type and age pavements. Further assessment would allow to link acoustic degradation trends with relevant influencing factors and noise generation mechanisms.

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