MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Life NEREiDE project: preliminary evaluation of road traffic noise after new pavement laying

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ABSTRACT

The LIFE NEREiDE project is aimed to evaluate the tyre/road noise reduction by means of recycled asphalt pavements and crumb rubber from scrap tyres, layered at temperature lower than normal ones. At present, six new pavements with different blend have been investigated, measuring the vehicle pass-bys noise in proximity of the house at road level using a binaural recording system. The measurements have been repeated before and one year after the new pavement laying. Among the objectives of the project there is the evaluation of the noise reduction achieved by the new pavements and how these are perceived by citizens. For this purpose some psychoacoustic parameters have been determined together with traditional acoustic descriptors. The paper will describe the preliminary results on noise reduction obtained by the new pavements, analysing the recorded data in each of the six sites, as well as perceived reduction and road traffic noise annoyance reported by citizens.

Keywords: Noise, Road pavement, Annoyance, Psychoacoustic, Road traffic
I-INCE Classification of Subject Number: 79

1. INTRODUCTION

Due to the significant reduction of noise from the several sources present in a vehicle (i.e. engine, power train, intake, exhaust, etc.) and the increased growing of hybrid and electric vehicles in traffic flow, the noise due to the interaction road pavement/tyre is becoming very important and many efforts are now focused to

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mitigate such noise [1-4]. The acoustic performances of road pavements can be characterized by the statistical pass-by SPB method (ISO 11819-1) and/or the ISO Close ProXimity CPX method (ISO 11819-2). However, the noise descriptors provided by these standardized measurement methods are not directly related to the sound perception of people. For instance, the real noise reduction due to the road pavement decreases over the time and it is often below the perceived just noticeable difference (JND). Thus, additional parameters more related to the sound perception are needed to provide further information on the potential benefit of low-noise road pavements.

The present paper describes the observed changes of the values of some psychoacoustic parameters corresponding to the conditions "before" and "after" the laying of new road surfaces with different acoustical characteristics, as well as the differences in noise annoyance responses given by the interviewed population sample.

2. METHODOLOGY

According to the programme of the NEREiDE LIFE project [5], "before" and "after" noise monitoring campaigns and social surveys have been carried out in the Municipality of Massarosa (Tuscany Region, Italy) in June 2017 and November 2018 respectively.

The acoustic and psychoacoustic parameters have been determined from binaural digital sound recordings of the road traffic noise, performed by the binaural headset BHS II (HEAD acoustics), a headset/microphone unit for aurally adequate recording, equipped with calibratable high-end ICP® microphones. The headset was connected to the SQobold mobile 4-channel recording and playback system.

The six sites, along the SR 439 "Sarzanese" road in the Municipality of Massarosa and shown in Figure 1, have been selected according to the plans of pavement restoration of Tuscany Region. In all the sites, the asphalt present, before of the new pavement laying, was older than 10 years and it has been replaced by new pavements composed by recycled asphalt and crumb rubber from scrap tyres, performing a lower noise emission than that by traditional asphalt, which has also a good duration [4].

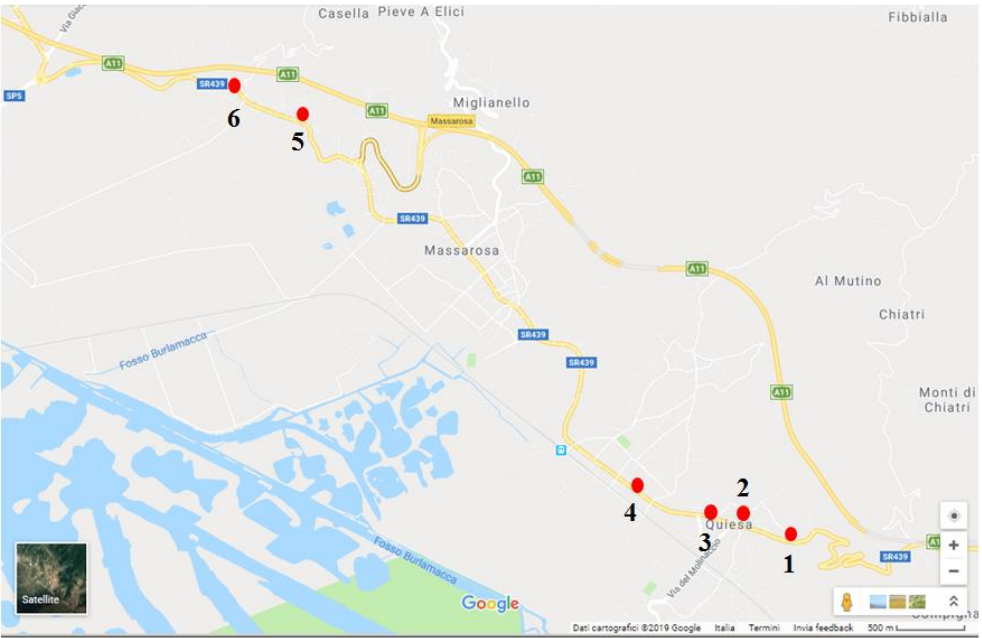

Figure 1. The six selected sites along the SR439 "Sarzanese" road in the Municipality of Massarosa (picture from Google Earth).

Figure 2 shows the noise map at the road stretches including points 5 and 6 due to road traffic in the "before" set-up, namely the old asphalt. The characteristics of the new pavement [6] at each site are little different in order to evaluate the best one by a comparison of the results of the "before" and "after" measurement campaigns. Table 1 shows the different typology of asphalt surfaces at each site, where has been used crumb rubber (CR) from end of life tyres.

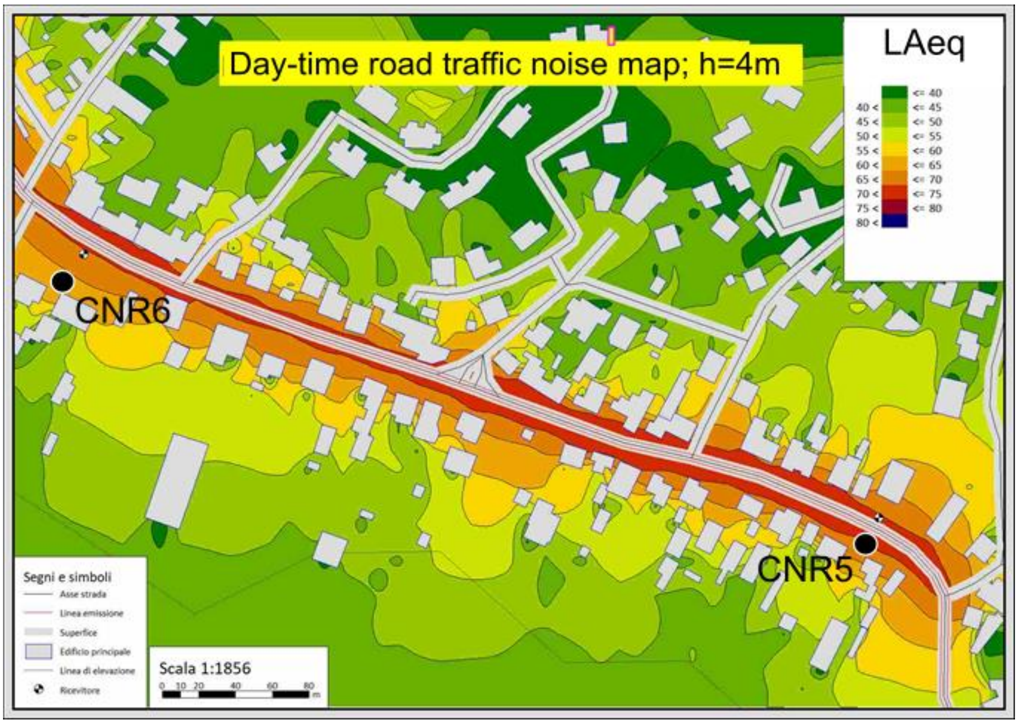

Figure 2. Noise map of the road traffic noise including sites 5 and 6 in the "before" setting; day-time L_{Aeq}; height from ground: 4 m.

Table 1 – Different type of road pavements used in step 1 of LIFE NEREiDE Project [6]

Site	*Typology of pavement*	*Description*
1	OPEN Wet	Open graded surface course 0-8 containing CR
2	GAP Wet	Gap graded surface course 0-8 containing CR
3	Reference GAP	Gap graded surface course 0-10
4	GAP Dry	Gap graded surface course 0-8 containing CR
5	OPEN Dry	Open graded surface course 0-8 containing CR
6	Reference OPEN	Open graded surface course 0-10

Each selected site was along a straight stretch of the road and the recordings were taken both at the kerbside and also behind the first row of houses facing the main road.

The binaural recordings, carried out during day-time period and in good weather conditions with wind speed less than 5 m/s, lasted the time needed to record a sufficient number of vehicle pass-bys to get an average variation in individual vehicle noise emission around 1 dB. Because it was not possible to control the composition of the traffic flow and its speed, only the total number of pass-bys was counted for later post-processing.

Afterwards, the sound recordings have been processed to remove sounds from sources different from road traffic and intervals of silence due to absence of vehicle pass-bys, being both not related to the tyre/road noise. The resulting recordings have been analysed using the ArtemiS SUITE v10.1, in order to determine the acoustic and psychoacoustic descriptors reported in Table 2, as well as the parameters: L_{Ceq}-L_{Aeq}, L_{A10}-L_{A90}, N_5-N_{50} and N_5/N_{90}. All the descriptors have been applied to evaluate the differences between the “before” and “after” settings in order to determine whether their performance in detecting the noise reduction obtained by the new laid pavement is more efficient than dB(A) level and if they are more effective also in detecting the difference in road traffic noise perception.

The benefit achieved by the new road pavement in terms of perceived noise annoyance reduction has been evaluated by comparing the subjective ratings reported by the population sample in the “before” [7] and “after” settings.

Table 2 – Acoustic and psychoacoustic descriptors determined for noise recordings

Equivalent continuous sound pressure level L_{eq} [dB], [dB(A)], [dB(C)]	Sharpness S, S_{max}, S_5, S_{10}, S_{50}, S_{90}, S_{95}, [acum]
Sound pressure levels (SPL) percentiles L_{A5}, L_{A10}, L_{A50}, L_{A90}, L_{A95} [dB(A)]	Roughness R, R_{max}, N_5, N_{10}, N_{50}, N_{90}, N_{95} [asper]
A-weighted SPL L_{Amax} [dB(A)]	Fluctuation Strength F, F_{max}, F_5, F_{10}, F_{50}, F_{90}, F_{95} [vacil]
Loudness N, N_{max} and percentiles N_5, N_{10}, N_{50}, N_{90}, N_{95} [sone]	1/3 octave band spectrum L_{eq} [dB] and its centre of gravity $G_{50\text{-}10000}$ [Hz]

Self-rating of noise annoyance has been assessed by two different scales: 5-point verbal and the 11-point numerical, as recommended by ICBEN [8]. Even though they look similar, the statistical procedure to be applied to the obtained data are rather different. As reference, the question regarding the annoyance due to road traffic noise is given in Figure 3 together with the scale used by the subjects to report their answers.

2.5 Give a score on the numerical scale from 0 (☺ not at all annoyed) to 10 (☹ extremely annoyed) to indicate how much the noise from the sources listed below annoys or disturbs you; give only an answer for each of the perceived sources; for those not perceived darken the circle box “NP”.
Thinking about the last few months, when you are at home, how much you were bothered, disturbed, or annoyed by the noise from the following sources?

Noise source	NP	☺ 0	1	2	3	4	5	6	7	8	9	☹ 10
1) Road traffic	O	O	O	O	O	O	O	O	O	O	O	O

Figure 3 – Question on road traffic noise annoyance

3. RESULTS AND DISCUSSION

3.1 Acoustic and psychoacoustic parameters

Because the real traffic flow was used as sound source, in order to directly compare the “after” and “before” settings the same number of vehicle pass-bys has been considered, that is the minimum value between the two ones, as reported in Table 3.

Table 3 – Number of vehicle pass-bys at each site during recording time

Site	1	2	3	4	5	6
Before	110	105	100	126	116	95
After	123	138	113	108	161	136
Selected for the “after” and “before” comparison	1 - 110	1 -105	1 - 100	1 - 108	1 - 116	1 - 95

It is not possible to compare every site with the others because the distance receiver/road was different. Actually, the recordings have been taken 1 m away from the façade of the receiver houses because the study is mainly focused on the perceived annoyance of the citizens living along the road.

The relative change in percentage of a parameter *x* between "after" x_a and "before" x_b settings was computed as following:

$$RelCh = \frac{(x_a - x_b)}{x_b} \cdot 100 \quad [\%] \qquad (1)$$

The bar chart in Figure 4 shows the relative change in percentage of the mean values of some acoustic and psychoacoustic parameters. The relative changes are negative in all sites, excepting a small increase (0.4 dB) in L_{Ceq} value at site 1. Thus, in the "after" setting all the values decreased from those observed in the "before" setting, corresponding to a reduction of noise immission at receiver. The centre of gravity of the spectrum $G_{50\text{-}10000Hz}$ shows a shift towards the low frequencies for all sites, with the largest relative change at sites 2 and 5. Fluctuation strength F shows the largest relative change at the remaining four sites.

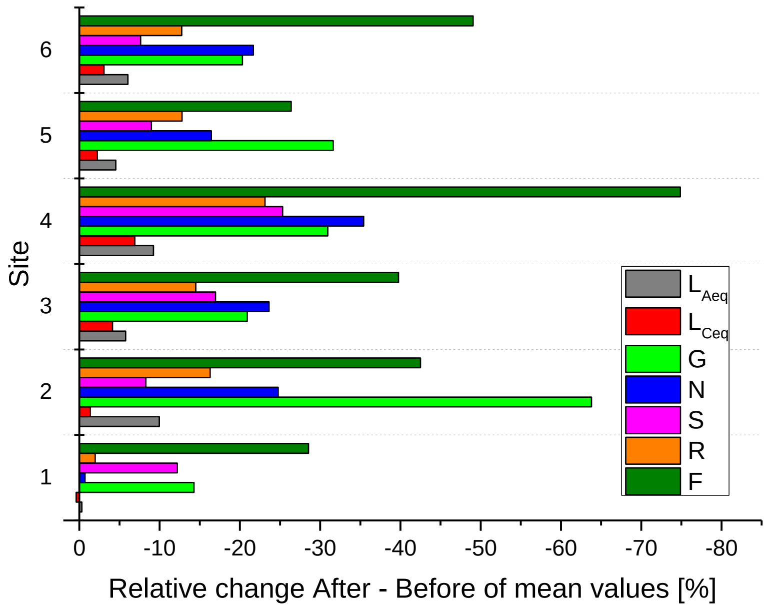

Figure 4 - Relative change in percentage of the mean values of some acoustic and psychoacoustic parameters

In the literature there is some evidence that prediction of human response to road traffic noise might be improved by accounting for the occurrence of noise events in addition to using indicators solely based on energy equivalent or percentile measures of noise exposure. Such event-based measures provide information about the traffic noise that is uncorrelated with energy-equivalent or percentile measures and, therefore, are useful supplementary indicators to conventional road traffic noise indicators for use in impact assessment and noise management [9, 10]. Thus, in the present study the percentile L_{A5}, more related to the noisiest events, has been considered in addition to the equivalent continuous L_{Aeq} level for the positions facing the road. On the other hand, in the positions behind the first row of houses facing the road the percentile L_{A95}, more related to the background noise and, therefore, less influenced by close sources and including that from the nearby main road, has been considered. The difference of these values between "after" and "before" settings are shown in Figure 5 where the change of difference of L_{Ceq}-L_{Aeq} is also reported. In all sites facing the road, excepting site 1, the noise reduction is greater than 3 dB and the differences L_{Ceq}-L_{Aeq} are always positive showing the increasing of low frequencies in the “after” setting. For the back sites, excluding site 5 where the measurements in the “before” setting were not available, only sites 4 and 6 show a reduction of L_{A95} values greater than 3 dB.

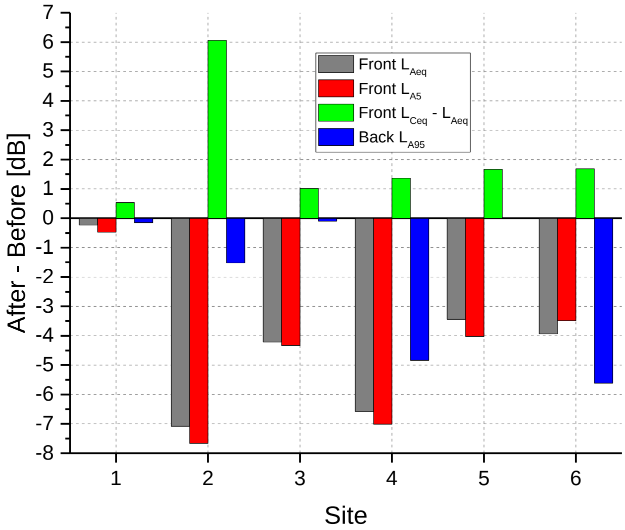

Figure 5 –Changes of the acoustic parameters (After – Before)

3.2 Social survey on road traffic noise annoyance

The questionnaire was delivered to about 800 people, the same sample selected in the “before” survey [7], and 279 forms were returned, corresponding to a response rate of about 35%.

The answers given on the self-rated perceived annoyance (box plot in Figure 6) show that the “after” setting median values are always lower than the corresponding values in the “before” setting; therefore, the new laying road pavement looks effective in reducing the noise immission at the receiver also from the point of view of the annoyance perceived. The percentage of the highly annoyed people is also decreased, as shown in figure 7.

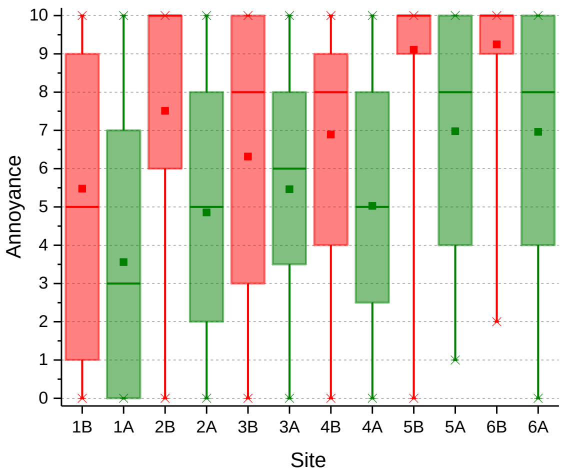

Figure 6 – Comparison of the self-rated road traffic noise annoyance (after and before)

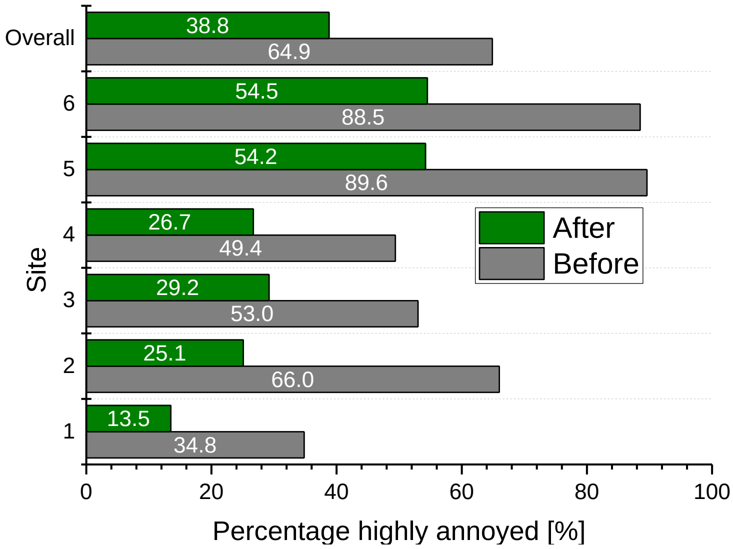

Figure 7 – Comparison of the percentage of highly annoyed people (after and before)

4. CONCLUSIONS

This work, focused on the perception of noise by citizens living along a very busy road, reports the results of the noise monitoring activities before and after laying of innovative low emission road pavement based on crumb rubber from end of life tyres.

Both psychoacoustical and acoustical measured parameters show a reduction of values and a decrease of the self-reported annoyance. Thus, the new road pavements look effective not only from the noise data but also in terms of perceived annoyance.

5. ACKNOWLEDGEMENTS

Authors express great appreciation to Head Acoustic Italia S.r.l., particularly to Marco Di Giusto for the hardware and software support.
The study was partially funded by the project NEREiDE LIFE15 ENV/IT/000268.

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