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A new tyre for the CPX method

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Abstract

The CPX method is a standard method for assessing the acoustic properties of road surfaces. The reference tyres to be used with this method are specified in ISO/TS 11819-3. The H1 tyre (AVON AV4) mentioned therein, which is used to characterize the tyre/road noise of trucks, has been discontinued since the end of 2014. This makes it necessary to find a suitable replacement for AVON AV4.

With project funding from the German Federal Ministry of Transport (BMV) and with the support of the German Federal Highway and Transport Research Institute (BASt), a consortium of all providers of CPX measurements in Germany has worked on project FE 04.0340/2021/AGB "Methodology for the selection of a new H tyre for the CPX process" and proposed a new H tyre (hereinafter: H2 candidate). For this H2 candidate, the correction coefficients for air temperature and shore hardness were determined, as well as a formula for converting results with the reference tyre H1 and the H2 candidate. In addition, the procedure used in this project has been described in a manual as a guideline for the future choice of new reference tyres.

Keywords: *CPX method, reference tyre, tyre-road noise*

1. Introduction

The acoustic properties of low-noise road surfaces can be assessed, inter alia, by close proximity noise measurements of tyre/road noise, which are carried out according to the CPX trailer method (Close-Proximity Method) [1]. ISO/TS 11819-3 [2] defines two types of tyres to be used with this method: a passenger car tyre, P1 (Uniroyal: Tiger PAW SRTT), which is specified in ASTM F 2493 and is used as standard reference test tyre C1 in the automotive industry. The second is a commercial vehicle tyre, H1 (Cooper: AVON Supervan AV4), which is used to characterise the tyre/road noise of truck tyres.

The current H1 tyre (AVON AV4) has been discontinued since the end of 2014, which means that the H1 tyres still in use are more than eleven years old now. As tyre hardness increases with mileage and age, the remaining service life of the H1 tyres still in use is limited: most H1 tyres used by German CPX suppliers approach the upper limit of shore hardness specified in [2]. Therefore, it was necessary to find a suitable replacement for the AVON AV4.

Therefore, the German Federal Highway and Transport Research Institute (BASt) in 2021 started a research project to identify a national successor to the H1 tyre in Germany.

2. Project objectives

The project had the following objectives:

1. Development of a suitable procedure for the search and determination of new reference tyres for CPX measurement purposes (in Germany) as well as the presentation of this procedure in a manual. The manual should also describe the procedure for developing the correction functions.
2. Application of the above-mentioned procedure for determining a (national) successor for the H1 tyre;
3. Identification of the tyre-specific correction coefficients for Shore hardness and ambient temperature for the new reference tyre;
4. Development of a conversion formula for the results with the H1 successor (H2 candidate) in order to allow comparisons with the results of the current H1 tyre (AV4).

The manual is particularly relevant as product cycles in tyre industry are getting shorter and shorter. It is therefore very likely that in the future CPX reference tyres will have to be redefined after five to eight years. Therefore, the procedures used, and the experience gained from the present project should be described in the handbook as future guidelines.

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3. Selection process

The selection process of the new CPX tyre has been described in detail in [6]. Here, a two-stage approach was chosen. First, laboratory measurements with ten possible tyres were carried out on the vehicle/pavement interaction facility (Prüfstand Fahrzeug/Fahrbahn, PFF; see [5]) of BASt. By a subsequent scoring procedure, the four tyres with the best spectral match to the AV4 tyre were selected. These four tyres were assessed in real road measurements on a total of approx. 60 road sections with different surfaces and at different speeds.

A second scoring procedure together with additional criteria led to the definition of the Firestone Vanhawk2 Winter as the new H2 candidate. In its acoustic properties, it shows a pronounced excitation in the low frequency range, which is also characteristic for the H1 reference tyre AV4. In addition, the Firestone Vanhawk tyre can be considered an all-rounder in terms of its sensitivity to texture-related excitations on individual surface layer types, which has neither pronounced strengths nor significant weaknesses.

All further work steps in the research project were carried out exclusively with the Firestone tyre.

4. Description of the H2 candidate

The key data for the tyre "H2-candidate / Firestone Vanhawk 2 Winter" are shown in Table **1** and compared to the data of the current H1 reference tyre AVON AV4.

Table 1. Description of the H2 candidate and the H1 reference tyre [2].

Tyre	H2 candidate	H1
Manufacturer / Type	Firestone / Vanhawk 2 Winter	Cooper Tires / Avon AV4
Size	205/70R15	195/80R14
Load index	106/104R	106/104N
Number of tread blocks	68	72
f_{res} **at 80 km/h, Hz**	720	763

5. Boundary conditions for measurements with the H2 candidate

Based on ISO 11819-2 and ISO/TS 11819-3, the following operating conditions for the H2 candidate for CPX measurements have been defined:

• Tyre pressure: 200 kPa ± 10 kPa (cold tyre)

• Air temperature: 5 °C – 30 °C (35 °C suggested as upper limit)

• Shore hardness: 66 Shore A – 70 Shore A (proposed)

• Maximum permissible decrease in tread depth compared to the initial state: 1 mm (proposed)

• The Firestone Vanhawk2 Winter 205/70 R15 is designed for 5 ½ J rims

6. Monitoring of the H2 candidate

Monitoring was carried out with the selected H2 candidate in order to check the acoustic, thermal and ageing behaviour and to create a database for the future conversion of the levels $L_{CPX,H2\ candidate}$ to $L_{CPX,H1}$ according to [1]. Therefore, the partners of the research project carried out a large number of comparative CPX measurements with the standard H1 (AV4) tyre and with the H2 candidate.

All H2 candidate tyres were first tested for Shore hardness and run in at least 300 km before monitoring measurements began. The Shore hardness for all H2 candidate tyres was about 65 Shore(A) to 66 Shore(A), while the Shore hardness for the H1 tyres was between 70 Shore(A) and 71 Shore(A).

The monitoring measurements were carried out at air temperatures between 5 °C and 35 °C on a total of 120 road sections with different road surface layers. The speeds ranged from 30 km/h to 80 km/h.

As an example, the results of the monitoring measurements at 80 km/h are shown below: Figure 1 shows the CPX levels on asphalt surface courses (dense, porous and open-pored), Figure 2 shows the corresponding results on concrete surface courses.

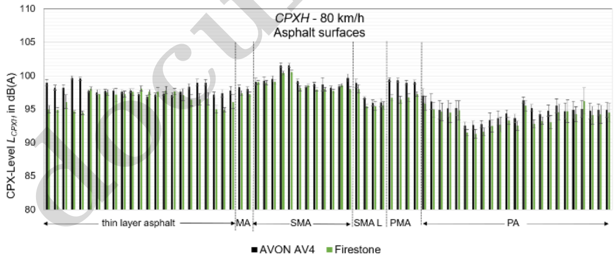

Figure 1: CPX level from CPX monitoring measurements for asphalt road surfaces; Author: Müller-BBM, Data: AED, Müller-BBM, SCRIM.

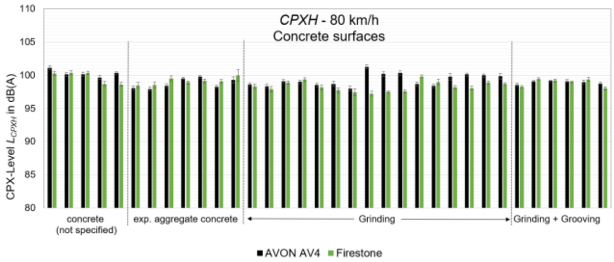

Figure 2: CPX level from CPX monitoring measurements for concrete road surfaces; Author: Müller-BBM, Data: AED, Müller-BBM, SCRIM.

From Figure 1 and Figure 2 it can be seen that the match between the H1 tyre and the H2 candidate is quite good in most cases. The overall average value of the level difference for 80 km/h is 0.9 dB with a standard deviation of 1.1 dB. Major level differences occur on two routes with DSH V 5. The reason for this is the fine-grain surface texture, which leads to a pronounced excitation of the block engagement frequency in the H1 tyre with its blocky tread pattern.

7. Determination of correction coefficients

In determining the correction coefficients, the already established functional relationships according to ISO/TS 13471-1 [3] and ISO/TS 11819-3 [2] were maintained:

•Temperature correction according to ISO/TS 13471-1:

$$C_{T,t} = -\gamma_t\,(T - T_{ref}) \qquad (1)$$

$$\gamma_t = -\gamma_1 + \gamma_2\,v \qquad (2)$$

•Shore hardness correction according to ISO/TS 11819-3:

$$C_{HA,t} = \beta_t\,(H_A - H_{ref}) \qquad (3)$$

$$\beta_t = \text{const.} \qquad (4)$$

The temperature correction coefficient for the Shore hardness in the measurement of the Shore hardness according to Formula A.1 in Annex A of ISO/TS 11819-3 remains unchanged:

$$0.25 * (T - T_{ref}). \qquad (5)$$

The following Table 2 indicates the air temperature correction coefficients $\gamma_{H2\text{-}candidate}$ and Shore hardness coefficients $\beta_{H2\text{-}candidate}$ for the various surface types according to ISO/TS 13471-1.

Table 2. Determined air temperature correction coefficients $\gamma_{H2\ candidate}$ and Shore hardness coefficients $\beta_{H2\ candidate}$ for the different surface types.

Road surface type	**$\gamma_{H2\ candidate}$ (v), dB/°C**	**$\beta_{H2\ candidate}$, dB/Shore A**
Dense Asphalt (void content < 18%)	-0.12 + 0.0006 v ± 0.01	0.22 ± 0.15
Concrete	-0.11 + 0.0006 v ± 0.02	0.03 ± 0.07
Porous asphalt (void content ≥ 18%)	-0.03 + 0.0003 v ± 0.01	0.19 ± 0.01

8. Development of a conversion formula

From the monitoring data, a formula was developed for converting results with the H2 candidate into corresponding results with the H1 tyre. This means that the data of longer time series of measurement data can be kept comparable. The procedure was as follows:

1. Calculation of the level difference between the 1/3rd octave levels of the H2 candidate and the H1 tyre for each road section k
   $DL_{CPX,k}(f_m) = L_{CPX,\mathrm{H1},k}(f_m) - L_{CPX,\mathrm{H2\ Candidate},k}(f_m)$
2. Grouping of $DL_{\mathrm{CPX}}(f_m)$ values by speed v (30 km/h, 50 km/h, 80 km/h) and surface course type p (asphalt, porous asphalt, concrete)
3. Calculation of the mean value of all $DL(v,\mathrm{p},f_\mathrm{m})$ for the calculation of the spectral conversion terms $C_{v,p}(f_\mathrm{m})$

The resulting spectral conversion terms are listed in Table 3

Table 3. Spectral conversion terms $C_{v,p}(f_m)$ for the different velocities v and surface types p.

			Spectral conversion terms $C_{v,p}(f_m)$ in dB												
Velocity	**Surface category**	**f_m, Hz**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**	**4000**	**5000**
30 km/h (v=1)	Asphalt, dense (p=1)	**Mean**	**7.1**	**3.7**	**3.5**	**3.8**	**-0.1**	**-3.6**	**-1.1**	**-1.2**	**-2.1**	**-2.4**	**-2.4**	**-3.6**	**-1.1**
		std. dev.	1.8	1.8	1.6	1.8	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
50 km/h (v=2)	Asphalt, dense (p=1)	**Mean**	**-1.1**	**2.2**	**4.6**	**2.6**	**-0.1**	**-2.1**	**-0.3**	**-0.6**	**-1.5**	**-2.6**	**-2.6**	**-4.0**	**-1.6**
		std. dev.	1.4	1.6	2.3	2.2	2.4	2.3	2.0	1.9	1.5	1.5	1.5	1.3	1.3
80 km/h (v=3)	Asphalt, dense (p=1)	**Mean**	**-1.7**	**0.1**	**2.3**	**2.5**	**2.6**	**-1.0**	**0.5**	**1.1**	**0.3**	**-0.7**	**-1.0**	**-2.5**	**-1.1**
		std. dev.	1.6	0.9	1.0	1.2	1.8	1.2	1.0	1.0	1.1	0.7	0.7	0.8	1.0
	Asphalt, open porous (p=2)	**Mean**	**-0.7**	**0.4**	**0.6**	**1.9**	**0.9**	**0.7**	**0.2**	**0.6**	**0.6**	**0.1**	**-0.5**	**-1.9**	**-1.8**
		std. dev.	0.9	0.6	0.6	0.5	0.7	0.9	0.6	0.8	0.7	0.7	0.8	1.1	1.0
	Concrete, all (p=3)	**Mean**	**-1.6**	**-0.9**	**1.7**	**1.3**	**3.3**	**-1.9**	**-0.5**	**1.1**	**0.3**	**-0.9**	**-1.5**	**-3.5**	**-2.4**
		std. dev.	0.9	1.1	0.9	1.0	2.0	0.8	1.0	1.3	0.8	0.7	0.8	0.7	1.0

The spectral conversion of the CPX levels $L_{\mathrm{CPX,H2\ candidate}}$ determined with the H2 candidate tyre into levels $L^{*}_{\mathrm{CPX,H1}}$ is carried out according to the formula

$$L^{*}_{\mathrm{CPX,H1}} = 10 \cdot \lg \sum_{f_\mathrm{m}=315\ \mathrm{Hz}}^{5000\ \mathrm{Hz}} 10^{\left(\frac{L_{\mathrm{CPX,H2,k}}(f_\mathrm{m}) + c_{\mathrm{v,p}}(f_\mathrm{m})}{10}\right)} \quad (6)$$

In Table 3, no conversion terms are given for open porous asphalt and concrete surface courses at 30 km/h and 50 km/h. This is due to the fact that 30 km/h and 50 km/h are typical velocities on urban roads, where neither open porous asphalt nor concrete courses are built in Germany. So, for these velocity/surface combinations no measurements could be performed.

9. Handbook

The project has produced a manual describing the procedure for selecting a new reference tyre for the CPX method. The aim of the procedure is to achieve the best possible spectral correspondence between the new and the old tyres and a similar speed-dependence of the tyre-road noise.

The focus points of the procedure described in the manual are listed below:

- Selection of tyre candidates for preliminary investigations
- Preliminary investigations on a test bench
- Evaluation of the test bench measurements: scoring procedure and selection of the most promising replacement candidates
- Comparative measurements on real roads and selection of the final tyre candidate
- Monitoring of the substitute candidate
- Determination of correction coefficients
- Nomenclature for the reference candidate tyre

10. Outlook

As the project is completed now, the exchange with the ISO WG33 regarding the integration of the H2 candidate as reference tyre H2 in international standardization is going on. The research report and the handbook have been published for information and further use by the professional public [7].

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