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CHANGES IN THE ACOUSTIC PROPERTIES OF ROAD POROUS SURFACE WITH TIME

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The low-noise surfaces such as porous asphalt have become more frequently used to reduce traffic noise. This method of noise control may be effective where reductions of the order of a few decibels are required, and may provide a more economic solution compared to other forms of noise control, such as noise barriers. The main disadvantage of the porous pavement is its decreasing acoustic effectiveness over time, caused by dirt blocking the pores on a road surface.

The paper presents the acoustic effectiveness of the two types of porous road pavements after a few years of use.

Keywords: porous pavement, noise reduction.

1. Introduction

There are three major sources of noise in a moving vehicle: a driving system (engine noise), an exhaust system and the interaction of tires and a road surface (rolling noise). The rolling noise dominates at speeds over 60 km/h. The level of the rolling noise depends on the speed and the type of tires, but the tire/road noise is mainly influenced by the road surface characteristics. Apparently the level of noise generated by a vehicle moving on the porous surface is lower than that generated by the same vehicle moving on the conventional asphalt. The porous road pavement has been used for many years because of the advantages it offers: a better drain of water from a road surface, which eliminates the water splash and reduces the glare and spray from a vehicle. It has been shown that porous surfaces reduce the traffic noise. Depending on the type of the porous pavement, the reduction can reach a few decibels [1].

Currently the one- and the two-layer pavements are in use. The one-layer pavement consists of one 2–4 cm thick porous drainage layer. This layer includes about 18–25 percent of voids in the form of pores on the surface. Two-layer pavement consists of two layers: coarse-grained (a top layer) and fine-grained (a bottom layer). The porous pavements offer the noise reduction by a decrease in the rolling noise power and its absorption by the pores [2]. The greater is the number of pores and the bigger they are, the better will be the acoustic effectiveness of the road surface. Unfortunately, it has been shown that the acoustic effectiveness of the porous pavement decreases with time. In Ref. [3] the noise level of pass-by noise increased by 1–2 dB in the first year of use. This is caused by dirt and pollution which penetrate and block the pores. This disadvantage characterizes mainly the one-layer porous pavement. The characteristics of a two-layer pavement is less changed by dirt and pollution. This kind of road pavement has the self-cleaning properties.

The purpose of this paper is to determine changes in the acoustic properties of the one-layer porous road pavement after a few years of use.

2. Acoustic effectiveness of porous pavement

The main problem with the road porous pavement is a decrease in its acoustic effectiveness with time due to the effect of dirt and pollution. The acoustic effectiveness of a one-layer pavement road disappears after 2–3 years of use [4]. To avoid degradation in the acoustic effectiveness, the porous pavement should be cleaned (by water [3, 5] or air under high pressure [6]). Such procedures would allow preservation of the reduction properties of the porous pavement over a long time. A few methods have been proposed to estimate acoustical effectiveness of the road porous pavement [7], among them the European standard method ISO 11819-1 [8]. According to this standard, before and after the deposition of the road porous pavement, measurements of pass-by maximum sound level $L_{pA\,\max}$ should be made as a function of velocity of the passing vehicles. A similar but not equivalent method is reported in Ref. [9]. In the present study, acoustic effectiveness of the road porous pavement is determined on the basis of the effective sound power level $\widetilde{L}_{WA}$ of moving vehicles (Eq. (19) – Appendix A). To determine $\widetilde{L}_{WA}$, the measurements of the sound exposure level L_{AE} of single pass-by noise must be performed.

The measurements of L_{AE} and the calculation of $\widetilde{L}_{WA}$ as a function of the vehicles velocity (before, just after, and a few years after replacement of the road surface) allow estimation of the acoustic properties of the new porous pavement and changes in its effectiveness over time.

3. Field measurements

The measurements were performed at two streets in Poznań. In the first street the studies were carried out four times: in 2000, when it was covered with old conventional pavement, then directly after deposition of new porous pavement, in 2003 and 2006, that is three and six years after its deposition (Pavement A, wearing course 0/8 mm, thickness 4 mm). At the second one (Pavement B, wearing course 0/8 mm, thickness

5 mm), the noise level was measured three times: in 2004 when it was covered with old conventional asphalt and then directly after deposition of new porous asphalt, and in 2006 – two years after the replacement of the pavement.

Pavement A

The sound exposure level was measured in the 1/3 octave band for a single pass-by noise. In 2000 the noise measurements of light and heavy vehicles (from the traffic flow) were performed. Seven cars (experimental cars) were selected for the measurements (in 2000): Daewoo Lanos, Fiat Uno, Fiat Cinquecento, Fiat 126 P, Opel Corsa, Renault Clio, and Toyota Corolla. After the pavement replacement, only Fiat 126 P did not take part in the measurements but the noise it produced did not change the mean value of the noise level of this group of vehicles. After the measurements we had to check the noise level of experimental cars and vehicles from the normal traffic flow (see Appendix B).

The cars were moving at three velocities close to: V = 20, 40 and 60 km/h. Each pass-by measurement was repeated three times under the same driving conditions. To compare the mean sound exposure level L_{AE} of the experimental cars with L_{AE} representative of a normal traffic flow, the measurements of the equivalent continuous A-weighted sound pressure level L_{AeqT} were performed. Over the time period T, the mean flow speed and the traffic flow intensity were measured (see Appendix B). The L_{AeqT} measurements were carried out a few days before and after the replacement of the road pavement at the same site of measurement. In 2003 and 2006, the L_{AE} measurements were carried out for the vehicles from a normal traffic flow. The measurements were performed in evenings and at nights.

Pavement B

The measurements of the sound exposure level L_{AE} were performed for the vehicles from a normal traffic flow (in evenings and at nights).

The observation points were located at the distance $D = 7.5$ m from the centre of the closest lane, with a microphone located at the height $H_o = 1.2$ m above the ground. In the measurements we used two sound level meters (Brüel&Kjær type 2231 and SVAN 945) and the two-channel real-time frequency analyzer Brüel&Kjær type 2144 (with two microphones B&K 4165). The radar speed meter (RAPID 1) was used to measure the velocity of vehicles.

4. Results

4.1. Change in the acoustic effectiveness of porous pavement with time (for light vehicles)

From the sound exposure level L_{AE} of a single drive-by noise of light vehicles, the level of the effective sound power $\widetilde{L}_{WA}$ was estimated (Eq. (19)) (for both pavements).

In all cases the regression line was fit using the following formula:

$$\widetilde{L}_{WA}(V) = A \cdot \log_{10}(V/V_o) + B, \quad V_o = 1 \text{ km/h}, \tag{1}$$

where A and B are the regression coefficients.

Pavement A

The values of $\widetilde{L}_{WA}$ (old dense asphalt and new porous asphalt) were obtained using the procedure described in Appendix B. This procedure allows a comparison of the noise generated by the experimental vehicles and vehicles from the traffic flow. The calculations have shown that the light vehicles from the traffic flow produced noise greater than the experimental vehicles by 3.0 dB and 1.5 dB on the conventional asphalt and the new porous pavement, respectively.

The effective sound power level of light vehicles on dense asphalt and porous asphalt (new, three- and six-year old) is presented in Fig. 1.

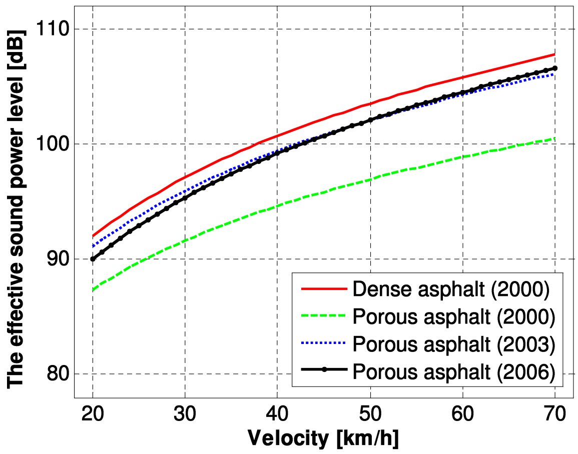

Fig. 1. The effective sound power level $\widetilde{L}_{WA}$ versus vehicle speed V on conventional asphalt, new porous asphalt and porous asphalt after three and six years of use (Pavement A).

The acoustic effectiveness for light vehicles (subscript l) was calculated as a difference between the effective sound power level $\widetilde{L}_{WA}$ on the old conventional asphalt (superscript "conv") and $\widetilde{L}_{WA}$ on the porous pavement (superscript "por"):

$$\Delta L_{WA,l}^{\text{por},2000} = \widetilde{L}_{WA,l}^{\text{conv}}(V) - \widetilde{L}_{WA,l}^{\text{por},2000}(V) \quad \text{– new porous pavement,} \tag{2}$$

$$\Delta L_{WA,l}^{\text{por},2003} = \widetilde{L}_{WA,l}^{\text{conv}}(V) - \widetilde{L}_{WA,l}^{\text{por},2003}(V) \quad \text{– three years old porous pavement,} \tag{3}$$

$$\Delta L_{WA,l}^{\text{por},2006} = \widetilde{L}_{WA,l}^{\text{conv}}(V) - \widetilde{L}_{WA,l}^{\text{por},2006}(V) \quad \text{– six years old porous pavement.} \tag{4}$$

The results obtained are presented in Fig. 2. As it can be seen, the acoustic effectiveness of the new porous pavement (in 2000) was 6.6 dB (at 50 km/h). Three years later (in 2003) the acoustic effectiveness decreased to 1.5 dB and six years after the pavement's replacement it was 1.4 dB, as a result of dirt and pollution effect (the road section under consideration was not cleaned).

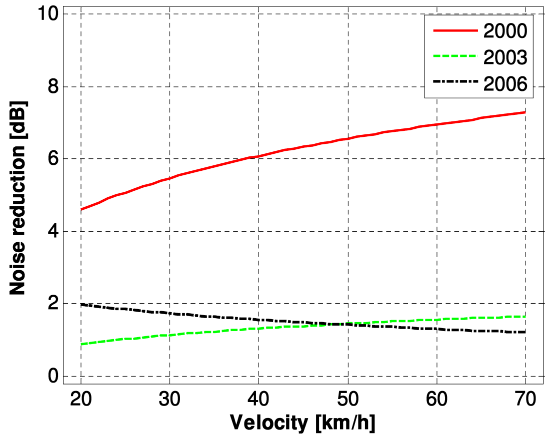

Fig. 2. The decrease in the acoustic effectiveness of the porous pavement (Pavement A).

Very similar results were reported in Ref. [3, 10]. In Ref. [3] the noise level measurements of the vehicles (on three types of porous pavements) were carried out for new pavements and for one year old ones. In Ref. [10] the noise level of vehicles was measured just after the construction and four years later. In both cases the measurements were based on the ISO 11819-1 [8]. The results of the noise level measurements one year after the construction of the pavement show that the noise level increased from 1.4 to 2.2 dB (depending on the pavement) when compared to the reference pavement (dense asphalt). The noise level of the vehicles on the four-year old porous pavement was higher by a few decibels. The decrease in the noise reduction was mainly due to clogging of pores.

The spectra of the referenced effective sound power level (the difference between the effective sound power level in n-th frequency band and the overall A-weighted effective sound power level $\widetilde{L}_{WA}$) of light vehicles are presented in Figs. 3–5. The spectra obtained for the old conventional asphalt (in 2000) for three velocities practically do not differ. The new porous pavement in 2000 reduces the noise of the moving vehicle for frequency above 2000 Hz (Fig. 4). The noise reduction increases with the vehicles velocity. The spectra presented in Fig. 5 show that three years after the replacement, the absorbing properties of the porous pavement are definitely poorer. The spectra of the effective sound power level are very similar. Because the total sound exposure level was measured six years after the replacement of the road pavement, so Figs. 3–5 do not include the spectra of the referenced effective sound power level for vehicles from this year (2006).

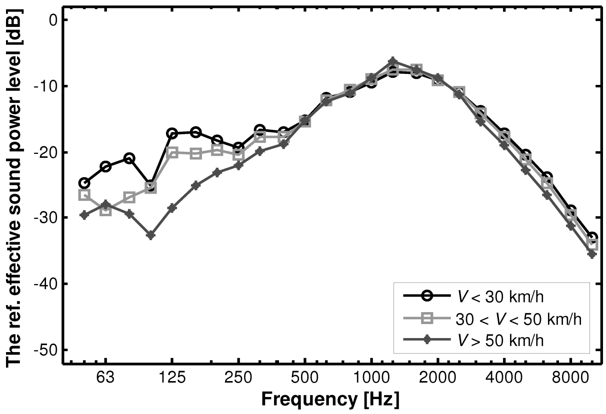

Fig. 3. The referenced level of the effective sound power on conventional asphalt (2000, Pavement A).

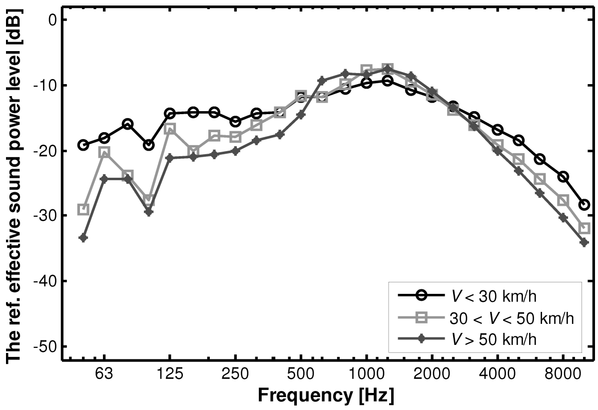

Fig. 4. The referenced level of the effective sound power on new porous pavement (2000, Pavement A).

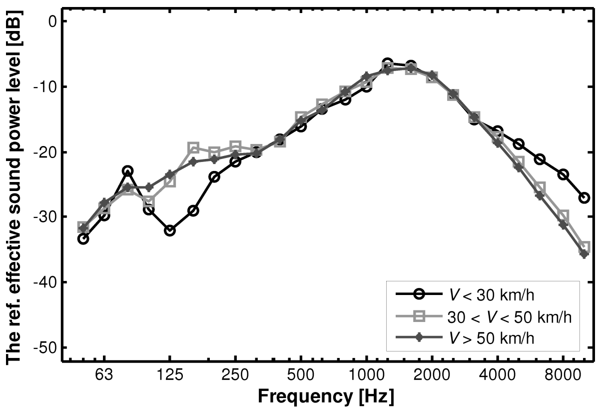

Fig. 5. The referenced level of the effective sound power on porous pavement after three years of use (2003, Pavement A).

Table 1. The regression and the correlation coefficients (Pavement A).

	The regression coefficients		The correlation coefficient	The number of vehicles measured
	A	*B*		
Conventional asphalt (2000)	29.0	54.2	0.94	68
Porous pavement (2000)	24.1	56.1	0.95	54
Porous pavement (2003)	27.6	55.2	0.82	84
Porous pavement (2006)	30.6	50.4	0.96	70

Pavement B

The noise reduction (the difference in the effective sound power level on the dense and porous asphalt) of the new porous pavement (at 50 km/h) was 5.2 dB. After two years the noise reduction was -0.7 dB. The results show disappearance of the noise reduction after two years of use.

4.2. The acoustic effectiveness of porous pavement for heavy vehicles

The measurements of the noise produced by heavy vehicles were performed before and just after the replacement of the road pavement (Pavement A). Unfortunately, the noise level produced by moving heavy vehicles on old dense asphalt and new porous pavement is the same. The lack of the acoustic effectiveness of the porous pavement for these vehicles is very difficult to explain. Presumably it is caused by the fact that different types of heavy vehicles (e.g. buses, trucks, lorries) took part in the experiment. Before and just after the replacement of the road pavement, the measurements were performed for a few dozen of heavy vehicles and different type vehicles participated in

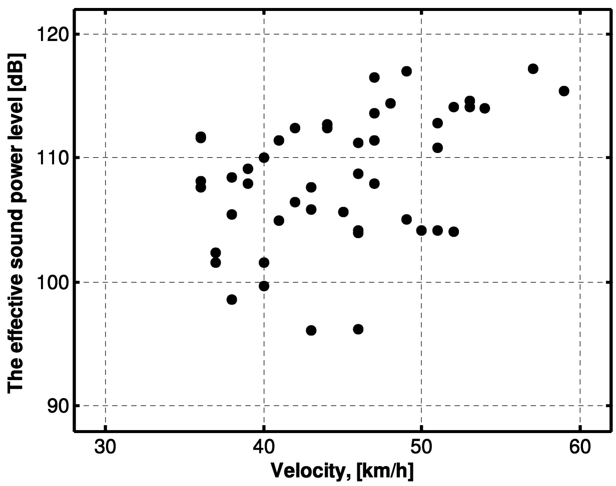

Fig. 6. The effective sound power level $\widetilde{L}_{WA}$ of heavy vehicles versus vehicle speed V on conventional asphalt.

each measurement. For this reason a large scatter of the effective sound power level was obtained. As an example, the results obtained before the replacement of the pavement are presented in Fig. 6. The standard deviation was 5.4 dB – before and 2.8 dB – after the replacement. The mean effective sound power level of the heavy vehicles on the dense asphalt, at $V = 50$ km/h, was 110.4 dB and on the porous asphalt it was 110.1 dB.

5. Changes in the equivalent continuous A-weighted sound level

The changes in the equivalent continuous A-weighted sound pressure level after the replacement of the road pavement depend on:

- the acoustic effectiveness of a road pavement for light and heavy vehicles,
- the number of light and heavy vehicles before and after the replacement of the pavement.

This section presents the example of the change in the equivalent continuous A-weighted sound level caused by the replacement of the road pavement. In the calculations, the results of the effective sound power level of light and heavy vehicles on the old dense asphalt, new and three years old porous pavement were used.

In Appendix A the method of traffic noise prediction is described. The equivalent continuous A-weighted sound level for a day period can be written in the following form:

$$L_{\text{day}} = 10 \log \left(\frac{s_o}{4VDT_{\text{day}}} \left(N_{\text{day},l} \cdot 10^{0.1 \cdot \widetilde{L}_{WA,l}} + N_{\text{day},h} \cdot 10^{0.1 \cdot \widetilde{L}_{WA,h}} \right) \right), \qquad (5)$$

where $\widetilde{L}_{WA,l}$ and $\widetilde{L}_{WA,h}$ is the effective sound power level of light and heavy vehicles, respectively.

Assuming that the mean speed of the traffic flow before and after the replacement of the pavement is the same, the change in the L_{day} (just after the replacement of the pavement) can be calculated from

$$\begin{aligned} \Delta L^{2000}_{\text{day}} &= L^{\text{conv}}_{\text{day}} - L^{\text{por},2000}_{\text{day}} \\ &= 10 \log \left(\frac{N^{\text{conv}}_{\text{day},l} + N^{\text{conv}}_{\text{day},h} \cdot A}{N^{\text{por},2000}_{\text{day},l} \cdot 10^{-0.1 \cdot \Delta \widetilde{L}^{2000}_{WA,l}} + N^{\text{por},2000}_{\text{day},h} \cdot A} \right), \end{aligned} \qquad (6)$$

where $N^{\text{conv}}_{\text{day},l}$ and $N^{\text{conv}}_{\text{day},h}$ denote the number of light and heavy vehicles on the conventional asphalt, $N^{\text{por},2000}_{\text{day},l}$ and $N^{\text{por},2000}_{\text{day},h}$ – the number of light and heavy vehicles on a new porous pavement, and $\Delta \widetilde{L}^{2000}_{WA,l}$ is the acoustic effectiveness of new porous pavement for light vehicles. The quantity A in Eq. (6) describes the difference of the effective sound power level between light and heavy vehicles on the conventional asphalt:

$$A = 10^{0.1 \cdot \left(\widetilde{L}^{\text{conv}}_{WA,h} - \widetilde{L}^{\text{conv}}_{WA,l} \right)}. \qquad (7)$$

Equation (6) can be rewritten in the following form:

$$\Delta L_{\text{day}}^{2000} = 10\log\left(\frac{N_{\text{day},l}^{\text{conv}}}{N_{\text{day},l}^{\text{por},2000}}\right) + 10\log\left(\frac{1+\dfrac{n^{\text{conv}}}{1-n^{\text{conv}}}\cdot A}{10^{-0.1\cdot\Delta\widetilde{L}_{WA}^{\text{light}}} + \dfrac{n^{\text{por},2000}}{1-n^{\text{por},2000}}\cdot A}\right), \quad (8)$$

where

$$n^{\text{conv}} = \frac{N_{\text{day},h}^{\text{conv}}}{N_{\text{day},h}^{\text{conv}} + N_{\text{day},l}^{\text{conv}}} \quad (9)$$

is the percentage of heavy vehicles in the global traffic flow on the conventional asphalt, and

$$n^{\text{por},2000} = \frac{N_{\text{day},h}^{\text{por},2000}}{N_{\text{day},h}^{\text{por},2000} + N_{\text{day},l}^{\text{por},2000}} \quad (10)$$

is the percentage of heavy vehicles in the global traffic flow on the new porous asphalt.

The change in the L_{day} in 2003 was calculated from the formula

$$\Delta L_{\text{day}}^{2003} = 10\log\left(\frac{N_{\text{day},l}^{\text{conv}} + N_{\text{day},h}^{\text{conv}}\cdot A}{N_{\text{day},l}^{\text{por},2003}\cdot 10^{-0.1\cdot\Delta\widetilde{L}_{WA,l}^{2003}} + N_{\text{day},h}^{\text{por},2003}\cdot A}\right), \quad (11)$$

where $N_{\text{day},l}^{\text{por},2003}$ and $N_{\text{day},h}^{\text{por},2003}$ denote the number of light and heavy vehicles on the porous pavement (in 2003) and $\Delta\widetilde{L}_{WA,l}^{2000}$ is the acoustic effectiveness of the porous pavement for light vehicles after three years of use.

The difference in the effective sound power level between light and heavy vehicles on the conventional asphalt is 7.1 dB (at V = 50 km/h) and A is 5.2. The results of the calculations are presented in Table 2. As it can be seen, the percentage of heavy vehicles in the global traffic flow on the conventional and porous asphalt determines the change in L_{AeqT} after the pavement replacement (in 2000 and 2003). If the percentage of heavy vehicles after the replacement of the road pavement increases, the difference $\Delta L_{\text{day}}^{2000}$ and $\Delta L_{\text{day}}^{2003}$ decreases.

Table 2. Changes in L_{AeqT} for different percent of heavy vehicles in the global traffic flow.

No.	n^{conv} [%]	$n^{\text{por},2000}, n^{\text{por},2003}$ [%]	ΔL_{day}[dB]	
			2000	2003
1	0	0	5.3	1.0
2	4	4	3.8	0.8
3	8	8	2.9	0.7
4	12	0	7.6	3.3
5	12	6	4.4	1.8
6	12	12	2.3	0.6
7	12	24	−0.5	−1.5

6. Conclusions

The main purpose of this study was to determine the acoustic properties of the porous pavements after a few years of use. The measurements of the sound exposure level L_{AE} of individual pass-by noise were carried out on the conventional asphalt, on the new porous pavement and on the porous pavement after a few years of use. Using the L_{AE} values obtained, the effective sound power level $\widetilde{L}_{WA}$ was estimated as a function of the vehicles velocity. The noise reduction of the new porous pavement (pavement A) was 6.6 dB (at 50 km/h). Due to the effect of dirt and pollution, after three years of use, the noise reduction decreased to 1.5 dB (at 50 km/h) and after six years — to 1.4 dB. For the second pavement (Pavement B) acoustic effectiveness of the new porous pavement (at 50 km/h) was 5.2 dB. After two years the noise reduction was -0.7 dB. The results clearly show the disappearance of the noise reduction after 2–3 years of use.

Appendix A. Prediction of traffic noise

According to the European Union recommendations, the noise indicators L_{den} and L_{night} should be used [11] in order to estimate the sound level of traffic noise. The indicator L_{den} (day-evening-night noise indicator) is derived from the following formula:

$$L_{\text{den}} = 10 \log \left(\frac{1}{24} \left(12 \cdot 10^{0.1 \cdot L_{\text{day}}} + 4 \cdot 10^{0.1 \cdot \left(L_{\text{evening}} + 5 \right)} + 8 \cdot 10^{0.1 \cdot \left(L_{\text{night}} + 10 \right)} \right) \right), \quad (12)$$

where L_{day} is the equivalent continuous A-weighted sound pressure level for day (7^{00} – 19^{00}), L_{evening} – the equivalent continuous A-weighted sound pressure level for evening (19^{00} – 23^{00}), and L_{night} – the equivalent continuous A-weighted sound pressure level for night (23^{00} – 7^{00}).

To exemplify L_{day} nearby the street with light and heavy vehicles we write:

$$L_{\text{day}} = 10 \log \left(\frac{t_0}{T_{\text{day}}} \left(N_{\text{day},\,l} \cdot 10^{0.1 \cdot L_{AE,\,l}} + N_{\text{day},\,h} \cdot 10^{0.1 \cdot L_{AE,\,h}} \right) \right), \quad t_0 = 1 \text{ s}, \quad (13)$$

where $N_{\text{day},l}$ and $N_{\text{day},h}$ denote the number of light and heavy vehicles, respectively, passing the receiver during the time period T_{day} = 12 h. $L_{AE,l}$ and $L_{AE,h}$ represent the sound exposure level of light and heavy vehicles. The calculation of the indicator L_{day} (similarly to L_{evening} with T_{evening} = 4 h and L_{night} with T_{night} = 8 h) is possible when the sound exposure levels L_{AE} for light and heavy vehicles are known.

A moving vehicle can be modelled by an omnidirectional point source [12]. The A-weighted squared sound pressure for the point source can be written as follows:

$$p_A^2 = \frac{W_A \cdot \rho c}{4 \pi d^2} \cdot Gr_A, \quad (14)$$

where W_A denotes the overall A-weighted sound power, ρc is the air specific impedance and d is the temporary distance between the source and the receiver (Fig. 7) and Gr_A describes the interaction between the noise and the ground surface, and depends on the frequency f_n, ground impedance in the n-th frequency band Z_n, height of the source H_s and receiver height H_o (Fig. 8).

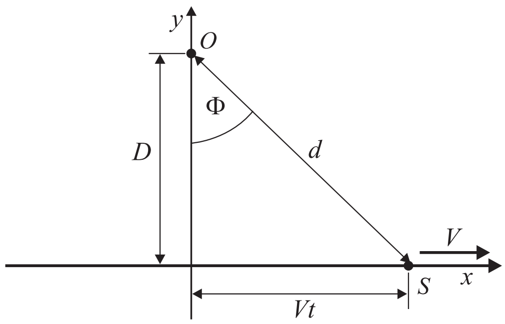

Fig. 7. The source – receiver geometry in the vertical plane.

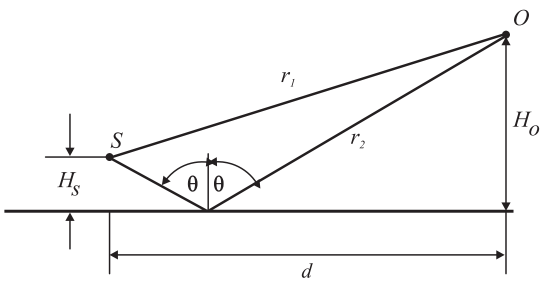

Fig. 8. The source – receiver geometry in the horizontal plane.

The explicit form of the function Gr_A for a flat, homogeneous and absorbing surface can be found in Refs. [13–15]. Close to the source, the function Gr_A oscillates around a constant value [16–18], therefore the A-weighted squared sound pressure (Eq. (14)) can be rewritten in the following form:

$$p_A^2 \cong \frac{W_A \cdot \rho c}{4\pi d^2} \cdot \beta, \tag{15}$$

where β represents the reflection from the ground close to the source.

A single event, i.e. a vehicle passing by, can be quantified by the sound exposure level:

$$L_{AE} = 10 \cdot \log\left(\frac{E_A}{p_o^2 t_o}\right), \qquad p_o = 2 \cdot 10^{-5}\ \text{Pa}, \tag{16}$$

where

$$E_A = \int\limits_{-\infty}^{+\infty} p_A^2\,(t)\,\mathrm{d}t \tag{17}$$

is the A-weighted sound exposure of noise generated by the point source moving from $x = -\infty$ to $x = +\infty$ (Fig. 7).

If the source moves at a constant velocity V along a straight road at a perpendicular distance D, the temporary distance $d = D/\cos\Phi$ (Fig. 7). It allows a transformation of Eq. (17) into:

$$E_A = \frac{D}{V} \int\limits_{-\pi/2}^{+\pi/2} \frac{p_A^2\,(\Phi)}{\cos^2\Phi} \mathrm{d}\Phi. \tag{18}$$

Making use of the source-receiver geometry and the Eqs. (15), (16), (18), one obtains the sound exposure level:

$$L_{AE}\,(V) = \widetilde{L}_{WA}\,(V) + 10 \cdot \log\left(\frac{s_o}{4VDt_o}\right), \tag{19}$$

where $s_o = 1$ m^2 and

$$\widetilde{L}_{WA}\,(V) = 10 \cdot \log\left(\frac{\beta W_A \rho c}{p_o^2 s_o}\right) \tag{20}$$

denotes the effective sound power level which is modified by noise reflection.

Appendix B

Before and just after the replacement of the road pavement, the acoustic measurements were carried out for experimental cars. To check if the noise level of these cars is the same as the noise level of the cars from traffic flow, the procedure presented below was applied.

Let us consider the noise level of the vehicles (experimental and from the traffic flow) before the replacement of the road pavement. From the L_{AE} measurements of the light, experimental vehicles at different velocity, the dependence $L_{AE}^{\text{light,exp.}}\,(V)$ was obtained. Due to the fact that the noise level of the experimental vehicles can be different from that of the traffic vehicles, the sound exposure level of the vehicles from the traffic flow, L_{AE}^{light}, should be written as:

$$L_{AE}^{\text{light}} = L_{AE}^{\text{light,exp.}} + \delta L, \tag{21}$$

where δL is the correction, which corresponds to the difference between the noise level of the two kinds of vehicles (experimental and those from traffic flow). A similar relation will be obtained for the effective sound power levels:

$$\widetilde{L}_{WA}^{\text{light}} = \widetilde{L}_{WA}^{\text{light,exp.}} + \delta L. \tag{22}$$

To compare the noise level of the experimental cars and vehicles from the traffic flow, the measurements of the equivalent A-weighted sound level, L_{AeqT} (under normal traffic flow) were performed. The speed of light and heavy vehicles and the traffic flow intensity were also measured. In the traffic flow, light and heavy vehicles participated. For this reason, the L_{AE} measurements of the heavy vehicles were carried out. On the basis of these measurements (for single pass-by noise) the values of $L_{AE}^{\text{heavy}}(V)$ and $\widetilde{L}_{WA}^{\text{heavy}}(V)$ were calculated.

The equivalent A-weighted sound level, L_{AeqT}, close to the street with light and heavy vehicles can be written as:

$$L_{AeqT} = 10\log\left(10^{0.1\cdot\ L_{AeqT}^{\text{light}}+\delta L} + 10^{0.1\cdot L_{AeqT}^{\text{heavy}}}\right), \tag{23}$$

where L_{AeqT}^{light} is the equivalent continuous A-weighted for light vehicles and L_{AeqT}^{heavy} is the equivalent continuous A-weighted for heavy vehicles. The L_{AeqT} is known from the field measurement. The L_{AeqT}^{light} and L_{AeqT}^{heavy} can be calculated using $\widetilde{L}_{WA}^{\text{light,exp.}}(V)$, $\widetilde{L}_{WA}^{\text{heavy}}(V)$ and the number of light, N^{light} and heavy vehicles, N^{heavy}, passing the observation point during the measurements. The effective sound power level for both kinds of vehicles has to be calculated for the mean velocity of light and heavy vehicles in traffic flow.

The correction δL is given by the following equation (Eq. (23)):

$$\delta L = 10\log\left(\frac{10^{0.1\cdot L_{AeqT}} - 10^{0.1\cdot L_{AeqT}^{\text{heavy}}}}{10^{0.1\cdot L_{AeqT}^{\text{light}}}}\right). \tag{24}$$

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