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LONG-TERM TYRE/ROAD NOISE COMPARISON OF DIFFERENT ROAD SURFACES MEASURED BY CPX METHOD

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ABSTRACT

Road traffic noise is the dominant factor in noise pollution. The European Union assesses the road surface acoustic properties by the internationally proven close-proximity (CPX) method. In this paper, exposed aggregate cement concrete, fine-grained asphalt concrete for very thin layers, low-noise pavements, and grinding treatment of cement concrete surface were compared with the reference stone mastic asphalt surface. The tyre/road noise levels of surfaces were performed by the CPX method using the maximum quantity (mandatory and optional) of microphones at a speed of 80 km/h. The noise levels of surfaces increase faster for the first few years after laying and much more slowly thereafter. The benefits of low-noise pavements have been demonstrated from the acoustic point of view. The intention is to use the obtained long-term acoustic behavior data of the road surfaces to refine and update the average noise values given in the national technical quality requirement (TKP 7). It contains noise levels of surface treatments that aren't longer in use and, on the contrary, doesn't provide sufficient data about new technologies.

Keywords: *tyre/road noise, CPX method, road surface, pavement, acoustic measurement.*

1. INTRODUCTION

Road traffic noise is a major environmental issue and the dominant factor in overall noise pollution, particularly in urban and suburban areas. High noise levels have been linked to adverse effects on human health, including stress, sleep disturbances and cardiovascular diseases [1, 2]. Therefore, assessing and mitigating road traffic noise is crucial to sustainable transportation planning and infrastructure management.

Road surface acoustic properties are evaluated using the internationally recognized close-proximity (CPX) method [3, 4] in the European Union. This method ensures consistent and reliable tyre/road noise measurements. This method is also integrated into Czech technical requirements, aligning national regulations with European standards. The CPX method provides a direct and repeatable means of comparing the long-term noise performance of different road surface types.

This paper presents tyre/road noise measurement results of road surfaces stone mastic asphalt with the highest grain size of 11 mm with increased resistance to permanent deformation (SMA 11S), cement concrete (CC) grinding, exposed aggregate cement concrete (EACC), asphalt concrete for very thin layers with the highest grain size of 8 mm class A (BBTM 8 A), low-noise asphalt concrete for very thin layers with the highest grain size of 8 mm (it's BBTM 8 B, but in the Czech national technical documentation it's BBTM 8 NH, where NH means Czech abbreviation for low-noise) and low-noise stone mastic asphalt with the highest grain size of 8 mm (SMA 8 NH) performed by the CPX method. These results were partly collected within the project of the Technology Agency of the Czech Republic "CK04000058 Consideration of other influences reflected in the measured noise values of pavement surfaces in dynamic measurement ".

The national technical quality requirement TKP 7 deals with asphalt pavements, but tyre/road noise levels are described for many surface types used in the Czech Republic. However, TKP 7 contains noise levels of surface treatments that aren't longer in use and, on the contrary, doesn't provide sufficient data about new technologies. So, the project results will help to update this information.

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2. METHODS

All measurements were carried out using a specialized open CPX trailer that followed the ISO/CD 11819-2 standard. The tyre model Uniroyal Tigerpaw 225/60 R16 SRTT (P1, as per ISO/TS 11819-3) was used as a standard reference tyre. Depending on the measurement year, the setup utilized the maximum quantity of microphones, so with using all mandatory and optional microphones.

2.1 Meteorological conditions for measurement

The CPX method is independent of the surrounding traffic intensity. It means that measurement days were selected freely within the following meteorological conditions, defined by ISO 11819-2:

- Measurements were conducted on a dry road surface.
- Wind speed didn't exceed 5 m/s.
- The air temperature was between 5 °C and 30 °C.

2.2 Conditions for road measurements in the Czech Republic

Measurements were performed at 80 km/h speed. They were carried out in the driving lane of the given road section, whereas in multi-lane roads, the most trafficked lane (usually the right slow lane) had priority. The acoustic pressure at the tyre/road interface was measured continuously throughout the entire section using a maximum quantity of microphones, positioned at defined distances from the test tyre (see Fig. 1).

Figure 1. Real locations of the individual measuring microphones around the reference tyre on CPX trailer.

During measurement, continuous recordings of vehicle speed, air temperature, and road surface temperature were collected for the following data corrections. Additionally, video recordings of the test setup, including both the test vehicle and the reference tyre, are recommended for later validation. So these records were also acquired.

2.3 Test tyre specifications

The Uniroyal Tigerpaw 225/60 R16 SRTT tyre was used for all measurements, as it is recommended by ISO/TS 11819-3 as P1 and recognized by the automotive industry as the standard tyre for ASTM F2493 reference tests. The ISO/TS 11819-3 standard outlines the tyre's use in CPX measurements, including guidelines for tyre storage and maximum wear limits, ensuring that tyre hardness adjustments stay within the specified range.

The maximum tread wear was up to 1.0 mm from the original depth. Tyre was stored indoors under dry conditions, protected from sunlight and artificial lighting, with temperatures not exceeding 10 °C. The maximum permitted usage period for reference tyres is two years. So, a new tyre was used each year for measurements to minimize the impact of wear and degradation of the tyre. Additionally, the test tyre had at least 400 km of mileage before testing.

2.4 Measurement equipment requirements

The sound analyzer covered a frequency range of 315 Hz to 5000 Hz and complied with IEC 61672-1 (Type 1 instruments). Microphones were equipped with wind protection covers with a diameter of 90 mm. Calibration devices met the requirements of IEC 60942 (Class 1). Also, the measured tyre/road noise level was at least 10 dB(A) above background noise.

3. NATIONAL TECHNICAL QUALITY REQUIREMENT (TKP 7)

Transport Research Centre (CDV) has long been involved in research about the acoustic properties of road pavements and aims to apply the findings nationally and internationally. This approach is reflected in the legislative measures on the noise performance of transport infrastructure and in the technical standards and guidelines used in practice. Thanks to cooperation with expert institutions and participation in international projects, the CDV contributes to reducing noise pollution around roads by developing modern road surface methods of assessment and optimization.

The Czech national technical quality requirement TKP 7 [5] describes all the parameters the asphalt surface must meet, such as the quality of materials, technological procedures, examinations, etc. It also contains two chapters on the noise performance of surfaces:

- Maintenance and operation of low-noise asphalt pavements.
- Procedure and monitoring of the tyre/road noise reduction effect.

It includes partial information on changes in road surface noise analyzed by the CPX method from the road network in the Czech Republic from several research projects. The average values of the surface noise decrease/increase compared to the reference value of 98 dB(A) for a speed of 80 km/h are shown in the table in Fig. 2. Several cells are marked with the symbol "X" due to insufficient data for various reasons, e.g. rarely used technologies, new technologies or technologies under innovation process, CPX monitoring isn't carried out for a significant period etc.

The table was created based on long-term noise measurements using the CPX method, with data collected until 2018. Since then, however, it needs to be updated due to newer acoustic data or regulation changes.

Speed 80 km/h	Age			
Surface:	0 year	2 years	5 years	10 years
AC 11	-1.0	0.0	+ 0.5	+ 2.5
AC 16	- 0.5	+ 0.5	+ 1.5	+ 3.5
BBTM 5 NH	X	X	X	X
BBTM 8 NH	- 3.5	- 2.0	X	X
CC – burlap drag method	- 2.0	- 1.5	- 1.0	0.0
CC – transverse tining method	+ 0.5	+ 1.0	+ 2.0	+ 3.5
CC – negative tining method	0.0	+ 0.5	+ 1.0	X
CC – EACC	- 0.5	+ 0.5	+ 1.5	X
Cobblestones	X	X	+ 6.5	+ 7.5
Slurry Surfacing	+ 1.0	+ 1.5	X	X
PA 8	- 4.0	- 2.0	- 0.5	X
SMA 8	-1.0	- 0.5	+ 1.0	X
SMA NH 8	- 4.0	- 2.0	X	X
SMA 11	- 0.5	+ 0.5	+ 1.5	+ 3.0
Cement concrete blocks	X	X	X	X

Figure 2. The average noise difference values compared to the reference noise value of 98 dB(A) for a speed of 80 km/h measured by the CPX method (TKP 7 table translated into English).[1]

[1] AC = asphalt concrete, BBTM = very thin asphalt concrete, NH = Czech abbreviation for low-noise, CC = cement concrete, EACC = exposed aggregate cement concrete, PA = porous asphalt, SMA = stone mastic asphalt.

Some technologies, such as porous asphalt, have been abandoned for road pavement usage. Finer or coarser aggregate fractions are starting to be used because of the lack of 11 mm aggregate, which is widely used in SMA 11 and AC 11 surfaces. Cement concrete surfaces are also moving to different arrangements. Tining method is no longer used, the burlap drag method is also being abandoned while grinding technology is becoming more popular. Most low-noise surfaces do not yet have some average values, as these were relatively new technologies at the time of table compilation. A low-noise asphalt surface is defined in the Czech Republic as a surface that reduces noise compared to the reference value by at least 2 dB(A), i.e. 3 dB(A) minus the uncertainty, which is 1 dB(A).

4. RESULTS AND DISCUSSION

The presented tyre/road noise level results (SMA 11 S, EACC, CC grinding, BBTM 8 A, BBTM 8 NH and SMA 8 NH) are focused on the motorway network in the Czech Republic (D1, D46). This study examines the long-term tyre/road noise performance of various surface types, comparing them to reference surfaces measured using the CPX method. In the Czech Republic, SMA 11 and AC 11 serve as standard reference surfaces. The data in chapter 4.1 were recorded at 80 km/h by the CPX method.

Sections with different surfaces were laid on the same road immediately after each other to maintain consistent measurement conditions, such as temperature and traffic intensity. The Czech national reference noise level for CPX-measured surfaces at 80 km/h is 98 dB(A), as was mentioned in chapter 3.

4.1 Tyre/road noise results

The measurement results presented include the parameter "years after laying," which represents the surface's age. For example, a surface laid in 2019 (year 0 after laying) and measured in 2023 would be 4 years old, corresponding to 4 years after laying. A value of 0 indicates measurements taken in the year of laying.

Fig. 3 below illustrates the noise levels of two different road surfaces – stone mastic asphalt with the highest grain size of 11 mm with increased resistance to permanent deformation (SMA 11S) and exposed aggregate cement concrete (EACC). Both surfaces show a gradual increase in values over time. The results are similar with a maximum difference of 0.5 dB(A). SMA 11 S surface noise levels are around 98.5 dB(A) one year after laying and rise by a further 1.4 dB(A) after another five years. Both surfaces can be considered normal based on a comparison with the national reference value.

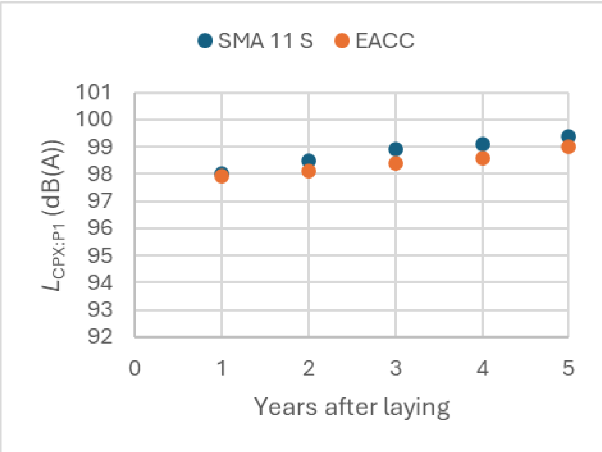

Figure 3. Comparison of the noise levels of SMA 11 S and EACC surfaces.

A comparison of pavement SMA 11 S and cement concrete (CC) grinding is shown in Fig. 4. The noise value of CC grinding in the fifth year after laying is 2.2 dB(A) lower than the SMA 11S value in the same year of service life. The noise level of CC grinding is increasing, but not very fast every year. The difference in noise level between year one after laying and year five after laying the SMA 11 S surface is 1.4 dB(A), while the grinding surface is 0.6 dB(A).

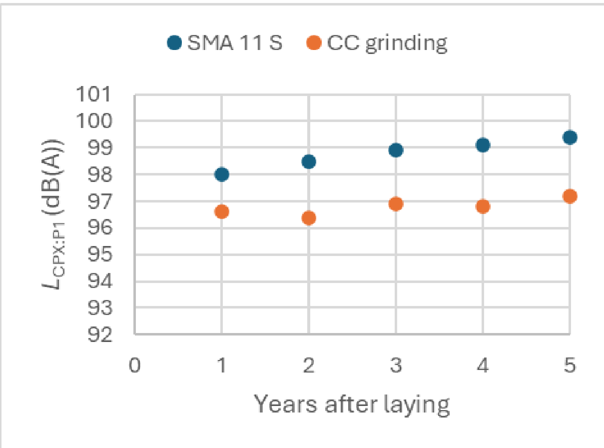

Figure 4. Comparison of the noise levels of SMA 11 S and CC grinding.

The differences (see Fig. 5) in the measured values in year zero after laying between SMA 11 S and asphalt concrete for very thin layers with the highest grain size of 8 mm class A (BBTM 8 A) is 2.6 dB(A). For the BBTM 8 A surface, the increase in time at year 6 after laying compared to year zero is 1.9 dB(A), for SMA 11 S it is 1.3 dB(A).

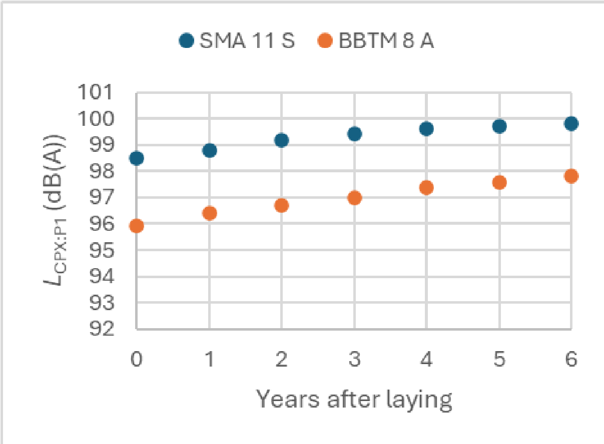

Figure 5. Comparison of the noise levels of SMA 11 S and BBTM 8 A.

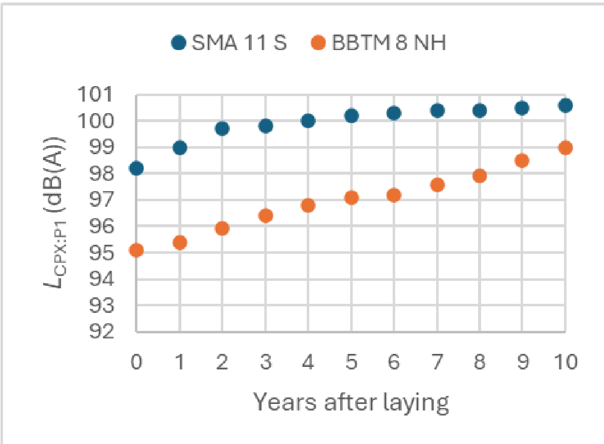

Figure 6. Comparison of the noise levels of SMA 11 S and BBTM 8 NH surfaces.

Tyre/road noise of low-noise very thin asphalt concrete with a maximum grain size of 8 mm (BBTM 8 NH) is lower than noise values of the SMA 11 S, as can be seen in Fig. 6. The noise level of low-noise pavement eight years after laying has not yet reached value 98 dB(A). The difference

between year zero and ten years after laying is 3.9 dB(A) for BBTM 8 NH and 2.6 dB (A) for SMA 11 S.
The graph in Fig. 7 compares noise levels between SMA 11 S and low-noise stone mastic asphalt with a maximum grain size of 8 mm (SMA 8 NH). Four years after laying, the noise level of SMA 8 NH is 3.6 dB(A) lower than SMA 11 S in the same year of service life. However, the noise level of the low-noise surface increases more rapidly each year compared to SMA 11 S. The noise difference between the year of laying and the fourth year is 1.9 dB(A) for SMA 11 S, whereas SMA 8 NH reaches 3.4 dB(A).

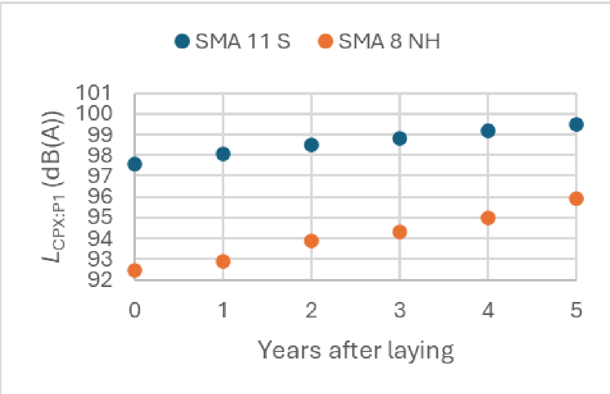

Figure 7. Comparison of the noise levels of SMA 11 S and SMA 8 NH.

5. SUMMARY OF RESULTS

CDV has been collecting data since 2012, so there is already a decent historical series for some sections, but the data is not entirely relevant considering the service life of the asphalt pavements (25 years) or the longer service life of cement concrete pavements (up to 40 years). For comparing different surfaces' noise, they must be free of significant defects such as potholes, rutting, extensive transverse or longitudinal joints, etc.
It can be concluded that the noise level of all surfaces changes acoustically over time. The tyre/road noise of the reference surface is 98 dB(A) for a speed of 80 km/h [5]. The noise level of conventional surfaces increases by 1–2 dB(A) compared to the reference value two years after laying and by around 3 dB(A) ten years after laying. So, the noise level increases faster for the first few years after laying and much more slowly thereafter. The development of noise over time is logarithmic.
The noise increase is about 1.5 dB(A) within five years of conventional surfaces (SMA 11 S, EACC). The average noise levels of the SMA 11 S surface in all measured years are approximately the same as for the EACC surface. This statement complies with the national reference values, according to which the noise level of the reference surface corresponds to SMA 11 or AC 11 surfaces.
Fine-grained asphalt surface BBTM 8 A with about 3 % void content isn't a low-noise surface but can be considered a noise-reducing surface. It has much lower void content than low-noise pavements but larger than conventional pavements. Its noise level was 2,4 dB(A) lower than the SMA 11 S surface in the third year of service life, and in the sixth year, only lower by 2 dB(A).
The benefits of low-noise pavements have been demonstrated from the acoustic point of view. They have a void content of approximately 11 %, making it suitable for tyre/road noise reduction. BBTM 8 NH noise level was 3.4 dB(A) lower than SMA 11 S in the third year after laying. This difference decreased to 2.5 dB(A) in the eighth year after laying, yet the BBTM 8 NH surface retained its low-noise properties. SMA 8 NH surface showed 4.5 dB(A) lower noise levels in the third year after laying than SMA 11 S surface. The SMA 8 NH surface is the youngest low-noise surface in the Czech Republic and has good acoustic potential.
The tyre/road noise increases more slowly each year for the grinding treatment of the cement concrete surface. The noise level difference between the first and the sixth year after laying is 0.6 dB(A). Its noise level is approximately 2 dB lower than the conventional SMA 11 S surface between two and five years after laying. The grinding method is not yet considered a low-noise treatment in the Czech Republic.

6. CONCLUSION

The paper presented the tyre/road noise levels of EACC 8, CC grinding, BBTM 8 A, BBTM 8 NH, and SMA 8 NH surfaces compared to SMA 11 S noise values. All measurements were performed using the CPX method at 80 km/h. Sections with two different surfaces were laid on the same road immediately after each other to maintain consistent measurement conditions, such as temperature and traffic intensity.
The tyre/road noise level increases with the surface ages (years after laying). This trend applies to all types of road surfaces if no defects appear. The noise level of the road surface increases most during the first three years after laying. At the same time, the noise reduction is highest at the beginning of the pavement service life from a long-term perspective.

The national technical quality requirement TKP 7 deals with asphalt pavements, but tyre/road noise levels are described for many surface types used in the Czech Republic. However, TKP 7 contains noise levels of surface treatments that aren't longer in use and, on the contrary, doesn't provide sufficient data about new technologies. So, the project results will help to update this information.

7. ACKNOWLEDGMENTS

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