Applied Acoustics 76 (2014) 169–179

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

A modified Close Proximity method to evaluate the time trends of road pavements acoustical performances

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ARTICLE INFO

Article history:
Received 4 June 2012
Received in revised form 8 July 2013
Accepted 24 July 2013
Available online 6 September 2013

Keywords:
CPX
Acoustical absorption
Tyre/road noise

ABSTRACT

The Close Proximity Index (CPX) measurement method is proposed in the ISO/DIS 11819-2:2011 and it aims to evaluate different road pavements with respect to their influence on traffic noise, under conditions when tyre/road noise dominates. In this paper, a modified CPX-based methodology is presented, in order to improve the usefulness of tyre/road noise measurement in the evaluation of acoustical performances of a road surface, in terms of both temporal and spatial stability and in terms of effectiveness of a mitigation action. In particular, the proposed methodology uses a finer spatial resolution and improves the speed-levels relationship knowledge. Moreover, data variability and uncertainty related to tyre/road noise measurement results are here investigated.

This paper is conceived within LEOPOLDO project, developed in Tuscany with the aim to study the acoustical characteristics of six new experimental road surfaces, and the proposed methodology has been applied to some of them. The evaluation of the local possible acoustical inhomogeneities of test pavements and a three years long monitoring of the time evolution of their acoustical performances were required by the project. Finally, a new criterion is proposed to make more reliable comparisons (differential criterion) between different road surface types and to better evaluate the temporal evolution.

1. Introduction

The Close Proximity Index (CPX) method is proposed in the ISO/CD 11819-2 [1] and it aims to evaluate different road surfaces with respect to their influence on traffic noise, under conditions when tyre/road noise dominates.

This paper has been conceived within LEOPOLDO project [2], developed in Tuscany since 2006. The project aims to study the acoustical characteristics of six experimental pavement types. These were laid on 200 m long stretches of six extra-urban main roads representing typical Tuscany roads (i.e. located in hills, mountains and plains along Tuscany region with different climate conditions).

In particular, the project requires the description of tyre/road noise emission through both the A-weighted level and the spectrum in third octave bands between 315 and 8000 Hz. Moreover, the evaluation of inhomogeneity for test surfaces and a 3 years long monitoring for time evolution of their acoustical performances need to be performed.

In this paper, an adapted measurement and data post-processing methodology based on the CPX method is presented for analyzing road pavements both in terms of acoustical homogeneity and time stability. Data variability is investigated in order to estimate the results uncertainty related and to assess the effectiveness of the methodology for evaluating not only performances among different surfaces, but also for analyzing single surface temporal evolution. The methodology is mainly focused on urban and extra-urban (not highways) contexts.

The methodology here presented is based on ISO/CD 11819-2 third release (2000) and the measurements carried out for this work are preceding the current draft for this standard, the ISO/DIS 11819-2, released in 2011 (approved in 2012) and subjected to definitive approval only in 2013, but this fact has not a significant influence on the analysis. Moreover, this paper deals with tyre/road noise levels, without referring to CPX indexes, although its remarkable to notice that some improvements presented in the 2011 release are towards the methodology here presented.

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http://dx.doi.org/10.1016/j.apacoust.2013.07.017

2. Measuring procedure and uncertainty according to ISO 11819-2

Previous and actual drafts of the ISO/DIS 11819-2 (2011) allow to perform the CPX measurements using a trailer towed by a separated vehicle or a self-powered vehicle. The application of the method for surveying large road networks requires only one single run. In this case, measurement has to be carried out on the wheel track closest the edge of the road and it is allowed to use just one reference tyre (annex G in [1]).

The current draft requires that:

> "… for each individual test run with the test tyre, the average sound levels over short measuring distances (segments of 20 m each), together with the corresponding vehicle speeds are recorded. The sound level of each segment is normalized to a reference speed by a simple correction procedure. Averaging is then carried out according to the purpose of the measurement (measuring a particular segment or a number of consecutive segments – a section)".

The resulting average sound level for the two mandatory microphones at that reference speed is called "Tyre/road Sound Level", L_{CPX}.

Moreover, it requires that:

> "The road section (excluding the run-in) shall be at least 20 m long, and preferably longer than 100 m.";

and

> "For each road segment of 20 m, the A-weighted equivalent third-octave-band level from 315 Hz to 5000 Hz shall be determined at each microphone position. This forms the basis for all further evaluations".

Guidelines for measuring the variability in tyre/road sound emission characteristics along a road surface test section recommend to calculate the standard deviation, around the mean, of the sound levels representing each 20 m long road segment. The arithmetic mean of the standard deviations obtained for each reference tyre used, L_{VA}, is an indication of the homogeneity (annex H in [1]).

ISO/DIS 11819-2 identifies the sources of uncertainty due to disturbances, which are:

> "either known but randomly distributed in an uncontrollable way, or are of a systematic nature, but affects the result in an unpredictable way".

The draft estimates the repeatability as 1 dB(A), the reproducibility as 2 dB(A), and it indicates the uncertainty of the measure as 0.5 dB(A) (annex K in [1]) [3,4].

As it will be shown here in after in detail, LEOPOLDO project required not only the survey of experimental surfaces, but also a reference road pavement, in analogy with the procedure described in the ISO/DIS 11819-2 (arbitrary reference case, annex O in [1]). In this case, the reference surface is a SMA 11/16, here in after denoted as type D.

2.1. Measurement set-up and general conditions

According to ISO/CD 11819-2 and taking into account previous studies available in literature [5–7], a self-powered vehicle has been developed, mounting the two mandatory free field microphones located close the rear right side pneumatic, far from the exhaust pipe (Fig. 1) [8]. In particular this set-up was tested in [5,9,10] against the influence of internal and external noise sources (exhaust, engine, other aerodynamic sources).

The tyre used is a Michelin XSE 185/65 R15 88T, according to the reference ones identified by the ISO/CD 11819-2 with a tread pattern similar to the B type. It ran less than 5000 km and it worked only during every measurement session. Before starting each measurement session the pneumatic was driven some minutes to be brought to the normal operating temperature.

A particular encoder is applied to the rear left tyre, and it returns a voltage signal alternately equal to 0 or 5 Volts per angle of 18°. Hence the output is a square wave signal, whose period is a function of vehicle speed. This data are used to calculate the covered length and the instantaneous speed profile.

As recommended by the ISO/DIS 11819-2, measurements are conducted only on perfectly dry surfaces (annex F in [1]). Measurement sessions are carried out when measured air temperature is within the range representative for the climatic zone and wind speed not exceeding 5 m/s. All along the measurement session, road temperature is also monitored, because of relationship existing between temperature and the tyre/road noise emission [11]. Further studies are to be developed to verify if it is possible to specify a road surface temperature correction for the CPX method.

Measurement sessions are planned without requiring the road closed to traffic, and many measurements are carried out with passing traffic on both the investigated lane and the opposite one. Measurements affected by the presence of heavy trucks or motorcycles are not used in post-processing, in order to avoid possible influences.

2.2. Reference surface

The A-weighted level $L_{EQ}(A)$ at reference speed of 50 km/h (±2 km/h) measured in seven different sessions on reference surface (type D) is plotted in Fig. 2. Here values are corrected in temperature as recommended by the draft.

Measurements on the reference surface have been conducted with one single acquisition chain, so it is not possible to calculate rigorously repeatability and reproducibility according the ISO 5725-2 [12].

Anyway it is possible to compare the pointed out variability and the estimated uncertainties. In fact, the reference surface was older than one year at the time of the first measurement session and it was spatially homogeneous. It can be reasonably supposed stable in time:

– Standard deviation computed in each session is about $\sigma^2 = 0.4$ dB(A). Taking into account also the measurement uncertainty, a confidence interval can be obtained

$$\Gamma_{95} = 1.96 \cdot \sqrt{\sigma^2 + 0.5^2} \approx 1.2 \quad \text{dB(A)}$$

which is in fair agreement with the repeatability of 1 dB(A) reported by the ISO draft.

– Taking also into account the variability between several sessions, Γ_{95} assumes the value 1.6 dB(A), consistent with the reproducibility of 2 dB(A) reported by the ISO draft.

Finally, it can be asserted that measurements returned good quality results, because they present an uncertainty value that agrees with what estimated by the ISO draft. Therefore, the acoustical characterization of the reference surface can be obtained through the mean level and related confidence interval: 92.5 ± 1.6 dB(A).

3. Adapted methodology and its application on LEOPOLDO sites

Data variability, already pointed out on the reference surface, is in agreement with what highlighted in literature [5] and it turns