PECULIARITY OF LOW NOISE PAVEMENT DESIGN UNDER LITHUANIAN CONDITIONS

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Abstract. The paper gives a detailed overview and analysis of road transport noise propagation, noise composition and impacts on the living conditions. Road transport noise has been rapidly growing and the traditional noise abatement solutions, such as noise barriers, are not always suitable and cost-effective for particular road infrastructure. One of the most promising and effective solutions is the use of low noise pavements. Presently, low noise pavements are not being used in Lithuania but expected to have a good environmental noise reduction potential. However, the most effective low noise pavement solutions according to other European countries' experience are not always applicable for Lithuanian road conditions. For these reasons, few low noise asphalt pavement mixtures were developed to achieve a relatively high noise reduction effect and maintain sufficient mechanical and operational characteristics under Lithuanian conditions. Laboratory testing results (including mechanical and physical, noise reduction and durability characteristics) and comparison with traditional asphalt mixtures are provided in the paper as well as recommendations for the use of the developed low noise asphalt mixtures.

Keywords: tyre/road noise, low noise asphalt, asphalt noise tests, pavement noise emission.

1. Introduction

Environmental noise generation is associated with many different social, transportation and industrial activities, but the major part of noise is generated by road, rail and air transport. According to the *European Commission Report from the Commission to the European Parliament and the Council: on the Implementation of the Environmental Noise Directive* it is estimated that annual socio-economic costs in European Union (EU) because of road and railway generated noise amount to about 40 billion EUR and 90% of these are caused by light and heavy vehicle traffic. It is also likely that the costs will increase to 20 billion EUR until 2050.

Noise emitted from road transport practically is one of the main sources of pollution in living environment of cities and around the exurbia roads. Urbanization processes require a development of road transportation system as close as possible near buildings and as a result permanently increase the noise level in the living environment. The last ten-year statistical data if Lithuanian confirms these tendencies:

– the overall length of roads have increased by about 10% during last 10 years;

– the amount of registered road vehicles have increased by 50% from 2002 to 2012 and exceeded 2 million vehicles;

– the annual growth of new transport registrations in the period from 2002 to 2012 is on the level from 7% to 10% in comparison with the total amount of registered vehicles.

Road transport noise is a dominant term in environmental noise and is caused by several factors: sound emissions from vehicle engine, propulsion and aerodynamic noise, as well as tire and pavement interaction. The latter factor as it was found is a major contributor to traffic noise for light vehicles driving at a constant speed greater than 50 km/h.

When vehicle moves at higher speed, tire and pavement interaction noise contributes to approximately 90% of emitted acoustics energy and becomes dominant component in the vehicle noise context (Fig. 1) (Rasmussen *et al.* 2007). As a result, pavement acoustic properties have become an important consideration for the
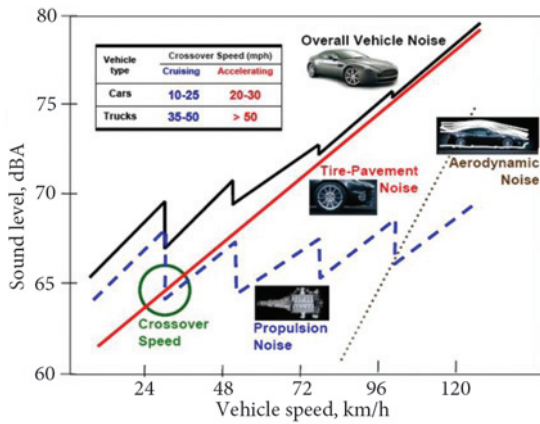
Fig. 1. Speed effects on vehicle noise sources and crossover speed (Rasmussen *et al.* 2007)

Table 1. The highest acceptable values of $L_{Aeq,night}$ indicator for noise from road traffic flow in the newly designed residential areas

EU member-state	$L_{Aeq,night}$, dBA
	outdoor/indoor
Austria	50/–
Estonia	45/–
Finland	46/–
France	62/–
Germany	49/–
Hungary	55/–
Latvia	40/–
Lithuania*	55/35
Netherlands	40/–
Spain	45/–
Sweden	–/30
Switzerland	50/–

Note: *allowable values in living environment estimated for outdoor and inside of dwelling (according to the Lithuanian Hygiene Norm *HN 33:2011 Acoustic Noise, Limit Values in Residential and Public Buildings and Their Environment*).
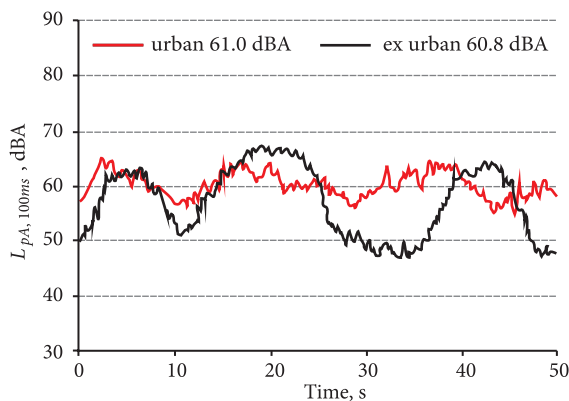

Fig. 2. Time histories of typical sound levels of short period (50 s) of vehicle passing by in suburban and urban living areas at a distance of 50 m from the road with the generated of about 61 dBA the same equivalent levels (Jagniatinskis *et al.* 2013; Jagniatinskis, Fiks 2014)

mitigation of traffic noise when constructing new and improving the existing roads.

The design goal related to traffic noise abatement in general is to provide around 7 dBA noise level reduction for the noise-sensitive living environment near first-row buildings adjacent to the road facilities. Traditionally, the most common method to obtain such results is a construction of noise barriers. However, there are limitations for constructing noise barriers, whereas, quiet (low noise) pavements may provide new advantages for noise mitigation.

2. Road traffic noise emission impacts and propagation peculiarity

The enhancement of road infrastructure and road pavement quality allows increase in transport flow under the same speed limits on the same road sections, while growing traffic volumes contribute to the higher noise emission.

Traffic noise is a growing concern for both public health and economy indicators of each country, especially in urban contexts. A study indicated that 30% of EU citizens are exposed to traffic noise exceeding the World Health Organization's recommended level described in the report *Burden of Disease from Environmental Noise*. In addition, e. g., the increase of noise by 1 dBA results in the decrease of dwelling prices near intensive-traffic roads approximately by 1%. In fact, the impact of traffic noise on communities is increasing all over the world due to growing traffic volume and development near highway facilities.

The above pointed tendencies of rising environmental noise obligate to control this situation because noise is one of annoying factors which affects human health. According to World Health Organisation's calculations made in the reports *Night Noise Guidelines for Europe* and *Burden of Disease from Environmental Noise*: about 40% of the population in EU countries is exposed to road traffic noise at levels exceeding 55 dBA; 20% is exposed to levels exceeding 65 dBA during the daytime; and more than 30% is exposed to levels exceeding 55 dBA at night. According to WHO studies the risk of cardiovascular disease arise from 2.3% to 23% beginning from $L_{Aeq,day}$ values of 60 dBA to 75 dBA. Sleep disturbance is caused by traffic noise with an outdoors levels started from 40 dBA of $L_{Aeq,night}$. Thus, the WHO's recommended outside limit value of $L_{Aeq,night}$ indicator is 40 dBA and the interim value of 55 dBA is suggested also. For dwellings (bedrooms) the value of 30 dBA of $L_{Aeq,night}$,indoor indicator is suggested. For comparison the corresponding values of night noise indicators in some EU countries is presented in Table 1.

In Lithuanian case, presented in Table 1, the allowable level concerns not only new residential areas, but also the noise from moving vehicles in overall living sites. For comparison, the analogous requirements for outdoor and indoor values of day indicator $L_{Aeq,day}$ in Lithuania are 65 dBA and 45 dBA, respectively.

A-weighted sound pressure level time histories of $L_{pA,100ms}$ which in decibels characterise noise produced from road traffic usually are different for urban and exurbia cases as shown in Fig. 2. But when the time-histories

of hourly whole-day levels $L_{Aeq,1h}$ are considered – the graphical presentation is analogous (Fig. 3).

The time histories of traffic noise, presented in Figs 2–3, are typical for Lithuanian roads and show that in suburban case (and also in urban night periods) the maximal levels of vehicle passing by additionally to equivalent levels are considered as a descriptor for noise impact evaluation in the living environment. Fig. 4 presents the measured spectrum data of noise produced by road traffic for typical newly laid Lithuanian roads at speeds of 50 km/h (urban case) and 90 km/h (suburban case).

From Fig. 4 the clear peaks on about 1 kHz one third octave frequency band were observed. Analogous frequency dependences were designed for pavement sound absorption characteristic. Additionally, as shown in (Jagniatinskis *et al.* 2013), the equivalent level $L_{Aeq,T}$ of environmental noise produced by road traffic in time interval T are presented as a sum of two contributions:

1) the level produced from vehicle noise emissions, which are expressed by the energy average sound exposure level (SEL) $\overline{L}_{AE}$ of all (N) vehicle passing by events in time interval T;

2) the term scored due to traffic intensity in time interval $T\left(\dfrac{N}{T}\right)$:

$$L_{Aeq,T} = \overline{L}_{AE} + 10\lg\left[\frac{\tau_{ref}}{T}N\right]. \qquad (1)$$

In nowadays, taking into account the growing economy development the value of first factor is likely to increase due to vehicle speed limitation weakening, and the value of second one due to traffic intensity growing. Now, as shown in formula (1) (Freitas *et al.* 2009), the increase of vehicle speed, e. g. by 20 km/h, produces SEL values about 2–3 dB higher (the first term of formula (1)). In another case, the expected future double grow of traffic intensity produce SEL values 3 dB higher (the second term of formula (1)). Thus, these increments of environmental noise levels are compensated by applying the suitable sound-absorbing road pavement materials which abate the overall traffic noise level by up to 5 dB (Luong *et al.* 2014).

3. Acoustical absorbing and lower noise generating road pavements

Tyre/road noise is as a complex of different noise generation and amplification mechanisms (e. g. mechanical vibrations, air pumping, adhesion, resonances, horn effect etc.) which are caused and influenced by various external and internal factors such as road surface, tyre, environmental characteristics and driver behaviour factors (Rasmussen *et al.* 2007; Sandberg, Ejsmont 2002). Road surface texture, mechanical impedance and absorption are the tree main pavement characteristics influencing tyre/road noise. Fig. 5 shows the relationship between these pavement characteristics and the noise generation range. Road surface texture mostly is related with noise generation in low frequencies (up to 1000 Hz) while

absorption – in high frequencies (over 1000 Hz) (Kuijpers, Van Blokland 2006).

Generally, two main types of asphalt pavements are being used for traffic noise reduction: acoustical absorbing pavements and pavements with optimised surface texture. When porosity of the pavement is higher than 10%, pavement becomes acoustically absorbing, but good noise absorption characteristics will be achieved when the porosity is higher than 20%. Acoustically absorbing pavements eliminate noise, generated due to air displacement mechanisms, impact mechanisms, reduce horn amplification and absorb the noise propagating above the surface. Pavements with optimised road surface texture reduce tyre vibrations, resulting from the surface roughness, and ensure adequate air propagation conditions at tyre and road surface contact area. According to research results in many countries, it is recommended to increase road surface texture in 2–8 mm
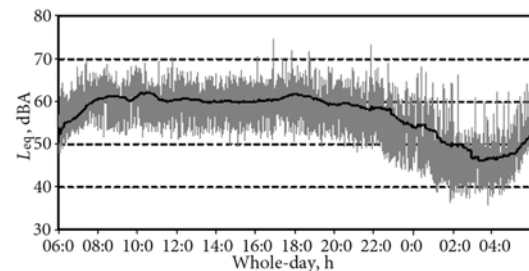
Fig. 3. Typical time-history of hourly (bold curve) whole-day equivalent levels for suburban and urban living areas (Jagniatinskis, Fiks 2014)
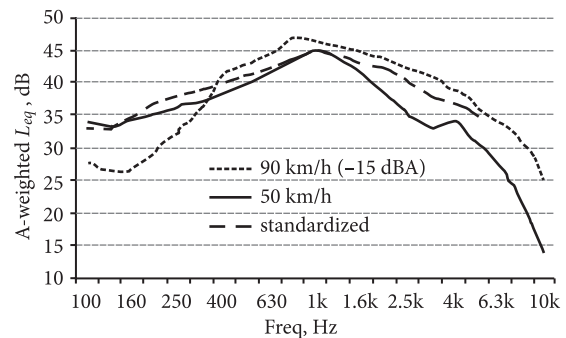
Fig. 4. Equivalent A-weighted spectrum levels of the road traffic noise produced from vehicle passing by at speeds of 50 km/h and 90 km/h (Jagniatinskis, Fiks 2014)
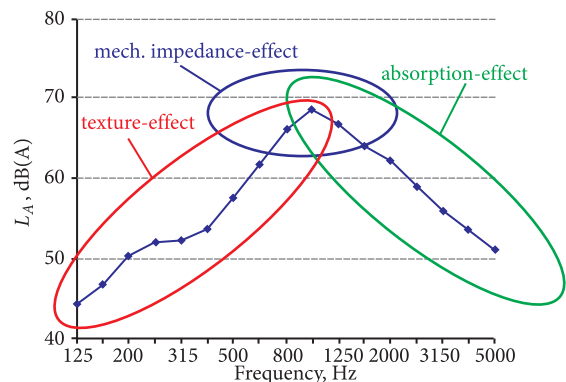
Fig. 5. A typical rolling noise spectrum and the frequency range of influence of the three main road parameters: texture, absorption and mechanical impedance (Kuijpers, Van Blokland 2006)

wavelength range and reduce texture in 20–250 mm wavelength range. To achieve this it is necessary to use smaller aggregate and to ensure "negative" surface texture (Sandberg, Ejsmont 2002; Sandberg *et al.* 2011).

According to the structure, pavements are divided into 3 categories: dense, semi-porous and porous (Beckenbauer 2011). As shown in Fig. 6, noise reducing potential and noise reducing mechanisms are different in these pavement types: noise reduction principles for dense pavements are associated with reducing tyre vibrations; for porous pavements – mostly, noise absorption and reduction of air pumping mechanism.

Development and use of noise reducing pavements is effective and inexpensive way to reduce tyre/road noise. According to the climate conditions, allowable loads, road environment, road noise mitigation and national abatement strategies different countries have different experience of using noise reducing road pavements.

Stone and mastic asphalt (SMA) mixtures with optimised road surface texture (recommended maximum aggregate particle size 5–6 mm) are one of the most common noise reducing pavements as they reduce tyre/road noise approximately up to 2–5 dBA (Sandberg, Ejsmont 2002; Sandberg 2009) and maintain sufficient pavement mechanical parameters for a longer period compared to porous pavements.

Another effective solution is thin asphalt layer technology (Sandberg *et al.* 2011). Thin asphalt layers could be easily laid without long traffic disruptions. According to the Denmark and UK experience thin layers with optimised surface texture helps to achieve good noise reduction – 3–4 dBA (Sandberg 2009).

Porous asphalt pavements are characterised by very good noise reduction properties – approx 6–7 dBA (Anfosso-Lédée, Dangl 2006; Sandberg 2009). 8 mm maximum aggregate size is commonly used for porous pavements, air void content of 20–25% and layer thickness of about 40 mm. However, due to clogging and poor climate resilience the durability of porous layers is only 3–5 years and noise reduction effectiveness is decreasing each year approx. by 1.0 dBA. Double layer porous asphalt is more resistant to clogging by dust and dirt because the upper layer is with smaller aggregate (5–8 mm) and bottom layer with larger (16–22 mm) what allows noise to dissipate
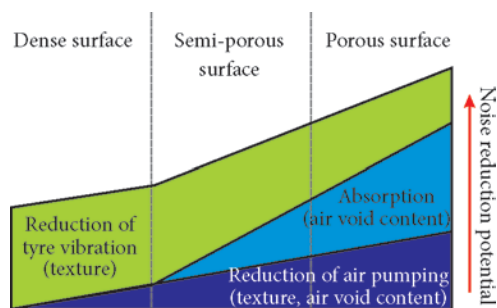
into the pores but also prevents the layers from clogging. The reduction of noise by using these pavements is about 7–9 dBA (Anfosso-Lédée, Dangl 2006; Sandberg 2009).

Other promising but rarer solutions are poroelastic asphalt road surfaces (PERS) (Biligiri *et al.* 2011) and rubber asphalt pavements (Sandberg, Ejsmont 2002) with a high content of rubber granules in the asphalt mixtures. Despite, these pavements are not very durable and the stability is lower, the noise reduction is very high – up to 10–12 dBA for PERS and 7 dBA for rubber asphalt. On the other hand, due to lower mechanical stability, asphalt mixtures with rubber granules are not very suitable for roads with higher heavy vehicle traffic.

As Portland Cement Concrete (PCC) pavements are very popular in warmer climate countries, available research concluded that in general PCC pavement gives 1–2 dBA higher tire/road noise values in comparison with dense-graded asphalt pavement. Surface tinning techniques helps to reduce noise for PCC pavements – diamond grinding of pavement has been found to successfully reduce tire/road noise (Ahammed, Tighe 2011) and presents good acoustics longevity. Sound absorbing properties of pavement types provide an additional criterion for pavement selection in noise sensitive areas. Laboratory based studies are focusing on the sound absorption properties of various pavements. These properties are investigated with plane waves in interferometer and/or with diffuse sound field in reverberation room. PCC pavement absorbs approximately 2–8% of sound energy at different frequencies.

4. Laboratory testing of acoustical asphalt mixtures

4.1. Research object and methodology

A set of research works were performed to evaluate the influence of asphalt composition materials on performance of pavements (Vaitkus *et al.* 2012; Vaitkus, Vorobjovas 2013), and bearing in mind specific Lithuanian climate conditions, this could be characterised as severe conditions for road infrastructure (60–80 frost-thaw cycles annually (Ratkevičius *et al.* 2013)), the use of traditional and popular noise reducing pavements in other EU countries is questionable if they could be suitable for Lithuanian climate conditions. For this reason it was decided to develop specific noise reducing asphalt mixtures for Lithuanian climate conditions and to compare them with the traditional noise reducing asphalt mixtures.

In reference to EU countries, especially to the German low noise asphalt pavement development experience (German low noise asphalt mixtures SMA 0/5 LA, SMA 0/8 LA) two types of Lithuanian noise reducing stone and mastic asphalt mixtures (SMA TM) were designed – SMA 5 TM, SMA 8 TM with the maximum aggregate size respectively 5 m and 8 mm (Vorobjovas *et al.* 2014). To adequately evaluate noise reduction and durability properties, these asphalt mixtures were compared with the commonly used SMA mixture in Lithuania SMA 11 S (reference asphalt mixture) and with the porous asphalt pavement

Fig. 6. Noise reduction potential and methods for different type of pavements (Beckenbauer 2011)

PA 8. Design characteristics of all the mixtures are shown in Table 2.

Asphalt mixtures for research were designed and produced in Vilnius Gediminas Technical University (VGTU), Faculty of Environmental Engineering, Road Research Institute (RRI). The main objective of the research was to assess and compare conceptual SMA 5 TM and SMA 8 TM noise reducing asphalt mixtures with traditional asphalt mixtures in terms of noise reduction characteristics, durability, mechanical strength and climate resistance. The research was executed in 3 stages. In first stage the following mechanical and physical properties of asphalt mixtures were determined:

– air void content according to the standard *LST EN 12697-8:2003 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 8: Determination of Void Characteristics of Bituminous Specimens*;

– Marshal stability and flow according to the standard *LST EN 12697-34:2012 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 34: Marshall Test*;

– indirect tensile strength ratio ITSR according to the standard *LST EN 12697-12:2008 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 12: Determination of the Water Sensitivity of Bituminous Specimens*;

– indirect tensile strength according to the standard *LST EN 12697-23:2003 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 23: Determination of the Indirect Tensile Strength of Bituminous Specimens*.

During second stage, laboratory tests for asphalt mixtures' durability and climate resistance properties were performed: testing of indirect tensile strength and particle mass losses after the frost-thaw cycles. One cycle – prepared asphalt samples (cylindrical Marshall samples, made by 50 blows per side) were sunk into water bath with 20 ± 5 °C water temperature where samples were kept until becoming fully saturated; then samples were put into the plastic bags and stored in the freezer where they frosted in -18 ± 3 °C temperature for at least 4 hours; hereafter the samples were taken out from the freezer and thawed for 2 hours in the water bath. The described frosting-thawing process was repeated 50 times to simulate 50 frost-thaw cycles. Laboratory tests were performed before the frost-thaw cycles and after 12, 25, 38 and 50 frost-thaw cycles. Indirect tensile strength was determined according to the standard *LST EN 12697-23* while particle mass losses according to standard *LST EN 12697-17+A1:2007 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 17: Particle Loss of Porous Asphalt Specimen* and testing samples using the Los Angeles machine (by standard *LST EN 1097-2:2010 Tests for Mechanical and Physical Properties of Aggregates – Part 2: Methods for the Determination of Resistance to Fragmentation*).

The third research stage covered testing and investigation of the acoustical properties of asphalt mixtures. For that purpose, surface mean texture depth (using traditional sand patch method according to standard *LST EN 13036-1: 2010 Road and Airfield Surface Characteristics –Test Methods – Part 1: Measurement of Pavement Surface Macrotexture Depth Using a Volumetric Patch Technique*) and sound absorption coefficient were determined. Sound absorption coefficient was determined in impedance tube using standing wave ratio (according to the standard *LST EN 10534-1: 2002 Acoustics – Determination of Sound Absorption Coefficient and Impedance in Impedances Tubes – Part 1: Method Using Standing Wave Ratio (ISO 10534-1:1996)*). Measurements of sound absorption were performed in the Laboratory of Acoustics of Scientific Institute of Thermal Insulation of VGTU.

4.2. Research results

Laboratory testing results of asphalt mixtures' mechanical and physical characteristics are shown in Fig. 7. It was determined that conceptual asphalt mixtures SMA 5 TM and SMA 8 TM have better properties than porous asphalt PA 8, however, worse than the conventional non noise reducing asphalt mixture SMA 11 S. Air void content was the highest for PA 8 mixture – 24.94% and the lowest for SMA 11 S – 1.96%. The tendency of this research results shows that the higher porosity results the better sound absorption, though on the other hand – the worse mechanical properties. This reliance was also noticed comparing conceptual asphalt mixtures SMA 5 TM

Table 2. Design characteristics of tested asphalt mixtures

	SMA 5 TM	SMA 8 TM	SMA 11 S	PA 8
Aggregate type	Granite	Granite	Granite	Granite
Content by fraction, %:				
Fr. 8/11		6.6	40.3	8.6
Fr. 5/8	9.3	67.5	15.9	82.3
Fr. 2/5	61.6	4.7	14.1	0.9
Fr. 0/2	16.8	6.6	12.2	1.9
Mineral powder	5.6	8.4	11.2	2.8
Adhesive additive, %	0.2	0.2	0.2	0.2
Stabilisation additive	Cellulose fibre	Cellulose fibre	Cellulose fibre	Cellulose fibre
Content, %	0.4	0.4	0.4	0.4
Binder type	PMB 45/80-55	PMB 45/80-55	PMB 45/80-55	PMB 45/80-55
Content, %	6.7	6.3	6.3	6.5

and SMA 8 TM. It was found that stability by Marshall (Fig. 7) and tensile strength before frost-thaw cycles (Fig. 8) of asphalt mixture SMA 8 TM is lower than SMA 5 TM. Mechanical characteristics of SMA 5 TM asphalt mixture are closest to the reference asphalt mixture SMA 11 S.

Durability testing results (Fig. 8) after the frost-thaw cycles allows to state that indirect tensile strength for conceptual asphalt mixtures SMA 5 TM and SMA 8 TM reduces drastically only after the first 12 frost-thaw cycles – by 25% and 35%, respectively. After the next cycles, the reduction was consistent – overall reduction of indirect tensile strength after each cycle is 0.65% and 0.34%, respectively. It was also observed that indirect tensile strength of SMA 8 TM after the 12, 25, 38 and 50 frost-thaw cycles was very similar to PA 8 mixture. The highest initial tensile strength was determined for SMA 5 TM – 0.00114 GPa, but after the frost-thaw cycles, it decreased to 0.00064 GPa while SMA 11 S maintained the highest value – 0.00079 GPa. However, SMA 5 TM has the closest indirect tensile strength after frost-thaw cycles values to the reference asphalt mixture SMA 11 S what means that durability of this conceptual asphalt mixture is sufficiently enough.

The largest particle mass losses (Fig. 9) were determined for PA 8 asphalt mixture – 13.04% before the frost-thaw cycles and 33.42% after 50 frost-thaw cycles. It was presumed that PA 8 mixture is very sensitive to cold climate conditions. Conceptual asphalt mixtures showed better resistance to frost-thaw cycles, SMA 5 TM was similar to SMA 11 S but for SMA 8 TM it was again at the lowest value – 9.63% after 50 frost-thaw cycles.

As indicated above, a higher air void content in the mixture leads to a better sound absorption, the testing results confirmed that dependence (Fig. 10). Very high sound absorption was determined for PA 8 mixture – in the 700–1200 Hz frequency range sound absorption coefficient is higher than 0.4 and in the 800–950 Hz frequency range it is higher than 0.8. SMA 8 TM has higher sound absorption in whole tested frequency range (300–2000 Hz) than SMA 5 TM and SMA 11 S mixtures – sound absorption coefficient is between 0.1 and 0.25. At the lower frequencies (350–550 Hz) it was observed that SMA 8 TM asphalt mixture has the best sound absorption characteristics compared to all the mixtures – sound absorption coefficient 0.2–0.25. The obtained results also confirmed the typical rolling noise spectrum and the frequency range
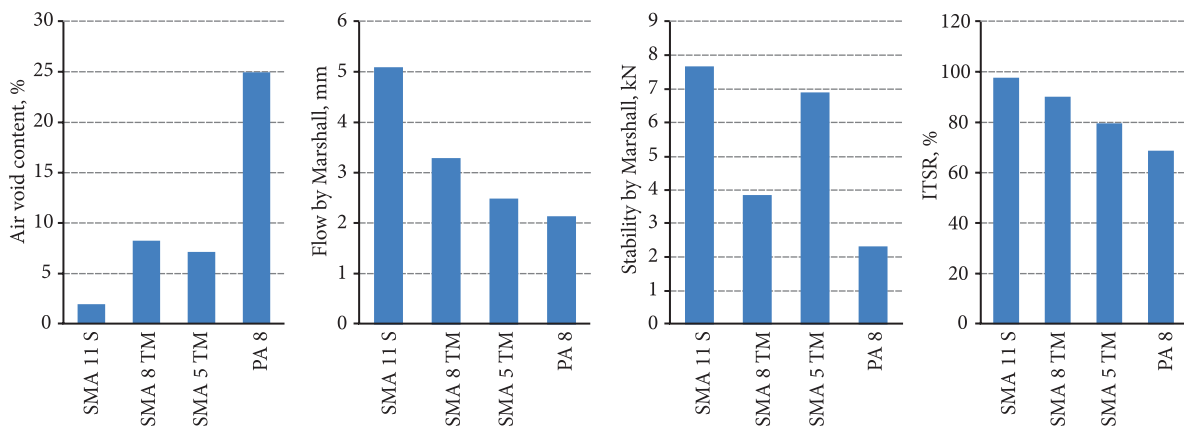

Fig. 7. Mechanical and physical characteristics testing results (from left: air void content; flow by Marshall; stability by Marshall; Indirect Tensile Strength Ratio (ITSR)
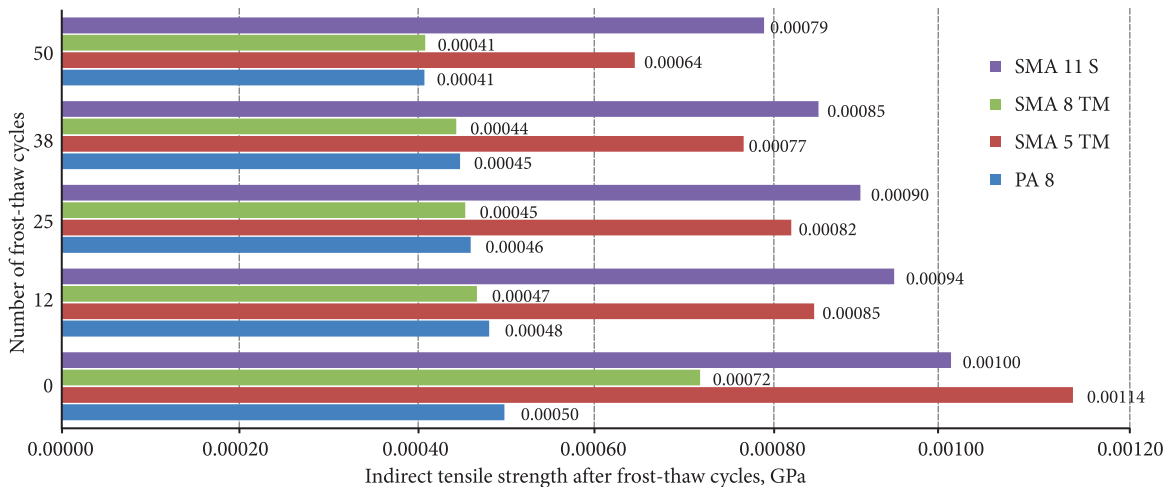

Fig. 8. Testing results of indirect tensile strength after frost-thaw cycles
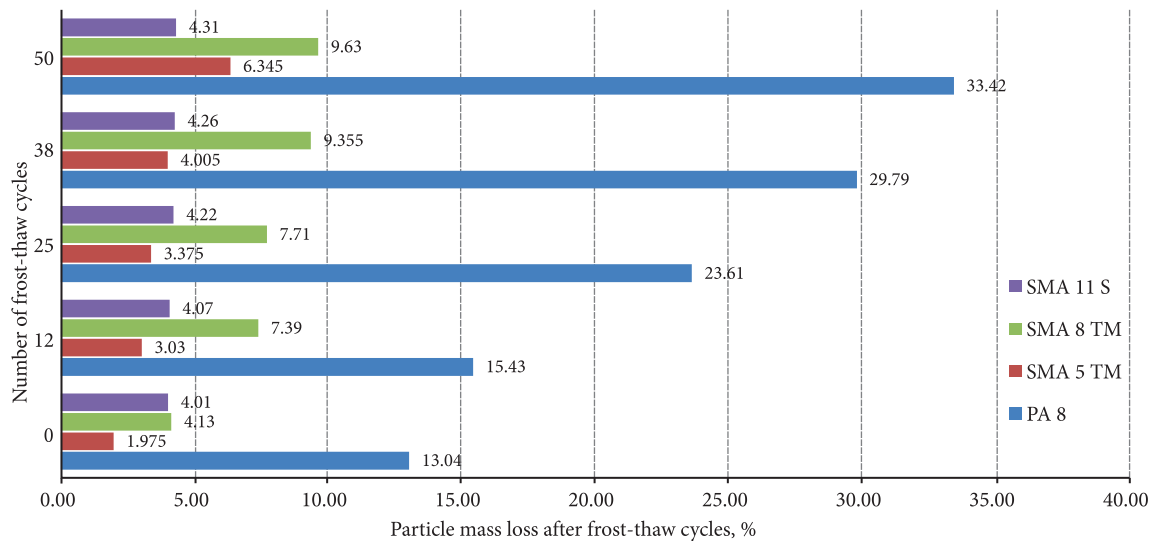
Fig. 9. Testing results of particle mass loss after frost-thaw cycles

of influence of surface texture and absorption, shown in Fig. 5. Porous asphalt mixture PA 8 with high air void content has very good absorption at middle noise spectrum frequencies and fairly good absorption at high frequencies while conceptual asphalt mixture SMA 8 TM with optimised surface texture reduces noise at low frequencies.

Another relevant parameter to assess noise reduction characteristics of asphalt mixture is surface texture. It was found that asphalt mixtures with higher air void content has higher MTD values (Fig. 11). MTD for PA 8 was determined – 6.07 mm and for SMA 8 TM – 2.71 mm. There were also found some evidences of correlation between MTD and sound absorption values. Unfortunately, the correlation was not precisely calculated as the MTD measurement method (sand patch method) has some restrictions and limitations regarding pavements with higher porosities.

5. Recommendations for the use low noise asphalt mixtures and further research

Accomplished laboratory tests and obtained results allow making general recommendations for the application of low noise asphalt mixtures. For purpose to achieve the highest noise reduction porous asphalt pavements, PA 8 would be the most effective solution as its acoustical performance is much higher than other examined asphalt mixtures. From the operational perspective, PA 8 asphalt mixtures have very poor physical and mechanical characteristics what means that the durability and reliability to use these pavements in Lithuanian climate conditions are short term and very limited. For comparison, SMA 5 TM asphalt mixture showed sufficiently good physical and mechanical characteristics as it is similar to reference mixture SMA 11 S. But on the other hand, the noise absorption for SMA 5 TM asphalt mixture is low. Despite the fact that conceptual asphalt mixture SMA 8 TM also has poor mechanical and physical characteristics, but not as bad as PA 8
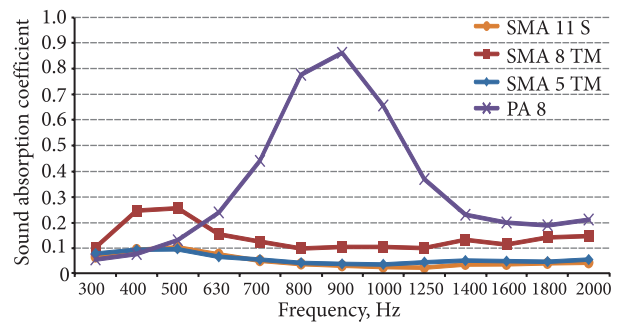

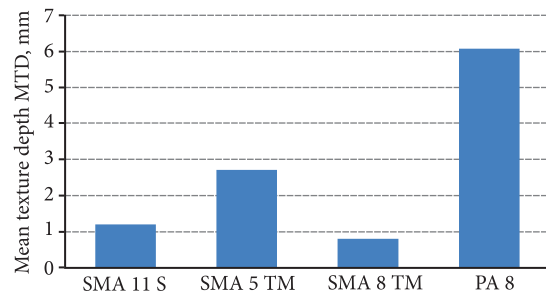**Fig. 10.** Sound absorption coefficient measurement results

Fig. 11. Mean Texture Depth (MTD) measurement results

mixture's, the acoustical noise absorption is comparatively higher than SMA 5 TM and SMA 11 S asphalt mixtures.

To bring more concrete recommendations for the use of conceptual asphalt mixtures, there is a need to assess these mixtures more comprehensively by field operational tests. Implementation of few short test sections with low noise asphalt pavements are intended in 2014. This will allow continuing research and evaluation process of the conceptual asphalt mixtures SMA 5 TM and SMA 8 TM in real life conditions. Asphalt pavement operational parameters such as bearing capacity, deterioration and their sensitivity to traffic loads, flows and climate conditions will be assess in the future research activities.

Acoustical properties will be measured not only from acoustical approach, which is limited because of its inappropriateness to measure vehicle noise generation mechanisms and practical noise reduction. Different noise measurement methods will be applied to assess optimised low noise asphalt pavements' performance of reducing noise emissions induced by tyre vibrations and other noise generation mechanisms, and sound propagation effects above the road surface.

Further research will also help to evaluate cost-effectiveness of conceptual asphalt mixtures as it will be possible to express the noise reduction potential and forecast the possible lifetime and deterioration of such pavements. The cost-effectiveness must also cover and the economic benefits of reduced noise levels in living environment.

6. Conclusions

1. Noise levels of vehicles passing by in urban and suburban living areas are similar to about 61 dBA when comparing noise level graphs of the whole-day time histories. But when comparing graphs of short-time histories, noise level situation in urban and suburban areas is different – constant sound level curve in urban areas and irregular sound level curve in suburban areas. In particular cases noise reduction in suburban areas would be more significant for people because of reduced frequent changes of noise levels after passing vehicles.

2. Asphalt pavements with high porosity and optimised surface texture are the two most commonly used and effective techniques in developing low noise asphalt pavements. They are recommended to be used in a complex way as it gives better result – high noise reduction and sufficient durability. Considering Lithuanian climate conditions, both techniques were used in developing low noise asphalt pavements SMA 5 TM and SMA 8 TM.

3. Laboratory testing methods were selected with purpose to compare physical, mechanical, acoustical, and durability characteristics of conceptual asphalt mixtures SMA 5 TM and SMA 8 TM with the reference asphalt mixture SMA 11 S and porous asphalt mixture PA 8. Modern methodology of durability testing, indirect tensile strength and particle mass losses determination before, after and between the frost-thaw cycles, were applied and used. Noise reduction characteristics at this stage were assessed only by sound absorption and mean texture depth measurement results.

4. Laboratory testing results have confirmed the tendencies that asphalt mixtures with high porosity (PA 8) significantly absorb noise at 700–1200 Hz frequency range and maintains good absorption at higher frequencies while the asphalt mixtures with optimised surface texture (SMA 8 TM) act good in reducing noise at low frequency range (350–550 Hz). Full assessment of noise reduction potential for each conceptual mixture will be done in the future by performing specifically tyre/road and/or whole traffic noise measurements on site.

5. Asphalt mixtures' durability testing provided results which show that SMA 5 TM asphalt mixtures has the closest indirect tensile strength and particle mass loss after the frost-thaw cycles to reference asphalt mixture SMA 11 S while other conceptual asphalt mixture SMA 8 TM has very poor indirect tensile strength (similar to PA 8 asphalt mixture) and quite large particle mass losses – 9.63% after 50 frost-thaw cycles while reference SMA 11 S – 4.31%, SMA 5 TM – 6.35%, though not so extremely high as PA 8 – 33.42%.

6. Concerning the research and laboratory testing results, the conceptual low noise asphalt mixtures SMA 5 TM and SMA 8 TM are ready to be introduced in real road test sections to continue investigation of these mixtures appropriateness and potential to reduce tyre/road noise. From laboratory testing perspective, SMA 8 TM asphalt mixture has respectable sound absorption properties and expected to be more effective for noise reduction purposes than SMA 5 TM asphalt mixture. However, from the durability and mechanical point of view, SMA 5 TM asphalt mixture has better characteristics and is expected to have longer lifecycle than SMA 8 TM asphalt mixture.

7. To obtain more detailed and precise information of the low noise asphalt mixtures additional measurements and research in real road conditions need to be carried out.

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