***inter.noise 2000***
***The 29th International Congress and Exhibition on Noise Control Engineering***
***27-30 August 2000, Nice, FRANCE***

**I-INCE Classification:** 5.2

# DETERMINATION OF THE CPX INDEX FOR A NUMBER OF SURFACES IN VARIOUS COUNTRIES

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**Keywords:**
TIRE/ROAD NOISE, ROAD SURFACE, MEASURING METHOD

**ABSTRACT**
In order to investigate the influence of the road surface on tire/road noise generation it is necessary to establish certain measuring procedures and indicators describing the results in a uniform and condensed form. One of the methods in use is the Close Proximity Method (CPX). This paper outlines the most important aspects of the CPX method. It also presents results of CPX tests performed recently on many roads in Sweden, Poland, Germany and the Netherlands. Certain "low noise" road surfaces were included to the test program so it is possible to compare their performance with other, more traditional road surfaces. Very noisy "block pavements" and paving stones were also covered since they are again becoming frequently used in certain "low traffic" and residential areas. The ranking of the surfaces according to their CPX indices is given as a final result of the investigation.

## 1 - INTRODUCTION

Road surfaces may influence traffic noise in two ways. They directly influence the generation of the tire/road noise that is one of the most important vehicle noise sources, and on top of it they may affect the propagation of noise emitted from all sources in the vehicle. In order to investigate the influence of the road surface on the tire/road noise generation it is necessary to establish certain measuring procedures and indicators describing the results in a uniform and condensed form.

The methods used for the evaluation and ranking of the road surface with respect to traffic noise exhibit certain particularities and differ in details from the methods used for example to evaluate tires or complete vehicles. One of the methods in use is the Close Proximity Method (CPX), which utilizes two microphones mounted close to the tire/road interface. The so-called CPX Index, which is the final indicator of the road surface "noisiness", is evaluated on the basis of measurements performed with the CPX method using reference tires. Measurements with this method in a standardized way have been possible only recently since the method is currently subject of standardization efforts within the ISO [1].

Another method, called the Statistical Pass-By method (SPB), is already standardized [2]. This method relies on measurements performed in the far field and is considered as more precise in comparison to CPX; thus also used as reference. In the SPB method, a statistically significant number of individual vehicle pass-bys are measured at a specified road-side location together with the vehicle speed. The vehicles are "picked" randomly in the existing traffic, on condition however, that their noise must be clearly separated from the noise of other vehicles.

## 2 - CLOSE-PROXIMITY METHOD

The Close-Proximity Method which was previously known as the Trailer method (TR) was designed to isolate and measure tire/road noise. In contrast to the Statistical Pass-By method, the CPX method neglects all other noise sources but the tire/road interaction.

A special test vehicle (self-powered or towed behind another vehicle) equipped with reference tire(s) is used in this method. Two measuring microphones are mounted very close to the test wheel – see Fig.

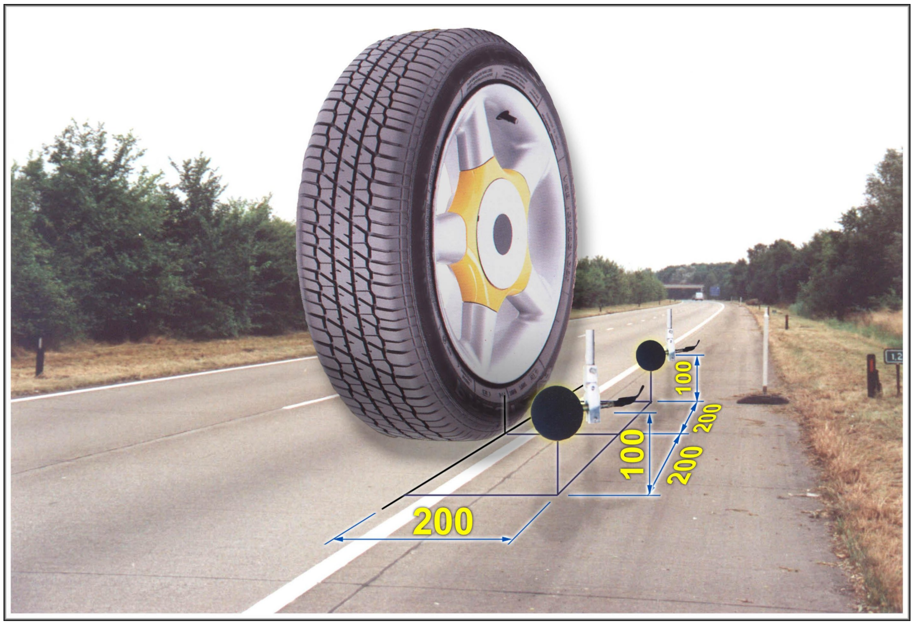


**Figure 1:** Position of microphones in the CPX method.

1. In principle it is possible also to mount the microphones close to the tire of a four-wheeled vehicle, thus no trailer is necessary. However, most users seem to prefer a trailer.
In most of the existing test vehicles (especially trailers) the measuring wheel and microphones are protected by special chambers. The chamber reduces background noise (most notably the noise from other tires, from other vehicles and wind noise) and must be constructed in such a way that it does not initiate undesired noise reflections. Fig. 2 shows the test trailer built at the Technical University of Gdansk, which was used during the measurements reported in this paper.

**Figure 2:** Test trailer "Tiresonic Mk 2" built at the Technical University of Gdansk, Poland.

The CPX tests were performed at speeds of 50, 80 and 110 km/h. The present draft of the standard requires that the measurements should be made with four different reference tires (two summer type tires called $A$ & $B$ as well as two winter tires $-$ $C$ & $D$). For each reference tire and each individual test run with that tire, the average sound level over the desired length of the road surface (preferably over 100 m long) and the corresponding vehicle speed are recorded. The sound levels for the two microphones

are averaged and corrected for speed deviation from the reference speed.
To report the acoustic performance of the tested road surfaces, the A-weighted sound pressure levels for each tire are combined together and constitute a so called CPX Index (CPXI). This index is used to compare surfaces. At present the CPX Index is calculated as an arithmetical average of the levels for all tires (weight for each tire is 25 %). There are however opinions that instead of using the same weights for each tire it is desired to give a higher weight (40 %) to the reference tire $D$ which is considered as a close representation of truck tires due to the aggressive and harsh tread pattern. It is also very likely that a simplified, "survey" CPX Index will be allowed which is based on two tires only ($B$ and $D$ with equal weighting).
As the measurements are carried out in the tire's near-field, the propagation effects do not influence the results very much. In several applications (like classification of the road surfaces, which is a main purpose of the CPX method) this particularity may be considered as an undesirable feature of the method.
The CPX method features a fair correlation with the SPB method for a wide range of surface types. Noise levels obtained on drainage pavements are, however, somewhat overestimated in comparison to the far-field measurements, due to the high absorption of such surfaces which influences long distance propagation considerably.

## 3 - CPX INDICES FOR DIFFERENT ROAD SURFACES

The results presented in this chapter were gathered from different experiments performed on European roads in the late nineties. They include testing of road surfaces performed in Sweden together with the *Swedish National Road and Transport Research Institute (VTI)*, the so called "International validation test for the Close Proximity Method" carried out in the Netherlands and Germany together with eight other teams (coordinated by *M+P Raadgevende ingenieurs bv* and *TÜV Automotive GmbH*) and, finally, tests performed in Poland together with the *Technical University of Bialystok* (sponsored by the Polish Scientific Research Board − KBN).
Although results for many more surfaces were available, only 23 surfaces were selected for this paper giving, in the opinion of those authors, a good overview of the most important currently used surfaces. On some of them SPB tests were also performed, giving an opportunity to compare results obtained by those two methods. In the case of SPB measurements the equivalent of CPXI is called SPB Index (SPBI) and is calculated in such a way that it merges results obtained for cars and different types of trucks. For more details see [2].
Fig. 3 presents the CPX Indices calculated with the same weights (25 %) applied to the results measured for each tire. The lowest indices (90.0 − 95.3 dB) were obtained for *porous asphaltic concretes (PAC)* also called *drainage pavements*. An especially low value of the CPXI was observed for double layer PAC with very fine top layer. Also a road surface laid according to the ISO 10844 standard shows a rather low value of the CPXI (94.3 dB).
The next group of surfaces which includes the very popular *stone mastic asphalt* of different chipping sizes, German "*Gussasfalt*" and *surface dressings* are characterized by CPX Indices 96.3 − 100.6 dB. For this group the higher values of CPXI are associated with the bigger chipping size. Most of the *cement concrete surfaces* (*CC*) also exhibit similar CPXI values, but within this group the indices are very much related to the noise reduction technologies applied to the surface (e.g. burlap drag) [3].
Finally, the noisiest surfaces (CPXI = 100.2 − 107 dB) are the "block type surfaces" like concrete blocks and paving stones. Those surfaces are nowadays not used on high-intensity roads, but they still exist in some countries on minor country roads. What is more interesting, concrete blocks and paving stones are being reestablished on certain streets in historic towns and also in modern residential areas due to their special visual appeal. Unfortunately all of the types we measured must be considered as noisy road surfaces, despite the fact, that proper patterning and very smooth laying may somewhat reduce their noisiness.

## 4 - RELATIONS BETWEEN CPX AND SPB INDICES

As the *Statistical Pass-By* method is considered to be a reference with regard to the noise properties of the road surfaces, it is important to monitor the relations between CPX and SPB Indices. Ideally, one would require very high correlation between those methods, but there is no doubt that the correlation cannot be perfect since the SPB method accounts altogether for tire/road noise and power train noise, as well as for propagation effects. Moreover, the CPX method is based on two microphone positions (both of them in the near-field of a single tire) and the SPB method "averages" the noise from all wheels of the vehicle and scans for the maximum level over a certain part of the tire noise radiation directivity pattern.

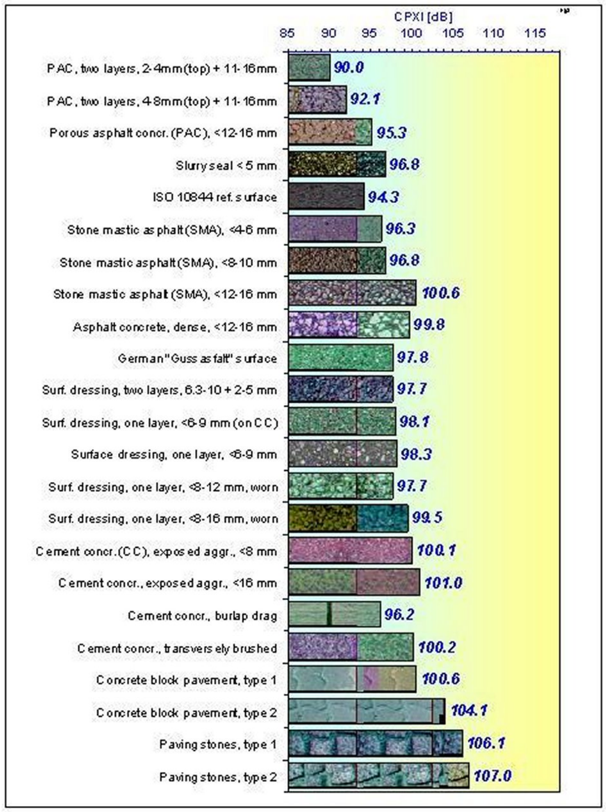


**Figure 3:** CPX Indices for different road surfaces calculated for the speed 80 km/h, using the same weights (25 %) for each tire.

As it was mentioned above, there is currently ongoing discussion about the best way to calculate the CPX Index. In order to investigate how the indexes would respond to the different algorithms of their calculation, three variants of the CPX Indices were calculated and correlated with the SPB Indices. The index calculated with the same weight for all four tires was named *CPXIa*, the index with 40 % weight for tire D and 20 % weight for tires A, B and C was named *CPXIb,* and finally, the index calculated as an average for tires B and D was named *CPXIc*. Fig. 4 shows the relation between the CPX Indices defined as above and the SPB Index calculated for the road speed category "Medium" [2].

As can be seen from the Fig. 4, all three ways of calculating the CPX Index give the very similar correlation with the SPB Indices. The correlation coefficients for CPXI and SPBI are around 0.90, independent of the CPXI calculation algorithm.

The biggest deviation from the regression line was observed for the very noisy surface − paving stones. This may be at least partly explained by the fact, that the tested surface was located in an area not trafficked by very heavy trucks. The algorithm of the SPBI calculation requires separate measurements for cars, dual-axle trucks and multi-axle trucks. In the case of the mentioned surface, as no multi-axle trucks were measured, the same value for all trucks was used. Most probably the multi-axle trucks would be at least 3-4 dB nosier than the dual-axle trucks so the SPBI for this surface would also be higher. Furthermore the average speed of cars and dual-axle trucks were lower on this road than on other surfaces. The bigger corrections that were necessary to normalize the results to the reference speeds for the road speed category "Medium" probably resulted in a lower precision of the SPBI evaluation.

## 5 - CONCLUSIONS

The CPX Index proposed by ISO/CD 11819-2 seems to be well correlated with the corresponding index estimated on the basis of SPB tests made according to ISO 11819-1. For the speed of 80 km/h, the tested road surfaces were characterized by CPX Indices from 90 to 107 dB. It means that vehicle noise may vary as much as 17 dB due to the road surface. On the other hand, most of the common surfaces (like SMA, surface dressing, cement concrete) were characterized by CPX Indices between 96 and 101 dB. The algorithm of the CPXI calculation (within the tested variations) is not very critical for the final result. Even a simplified algorithm accounting for only two reference tires instead of four, gives

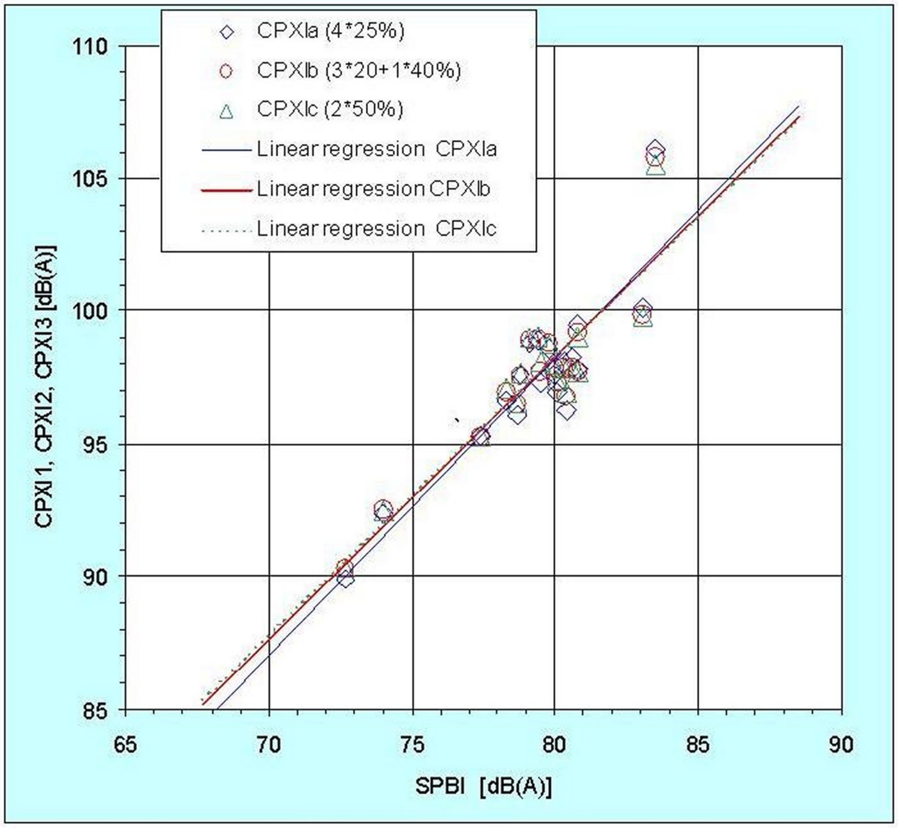


**Figure 4:** Relation between the CPX and SPB Indices on different road surfaces.

satisfactory results and a high correlation with the SPBI.

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