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VEHICLE/ROAD NOISE AS ONE OF THE FACTORS DETERMINING THE LEVEL OF TRAFFIC NOISE IN THE VICINITY OF ROADS

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Abstract

Road surfaces have a significant impact on the vehicle/road noise which is important in terms of environmental noise levels. Research into vehicle/road noise using Statistical Pass-By method (SPB), conducted by a research team from the Bialystok University of Technology, have shown that the technologies used to construct the wearing course of pavements differ significantly in terms of the maximum sound pressure level emitted by a passing cars. The noisiest solutions in the asphalt pavements include asphalt layers with a maximum aggregate size of over 11 mm. It has been established that thin BBTM8 asphalt layers are a very advantageous solution. Their advantage is also greater acoustic durability compared to porous asphalt layers. The research confirmed that SMA8 LA wearing courses are a better solution than SMA11 pavements. In the case of cement concrete pavements, the following methods proved to be very good techniques for texturing their surface: exposed aggregate and grooving/griding. Spectral analysis of emitted sound pressure levels was used to determine the causes of differences in pavement noisiness depending on the type of road surface and its characteristics. The paper shows that using the CNOSSOS-EU method and the SoundPLAN program, it is possible to compare the impact of selected types of road surfaces on noise levels in the vicinity of roads.

Keywords: vehicle/road noise, SPB method, CNOSSOS-EU, road traffic noise prediction

1 Introduction

One of the main sources of noise pollution in the environment is traffic noise. It has a significant impact on the daily activities, well-being and even the mental health of people living near busy roads. The solutions currently used to improve the acoustic environment along roads are not always sufficient. Research confirms that measures which reduce noise at source deliver the best results. One of these solutions is the construction of low-noise or quiet road surfaces. Research into road surfaces that reduce vehicle/road noise has been the subject of numerous research projects including, among others: SI.R.U.US, QCITY, HARMONOISE, IMAGINE, SILVIA, SILENCE, ROSANNE, PERSUADE, also including projects carried out at the Bialystok University of Technology, such as SEPOR, INREH and others, the results of which are described in [1]. Understanding the acoustic characteristics of road surfaces in connection with traffic characteristics is essential for predicting noise levels in the vicinity of roads in accordance with the CNOSSOS-EU (Common noise assessment methods), which is a main method currently in use across Europe [2]. The CNOSSOS-EU method is a standard established by Directive 2015/996/EC of 19 May 2015 [3] for EU member states, in accordance with the provisions of the Environmental Noise Directive (END, 2002/49/EC) [4].

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Due to the fact that road surfaces vary in terms of their acoustic properties, Annex II to the END Directive (updated by Directive 2021/1226/EC [5] of 21 December 2020) provides road surface correction coefficients for the CNOSSOS-EU method which account the influence of road surfaces on noise emission levels for 14 types of surface based on Dutch solutions. Since various road surface construction technologies are used across Europe, which often differ from those specified in Annex II of the END Directive, some countries are working on developing their own national correction coefficients accounting for the influence of road surfaces on vehicle/road noise levels for use in the CNOSSOS-EU method, partly due to changes in the vehicle fleet (a higher proportion of electric vehicles on the roads, newer developments in engines, propulsion systems and tires). In view of the above, as part of the research project 'INREH – Innovative methods for reducing road noise and principles for their application', carried out between 2023 and 2026, a research team from the Bialystok University of Technology carried out measurements of the tire/road noise levels of passing vehicles using the Statistical Pass-by Method (SPB) across a total of 26 test sections with road surfaces differing in construction technology. The results of this research formed the basis for the development of noise emission correction coefficients for road surfaces used in Poland for application in the CNOSSOS-EU. The article presents the results of research into road surface noise in Poland and a comparison of the results of equivalent sound pressure level calculations using the CNOSSOS-EU method in the SoundPLAN software, applying the developed road surface correction coefficients for SMA11, BBTM8 and EAC8 with the results of field measurements of noise levels in the vicinity of roads with these types of surface.

2 Tests on the vehicle/road noise

2.1 Statistical pass-by method – the assumptions of the research method

Statistical Pass-by method (SPB), in accordance with ISO 11819-1:2023 [6], is based on measuring the maximum sound pressure level L_{Amax} from the passage of a sufficient number of individual vehicles travelling freely at a constant speed of over 45 km/h, together with simultaneous measurement of their speed V (figure 1). Measurements are carried out at a distance of 7.5 m from the centreline of the traffic lane on which the test vehicles are travelling, at a height of 1.2 m above the road surface. The maximum sound pressure level L_{Amax} is determined for the passage of three categories of vehicles: passenger cars (P), dual-axle heavy vehicles (H2) and multi-axle heavy vehicles (H3+). The measurement results form the basis for determining regression relationships:

$$L_{Amax,\,m} = A + B \cdot \log\,(V_m) \qquad (1)$$

where:

- $L_{Amax,\,m}$ [dB] – maximum sound pressure level from the passage of a category m vehicle
- A, B – the constants in the linear regression equation
- V_m [km/h] – speed of a category m vehicle.

These relationships make it possible to determine the average maximum sound pressure level from the passage of a statistical vehicle of category m at the appropriate reference speed for the tested road surface.

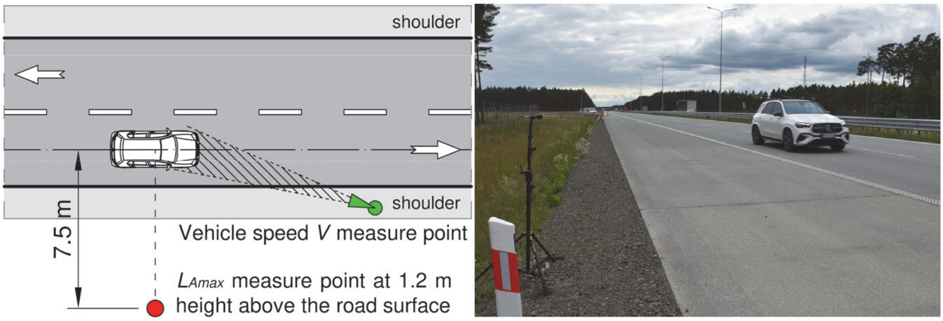

Figure 1 Measurements of vehicle pass-by noise by SPB method

As a part of the research carried out using the SPB method, measurements were taken at 26 road sections with specified test cross-sections in Poland:

- on asphalt surfaces: • 3 sections of asphalt concrete (AC11); • 4 sections of stone mastic asphalt with a maximum grain size 11 mm (SMA11); • 2 sections of SMA with a maximum grain size 8 mm (SMA8); • 2 sections of stone mastic asphalt with reduced noisiness (SMA8 LA – ger. Stone Mastic Asphalt Lärmarmer); • 3 sections of asphalt concrete for very thin layers (BBTM8 – fr. Béton Bitumineuse Très Mince).
- on cement concrete surfaces: • 8 sections of exposed aggregate concrete (EAC8); • 2 sections of cement concrete textured by burlap drag (CC-BuD); · 2 sections of cement concrete textured by grooving/grinding method (G&G).

2.2 Research results

Based on SPB measurement data, in accordance with the ISO 11819-1:2023, regression relationships were established between maximum sound pressure levels and the logarithm of the speed of single vehicles. Figure 2 shows example results of L_{Amax} measurements at three test sections for the SMA11, BBTM8 and EAC8 pavements, as well as the corresponding L_{Amax} frequency spectra determined at V = 110 km/h and 85 km/h for the passage of a statistical passenger car (P) and a multi-axle heavy vehicle (H3+), respectively. These results indicate that the SMA11 and EAC8 pavements are similar in terms of noise levels, while the BBTM8 pavement is a significantly quieter option.

Table 1 presents the L_{Amax} values determined for the tested surfaces from the passage of a statistical passenger car (P) travelling at 110 km/h and a multi-axle heavy vehicle (H3+) travelling at 85 km/h, with the maximum differences (ΔL_{Amax}) within the same surface technology. The results show that the technologies used in Poland for constructing the wearing course of road surfaces differ in terms of the maximum sound pressure level emitted by a passenger car travelling at 110 km/h by as much as 12.8 dB. In the case of a multi-axle heavy vehicle travelling at 85 km/h, this difference is 7 dB. SMA11 pavements are one of the most noisy solutions among the tested asphalt road surfaces. It has been established that thin BBTM8 asphalt layers are a highly effective solution in terms of noise reduction. Another advantage is their greater acoustic durability compared to a porous asphalt layer [1]. In the case of cement concrete pavements, exposed aggregate (EAC8) and grooving/grinding (G&G) methods have proved to be very effective surface texturing techniques in terms of noise reduction.

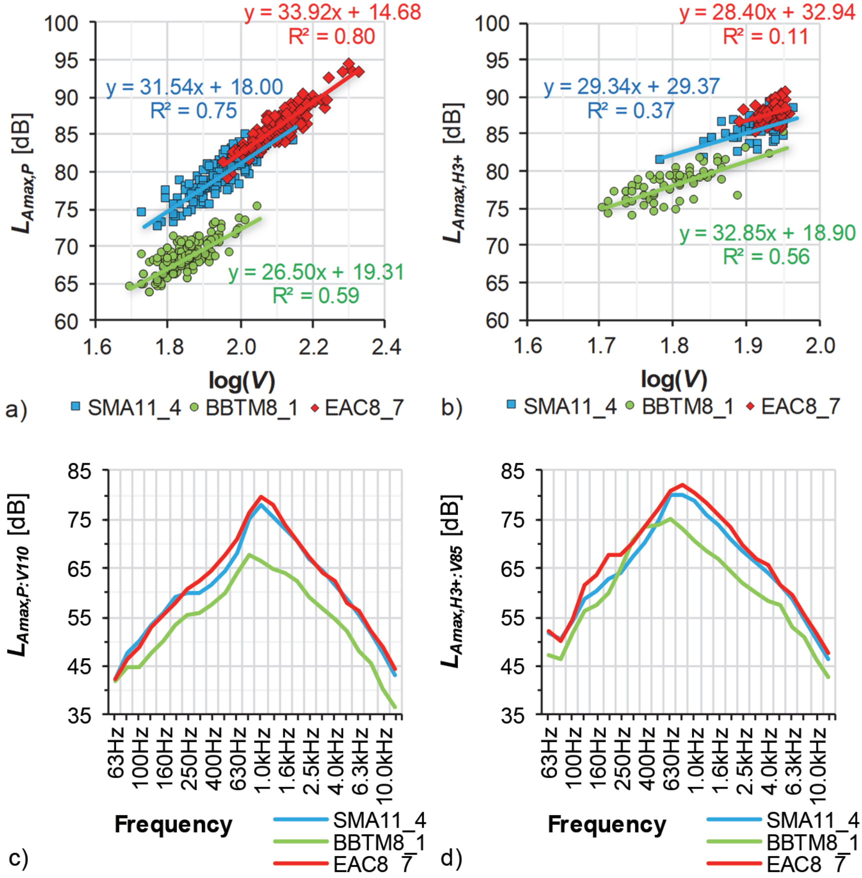

Figure 2 L_{Amax} values from passing cars P (a) and H3+ (b) with its frequency spectra (c, d) for the sample sections of SMA11, BBTM8 and EAC8

According to the analysis of the values presented in table 1, for some test sections with pavements constructed using the same technology, the differences between L_{Amax} levels are minor, whereas for other technologies, relatively large differences were observed – the greatest being on BBTM8, SMA8 LA, EAC8 and G&G. This difference was influenced by the method of constructing the wearing course and the macrotexture of the road surface; for example for the EAC8 surface in two test sections with macrotexture values of MPD (Mean Profile Depth) = 0.74 mm and 1.57 mm a difference of 4.1 dB was observed between the tyre/road noise levels of a passenger car. A detailed analysis of road surface noise in Poland, together with a spectral analysis of the emitted sound levels is presented in [7, 8]. The obtained measurement data formed the basis for calculating the road surface correction coefficients $a_{i,m}$ and $\beta_{i,m}$ in the octave bands (i = 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz), which correct the impact of the eight types of tested road surface on tire/road noise emission, in accordance with the procedure described in [9].

Table 1 L_{Amax} values from passing vehicles P and H3+ at V = 110 / 85 km/h

Asphalt technol.	No.	L_{Amax} [dB]				Cement concrete technol.	No.	L_{Amax} [dB]			
		P:V110	Δ	H3+:V85	Δ			P:V110	Δ	H3+:V85	Δ
AC11	1	79.5	2.4	84.0	2.0	G&G	1	84.6	2.3	88.3	2.7
	2	80.9		86.0			2	82.3		85.6	
	3	78.5		-		CC-BuD	1	83.0	0.4	89.7	0.7
SMA11	1	83.0	0.7	86.7	1.9		2	82.6		89.0	
	2	83.0		87.9		EAC8	1	84.6	4.5	88.5	2.8
	3	82.7		87.3			2	84.3		87.7	
	4	82.3		86.0			3	86.7		89.0	
SMA8 LA	1	81.6	2.8	86.0	2.5		4	83.5		87.4	
	2	78.8		83.5			5	82.6		88.0	
SMA8	1	81.4	0.7	85.9	1.1		6	84.1		87.3	
	2	80.7		84.8			7	84.2		87.8	
BBTM8	1	73.9	3.1	83.0	0.8		8	82.2		86.2	
	2	77.0		82.7							
	3	76.5		83.5							

3 Maximum noise pressure level from passing vehicles in calculations using the CNOSSOS-EU method

The calculations were carried out in the SoundPLAN software using CNOSSOS-EU emission and propagation models, applying the developed sound emission correction coefficients for three sample road surfaces: SMA11, BBTM8 and EAC8. In the first stage of the analysis, a comparison was made between the results of the $L_{Aeq}^{calc.}$ calculations and the equivalent sound pressure level $L_{Aeq}^{measur.}$ obtained from hourly field measurements in the vicinity of roads with three types of analyzed road surfaces. Vehicle traffic data and road geometry corresponding to the site conditions were incorporated into the calculations.

$L_{Aeq}^{measur.}$ measurements were carried out in all three cases in the vicinity of dual-carriageway roads with two lanes in each direction (2/2). In the case of SMA11 and EAC8 surfaces, the situation involved expressways outside built-up areas with a speed limit of V = 120 km/h, featuring a 12 m wide central reservation and two carriageways, each 9.5 m wide (2 x 3.5 m traffic lanes + 2.5 m emergency hard shoulder). In the case of the BBTM8 surface, the situation involved an urban road with a speed limit of V = 70 km/h, featuring a 3 m wide central reservation and two carriageways, each 7 m wide (2 x 3.5 m traffic lanes). The $L_{Aeq}^{measur.}$ measurement was taken at points located 7.5 m from the centreline of the outermost traffic lane (P1) and 10 m from the edge of that lane (P2), each at a height of 4 m above the carriageway level. The traffic volume of individual vehicle types and their speeds were measured simultaneously with the sound level measurements using radar detectors. Table 2 presents the detailed results of the field measurements. Figure 3 shows a comparison of the calculation results with field data.

Table 2 Results of field measurements of noise and traffic (m = vehicle cat.)

No.	Road surface type	Traffic on the carriageway [P/h]								$V_{avg.}$ [km/h]		$L_{Aeq}^{measur.}$ [dB] at the point	
		closest to the measurement points				farther from the measurement points							
		m = 1	2	3	4	1	2	3	4	m = 1	2+3	P1	P2
1	SMA11	384	24	128	4	332	4	68	0	125, 1	86, 8	76, 7	75, 5
2	BBTM8	456	8	52	0	344	12	44	0	73, 5	66, 3	68, 0	65, 7
3	EAC8	564	12	120	0	684	16	132	0	123, 4	88, 0	78, 6	77, 6

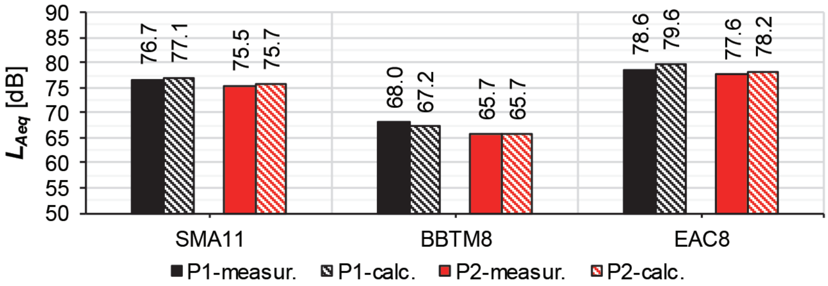

Figure 3 Comparison of the calculation results $L_{Aeq}^{calc.}$ with field data $L_{Aeq}^{measur.}$

Based on the obtained results, it was found that the differences between the predicted $L_{Aeq}^{calc.}$ values calculated using established correction coefficients for the influence of road surface on sound emission levels and the $L_{Aeq}^{measur.}$ values from field measurements do not exceed ±1 dB, which is less than the measurement error. This confirms the accuracy of the sound emission correction coefficients developed for SMA11, BBTM8 and EAC8 road surfaces. In order to demonstrate the impact of the three types of analyzed road surfaces on noise levels in the vicinity of roads, another calculations were carried out in the SoundPLAN software for a case of single-carriageway two-lane road (1/2), assuming identical traffic data for each analyzed surface type: traffic volume 1200 P/h (80% for vehicle category m = 1; 5% for m = 2 and 15% for m = 3); average vehicle speed: V = 90 km/h for m = 1, and V = 80 km/h for m = 2 and 3. The results of the calculations are presented graphically in figure 4. Obtained values indicate that the BBTM8 surface is a better solution in terms of its impact on the acoustic environment of the road surroundings – based on the assumed data, noise levels for this surface were approximately 5 dB lower than for the SMA11 and EAC8 surfaces. The SMA11 and EAC8 pavements affect noise levels in the road environment to a similar extent.

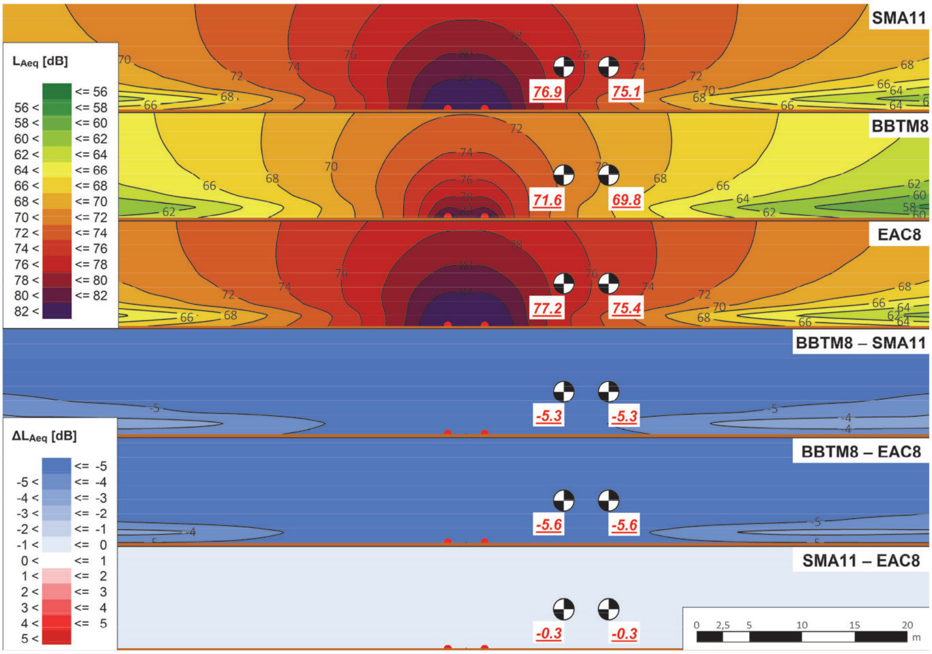

Figure 4 Comparison of the impact of the three types of analyzed road surface on noise levels in the vicinity of the road

4 Conclusion

The conducted research and analyses have led to the following conclusions:

- The technologies used to construct the wearing course of road surfaces vary significantly in terms of the maximum noise pressure levels emitted by passing vehicles. Significant differences have also been confirmed within the same construction technologies.
- The road surface correction coefficients, developed on the basis of SPB test results, which account the impact of road surface on the vehicle/road noise emissions relative to a reference surface, enable the determination of the impact of the road surface on the equivalent sound pressure level in the vicinity of road routes using the CNOSSOS-EU method.
- Noise level calculations using the CNOSSOS-EU method in SoundPLAN, with the application of road surface correction coefficients developed for SMA11, BBTM8 and EAC8, confirmed consistency with the field test results within ±1 dB.
- The construction of the wearing course using BBTM8 technology proved to be the most advantageous solution in terms of minimizing the negative impact of vehicle traffic on the environment.

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