Long Term Monitoring Of Acoustic Performances Of Rubberized Surfaces

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ABSTRACT: The use of road surfaces with low noise emission characteristics is one of the actions mostly applied all over the world to decrease the number of people annoyed by road traffic noise. In Italy, the rubberized technologies have been introduced quite recently and some experimental installations have been acoustically studied in the last years. In particular, some experimental surfaces have been laid on extra-urban roads, exposed to the wear due to the actual traffic flow and climatic conditions. In order to verify the effectiveness of the noise mitigation action, the road pavements have been surveyed for some years by means the CPX method. Several rubberized road surfaces have been analyzed in terms of spatial homogeneity, spectral composition and performance durability of their noise emission reduction, comparing them to coeval road surfaces used as reference. Different regression models were proposed and applied to estimate the acoustic aging of analyzed pavements.

The obtained results provide important information about the noise characterization of rubberized road surfaces for practitioners and researchers.

KEYWORDS: rubberized surfaces, CPX, noise mitigation action, long term monitoring

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1. Introduction

1.1. *Rubberized road surfaces*

The tire/road noise constitutes the most important generation factor of traffic noise in the mid-to-high speed range and is strongly variable with tire and pavement type.

Therefore, the use of road surfaces with low noise emission characteristics represents one of the actions mostly applied all over the world to decrease the number of people annoyed by road traffic noise.

Today, different classes and types of quite pavements have been developed and applied in the mitigation of road traffic noise (as Porous asphalt, Rubberized asphalt, Poroelastic road surface, thin and very thin layers) [Praticò and Anfosso-Lédée, 2012].

Rubberized asphalt pavements, built using hot asphalt mixes containing crumb rubber, constitute an efficient road surface technology in terms of traffic noise reduction that ranges up to 8-10 dBA [Licitra et al. 2015].

Crumb rubber can be added into hot mix asphalt (HMA) through two main different methods: the ‘‘wet process’’ and the ‘‘dry process’’.

In the wet process, the crumb rubber is blended with liquid asphalt cement (AC) before to mixing AC with the aggregates. Differently, in the dry method, rubber is blended to the hot aggregates before the addition of the asphalt cement AC.

In Italy, the rubberized technologies have been introduced quite recently and some experimental installations have been acoustically studied in the last years.

In the present work, three experimental asphalt rubber friction courses (wet process), laid on extra-urban roads in the north of Italy and surveyed for some years by means the CPX method, have been studied in order to verify the effectiveness of the noise mitigation action and to analyze their long-term acoustic performances.

1.2. *Acoustic aging of road pavements*

The phenomena involved in the acoustic aging of road surfaces depend on layer and surface characteristics and may concern the clogging of the pores (in the case of porous pavement) and the variation/degradation of the texture (in terms of polishing of the surface, roughening of the surface by stone loss, superficial closing due to dust accumulation and post-compaction) [van Loon et al. 2015].

The acoustic performances of road pavements deteriorate during their service life.

This fact involves an increase with time in tire/road noise levels that in literature is expressed as a function (linear, exponential or logarithmic) of the pavement age as shown in Table 1 listing monitored pavements and measured noise indicators.

Table 1: *Models of acoustic aging of road surfaces*

Pavement type	Method/ Indicator	Model	References
DGAC, OGAC, SMA, UTLAC	SPB	Lin, Exp, Log	[Iversen and Kragh, 2014]
SMA, ACMR, SDA	SPB, CPX	Exp, Log	[Hammer et al., 2015]
SMA, LN-SMA, 1L-PA, 2L-PA	SPB, RVS, CPX	Log	[Wehr et al. 2015]
DGAC, OGAC, 1L-PA, RAC, UTLAC, SMA	SPB, OBSI	Lin	[Bendtsen et. al. 2009]
ARFC	CPX	Lin	[Arizona, 2003]
1L-PA, 2L-PA, TSL, SMA DGAC, OGAC	SPB, CPX	Lin	[van Blokland et al. 2014]

Legend

1L-PA = Single-layer Porous asphalt; 2L-PA = Double-layer Porous Asphalt; ARFC = Asphalt Rubber Friction Course; CPX = Close Proximity method; Exp = Exponential; DGAC = Dense Graded Asphalt Concrete; Lin = Linear; LN-SMA = Low-noise Stone Mastic Asphalt; Log = Logarithmic; OBSI = On-Board Sound Intensity method method; OGAC = Open Graded Asphalt Concrete; RAC = Open and Dense Graded Asphalt Concrete with rubber; RVS = RVS 04.02.11 method; SMA = Stone Mastic Asphalt; SPB = Statistical pass-by method; TSL = Thin Surface Layers; UTLAC = Ultra thin asphalt layers.

2. Experimental Plan

2.1. Experimental installations

Three experimental rubberized road surfaces, built using a gap-graded asphalt mix containing crumb rubber (wet process), laid on extra-urban roads in Coldrano and Ciardes, in the north of Italy, have been surveyed for some years by means the CPX method.

Two Asphalt Rubber (wet process) Gap Graded 0/16 pavements, named AR1 and AR2, laid in Coldrano, in 2011, have been monitored over a period of 6 years. To verify the effectiveness of the noise mitigation action of AR1 and AR2, a coeval Stone Mastic Asphalt 0/12 has been used as reference. In addition, a third Asphalt Rubber pavement, named AR3, laid in Ciardes, in 2013, has been monitored over a period of 4 years.

Two lanes (for two opposite traffic directions) have been surveyed for each pavement.

The same mix design has been used for all the rubberized pavements (AR1, AR2 and AR3). Aggregate gradation and asphalt binder content (b%) referred to mixture weight are detailed in Figure 1.

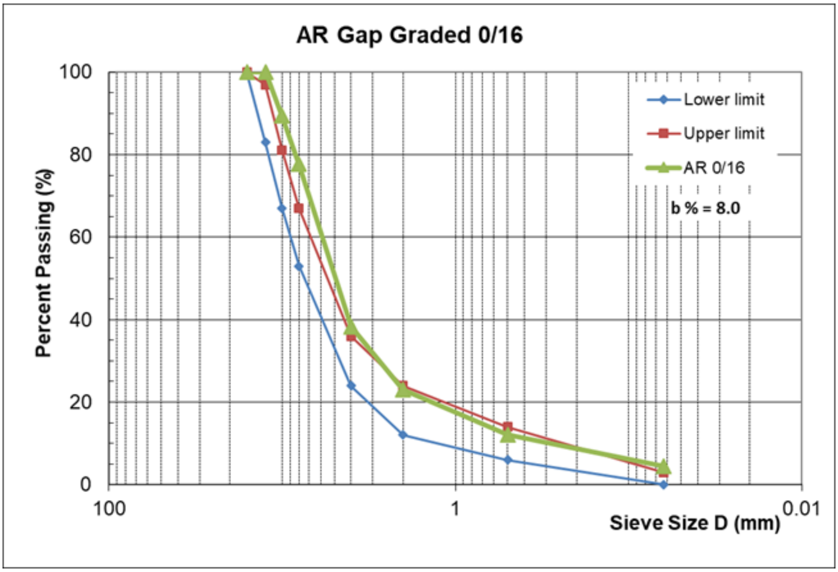

Figure 1: Aggregate gradation and asphalt binder content for AR Gap Graded 0/16

2.2. The Method

The CPX method, described in the standard UNI EN ISO 11819-2:2017, uses two microphones placed in proximity to the tire/road contact to evaluate the road-tire noise as far as it dominates all other noise sources, such as the power unit.

A trailer towed by a separated vehicle or a self-powered vehicle may be used to carry out CPX measurements.

In the present work, a self-powered vehicle was used adapting the protocol for measurement and data post-processing developed within the LEOPOLDO project [Licitra et al. 2014]. The results are expressed in terms of overall A-weighted equivalent sound pressure level, at the reference speed, L_{CPX}.

For all the analyzed pavements (AR1, AR2, AR3 and SMA), the considered reference speed was 50 km/h.

For excessive wearing of the first test tire, two types of reference tire have been used during the monitoring period of three pavements laid in Coldrano.

3. Analysis of results

3.1. Comparison of AR1 and AR2 to coeval SMA surface used as reference

The pavements AR1, AR2 and a coeval SMA surface used as reference have been monitored over a period of 6 years. Figure 2 shows the comparison between the acoustic performances of the three pavements in terms of time evolution of L_{CPX} differential values obtained by "the differential criterion", came from the necessity to avoid influence by measurement conditions [Licitra et al. 2014].

It is important to specify that the use of different reference tires gives appreciable differences in terms of L_{CPX} absolute values, but permits to obtain the same differential values [Licitra et al. 2017] between new and reference pavement acoustical performances.

One can observe that both rubberized pavements allow to gain appreciable acoustic benefits during their service life. In particular, noise reductions compared to the coeval SMA surface range between -3.2 (after 8 months) and -1.1 dB(A) (after 72 months).

It is important to remark that AR1 values have a worse time evolution than AR2 values although the same mix design and exposure to traffic flow and climatic condition.

This different trend is explained through Figure 3 that illustrates time evolution of L_{CPX} differential values for opposite traffic directions (two lanes for each pavement).

In fact, only one lane (named AR1-M) shows a different trend with respect to all the others, probably due to a non-identified problem occurred in paving operations.

Therefore, it is important to underline that, even in the presence of a good mix design, an imperfect paving may compromise the final result in terms of noise abatement.

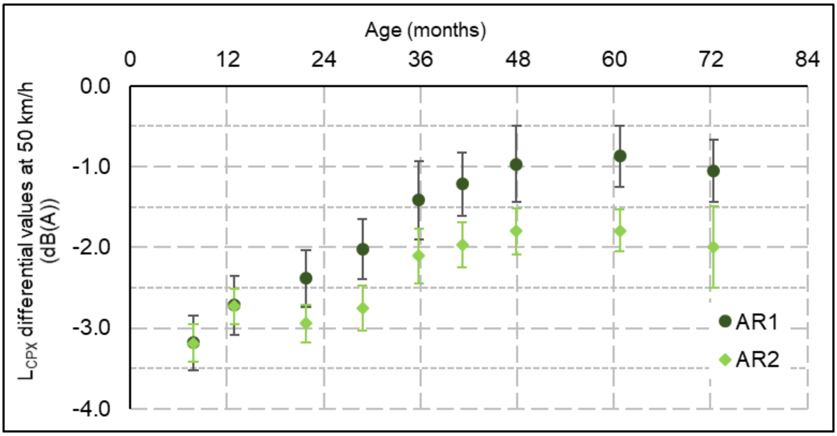

Figure 2: Time evolution of L_{CPX} differential values for AR1 and AR2 vs. SMA

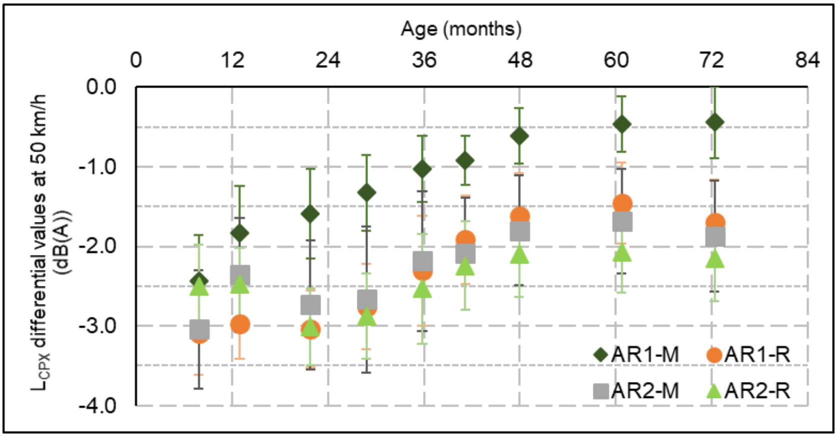

Figure 3: Time evolution of L_{CPX} differential values for opposite traffic directions

3.2. Application of regression models to pavement AR3

Different regression models (linear, exponential and logarithmic) were applied to estimate the acoustic aging of the rubberized pavements in terms of increase of L_{CPX} absolute values.

Regression analyses were applied only to pavement AR3. The collected data of this pavement, as the monitoring over a period of 4 years has been performed by the same reference tire, haven't been affected by the variability related to its change in terms of absolute values of L_{CPX}.

Note that, for each measure session, L_{CPX} values were also corrected for air temperature and rubber hardness of reference tire, that represent the most important influence factors of these measurements [Bühlmann and Ziegler, 2013; Bühlmann and van Blokland, 2014; Sandberg et al. 2016; Werh and Fuchs, 2016].

Table 2 summarizes the main results of regression analyses.

Table 2: *Main results of regression analyses*

Model	Equation	Coefficients	RMSE
Linear	$\boldsymbol{L_{CPX} = Y_0 + C_A * (A)}$	$Y_0 = 88.83$; $C_A = 0.04$	1.32
Exponential	$\boldsymbol{L_{CPX} = Y_0 + C_A * e^{(\beta * A)}}$	$Y_0 = 90.83$; $C_A = -2.38$; $\beta = -0.05$	1.34
Logarithmic	$\boldsymbol{L_{CPX} = Y_0 + C_A * ln(1 + A)}$	$Y_0 = 87.79$; $C_A = 0.72$	1.24

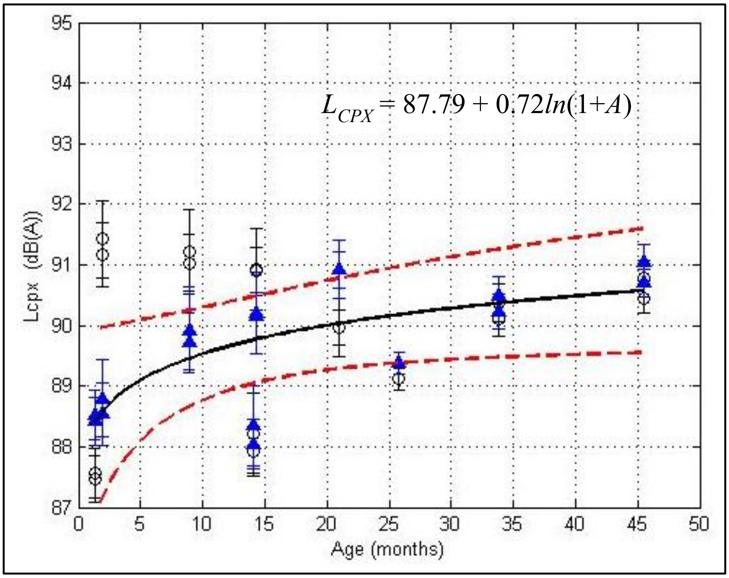

Figure 4: Logarithmic regression model for L_{CPX} vs Age: uncorrected data (empty points) and corrected (blue triangles) for tire hardness and air temperature ones.

In spite of linear models proposed in literature to describe acoustic aging of rubberized pavements, the best model for the analyzed pavement AR3 seems to be the following logarithmic model:

$$\boldsymbol{L_{CPX} = Y_0 + C_A * ln(1 + A)}$$

where the variable *A* stands for the age of the pavement, whereas Y_0 and C_A are constant coefficients.

The intercept Y_0 represents the initial L_{CPX} value of the pavement and depends on mix type and construction practices, whereas C_A depends on mix susceptibility to the factors of acoustic aging (as exposure to traffic flow and climatic conditions).

Figure 4 shows L_{CPX} values versus the pavement age according to the logarithmic model.

3.3. Analysis of the spectral composition of the CPX-results for AR3

Time evolution of the spectral composition of the CPX-results for AR3 is shown in Figure 5.

The maximum level is observed at 800 Hz after 9 months and remains constant over the next measures.

In the mid-to-high frequency range, levels significantly increase after 14 months and remain more or less the same over the next times.

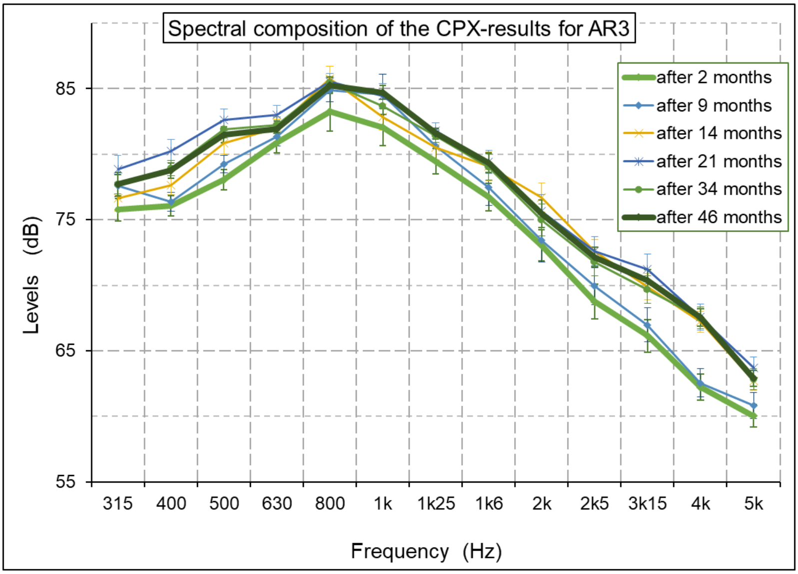

Figure 5: Spectral composition of the CPX-results for AR3 at 50 km/h

This increase is probably due to phenomena of polishing of road surface and compaction of the top layer under traffic loads that amplify aero-acoustic noise generation.

A more gradual increase of levels is observed at the lower frequency range related to the progressive degradation of surface texture that increases the vibrations of the tire structure.

4. Conclusions

Three experimental rubberized surfaces (wet process), laid on extra-urban roads in the north of Italy, have been surveyed for some years by means of the CPX method in order to verify the noise mitigation action effectiveness and to analyze their long-term acoustic performances.

The analyzed rubberized pavements showed appreciable acoustic benefits during all their life service, quantifiable in noise reductions ranging between -3.2 (after 8 months since installation) and -1.1 dB(A) (after 72 months), if compared to a coeval SMA surface. One lane showed a different trend with respect to all the others, probably due to a non-identified problem occurred in paving operations. Therefore, even in the presence of a good mix design, an imperfect paving may compromise the final result in terms of noise abatement.

Different regression models were applied to estimate the acoustic aging of the rubberized pavements. The best model resulted to be the logarithmic one, in spite of the common linear ones in literature.

Time evolution of the spectral composition of the CPX-results shows a significant increase of levels after 14 months in the mid-to-high frequency range, whereas at the lower frequency range a more gradual increase is observed. This is probably related to the progressive degradation of surface texture that increases the vibrations of the tire structure.

Future research will need to address a better understanding of the above-mentioned phenomena.

Acknowledgement

Authors want to express their gratitude to Daniele Fornai (Ecopneus S.c.p.a) for useful discussions. This paper could not be written without the financial support of Ecopneus s.c.p.a., which funded a research project carried out by CNR-IPCF and its spin-off IPOOL s.r.l..

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