Impact of the Application of Grinding and Grooving of a Concrete Road Pavement on Noise Level in the Environment

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Abstract. A growing number of cars and trucks moving around on our roads contributes to the rise of noise level to which people in their immediate vicinity are exposed. The regulations in force impose on road managers the obligation to limit road noise to the permissible level in compliance with the applicable regulations. The obligation to ensure protection against traffic noise applies equally to newly designed roads and to the existing ones which are being extended or modernized. This type of noise is generated principally by the interaction between tires and road pavement. Therefore, the design and construction of quiet pavements plays a very important role in reducing environmental noise and may in some cases be an alternative to other noise reduction methods. The article undertakes the task of assessing the impact of grinding technology and grooving technology of the existing concrete pavement on the reduction of noise propagation in the environment. The article involves the tests of road pavement made of cement concrete. The tests were carried out on the road section before and after the above-mentioned works, using the method similar to Close Proximity Method (CPX) and the noise measurement method at road edge at a distance of 10.0 m and height of 4.0 m. The obtained results were illustrated with a noise range map for the modified and standard road pavements.

1. Introduction

The problems of architectural acoustics involve both school classrooms [1], sacral interiors [2], industrial halls [3] and the certification of buildings [4]. The acoustics of the interior are dependent on such parameters as reverberation time [5], [6] or the speech transmission index [7]. Another area of interest for acousticians involves environmental noise.

Road noise is the most common source of environmental pollution in the vicinity of people's dwellings [8]. The impact of road networks on environmental noise has been investigated in many research studies. For example, Ryu et al. [9] found a positive relationship between road pavement density and road noise, which contradicts previous studies by other researchers [10]. Apart from appropriate design of road networks, noise can be reduced by the application of quiet pavements [11], [12]. Many studies have demonstrated that road traffic noise is a complex phenomenon related to the drive unit, aerodynamics and the interaction of tires with road pavement [13]. Frequently, porous asphalt or various asphalt mixtures are used for road pavement applications [14]. Porous mixtures are used for safety and environmental aspects [15]. They improve anti-slip properties [16], reduce traffic noise and moderate the urban heat island effect [17]. In recent years, many works have been published on innovative road pavements [18] as well as works that contribute to the improvement of asphalt mix by the application of various types of additives [19], [20], [21], [22], [23].
2. Methodology

2.1. Road pavement

The research was conducted on two test sections (Figure 1). The said sections follow one another, and there is no intersection along their length which allows to leave the road. This means that they are subjected to the same traffic load. Both sections are outside built-up areas and the speed limit on both sections is 120 km/h.

![Test section with an enlarged fragment at the contact of NB and NBF pavements.](image)

**Figure 1.** Test section with an enlarged fragment at the contact of NB and NBF pavements.

The structure of the tested pavement is presented in Fig.2.

![Cross-section of road structure for the NB pavement (not subjected to grinding and grooving) [24].](image)

**Figure 2.** Cross-section of road structure for the NB pavement (not subjected to grinding and grooving) [24].
2.2. Close Proximity method

The pavement test by means of Close Proximity Method (CPX) consists in checking the acoustic characteristics of the pavement [X26, X27] at the contact place between the tire and the pavement. The test is performed on the basis of the standard ISO 11819-2: 2017 [22]. In the CPX method, the microphone is attached directly to the standard-specific measuring wheel, which rolls at a constant speed on the tested pavement. The standard recommends the use of two measuring wheels: one reflects the noise generated by passenger cars, the other one by trucks. In compliance with the provisions of the standard, the measurements can be carried out in 3 ways, and for the present study we selected the measurement with the measuring wheel mounted on a self-propelled vehicle (right rear wheel of a passenger car).

In the present study, an internally prepared measuring system was used. A Pirelli tire with a tire pressure of 230 kPa was used in the tests. One measuring microphone was used for the measurement, mounted in the immediate vicinity of the tire, as shown in Fig. 3.

![Figure 3. View of the microphone installed at the wheel on the rear axle of the car.](image)

2.3. Measurement of noise at the reference distance from the source

The measurements of noise in the vicinity of the test section were made using the method of single acoustic event detection by registering elementary noise samples while the vehicles were in motion. The measurements were carried out using integrating-averaging sound level meters of the accuracy class which had the following settings: frequency characteristic A and LIN, time constant F (fast) and spectral analysis in 1/3 octave bands. In the measurements, the values of noise indicators were determined. Standard noise measurements in the vicinity of roads consist in storing in the memory of the measuring device a representative number of single acoustic events \( L_{\text{SEL}} \) used to determine the equivalent sound level \( L_{\text{Aeq}} \) characterizing the measured source. Logarithmic summation is performed using the equation (1).

\[
L_{\text{AeqT}} = 10 \log \left[ \frac{1}{T} \sum_{i=1}^{n} t_i 10^{0.1L_{\text{SELi}}} \right]
\]  

(1)

The measurements were made in a representative cross-section of the road with established and undisturbed characteristics. The generated noise depends on the type of vehicles, intensity and speed of traffic and road pavement. One of the assessment methods of the acoustic properties of a traffic route is to measure the instantaneous peak value of the acoustic pressure. During the measurements
carried out by the authors, the measuring microphone was placed at a distance of 10 m from the edge of the road, at a height of 4.0 m. The view of the test stand is presented in Fig. 4.

![Image of the measurement system](image)

**Figure 4.** Measurement system in the vicinity of the test section at a distance of 10 m from the edge of the road at point P1.

3. Measurement results and discussion

Using the CPX method, the length of the route was 1.9 km. The measurements were made on two test sections, i.e. the section with the NBF pavement (approx. 0.9 km) and the section with the NBF pavement (approx. 1.0 km). On both sections, the car with microphones moved once on the left-hand lane and once on the right-hand lane. The results were collected by one measuring microphone directed in the direction of travel.

The measured sound levels for the frequencies of 1000, 2000 and 4000 Hz are presented in Figure 5 for both types of pavement.

![Graph of sound levels](image)

**Figure 5.** Changes in sound level at successive measurement points during the travel along the right lane towards Wroclaw at a speed of 80 km/h.
As we can observe below, the values of sound level fluctuate depending on the frequency. Therefore, it was reasonable to determine the average value of sound levels and to present their forms as a function of frequency. The results are presented in the diagram and shown in Figure 6.

![Sound Level Diagram](image)

**Figure 6.** Sound levels measured in the immediate vicinity of NB and NBF pavements for the travel on the right lane towards Wrocław at a speed of 80 km / h.

The measurements whereof results are presented in Figure 6 were made in very similar meteorological conditions, maintaining a constant vehicle speed. The air temperature during the measurements and the speed were as follows:

- NB and NBF \( T = 1.2 ^\circ C \pm 0.1 ^\circ C \)
- NB and NBF \( V = 80 \text{ km/h} \pm 0.2 \text{ km/h} \)

The graph presented in Figure 6 clearly shows that for the NBF pavement, a significant reduction in noise is observed as compared to the NB pavement in the range of higher frequencies. For noise measurements at the reference point (measurement points P1 and P2), the measurement points were located at a distance of 10.0 m from the edge of the road, where also the spectral analysis was performed, as shown in Figure 7.

![Sound Level Diagram](image)

**Figure 7.** Sound levels measured by noise measurement method in the measurement point P1 - pavement NB, and in the measurement point P2 - pavement NBF.
To compare spectral distributions of both methods and to illustrate the reduction of sound level by attenuation with pavement, the results are presented together in one Figure 8.

As we can observe in Figure 8, the spectral characteristic of noise does not depend on the measurement method. Moreover, due to noise attenuation, including the one effected by the pavement, sound levels at the edge of the road are lower by approx. 25 dB than those at the wheel during the travel of the vehicle.

![Figure 8](image_url)

**Figure 8.** Sound levels measured by two methods. Legend: A_P1 - NBF surface, measurement point P2; NBF_CPX - NBF pavement, right lane towards Wrocław.

To accurately estimate the level of sound reduction, a single-number sound level indicator was calculated. The results are presented in Figure 9.

![Figure 9](image_url)

**Figure 9.** Sound levels measured at the reference measuring points P1 and P2.

The bars shown in Figure 9 clearly demonstrate the impact of the NBF pavement on sound reduction level in relation to the NB pavement.

Due to a noticeable impact of the NBF pavement on the reduction of environmental noise, we decided to carry out a computer simulation to illustrate the range of noise in real conditions. For this purpose, the SoundPlan 8.1 software was used. The analysis was performed for daytime and nighttime.
As the input data for the simulation, we adopted the measured intensity and speeds of the vehicles, which in numerical values were as follows: 23,810 vehicles / 24h with a 36.3% share of heavy-duty vehicles, 20,266 vehicles / daytime and a 31.6% share of heavy-duty vehicles, 3,544 vehicles / nighttime and a 63.1% share of heavy-duty vehicles. The average speed of light-duty vehicles was 112 km / h in the daytime and 115 km / h in the night time, and for heavy-duty vehicles it was 85 km / h in the daytime and 86 km / h in the nighttime.

The noise map for the daytime period is presented in Fig. 10 and for the nighttime period - in Fig. 11.

![Figure 10. Noise map in the vicinity of S8 expressway during the daytime at the contact place of pavements NB and NBF.](image)

4. Conclusions

The article presents research studies on concrete pavement which was subjected to grinding and grooving. The concrete pavement NB, consisting of three layers in the technology of lean concrete, 0.2 m thick, geotextile and the wearing course made of cement concrete class B40, 0.27 m thick. The NBF pavement was developed by subjecting the NB pavement to grinding and grooving. The grinding process consisted in grinding the concrete surface to a depth of 5 mm, and grooving was made to a depth of 6.5 - 8 mm, spaced at 20 mm. It turned out that apart from the improvement of road pavement parameters, i.e. evenness, roughness and macrotexture, there is also an innovation involving the reduction of noise generated through the interaction of car tire and road pavement. The noise tests were performed using two methods: CPX and noise measurement method in reference mode, i.e. 10 meters from the edge of the road. It turned out that for both methods the measured noise spectra have a similar distribution, and both spectra indicate noise reduction with the application of grinding and grooving for high frequencies. In effect of the grinding and grooving process, we obtain the reduction of noise level by 2.3 dB at the reference point P2 in relation to the level obtained at the point P1. It turned out that the range of road noise was noticeably reduced following the application of grinding and grooving process, as shown on the created noise maps. In effect of grinding and grooving, noise ranges were reduced. The reduction of noise range for the standard of 61 dB (A) for daytime was 35 m and for the standard of 56 dB (A) for nighttime it was 30 m.

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