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LIFE SOUNDLESS: New Generation of Eco-friendly Asphalt With Recycled Materials.

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ABSTRACT

The Life Project Soundless attempts to improve noise attenuation of pavements using different ways to modify the SMA mixes. Several mixes with different additives has been chosen, where some waste materials have been used. The selection of the best mixtures has been done not only according to traditional mechanical parameters but also others, like damping and dynamic stiffness. Once the best mixtures were paved, the acoustic performances have been measured several times in order to evaluate the performance durability. Several experimental methods like close proximity method and statistical pass by method have been used in order to check the sound generation and propagation of every pavement. The project has been carried out in two roads of Junta de Andalucía in Seville (Spain) where different traffic density and average speed in order to reproduce different traffic conditions as urban road and interurban road. Noise level has been reduced at 3 dB and 7 dB in booth sites.

Keywords: Road noise, CPX test, SPB test, Mechanical impedance.
I-INCE Classification of Subject Number:

1. INTRODUCTION.

Despite all the efforts made in terms of noise control since 2002 when European administration established the need of doing noise maps and action plans [1], noise pollution continues to be a worrying problem for European health authorities. It is still an important environmental issue, especially in urban areas, as it affects a large number of people.

Nowadays, nobody question the relationship between environmental noise and specific effects on health, such as cardiovascular disease, cognitive impairment, and sleep disorders [2]. Epidemiological studies suggest an increased risk of cardiovascular diseases, including high blood pressure and myocardial infarction, at high exposed levels of road or air traffic noise [3].

Going deeper into this idea, it is worth highlighting the results published in the EBoDE project [4], which point to traffic noise as the second factor causing environmental stress. Besides it is remarkable that the trend is that exposure to noise increases in Europe compared to other stressors (for example, exposures to smoke, dioxins and benzene), which are decreasing.

Also learning impartment issues have been reported in several studies like Chetoni [5] in the LIFE project GIOCONDA, where it is established some global noise score indicators for classroom evaluation of acoustic performances.

Road noise is one of the most important noise sources in cities. Road noise is highly dominated as road surfaces and tire state. From the road surface point of view texture, mechanical impedance and acoustic absorption of the pavement are the key parameters to achieve a noise reducing pavement.

Several additives have been used as modified binders in order to improve the mechanical and thermal behavior, as well as an aging resistance. There are some products as fibers, rubber polymers which are commercialized in the asphalt market. Some of them are current raw materials coming from fuel industry, but others are waste materials which have been recycled in order to find a second use.

With the aim of deepening in this subject, the project LIFE SOUNDLESS "New generation of eco-friendly asphalts with recycled materials and high durability and acoustic performance" is proposed. This project is leaded by the General Directorate of Infrastructures of the Junta de Andalucía and in which they participate as partners the construction company Eiffage Infraestructuras, specialist in design and implementation of asphalt mixtures and Cidaut Foundation, specialized among other fields in the analysis and proposal of solutions related to noise and vibration. This project has the financing of the LIFE program of the European Union.

LIFE-SOUNDLESS aims to demonstrate the effectiveness and durability of noise-reducing mixtures type SMA (Stone Mastic Asphalt) to mitigate noise pollution at source. It also focuses on the effectiveness of these mixtures in Mediterranean climates (southern Europe), in which the weather conditions are very different from those in northern countries, where they have more experience in employment and benefits of this type of open quiet pavements. The quiet open mixes tested in countries with warm weather sometimes give problems of segregation of aggregates becoming in a short time noisier surfaces.

Two test tracks were selected in order to shown how these mixtures could reduce the acoustic contamination. Both test tracks are located in Seville in two roads which connect Seville with two dormitory towns as Utrera and Coria.

2. INITIAL ANALYSIS OF TEST TRACKS.

In the LIFE SOUNDLESS project two test tracks near Seville city were chosen. One of them is in A-376 road between pk 2 and pk 3, in Montequinto. This test track has an average daily traffic (ADT) of 100.000 vehicles. The average speed of this track is 70km/h. The road was paved with old dense asphalt with so bad texture with lot of fails as cracking and raveling.

The second test track is located in the road is A-8058 between pk 3 and pk4, in Gelves. This second test track has got an ADT of 26.000 vehicles and an average speed of 50km/h. In this section, double layer porous asphalt 9 years old was set before starting the project.

The first acoustic test done in the project was an evaluation of sound pressure level during one day in different points as it can be seen in the figure 1.

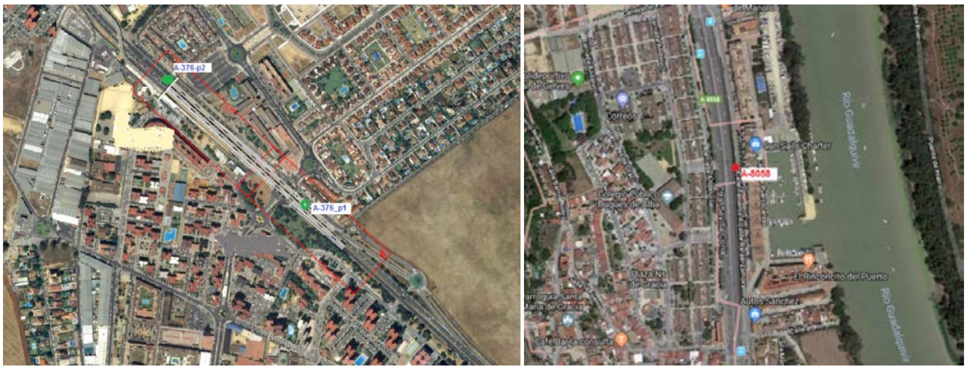

Figure 1. a) Image of the test track in A-376 road. Points 1 and 2 are the points where the microphones. b) Image of the test track in A-8058 road.

The sound pressure equivalent levels for different day periods were calculated and they are presented in the table 1.

Table 1. Equivalent Sound Pressure Level values.

	A-8058	A-376-1	A-376-2
L night (dBA)	63	70	73
L day (dBA)	70	76	79
L evening (dBA)	69	76	78

Not only noise levels have been evaluated, but also frequency analysis has been done. The aim of this analysis is to evaluate the dominant source in these test tracks. Dominant frequencies around 1000 Hz were found, in both test tracks which are compatible with road noise sources.

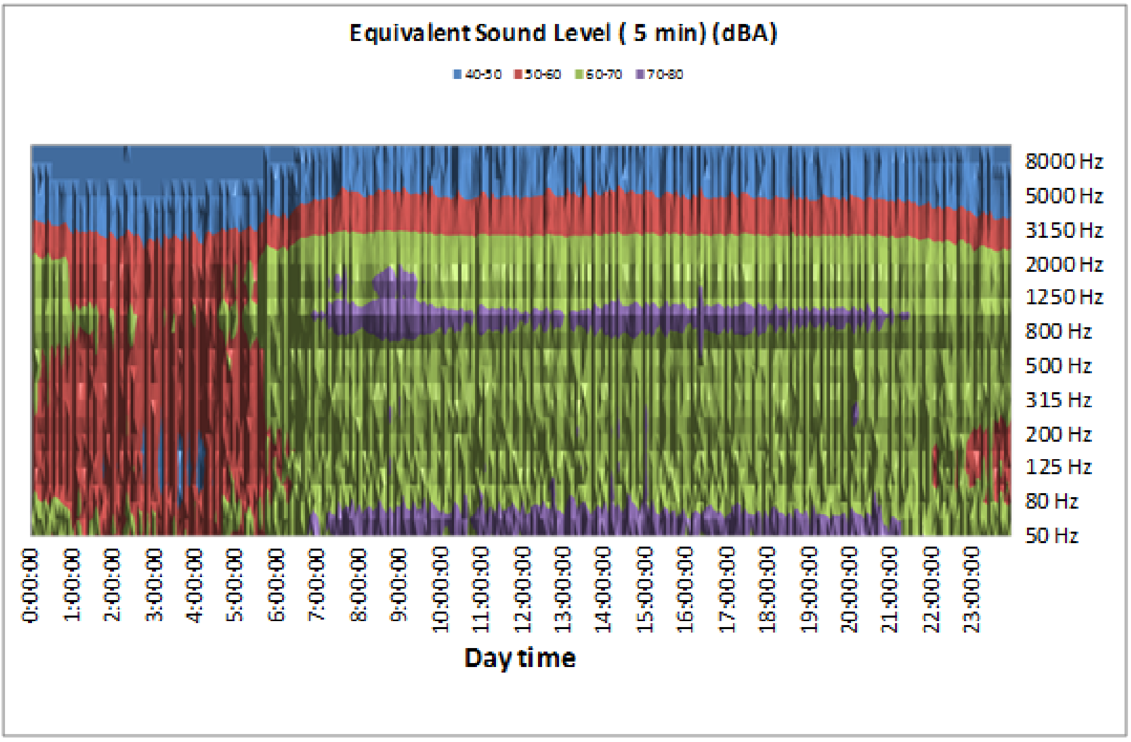

Figure 2. Frequency analysis of Sound pressure level at point 1 in A-376 site.

This noise measure is an easy way to get a first valuation of the noise issue but it cannot allow to compare between different situations (different places, different times). In order to compare the acoustic performance of the solutions developed, other standardized traffic noise measurements were assessed at the two selected sections.

Statistical Pass By Noise test (SPB)[6] leads to assess the noise traffic in one section in correlation with vehicle speed. This test is used to characterize the noise of the whole traffic. On the two selected sections SPB tests were carried out. Backing Board variant was used because there are important obstacles (fences, safety barriers, park cars…) in the area which make that the environment is far from free field. The next photos (figure 3) show the setup of the test performed to achieve data from this test, and also an analysis of the data. Due to lack of heavy vehicles in these roads (ISO standard recommends at least 40 vehicles), the results for this vehicle type are not considered in this paper.

Figure 3. (a) Image of the SPB test at A-376 site.

The measurements were analyzed according the procedure established in the ISO 11819-1 standard. The SPB values obtained for every site are presented in the table 2.

Table 2. SPB values measured in both test tracks at the beginning of the project.

	SPB (dBA) at 50 km/h
A-8058	74
A-376	77

Also it was carried out on the two selected sections Close Proximity Method (CPX)[7]. This method leads to get a continuous measurement (every 20m) throughout all test track. This test is used to characterize the rolling noise in proximity. The CPX (self-propelled vehicle) tests were carried out by Fundación Cidaut. The CPX_p parameter was determined with the SRTT tires in the rear axle of the vehicle according ISO 11819-2 standard specifies. For all CPX measurements carried out in this project temperature correction has been done according normative, and speed correction too (B=30).

Site A-8058 was characterized at 50 km/h and Site A-376 at 50 and 80 km/h. Tests were performed in both directions.

Figure 4.(a) Image of the self-propelled vehicle used for CPX measures

The overall values for every test track are shown in the table 3. Also standard deviation of every test track is also presented.

Table 3. CPX values measured in both test tracks at the beginning of the project.1

	CPX (dBA) at 50 km/h		CPX (dBA) at 80 km/h	
	Mean Value	**Dev std**	**Mean Value**	**Dev std**
A-8058	**93**	**1**	**-**	**-**
A-376	**96**	**1**	**104**	**1**

Initial noise levels measured in booth test tracks were high and the road noise was dominant over other sources.

3. DESIGN AND IMPLEMENTATION OF THE SOLUTION

As it has been commented before, the aim of the project the search of new additives that can improve the contact between tire and pavement in order to reduce the noise radiation of the tire. A task in the project was considered in order to choose these additives.

Additives and new mixtures were collected by Eiffage Infraestructuras. Eiffage also designed the mixes in order to ensure, that they comply with the PG3 (Spanish standard for asphalt mixtures) requirements.

The figure 5 shows the different waste materials used as additives for improving the acoustic properties of the pavements. Several materials as rubber crumb and nylon fibers coming from end of life tires (ELT), and plastics coming from green houses, wires and masterbaches are employed as additives.

[1] All values are rounded to the nearest integer. Uncertainty is not estimated for these CPX measurements. According normative the expanded uncertainty for 95 % coverage probability could be considered as 1dB.

Figure 5.Waste materials used for generating the additives for asphalt mixes.

In order to deep the study of additives, different compositions of materials leaded to 23 different mixtures which have been designed and tested. Four of them were used as reference (1 AC16 and 3 SMA8); two of them with greenhouse plastic (0.5% -1%); two of them with plastic coming from recycled wires (0.5% -1%); two of them with nylon from ELT (end life tires) (0.2% -0.5%); six of them with ELT (0.5% -1% -1.5% -2%) (with different percentage of bitumen), one of them with ELT and plastic cables (0.5%; + 0.5%), two of them with ELT and plastic greenhouse (0.5% + 0.5% - 1% + 0.5%), two of them with plastic from masterbatch (0.5% - 1.0%). All SMA mixtures have been built with the same aggregates.

All the mixtures fulfill the requirements of Spanish normative (PG-3) for bituminous mixtures, in terms of voids, water sensibility and resistance to permanent deformations. Thus, the final criterion for selection of the mixtures was the acoustic performance. Although several tests as texture and acoustic absorption were done the main differences between specimens were observed in the mechanical impedance. This method measures the stiffness of the pavement and gives an idea of the type of contact between pavement and tire and, thus, the easy for exciting the vibrations in the tire which cause the sound. The main parameters estimated from frequency response functions are the Young modulus and damping. The frequency response function is measured in a 1 degree of freedom system simply supported on the mixture specimen. An impact hammer and accelerometer are used for measuring the frequency response function.

Figure 6. Mechanical Impedance setup.

In the figure 7, the values for stiffness and damping are presented in order to make the best choice of mixtures. Low stiffness and big damping characterized by mechanical impedance test are the key parameters.

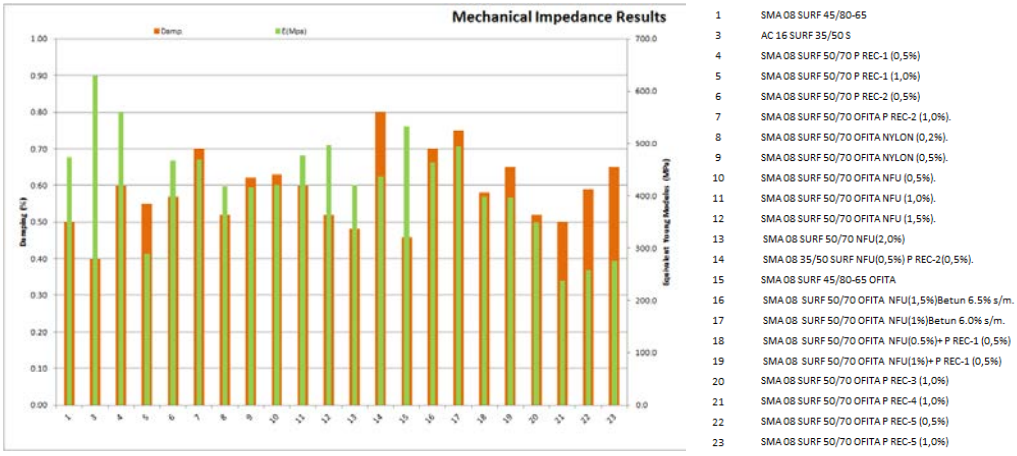

Figure 7. Mechanical Impedance results for 23 different mixtures. All of them are SMA8 with different additives.

As may be checked reference mixtures have higher Modulus and lower damping (mixture 3). As higher is the Young modulus of the pavement, as lower is the contact time between tire and pavement. This means that higher frequency range for excitation modes is found and radiation of tire is higher. As higher the damping lower excitation of the tire is also produced. On the other hand there are some mixtures as numbered from16 to 23, where the damping is higher and Modulus is lower which are more suitable under an acoustic point of view.

From this analysis of the results obtained the following mixtures have been defined for demonstrations sites:

• Test track 1. A-8058.SMA8 with 1% ELT with 6 % bitumen 50/70; SMA8 with 1,5% ELT with 6,5 % bitumen 50/70.

• Test track 2. A-376. SMA8 with 0,5% NYLON; SMA8 with 0,5% P REC-4; SMA8 with 0,5% P REC-4+0,5 % ELT. Also in this road a Reference mixture: AC16 surf 35/50 S with 200 m was layered.

4. IMPLEMENTATION OF THE SOLUTION AND ACOUSTIC PERFORMANCE ASSESSMENT.

The selected mixtures were paved in the test track sites. All the project partners decided the correct placed where kilometric points for paving these mixtures are:

• A-8058: From 3+350 km to 3+867 km (both directions).

• A-376. Direction Sevilla-Utrera: from 2+200 km to 3+100 km. Direction Utrera-Sevilla: from 2+200 km to 2+745 km.

The figure 10 shows both test tracks after finishing the asphalt mixture paving.

Figure 10. (a) Image of the road A8058 after paving mixtures. (b) The same at A-376.

One month after finishing works, SPB and CPX tests were practiced again in order to know the acoustic reduction from every type of asphalt. The results are presented in the tables below.

Table 4. SPB values after and before paving mixtures.[2]

	Initial situation before works	After paving SOUNDLESS mixtures
	SPB (dBA) at 50 km/h	SPB(dBA) at 50 km/h
A-8058	73.4	68.2
A-376 _ 1% Plast	-	64.3
A-376-0,5% ELT+0,5%plas	77.2	68.3

From these data, it can be concluded that 6 dB have been reduced in the test track A8058 (low traffic and low speed) and 9 dB in the test track A376 (high traffic and medium speed).

Also CPX method was used in the different roads considered. As it was explained in the point 3 the CPX evaluation is carried out only with SRTT tire so the parameter which shows the acoustic performance is CPX_p.

Table 5. CPX_p values after and before mixtures paving.

	Initial situation		After paving SOUNDLESS mixtures	
	CPX (dBA) at 50 km/h	CPX (dBA) at 80 km/h	CPX (dBA) at 50 km/h	CPX (dBA) at 80 km/h
A-8058_SMA8 1% ELT_ 6 % bit 50/70	92.2		89.8	
A-8058_SMA8_1,5%ELT_6,5%bit50/70	93.3		88.7	
A-376_SMA8_0.5 Nylon fibers	94.6		90.7	
A-376 _SMA8_ 1% Plast	96.1	104.2	91.4	96.9
A-376_SMA8_0,5% ELT+0,5%plas	94.6	104.1	90.8	96.9
A376 _AC16 surf	94.6	104.1	92.9	101.4

From these values it can be concluded that these mixes may reduce until 7 dB at medium speeds (80km/h) from an old mixes (10 years) and 4 dB from and standard new mixes (AC 16 surf). At low speed (50 km/h) the reduction from old standard mixture is 5 dB and only 2 dB if the reference is taken a standard new asphalt mix.

Mixes with high percentage of rubber crumb allow to achieve more silent roads. One explanation for this effect is the high percentage of bitumen that allows to increase the damping of the contact and tire does not emit louder.

If the average sound spectra for every mixture are analyzed, relevant differences can explain better last comment. Mixes with high quantity of crumb and bitumen presents lower values of sound pressure level at frequencies where tires emit (315-800

[2] The data reported in the table 4, relative to the tests done for SOUNDLESS mixtures have been obtained from a regression analysis with R2 values of 30%; 42% and 40% respectively.

Hz). Higher frequencies (1000-5000 Hz) explain other mechanisms based on aerodynamic noise where aspects like texture have more importance than contact forces.

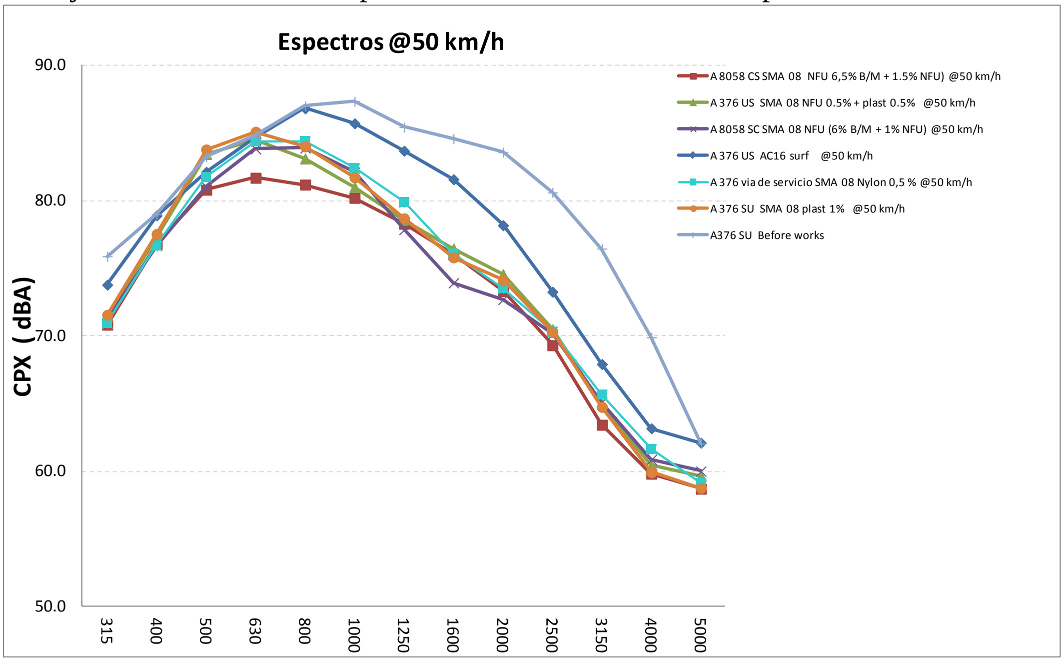

Figure 11. Average spectrum obtained in booth test tracks before and after paving LIFE Soundless Mixtures at 50 km/h.

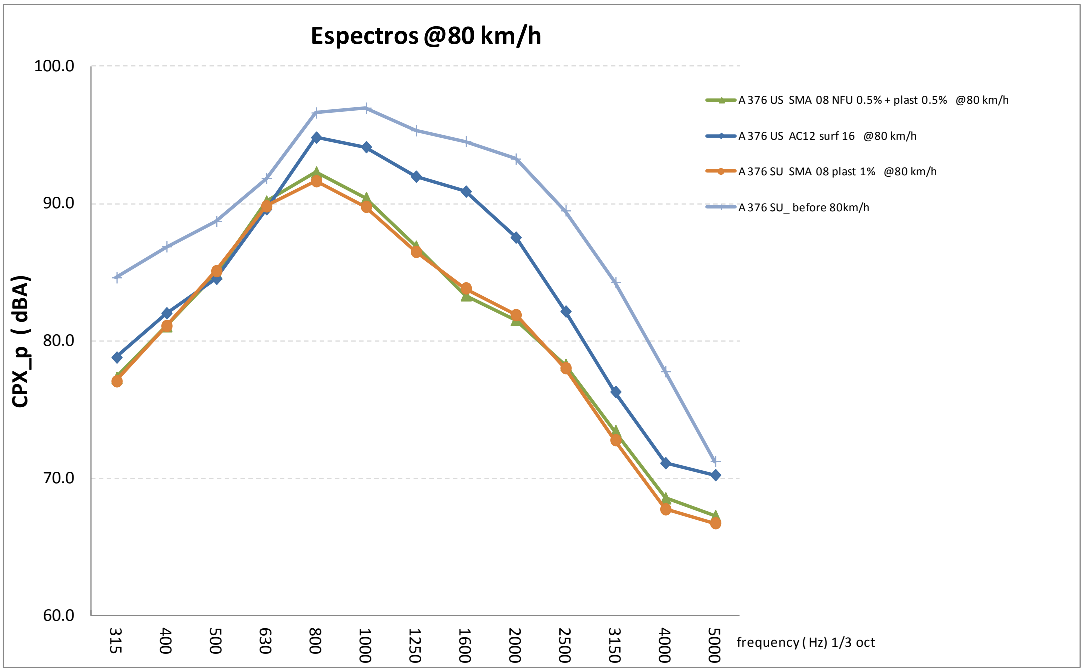

Figure 12. Average spectrum obtained in booth test tracks before and after paving LIFE Soundless Mixtures at 80 km/h.

In order to evaluate the acoustic performance durability, the booth SPB and CPX measurements are repeated every six months.

Next tables present the data which have been got at three more measurement campaigns after paving the SOUNDLESS mixes.

Table 6. SPB values after and before paving mixtures.

	Initial situation	New pavements (0m)	New pavement (6m)	New pavements (12m)	New pavements (18m)
	SPB (dBA)	**SPB(dBA)**	**SPB(dBA)**	**SPB(dBA)**	**SPB(dBA)**
A-8058	73.4	68.2	67.8	68.0	68.7
A-376 _ 1% Plast	-	64.3	66.8	63.8	63.8
A-376-0,5% ELT+0,5%plas	77.2	68.3	68.2	68.4	68.7

From a global point of view, the traffic noise has not incremented during the first year, but at in the end measurement the values have been increased.

The next table takes data relatives to road noise measured with CPX method.

Table 7. CPX_p values after and before paving mixtures.

	Initial situation before works		Campaign one (0m)		Campaign two (6m)		Campaign three (12m)	
	CPX (dBA) at 50 km/h	**CPX (dBA) at 80 km/h**	**CPX (dBA) at 50 km/h**	**CPX (dBA) at 80 km/h**	**CPX (dBA) at 50 km/h**	**CPX (dBA) at 80 km/h**	**CPX (dBA) at 50 km/h**	**CPX (dBA) at 80 km/h**
A-8058_SMA8 1% ELT_ 6 % bit 50/70	92		90		90		90	
A-8058_SMA8_1,5%ELT_6,5%bit50/70	93		89		90		89	
A-376 _SMA8_ 1% Plast	96	104	91	97	91	96	91	97
A-376_SMA8_0,5% ELT+0,5%plas	96	104	91	97	90	96	91	97
A-376_SMA8_0.5 Nylon fibers	96		91		91		91	
A376 _AC16 surf	96	104	93	101	93	101	95	102

One year later no relevant modifications have occurred in the SOUNDLESS pavement under an acoustic point of view. The same conclusions that have been explained in the point 4 of this paper may be hold.

In order to check the noise in the area, one year later from the same global measurements in the same points have been repeated. The table 8 shows the new values one year later from the SOUNDLESS pavements have been paved.

Table 8. Equivalent Sound Pressure Level values, one year after asphalts paving.

	Before Soundless project			After 1 year from SOUNDLESS project		
	A-8058	**A-376-1**	**A-376-2**	**A-8058**	**A-376-1**	**A-376-2**[3]
L night (dBA)	63	70	73	60	64	72
L day (dBA)	70	76	79	67	69	78
L evening (dBA)	69	76	78	66	69	77

[3] The point 2 in the A-376 is out from the SOUNDLESS mixtures influence as may be seen in figure 1a.

If these values are compared with the presented in table 1, it may be check that the overall Sound pressure level has decreased 3dB lower in the area of A8058, and 6 dB lower in the area A376 (night) and 7dB during day. In the point 2 of the A-376 which is influenced by last pavement and AC 16 surf (dense asphalt) only one dB has been decreased the sound pressure level.

4. CONCLUSIONS

Life SOUNDLESS project has permitted that the noise contamination has been reduced in the test track areas. In urban area like A8058 road with low speed (50 km/h) equivalent level during day has been reduced 3 dB. In the other test track (interurban road) A-376 with medium speed (70 km/h), Lday has been reduced 7 dB.

If only road noise levels are taken into account as CPX index, SOUNDLESS mixes allow to reduce the road noise 3 dB respect a new dense asphalt (AC 16 surf) at low speed (50km/h) and 4 dB at medium speed (80km/h).

These mixes have been checked during the first year and no significant reduction has been detected.

The best Soundless mixture has been made with 1.5% ELT rubber crumb. This mixture leads to reduce the radiation noise of the tire.

Waste materials as rubber crumb coming from end of life tires and plastics could be used as new additives which can improve the acoustic properties of close gap mixtures as SMA.

5. ACKNOWLEDGEMENTS

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