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A NEW PROCEDURE TO DETERMINE CORRECTION COEFFICIENTS FOR CNOSSOS DATABASE FOR MOTORWAYS ROAD SURFACES

Francesco Borchi[1*] **Gianfrancesco Colucci**[1] **Andrea Falchi**[1]
Paola Pulella[1] **Sergio Luzzi**[1]
Alessandro Ciampini[2] **Fabio Giuseppe Donorà**[2] **Antonietta De Benedittis**[2]

[1] Vie en.ro.se. Ingegneria S.r.l., Viale Belfiore 36, 50144 Firenze, Italy
[2] Autostrade per l'Italia S.p.a., Via Bergamini 50, 00159 Rome, Italy

ABSTRACT

In the frame of the new round of the Noise Mapping and Action Plan for Autostrade per l'Italia S.p.a. motorway network, a study concerning the influence of road surfaces on traffic noise has been carried on. In particular, a new procedure to determine correction coefficients for CNOSSOS database has been developed. Sound pressure levels and vehicle pass-by speed have been measured to analyse the traffic noise component due to tyre-pavement interaction. The measurements have been carried out simultaneously in three motorway sections placed in the A14 motorway, characterised by the laying of three different pavements, in order to compare their acoustic performance. For the noise emission measurements, the Statistical Pass-By method has been used, according to EN ISO 11819-1:2001. A comparison of the sound emission of three vehicle categories (light, medium, heavy) is presented with reference to the different pavements. The outcomes have been preparatory for the determination of correction coefficients for CNOSSOS database, defined by the EU Directive 996/2015 and also in accordance with the recent update introduced by the Delegated Directive 2021/1226/EU.

[*]*Corresponding author*: *francesco.borchi@vienrose.it.*

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1. INTRODUCTION

In the frame of the Italian legislation, the Decree of the President of the Republic 142 dated 30 March 2004 [1] defines the noise emission limits of the major roads and highlights the need to implement noise mitigation plans for the most exposed receivers.
In order to ensure the achievement of the mitigation purposes, [2] establishes the technical criteria for the preparation, by the companies and bodies managing public transport services or related infrastructures, including motorways, of plans for the containment and abatement of noise produced in the operation of the infrastructures themselves. The priority scale requires that mitigation measures must be carried out firstly at the source, then on the propagation paths and lastly at the building receivers [2].
The emission of road sound sources is due to the noise of vehicles themselves - such as engine components and airborne noise - and to the interactions between tyres and road surfaces - rolling noise -. The road pavement contributes to noise emissions in function of the materials used, the laying of road surface and the state of the surface, which determine acoustic characteristics of road pavement emissions.
Among the methods for determining the global influence of road surfaces on traffic noise, the Statistical Pass-By (SPB) method is used [3].

The SPB method has been implemented in three motorway sections placed in the A14 motorway, characterised by the laying of three different pavements. The study aimed at determining the sound emission of three vehicle categories - light, medium, heavy – and, particularly, the correction coefficients for CNOSSOS database, defined by the EU Directive 996/2015 [4], and also in accordance with the recent update introduced by the Delegated Directive 2021/1226/EU [5].

2. MATERIALS AND METHODS

2.1 Description of test sites

The three road sections are located in the A14 motorway, in Forlì, Italy. They are characterized by three lanes in each direction, in addition to the emergency lane, and the speed limit, as in Italian motorways, is 130 km/h. The description of the test sites is reported in Table 1. A different pavement was laid for 200 m length: the 2016 Draining Asphalt according to standard mix, in section 1 (T1); the Draining asphalt with optimised grain size with end-of-life tyres, in section 2 (T2); Draining asphalt with optimised grain size, in section 3 (T3).

Table 1. Description of test sites.

Name	Description of surface	Air test temperature
T1 km 87+650 – km 87+900	2016 Draining Asphalt according to standard mix	17.3°C
T2 km 87+900 – km 88+150	Draining asphalt with optimised grain size with end-of-life tyres	17.3°C
T3 km 88+150 – km 88+400	Draining asphalt with optimised grain size	17.3°C

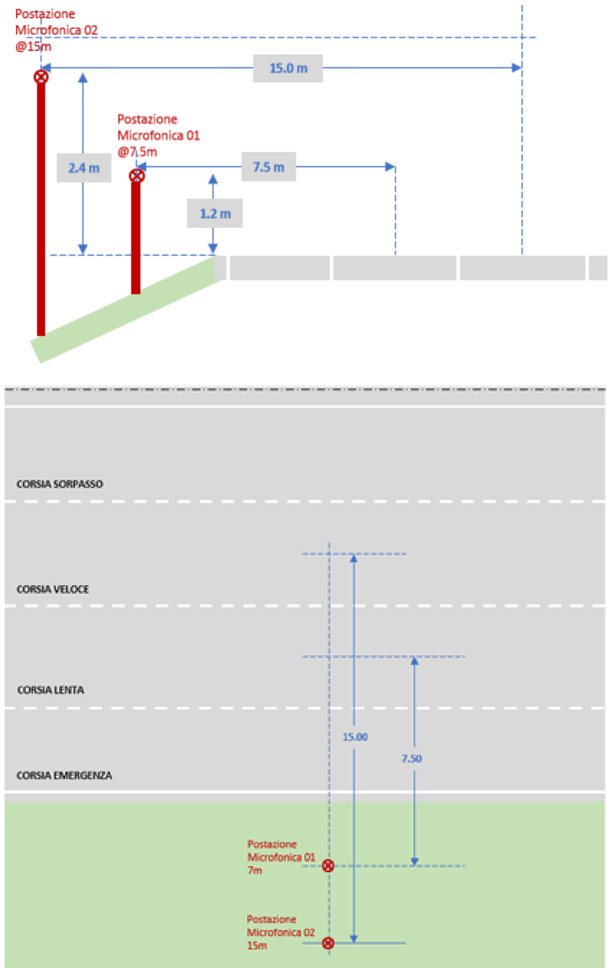

Figure 1. Scheme plan and section of a test site.

2.2 Data collection

The procedure adopted for the Statistical Pass-By method has been carried out according to EN ISO 11819-1:2001 [3].
It consists of measuring the maximum A-weighted sound pressure levels measured with the time constant "Fast" and detecting the speed of a statistically significant number of vehicle passages, classified according to their type (light, medium, and heavy vehicles). The standard provides information on vehicle categories, speed classes and sample type.
Concerning the motorway sections under investigation, for each vehicle passage, the time history of the A-weighted sound pressure level with Fast time weighting ('LAF' parameter) was recorded at 0.1 s intervals. The weather

conditions during the measurements ensured the compliance with the standards.
According to the standard, for this measurement, a microphone was placed at a distance of 7.5 m from the axis of travel of vehicles in the low-speed lane at a height of 1.2 m from the road surface; moreover, a second microphone was placed at a distance of 15 m from the axis of travel of vehicles in the fast-speed lane at a height of 2.4 m from the road surface. Data collection was possible in parallel by the setting up of six measuring stations, two for each motorway section under analysis. At each section, two sound level meters and one speed measuring device were positioned.
The measuring sections were located approximately in the centre of each 200 m long stretch of motorway under evaluation.
The selection of the pass-by events was subsequently carried out in post-processing by considering only those events clearly distinguishable from the rest of the road traffic, in accordance with the selection criteria defined by the standard [3] in paragraph 7.2.

2.3 Methods

A simplified acoustic model of the SPB test scenario was built using a commercial software implementing CNOSSOS emission database. Both the location at 7.5 m from the axis of the slow lane at 1.2 m height and the location at 15 m from the fast lane at 2.4 m height were used as calculation points. In Italian motorways the legal maximum speed is 130 km/h for light vehicles, whereas for medium and heavy vehicles is limited to 100 km/h. However, during the SPL measurement campaign, speeds above the limits have been observed. The modes of the measured values are 130 km/h for light vehicles, 120 km/h for medium vehicles and 90 km/h for heavy vehicles. Consequently, reference speeds have been defined in accordance with mode values. Simulations were carried out at different speeds (from 80 km/h to 130 km/h for light and medium vehicles and from 80 km/h to 100 km/h for heavy vehicles).
To update the CNOSSOS emission databases, a specific procedure was developed. In particular, the proposed procedure was based on the definition of specific corrections related to the type of pavement.
The procedure aims at defining reference coefficients for the specific pavements adopted on the investigated A14 motorway sections.
In particular, the CNOSSOS parameters to determine are:

- $\alpha_{i,m}$ - expressed in octave bands - , which represents the corrections in terms of pavement absorption;
- β_m, which defines the angular coefficient of the curve and introduces a correction dependent on speed and therefore directly related to rolling noise.

In the defined model, for each category of vehicle in the slow lane, a single vehicle is considered using the standard pavement. The type of asphalt, defined as a starting point, is the CNOSSOS reference pavement for which the values of parameters $\alpha_{i,m}$ and β_m are zero. Then, from the comparison between simulated and measured $L_{eq,h}$ at 7.5 m (see Table 2), the corrective coefficients of the pavement for the three vehicle categories were defined, while the $L_{eq,h}$ measured at 15 m was used for the validation.
Using an iterative process, the values of $\alpha_{i,m}$ were determined so that the spectrum simulated and determined by SPB measurements was well aligned with a reference speed considered as the most representative for the different vehicles categories: 130 km/h was defined as the reference speed for light vehicles, 120 km/h for medium vehicles and 90 km/h for heavy vehicles.

3. RESULTS AND VALIDATION OF COEFFICIENTS FOR CNOSSOS

The coefficients $\alpha_{i,m}$ and β_m to be associated with the new pavement are determined from the comparison of simulated and measured $L_{eq,h}$ at 7.5 m, for the three vehicle categories. In particular, the value of β_m is first determined from the comparison of global values in dB(A). Then, in an iterative manner, the values of $\alpha_{i,m}$ are determined so that the spectrum simulated and determined by SPB measurements is well aligned with the reference speed for each vehicle category.
The determination of the coefficients was carried out iteratively on the basis of the formulae given in the Directive [4]:

$$\Delta L_{WR,road,i,m} = \alpha_{i,m} + \beta_m \times \lg\left(\frac{v_m}{v_{ref}}\right)$$

$$\Delta L_{WP,road,i,m} = \min\{\alpha_{i,m};0\}$$

The respective resulting values of parameters $\alpha_{i,m}$ and β_m are reported in Table 3 and are referred to section T1.

In brief, the modelling input data of the road noise source are:

- traffic volume: 1 light/medium/heavy vehicle per hour;
- transit speed: 80-90-100-120-130 km/h (for light and medium vehicles), 80-90-100 km/h (for heavy vehicles);
- type of asphalt: a new pavement characterised by the coefficients defined in Table 3 was introduced instead of the reference pavement.

In Table 4 and Table 5, the validation check is reported. In general, the difference between the measured and simulated levels are within 0.5 dB in the closer measurement point (7.5 m – calculation points called “P_s” in Table 4) and 1 dB in the further point (15 m – calculation points called “P_r” in Table 5).

Table 2. Example of section T1: A-weighted SPL resulting from acoustic simulations, for $\alpha_{i,m}=0$ and $\beta_m=0$.

A-weighted SPL ($L_{Aeq,1h}$) @ “P_s” – [dB(A)]											
Vehicle	Reference speed [km/h]	Simulated									Measured
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Overall [dB(A)]	Overall [dB(A)]
Light	130	4.5	19.4	25.4	31.5	42.2	41.3	32.3	20.5	45.3	42.8
Medium	120	10.7	22.2	32.8	38.3	43.3	40.0	32.9	25.5	46.3	41.9
Heavy	90	16.3	24.2	33.3	40.6	43.8	39.5	33.1	24.8	46.9	45.0

Table 3. Example of section T1: values of parameters $\alpha_{i,m}$ and β_m.

Frequency	α								β
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	
Light	10	8	10.3	11.4	-2.1	-6.4	-6.7	-3.1	-8
Medium	4	2.5	-2	1	-5.4	-7	-7.8	-7.6	-2.4
Heavy	1.6	2.7	6	6.2	-3.5	-4.9	-6.8	-6.1	-18

Table 4. Example of section T1: A-weighted SPL resulting from acoustic simulations and a comparison with measured values – in measurement points called “P_s”.

A-weighted SPL ($L_{Aeq,1h}$) @ “P_s” – [dB(A)]												
Vehicle	Speed [km/h]	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Simulated overall	Measured overall	D SPL
Light	80	8.2	19.0	27.1	37.9	35.0	29.1	20.1	12.0	40.3	39.5	0.8
	90	7.9	20.1	28.1	38.3	35.7	30.0	21.0	12.9	40.9	40.3	0.6
	100	7.8	21.1	29.0	38.6	36.4	30.8	21.8	13.8	41.5	41.0	0.5
	110	7.7	22.0	29.8	39.0	37.0	31.6	22.6	14.6	42.0	41.7	0.3

Table 5. Example of section T1: A-weighted SPL resulting from acoustic simulations and a comparison with measured values – in measurement points called “P_r”.

A-weighted SPL ($L_{Aeq,1h}$) @ “P_r” – [dB(A)]

Vehicle	Light						Medium					
Speed [km/h]	80	90	100	110	120	130	80	90	100	110	120	130
63 Hz	6.3	6.1	5.9	5.8	5.8	5.9	11.4	10.7	10.2	9.7	9.4	9.1
125 Hz	17.2	18.2	19.2	20.1	21.0	21.8	19.0	19.5	20.0	20.6	21.1	21.7
250 Hz	25.2	26.2	27.1	27.9	28.7	29.4	26.5	27.0	27.6	28.1	28.7	29.3
500 Hz	36.0	36.4	36.7	37.1	37.4	37.7	34.6	35.1	35.6	36.1	36.6	37.1
1 kHz	33.2	33.9	34.6	35.2	35.7	36.3	33.3	33.9	34.6	35.2	35.8	36.4
2 kHz	27.3	28.2	29.1	29.8	30.6	31.3	28.2	28.9	29.6	30.3	31.0	31.7
4 kHz	18.2	19.1	19.9	20.8	21.5	22.3	20.1	20.8	21.5	22.2	23.0	23.7
8 kHz	9.9	10.8	11.6	12.5	13.3	14.0	11.9	12.8	13.7	14.6	15.4	16.2
Simulated A-weighted SPL [dB(A)]	38.5	39.1	39.6	40.1	40.6	41.0	38.0	38.6	39.2	39.7	40.3	40.9
Measured A-weighted SPL	39.2	39.7	40.1	40.5	40.8	41.2	39.0	39.6	40.1	40.6	41.0	41.4
D SPL	-0.7	-0.6	-0.5	-0.4	-0.2	-0.2	-1.0	-1.0	-0.9	-0.9	-0.7	-0.5

Vehicle			Medium						Heavy		
Speed [km/h]	120	130	80	90	100	110	120	130	80	90	100
63 Hz	7.7	7.7	13.3	12.6	12.1	11.6	11.2	10.9	16.7	16.2	15.8
125 Hz	22.8	23.6	20.9	21.4	21.9	22.5	23.0	23.6	24.4	24.3	24.4
250 Hz	30.6	31.3	28.4	28.9	29.4	30.0	30.6	31.2	34.4	34.6	34.8
500 Hz	39.3	39.6	36.5	37.0	37.5	38.0	38.5	39.0	43.5	43.5	43.4
1 kHz	37.5	38.1	35.1	35.7	36.3	37.0	37.6	38.2	38.9	39.1	39.3
2 kHz	32.4	33.0	30.0	30.6	31.4	32.1	32.8	33.5	33.3	33.6	34.0
4 kHz	23.4	24.2	21.9	22.7	23.4	24.1	24.8	25.6	25.3	25.6	25.9
8 kHz	15.4	16.2	14.0	14.9	15.8	16.7	17.5	18.4	17.4	17.8	18.2
Simulated A-weighted SPL [dB(A)]	42.4	42.9	39.9	40.4	41.0	41.6	42.2	42.7	45.5	45.6	45.7
Measured A-weighted SPL	42.3	42.8	39.6	40.2	40.8	41.4	41.9	42.3	45.2	45.0	44.9
D SPL	0.1	0.1	0.3	0.2	0.2	0.2	0.3	0.4	0.3	0.6	0.8

Heavy		
100	90	80
13.9	14.4	14.9
22.5	22.5	22.5
32.9	32.7	32.6
41.5	41.6	41.6
37.5	37.3	37.1
32.2	31.9	31.5
24.0	23.7	23.4
16.0	15.6	15.3
43.8	43.7	43.7
44.0	43.8	43.6
-0.2	-0.1	0.1

4. CONCLUSIONS

The analysis of noise emission of motorway sections, with particular reference to the T1 section, led to the determination of new CNOSSOS coefficients, updated for the specific motorway pavement. This data is of even greater interest, since it can be applied to numerous motorways: more than 2400 km are characterized by the laying of draining asphalt. It can be noticed that measurements were performed on road surfaces laid in 2016, therefore the CNOSSOS parameters may not be coherent for all the mentioned motorway pavements with different age. Further measurement campaigns could interest how the aging of asphalt influences CNOSSOS parameters and how to update the dataset in relation to the aspects of aging. However, the analysis of this type of draining pavement makes it possible to implement the database provided by the Directive by reducing the noise estimation error of the specific road infrastructure when the T1 pavement is laid.

5. REFERENCES

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[3] EN ISO 11819-1:2001 Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 1: Statistical pass-by method.

[4] COMMISSION DIRECTIVE (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council.

[5] COMMISSION DELEGATED DIRECTIVE (EU) 2021/1226 of 21 December 2020 amending, for the purposes of adapting to scientific and technical progress, Annex II to Directive 2002/49/EC of the European Parliament and of the Council as regards common noise assessment methods.