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CPX METHOD – CRUCIAL MICROPHONE FOR LOW-NOISE SURFACES ASSESSMENT

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Abstract

The CPX method uses two mandatory microphones and up to four additional (optional) microphones to assess road surface noise. The microphones are positioned around a reference tyre and record noise generated at the tyre–road contact. However, the overall noise levels may vary depending on the number and placement of the microphones. This raises the question of whether the currently mandatory microphones are sufficient for the proper assessment of low-noise surfaces.

This paper presents noise levels measured by all six microphones on conventional and low-noise surfaces of different ages. Microphones located along the tyre (Nos. 1, 2, and 3) recorded nearly identical values for both surface types. In contrast, differences between microphones 4 and 5 were already evident for low-noise surfaces. The measurement from microphone 5, located at the trailing edge, is strongly influenced by void content. The largest difference, up to 2.5 dBA, was observed on the newest surface.

Keywords: *CPX method, tyre/road noise, six microphones, low-noise surfaces*

1. Introduction

The close-proximity (CPX) method is one of the most widely used and objective methods for assessing road surface noise. Measurements are performed in accordance with ISO 11819-2 [1], which requires the use of two mandatory microphones, while up to four additional microphones may be used optionally. Different parts of the tyre–road contact area contribute differently to the overall noise emission, particularly in the case of low-noise surfaces, where the acoustic behavior is strongly influenced by surface texture and void content. As a result, the measured noise levels may vary depending on the number and position of the microphones used. This raises the question of whether the current standard configuration is sufficient for accurately assessing all types of road surfaces, especially low-noise ones.

This paper compares noise levels obtained using the CPX method for conventional and low-noise surfaces based on measurements from all six microphones in accordance with ISO 11819-2. It builds on results from 2024 [2], which examined the averaging of various microphone combinations using the CPX method.

2. Tyre/road noise generation

The mechanisms of the tyre/road noise generation [3] can be divided into two main groups: structural (vibrational) and aerodynamical, each comprising several sub-mechanisms. The most relevant mechanisms for CPX measurements are summarised below.

Impact – The road surface is incompressible, when the tread impacts the surface (*tread impact*) or surface structures impact the tyre (*texture impact*), the resulting forces excile vibrations in the tyre.

Running deflection – Caused by tyre rotation during vehicle motion. Vibrations are generated in the contact area and propagate along the tread and into the sidewalls.

Air pumping – Air trapped in tread grooves and surface voids is compressed as it enters the contact patch and rapidly expands upon exit. This effect is more pronounced on dense surfaces, while on porous surfaces the air can dissipate more easily through the void content.

Helmholtz resonance – A mass-spring system is formed when the cavity created as the tyre lifts off the road surface interacts with the enclosed air. The cavity acts as a spring and the air as the oscillating mass, producing a characteristic tonal component.

Horn effect – The horn-shaped space between the tyre tread and the road surface amplifies the radiated noise, acting similarly to an acoustic horn.

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Stick/slip effects are not expected under steady-speed conditions during CPX measurement. The contribution of stick/snap is considered negligible due to the presence of debris on road surfaces.
Road surface assessment

2.1 Measurements

Measurements were performed in 2025 on expressways by the CPX method. The used open CPX trailer was described in article [4]. For the measurements described in this paper, all six microphones from the standard were used, including the four optional ones. The reference speed during the measurements was 80 km/h. Microphones 1 (M1) and 2 (M2) are mandatory; 1 is front, and 2 is rear. Microphone 3 (M3) is middle optional. These three microphones are located on the side of the tyre. Microphone 4 (M4) is front optional and microphone 5 (M5) is rear optional. Both are positioned equally far from the tyre, but one is on the leading edge and the other on the trailing edge. Microphone 6 (M6) is the rearmost optional one.

2.2 Surfaces

Conventional and low-noise asphalt mixtures were compared. As a conventional mixture, stone mastic asphalt with the maximum grain size of 11 mm (SMA 11) was chosen. As low-noise mixtures, stone mastic asphalt with the maximum grain size of 8 mm (SMA 8 NH) and asphalt concrete for very thin layers (BBTM 8 NH) – both with modified binder – were measured. NH is a Czech abbreviation for low-noise.
Void content of the SMA 11 surfaces must be within the range 2 – 4 % [5]. Void content of low-noise surfaces is then much higher. For BBTM NH surfaces, it needs to be between 10 – 14 %, and for SMA NH surfaces, between 9 –12 % [6]. In contrast, porous asphalt and similar surfaces with void content of more than 15 % are not considered low-noise in the Czech Republic.
The compared surfaces were laid on the same road, always one after the other, meaning ensuring identical wear conditions, such as weather or traffic intensity. The surfaces were compared across five sections: four sections with a combination of SMA 11 / SMA 8 NH and one section with a combination of SMA 11 / BBTM 8 NH. Three sections were relatively new, laid in 2024/2025, and two sections were older, laid in 2020. Surface details are shown in Table 1.

Table 1. Surface details.

Section No.	Surface combination SMA 11 /	Laying
1	SMA 8 NH	10/2024
2	SMA 8 NH	10/2024
3	SMA 8 NH	07/2025
4	BBTM 8 NH	10/2020
5	SMA 8 NH	09/2020

Sections 1 and 2 are located on the same part of the highway, but in opposite directions. They were measured after 9 months of use. The annual average daily traffic (AADT) for 2025 was just under 15,000 for both sections. Section 3 is located at the bypass of a city with a population of 9,000. When section 3 was measured, less than a month had passed since it was laid. The AADT for this section has not yet been calculated. Sections 4 and 5 were the oldest at the time of measurement, at 57 months. Section 4 is situated on the main road connecting cities with populations of 90,000 and 46,000. The AADT was 12,109 in 2020 and 11,475 in 2025. So, the number of vehicles dropped slightly. Section 5 is located on the most heavily utilized highway segment with occasional congestion. The AADT was around 80,000 in 2020, and by 2025, the number of vehicles had risen to around 100,000.

3. Results and discussion

According to ISO 11819-2, microphones can be grouped into two categories (see Figure 1): microphones positioned along the tyre (M1, M2, M3) and microphones positioned at the edges of the tyre (M4, M5), which are mounted at the same height and distance. Microphone 6 is the rearmost one and has no other microphone positioned similarly to it.

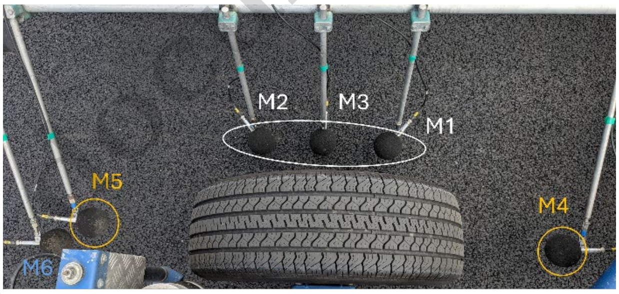

Figure 1. Microphones mounted around the tyre.

Figure 2 shows the LCPX values measured by individual microphones for all sections (numbers 1–5) and surfaces (C = conventional SMA 11; LN = low-noise SMA 8 NH or BBTM 8 NH). Low-noise surfaces on all microphones have lower values than conventional SMA 11. The sixth rearmost microphone consistently recorded the lowest noise level. Considering its position, this is to be expected.

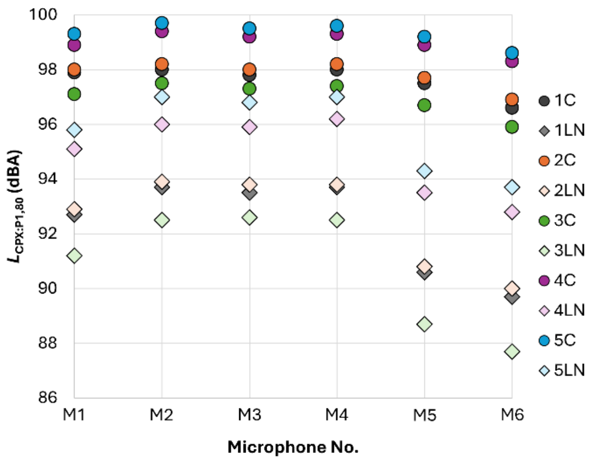

Figure 2. Noise values of monitored surfaces (Number = section No., C = conventional surface (SMA 11), LN = low-noise surface).

The values from microphones 1, 2, and 3 appear very similar. They differ by only a few tenths of a decibel, as shown in Table 2 (the minimum and maximum values for microphones 1, 2, and 3, and the difference between the maximum and minimum). These microphones are located along the tyre and are affected by similar noise-generating mechanisms, which are not influenced by the void content of the low-noise surfaces. Noise level values of SMA 8 NH surface (section 5) at 57 months of age begin to approach those of a conventional SMA 11 surface (section 3) at 1 month of age.

Table 2. Noise level values of M1, M2, and M3 in dBA.

Section No.	Surface	min	max	diff
1	SMA 11	98.0	97.8	0.2
	SMA 8 NH	93.7	93.5	0.2
2	SMA 11	98.2	98.0	0.2
	SMA 8 NH	93.9	93.8	0.1
3	SMA 11	97.5	97.3	0.2
	SMA 8 NH	92.6	92.5	0.1
4	SMA 11	99.4	99.2	0.2
	BBTM 8 NH	96.2	95.9	0.3
5	SMA 11	99.7	99.5	0.2
	SMA 8 NH	97.0	96.8	0.2

Nearly identical values were measured by microphones M4 and M5 for the conventional surface SMA 11. The noise level values differ again by only tenths of a decibel (see Table 3). However, for low-noise surfaces, the noise level measured by M5 is much lower than that measured by M4. The values differ by whole decibels, as shown in Table 3. The higher void content of the low-noise surfaces plays a significant role, as it reduces the noise caused by air pumping or Helmholtz resonance. This difference decreases (void content decreases) as the low-noise surface ages, wears down, and gets clogged. These effects are also logically applied to M6, which measures noise behind the tyre just like the M5.

Table 3. Noise level values of M4 and M5 in dBA.

Section No.	Surface	M4	M5	diff
1	SMA 11	97.9	97.5	0.4
	SMA 8 NH	92.7	90.6	2.1
2	SMA 11	98.0	97.7	0.3
	SMA 8 NH	92.9	90.8	2.1
3	SMA 11	97.1	96.7	0.4
	SMA 8 NH	91.2	88.7	2.5
4	SMA 11	98.9	98.9	0.0
	BBTM 8 NH	95.1	93.5	1.6
5	SMA 11	99.3	99.2	0.1
	SMA 8 NH	95.8	94.3	1.5

The difference between values measured by microphones 1 through 5 is significant for low-noise surfaces. However, this difference decreases as the surface ages. For a 1-month-old surface, it is 3.9 dBA; for both 9-month-old surfaces, it is 3.1 dBA; and for the 57-month-old surfaces, the difference is 2.7 dBA. The lowest values were, of course, recorded by microphone 5. For SMA 11 surfaces, the overall difference between microphones 1 through 5 was only 0.5 dBA. Only the surface measured at 1 month of age showed a difference of 0.8 dBA, with the minimum recorded by microphone 5. This larger difference is because the measured surface was nearly new. It had the highest void content of all measured surfaces. Voise content gradually decreases over time as a result of clogging.

This difference is then reflected in the calculation of the total L_{CPX} value, as shown in Table 4. The average noise level of the two mandatory microphones is designated M1+2, the average value of the first five microphones (except M6) is marked M1–5. For conventional SMA 11 surfaces, the difference between calculations based on two mandatory microphones and those based on five microphones (diff M) does not exceed 0.3 dBA. For low-noise surfaces, this difference is around 1 dBA. In all cases, calculations based on five microphones yield lower values. The noise difference between conventional and low-noise surfaces (diff S) is also more noticeable when the calculation is based on all microphones than only the mandatory ones.

Table 4. $L_{\mathrm{CPX:P1,80}}$ values in dBA measured by mandatory and five microphones (diff M = microphone difference, diff S = surface difference).

Section No.	Surface	M1+2	M1–5	diff M
1	SMA 11	98.0	97.8	-0.2
	SMA 8 NH	93.7	92.8	-0.9
	diff S	-4.3	-5.0	
2	SMA 11	98.2	98.0	-0.2
	SMA 8 NH	93.9	93.0	-0.9
	diff S	-4.4	-5.0	
3	SMA 11	97.5	97.2	-0.3
	SMA 8 NH	92.5	91.5	-1.0
	diff S	-5.0	-5.7	
4	SMA 11	99.4	99.1	-0.3
	BBTM 8 NH	96.1	95.3	-0.8
	diff S	-3.3	-3.8	
5	SMA 11	99.7	99.5	-0.2
	SMA 8 NH	97.0	96.2	-0.8
	diff S	-2.7	-3.3	

A similar situation arises when the average from two mandatory microphones is compared to the average from all six microphones (marked as M1–6 in Table 5). The differences for conventional SMA 11 surfaces differ from the M1–5 values in the previous table by no more than 0.2 dBA. For the low-noise surfaces, the difference is greater, up to 0.5 dBA.

Tables 4 and 5 clearly show the influence of the sixth microphone. It records the lowest value because it is located furthest from the tyre. This value then affects the average value obtained by calculating from all six microphones. This influence is most noticeable in the case of low-noise surfaces.

Table 6 shows the differences in noise levels obtained by averaging values from different microphones. The absolute values in the columns indicate the differences between the averages of the selected microphones. M1–3 refers to the average noise value from microphones mounted along the tyre, M1–4 refers to the average noise value from microphones mounted in front of (leading edge) and along the tyre, and the average value of microphones 1 and 5 is listed as M1+5. These absolute differences can be illustrated, for example, by the case of M1+2 / M1–3: the average value of microphones 1, 2, and 3 is subtracted from the average value of the two mandatory microphones 1 and 2.

Table 5. $L_{\mathrm{CPX:P1,80}}$ values in dBA measured by mandatory and all six microphones (diff M = microphone difference, diff S = surface difference).

Section No.	Surface	M1+2	M1–6	diff M
1	SMA 11	98.0	97.6	-0.4
	SMA 8 NH	93.7	92.3	-1.4
	diff S	-4.3	-5.3	
2	SMA 11	98.2	97.8	-0.4
	SMA 8 NH	93.9	92.5	-1.3
	diff S	-4.4	-5.3	
3	SMA 11	97.5	97.0	-0.5
	SMA 8 NH	92.5	90.9	-1.6
	diff S	-5.0	-6.1	
4	SMA 11	99.4	99.0	-0.3
	BBTM 8 NH	96.1	94.9	-1.2
	diff S	-3.3	-4.1	
5	SMA 11	99.7	99.3	-0.3
	SMA 8 NH	97.0	95.8	-1.2
	diff S	-2.7	-3.6	

Table 6. Absolute differences between selected microphone combinations in dBA.

Section No.	Surface	M1+2 M1–3	M1+2 M1–4	M1+5 M1–6
1	SMA 11	0.1	0.1	0.2
	SMA 8 NH	0.1	0.3	0.1
2	SMA 11	0.1	0.1	0.2
	SMA 8 NH	0.1	0.3	0.1
3	SMA 11	0.1	0.2	0.1
	SMA 8 NH	0.0	0.3	0.3
4	SMA 11	0.1	0.2	0.2
	BBTM 8 NH	0.1	0.3	0.1
5	SMA 11	0.1	0.2	0.2
	SMA 8 NH	0.1	0.3	0.1

The overall average value remains almost unchanged when the M3 value is added to the two mandatory microphones. The situation is very similar when comparing the values of the mandatory microphones and microphones 1 through 4 (side and front). As demonstrated in Table 3, the rear microphones have a significant impact primarily on the overall noise level of the low-noise surfaces. The last column of Table 6 shows that the differences between the average of M1 and M5 and the average of all six microphones are minimal.

4. Conclusions

Higher noise levels were consistently measured by the microphones located along the tyre (microphones 1, 2, and 3). They are positioned closest to the noise source at a height of 10 cm above the road surface. Microphones 4 and 5 are both positioned at a height of 20 cm above the surface, while microphone 4 is located at the leading edge and microphone 5 at the trailing edge of the tyre.

For SMA 11 surfaces, the measured values were very similar across all five microphones. For low-noise surfaces, there were significant differences in noise values of microphones 4 and 5. In particular, microphone 5 is strongly affected by the characteristics of low-noise surfaces, which have a much higher void content than dense asphalts.

The differences among the side microphones (1, 2, and 3) are very small for both surface types, remaining within 0.3 dBA. In contrast, differences between surface types become apparent when comparing measurements from microphones 4 and 5. While for conventional SMA 11 surfaces this difference is within approximately 0.5 dBA, for low-noise surfaces it becomes much more pronounced, reaching several decibels. For a new low-noise surface, the difference is 2.5 dBA, while for a surface aged 57 months, it decreases to 1.5 dBA.

The results suggest that mandatory microphone 2 should be relocated to the position of microphone 5. This adjustment would improve the assessment of surface noise, particularly for the low-noise surfaces.

5. Acknowledgments

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