LIFE SOUNDLESS: New generation of eco-friendly asphalt with recycled materials.

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Summary

This article aims to show the steps followed in the solution of a noise pollution problem in an urban area. The actions which have been carried out not only aim the reduction of the noise level but also reduce the number of people affected. The methodology followed starts with the initial study of the strategic noise maps of the affected area with the acoustic problem (in this case, the area of the autonomous road A-376 at the height of Montequinto has been analyzed). It is important to show that the models currently used in the preparation of the strategic maps assume very basic calculation hypotheses, which do not allow us to faithfully represent the real situation, so it is very complex to make decisions in order to establish action plans only from them. In order to solve this problem and after analyzing the maps of the area, an experimental diagnosis of the area was made. The main objective of this second step was to bear out if the road noise was one of the dominant sources in the studied area.

Once verified that the origin of the problem was the road noise, we proceeded to the design of the bituminous mixtures incorporating special additives to increase the sound reduction. An experimental design was made with more than 20 different formulas where different parameters that influence the noise produced by the rolling of the vehicles were evaluated as output variables. Subsequently, the paving and subsequent acoustic evaluation of the levels and people affected in the area was carried out.

This example has been developed within the LIFE-SOUNDLESS demonstration project co-financed by the European Union and whose main objective is the mitigation of noise pollution in urban agglomerations using noise-reducing bituminous mixtures that generate less sound emission levels..

1. Introduction

Urbanization, economic growth and motorized transport are some of the forces that drive the continued exposure of the urban population to environmental noise. Noise is an important environmental issue, especially in urban areas, as it affects a large number of people. Today nobody questions the evidence on the relationship between environmental noise and specific effects on health, such as cardiovascular disease, cognitive impairment, and sleep disorders [1]. 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.

Going deeper into this idea, it is worth highlighting the results published in the EBoDE

project [2], which point to traffic noise as the second factor causing environmental stress. With the addition 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.
Given the importance of the problem, the European Commission is developing an action plan aimed at controlling this problem. With the environmental noise directive, the administrations responsible for the ownership of noise sources are allowed to establish corrective actions in order to reduce not only the noise levels, but also the people affected by noise as effectively as possible.
To this end, public administrations, civil engineering companies and research entities are working on the development of new tools and solutions to reduce noise levels as well as the population affected by these levels, using the new guidelines that are applied within the circular economy.

In order to guarantee the success of the applications, it is important to establish a system of operations with ordered steps, which allow to find the best solution for the issue.

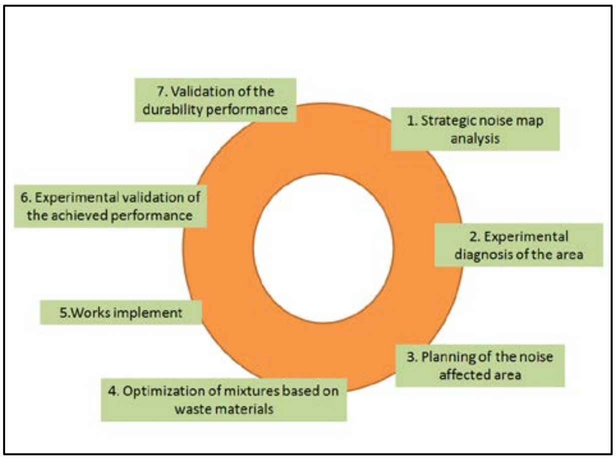

Figure 1. Steps followed in the proposed study.

Within this priority area is part of the project funded by the European Union LIFE SOUNDLESS "New generation of eco-friendly asphalts with recycled materials and high durability and acoustic performance", coordinated by the Directorate General of Infrastructures of the Junta de Andalucía and in the Participating as partners are the construction company Eiffage Infraestructuras, a specialist in design and implementation of asphalt mixtures and the Cidaut Foundation specialists in analysis and solutions related to noise and vibration.

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.
In order to increase the stability of the mixtures, the incorporation of additives manufactured from waste material from other industries has been proposed. This project aims to encourage Public Organizations to apply this type of solutions to noise pollution.

2. Initial analysis of the study area.

As a first activity of the Project, a preliminary study of the sections where the demonstrations were planned with LIFE SOUNDLESS mixtures was planned. The purpose of this task was firstly to justify the goodness of the section in order to evaluate the proposed solution and, secondly, to carry out a current assessment of the existing solutions with the aim of being able to be compared later.
The study section that is presented is located on the A-376 road (Sevilla-Utrera) with an analyzed length of 800 m. This section has a speed of 80 km / h with an 80,000 ADT (Average Dayly Traffic).

Figure 2. Image of the study area taken from the Google maps tool.

In the first place, the strategic noise maps made in 2015 by the General Directorate of Infrastructures of the Junta de Andalucía have been revised. In addition to analyzing the noise levels produced by traffic in each of the periods, a count has been made of the people affected by the traffic noise.

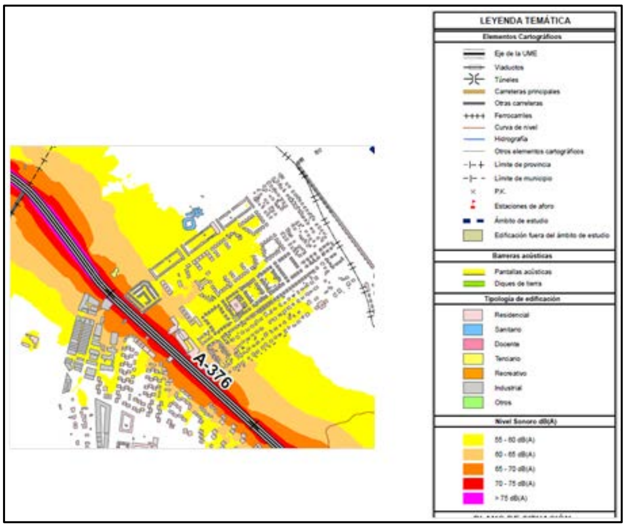

Figure 3. Noise map (Lden) for the scenario analyzed.

As can be deduced from the preliminary analysis of the noise maps, there are buildings in which the maximum noise level allowed in the legislation is exceeded.

The population count exposed within the study area is also presented below.

Figure 4. Scenario analyzed

Table I. Environmental Noise exposed population.

	Day	*Evening*	*Night*	*Average*
50-55 dBA	*4323*	*4315*	*1562*	*4372*
55-60 dBA	*1969*	*2207*	*1227*	*3311*
60-65 dBA	*1079*	*1063*	*344*	*1381*
65-70 dBA	*980*	*988*	*0*	*1154*
70-75 dBA	*174*	*25*	*0*	*354*
>75 dBA	*0*	*0*	*0*	*0*

Once the importance of the issue was verified, more than 1500 people affected in global value and another 1500 at night, it is carried out an experimental study to confirm that the dominant source is road noise.

To this end, a series of continuous measurement stations were placed, which carried out a detailed study during 24 hours with a sampling interval of 5 minutes. In addition to recording the equivalent noise level at each point, a frequency analysis was carried out that made it possible to evaluate whether the rolling noise is predominant in the chosen sites or, on the contrary, there are other predominant focus that could cause that the solutions considered in the section of study do not suppose the noise reductions expected in the area.

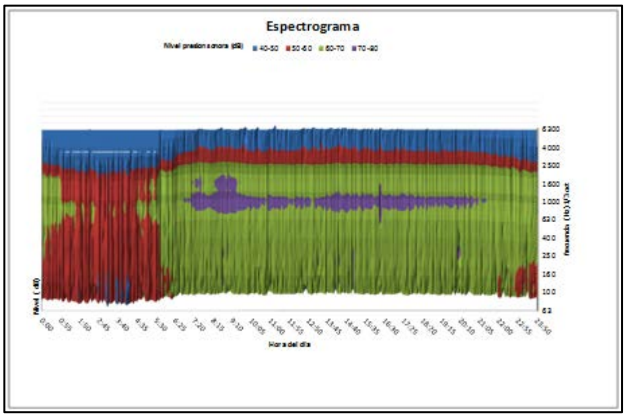

Figure 5. Sound pressure spectra obtained at the station placed in the test section

The spectral analysis is presented in a 3D graph where the x axis corresponds to the measurement time (starts at 00:00 in the morning), the Y axis (vertical) is the frequency axis and the level in dB is corresponds with the colors. It can be seen perfectly how the 1000 Hz band dominates. This phenomenon is typical in the identification of rolling noise, and confirms the objective of noise reduction acting on the replacement of the current pavement with quiet one.

Once the problem was diagnosed, it is important to evaluate the real contribution that the proposed solution would make. For this, a priori assessment of the section is carried out with two tests.

The CPX (Close ProXimity method) method allows to know in detail the level of rolling noise generated by the pavement. It consists of the noise measurement of the exterior next to a standardized wheel according to ISO 11819-2. The sound levels are obtained by means of an average of three passes, of two microphones (front and rear) in two rounds (left and right), and integrating their value every 20m of distance traveled at the consigned speed of the track. In the case study, two speeds of 50 km/h and 80 km/h were used.

Figure 6. CPX test system of F. CIDAUT

The traffic noise level was also measured according to the SPB (Statistical Pass By Noise) method, which takes into account the contributions of real traffic. The Backing Board variant has been chosen because the analysis area is an urban area with reflections of buildings. The method consists in measuring the equivalent sound pressure level and the speed of different isolated vehicles of a given traffic composition. With these statistically ordered data, a regression is constructed and the level of sound pressure corresponding to the speed of the stipulated road is reported (in this case 80 km / h).

Figure 7. SPB test system of F. CIDAUT

In the case of A-376, rolling noise at 50 and 80 km/h was measured. At 50 km / h, a value of 96 dBA was obtained in the Utrera direction and 94 dBA in the Sevilla direction. At 80 km / h the value obtained was around 104 dBA in both directions.

The results obtained for the test section considered are presented below.

Table II. Test results.

	Speed (km/h)	*SPB (dBA)*	*CPX (dBA)*
A-376 S-U	*50 km/h*	-	*96.1*
A-376 U-S	*50 km/h*	*77.2*	*94.6*
A-376 S-U	*80 km/h*	-	*104.2*
A-376 U-S	*80 km/h*	-	*104.1*

3. Design and implementation of the solution

At this point, the tasks carried out for the design of noise-reducing mixtures of the LIFE SOUNDLESS Project are summarized. This action is focused on the design of a high durability SMA type mixture incorporating waste materials with the aim of achieving a reduction of rolling noise at the origin due to the interaction between tire and pavement. In addition, environmental sustainability is another objective of this project, therefore, residual materials will be used as additives in the process. Specifically, plastic waste, rubber and nylon fibers from unused tires will be used.

The choice of a granular structure of SMA type mixture instead of a porous type PA (Porous Asphalt) mixture, has been motivated by the interest of proposing a type of mixtures that did not lose their acoustic properties in Mediterranean climates of low rainfall. It is well known that one of the problems of porous mixtures in this type of climate is the clogging of the holes with the dust and dirt of the pavement, which causes them to lose their sound-absorbing characteristics in a relatively short time. In addition, it is also common the failure of this type of mixtures in urban areas subjected to tangential efforts (turns in roundabouts, accelerations and braking in areas of traffic lights, etc.). These drawbacks have been sought to overcome with the design of SMA-type mixes, which, although they do not at first obtain the noise reduction achieved with porous mixtures, it is expected that the quiet effect will be maintained for a longer time, due to their great cohesion while endowed with good surface characteristics thanks to their negative macro texture.

As a starting point for the granulometric composition of the SOUNDLESS mixtures, the granulometric spindle of the Proposal for the Technical Specifications of the SMA Type Mixtures was taken as reference (Table II). This proposal is drawn up based on the experiences gathered throughout the SMA Project "Environmentally friendly sustainable SMA mixtures" funded by the Technological Center for Industrial Development (CDTI) and led by Eiffage Infraestructuras [3].

Table II. Sieving of the particles (UNE 933-1).

Sieve (mm)	*11,2*	*8*	*4*	*2*	*0,5*	*0,063*
	100	*90-100*	*30-45*	*25-35*	*12-22*	*7-10*

For the design of the SOUNDLESS mixtures, the granulometric composition was modified with respect to the average of the reference spindle, looking for a more open granulometric curve (greater void content) that promoted a greater macrotexture and thus reduce the contact noise of the tire with the pavement. The mixture has got a content of 5.8% bitumen.

In order to improve the behavior of the mixture, additives from recycling have been used, as shown in Figure 8.

Figure 8. Waste materials studied in the design phase of LIFE SOUNDLESS mixtures.

The rest of the components of the mixtures were:

- Bitumen: 50/70 (except for the conventional reference mix that has been used bitumen 35/50)
- Arid thick ofitic nature
- Fine limestone barren
- Filler: calcium carbonate

The variables in the optimal design of SOUNDLESS mixtures were the percentage of waste used and the granulometric curve, looking for gaps in the mix of around 12%. As a consequence, 22 SMA mixture compositions were studied as indicated in Table III.

Table III. Mixtures studied in the LIFE SOUNDLESS Project

Studied mixes	*TESTS*
3 references (1 AC16 y 2 SMA8)	*Dmax, Dapa, %voids*
2 PE used in greenhouses (0,5%-1%)	*Water sensitivity*
4 with wire plastics (0,5% - 1%)	*Wheel tracking*
2 with masterbach plastics (1%)	*Particle Loss*
2 with nylon (0,2%-0,5%)	*Marshall test*
6 with ELT (0,5%-1%-1,5%-2%)	*Stiffness and fatigue*
1 with ELT and wire plastics (0,5%+0,5%)	
2 with ELT and used greenhouses plastics (0,5%+0,5% - 1%+0,5%)	

As a summary of all the laboratory work, it is indicated that all the mixtures studied except those that incorporated plastic waste from wires met the Spanish specifications for the tread layer (Table III), except for the specification of gaps, since as mentioned above , a percentage similar to that of BBTM B type mixes (around 12%) was sought. The mixtures with wasted wires presented plastic deformations above what was allowed. The definitive criterion for the selection of the mixtures would be the one corresponding to the acoustic behavior, once assured its compliance from the mechanical and structural point of view. For a closed mixture of this type, the parameter associated with the material, not the work that best defines its future acoustic performance is the mechanical impedance since it somehow indicates the excitation produced by the radiation of the tire.

Two parameters are extracted from the mechanical impedance test, one is the dynamic stiffness. The lower this value the lower the excitation of the tire's frequency ranges. The other is the damping. As greater was the lag between the response of the tire and the excitation force thereby will be higher, generating a lower level of noise.

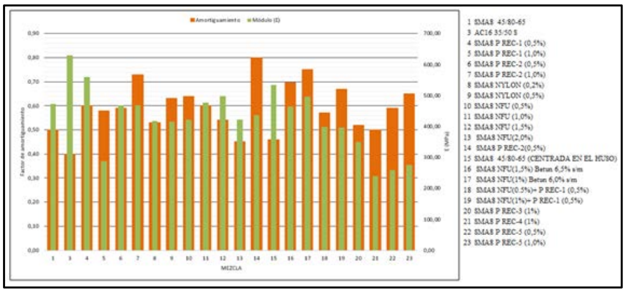

Figure 9. Result of the mechanical impedance measurements.

In April 2017, the pilot section was executed as can be seen in figure 10. Three sections have been executed, in the Utrera-Sevilla direction, an SMA-8 mixture with 0.5% NFU and 0.5% plastic was installed, and it was installed also a section 200 m of a section with a dense pavement (AC Surf 16). In the Sevilla-Utrera direction, an SMA-8 mixture with 1% plastic was installed.

Figure 10. Sound-reducing pavements executed on A - 376 at Montequinto.

4. Evaluation of noise results after the execution of the work.

The results obtained after the first characterization are presented below. It is planned to make another 4 additional characterizations every 6 months to evaluate the durability of these mixtures.

1.1. Reduction of the noise level

In May 2017, the first acoustic campaign on the new pavements was carried out (during the LIFE SOUNDLESS Project, 5 acoustic auscultation campaigns are planned every 6 months).

The results obtained are presented along with the initials for the CPX test.

Table IV.CPX results.

	Initial Feb-16		*1st round May-17*		*2nd round Nov-17*	
SMA8 mixe	*CPXI50 (dBA)*	*CPXI80 (dBA)*	*CPXI50 (dBA)*	*CPXI80 (dBA)*	*CPXI50 (dBA)*	*CPXI_80 (dBA)*
1% Plast	*96,1*	*104,2*	*91,4*	*96,9*	*90.7*	*96.4*
0,5% ELT+0,5	*94,6*	*104,1*	*90,8*	*96,9*	*90.3*	*96.3*
Dense Asphalt	*94,6*	*104,1*	*92,9*	*101,4*	*93.4*	*100.8*

These results allow us to conclude that the reductions achieved by resurfacing at 50 km / h are in the order of 4 dB and would be 7dB for the case of 80 km / h. In the case of a resurfacing with a normal surface (AC surf 16), the reductions achieved would be 1.7dB for 50 km / h and 2.7 dB for 80 km / h.

At the spectrum level, the differences found between before executing the solutions and afterwards are also substantial.

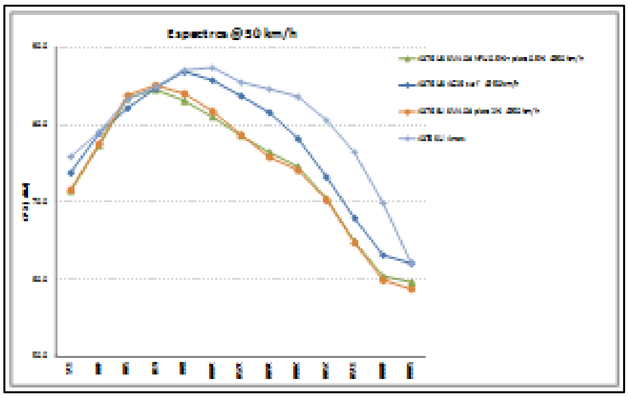

Figure 11. CPX spectra measured at 50km/h.

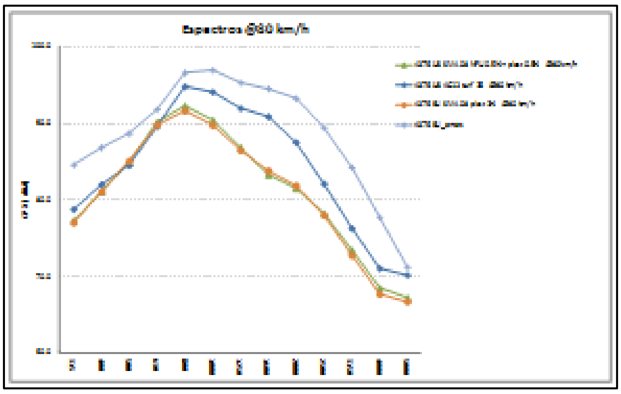

Figure 12. CPX spectra measured at 80km/h.

Fundamentally it is appreciated that the use of additives in SMA mixtures allows to reduce the level in the dominant frequencies of the problem (800-1600 Hz) while the effects of the resurfacing although they are especially noticed in the bands of high frequency with lower level. These results confirm the results obtained in the design tests of the pavements with the measurement of the mechanical impedance.
The results of the Statistical Pass by Noise (SPB) tests before and after the execution of the work are presented below.

Table V.SPB results.

		Initial Feb-16	*1st round May-17*	*2nd round Nov-17*
Mix SMA8	*Veh type*	*Lveh (dBA)*	*Lveh (dBA)*	*Lveh (dBA)*
1% Plast	*Passenger*	*77,2*	*68,3*	*68.2*
	Heavy	*80,7*	*72,5*	*74.8*
0,5% ELT+0,5% Plast	*Passenger*		*64,3*	*66.8*
	Heavy		*79,3*	*77.4*

As can be seen in the results table, a significant reduction in the noise level has been observed, around 9 dB on the A-376 Utrera-Sevilla road. The explanation for this reduction is that the resurfacing of the section affects significantly the generation of background noise.
On the other hand there is the reduction in the sense Sevilla Utrera that for vehicles reaches 13 dB. This second measurement had to be carried out at night because during the day the excessive density of vehicles prevented a correct data collection. Each point of the graph corresponds to an isolated vehicle. The fact of making the measurement at night makes the background noise in the area lower and therefore the result is spectacularly good.

1.2. Reduction of the people affected.

For the estimation of the people affected, the pressure levels on the analysis area have been recalculated with a 6 dB noise source decrease, which corresponds to an average traffic speed of 70km/h.

Table VI. Reduction of the affected population (people).

	Day	*Evening*	*Night*	*Average (Lden)*
50-55 dBA				
55-60 dBA			*873*	
60-65 dBA			*229*	
65-70 dBA	*683*	*710*	*0*	*812*
70-75 dBA	*147*	*25*	*0*	*235*
>75 dBA	*0*	*0*	*0*	*0*
Global	*830*	*735*	*1102*	*1047*

In view of the results, it could be concluded that the reduction of the affected population is important, reducing the number of people affected in the studied area by half.

5. Conclusions

Based on the results obtained, the following conclusions are reached:

- Planned action on a specific area, taking into account the main noise sources, allows to reduce 50% of the population's impact.
- Taking a average speed of the track, the noise level near the test track has been reduced around 9dB and 6 dB in the generation of rolling noise if the comparison is made between the previous situation and the current.
- If comparison is done respect a new a dense pavement (AC surf 16) the reduction in the noise generation is 4 dB.
- It has been selected from among 21 samples of pavements those with characteristics of mechanical impedance more convenient to the established criterion: lower rigidity and greater mechanical damping.
- Finally and although it has not been proven yet, it is expected that these values will last for at least the three years of the project.

Acknowledgement

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References

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