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Analysis of the effectiveness of a predictive model during the execution of the A-66 highway (Spain)

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Abstract In a new infrastrucuture, it is necessary to diminish the acoustical impact produced on the inhabitants of near residential nuclei. Before the execution of the infrastrucuture, the only possibility is to calculate a strategic noise map. During the execution of the A-66 motorway between the cities of Leon and Benavente (in the northwest of Spain), the Acoustics Laboratory (University of Leon) -in collaboration with ACS group, responsible for building the highway, and the Spanish Public Work Ministry- developed a noise map by means of techniques of computer simulation in which the corrections to implement in the project were propose and its repercussion studied. The simulated map analyzed the Metropolitan Area of the city of Leon affected by the infrastructure Then the highway was not constracted and it was not possible to validate the model in order to know if the calculated levels of sonorous pressure were fit to the reality. At the moment of its opening to the vehicles traffic it has been possible to make measures in situ and to verify if the margin of error established on the noise levels recommended by the WHO, as well as the location of the most conflicting zones, were correct.

1. INTRODUCTION

The study has allowed the Acoustics Laboratory of the University of Leon to deepen in the experience in noise prediction by means of the software MITHRA based on finite elements method.
It has been made in the collaboration with the company ACS, awardee of the accomplishment of the highway, with the purpose of which the conclusions of this project are gotten up in the execution of the definitive project.
The increasing preoccupation on the part of the society with acoustic contamination problems makes necessary to prevent the situations and power to take cogoverning measures in the execution phase. However, the prediction of noise, and even its control, is, practically, an

unpublished matter in Spain. Except the acoustic maps of urban areas made in the last decade in many spanish cities, the studies of environmental noise for communication routes have not been made. In fact, the strategic maps of noise are beginning to be proposed to all the states of the European Union by means of European laws. In any case, in other european countries the experience in the accomplishment of sonorous levels prediction exists already.

2. PREVIOUS CONSIDERATIONS

In the Study of Environmental Impact it was prohibited the use of acoustic meth-acrylate screens, due to the danger that suppose these barriers for the birds.
We considered this measurement like right and, in addition, we extended the restriction to the acoustic screens of meth-acrylate since these work fundamentally turning aside rays acoustic, passing the problems from a margin to the other, but without diminishing their levels.
The minimum required by the project is the exigency of the WHO (55 dBA at night and 65 dBA by day. This minimum has been extended in most of the situations to follow the restriction recommended by Green Libro against the Noise (48-55 dBA at night and 58-62 dBA in diurnal period).
The elaboration of a model to calculate the sonorous pressure on the receivers has taken to the necessity to create a noise map, whose height (1,5 meters) allows that it is considered like strategic map of the noise (.
The necessity to elaborate a model to calculate the sonorous pressure on the receivers has taken to the necessity to create a noise map, whose height (1.5 meters) allows that it is considered like strategic map of noise (2002/49/EC in the evaluation and the management of the environmental noise)).
The study has been made in three populations near Leon:

- Janodembra..
- Viloria de La Jurisdicción.
- Cenbranos

3. METHODOLOGY

The first consideration that is due to do is the nature of the route. It is a highway located in a runner with high levels of traffic that, as well, are conditional in a next future by the execution of other infrastructures.
The most unfavorable levels in 2023 have been chosen, taking for each section the highest levels of traffic. In particular, these levels are in hour average intensities, according to diverse studies (table 1):

Table 1: Levels of traffic.

	2003		**2023**	
	Day	*Night*	*Day*	*Night*
Janodembra	1305	569	2747	1198
Viloria	1486	648	3128	1363
Cembranos	2335	1018	4914	2142

In any case, it has considered 18 % of heavy vehicles and fluid traffic. The supposed average speed is 120 km/h.

On the other hand, it is assumed that the asphalt used in the route is not totally clean, that is to say, have not considered its characteristics just thrown the asphalt conglomerate but that has introduced a type of asphalt with a part of dirt caused by the friction of the wheels with the tread layer.
The computer model has been modeled in three dimensions, being the real surface interpolated between contours each 5 meters (although the recommendation of the software manufacturer is 20 meters) and the topography of the highway introduced in real level each 100 meters.
The rays sent by the linear sonorous source that forms the highway have a length of 2000 meters. The model has calculated up to five reflections of these rays and 99 intersections.
The prediction of the levels of equivalent noise has calculated with norm ISO 9613.
For the calculation of necessary the acoustic screens, an absorption model has been followed, introducing the coefficients of absorption of these barriers by octave band.
The nature of the ground is herbaceous, dedicated fundamentally to the cereal culture . This type of grounds presents a coefficient of acoustic absorption that, according to software MITHRA, can be fixed to 0,64.
The used climatic conditions are the annual average temperature and the annual relative humidity in the Leon-Virgen del Camino Airport:

- 10,9 º C
- 68 % RH

The wind predominant directions have not been considered since norm ISO 9613 does not consider them.
The software used for prediction (MITHRA V4.0) is a software package designed for the study of the acoustic propagation in outer applications. It considers factors as the design of buildings, the local topography, the acoustic barriers, the type of ground or even the meteorological effects.
The acoustic calculation is made for each ray emitted from the receiver towards the line of the source. If the angular resolution is sufficiently small (some degrees), one supposes that the topography represented by the segments intercepted by the ray does not vary in the angular cone; in other words, that the average propagation does not vary in the cone. In these conditions, the problem limits the calculation in the seccional cut between a point source and a receiver. For this, it is necessary to define the associate acoustic power to the cross-sectional section, the attenuation by spherical divergence (Adiv), absorption of the air (Aatm), diffraction (Adif), effects of the ground (Aground) and absorption by the vertical surfaces (Aref) in which has been reflected in the horizontal plane. The norm international ISO 9613 uses the algorithms that are exposed next.

Norm ISO 9613-2

The level of sonorous pressure in a cross-sectional section is calculated with the following expression (1):

$$L_p = L_w - A_{div} - A_{atm} - A_{ground} - A_{screen} - A_{ref} \quad (1)$$

- A_{ground} is the attenuation due to the effect of the ground with favorable meteorological conditionses to the propagation of the sound
- A_{screen} it is the attenuation due to the diffraction with favorable meteorological conditionses to the propagation of the sound

4. PROJECT SOLUTIONS

Three acoustic barriers in three localities have been projected.

i. First of the acoustic screens is located in the surroundings of the Janodembra urbanization, between kilometric points 2.950 and 3.500, to the left of the road following the direction from Leon to Benavente and located to 6 meters of the axis of the road.
ii. In the locality of Viloria de La Jurisdicción screens have been placed between kilometric points 12.500 and 13.080 , in the left margin following Benavente direction, located to 6 meters of the axis of the road.
iii. The third and last locality in which the corrections have been calculated is Cembranos, where it will go located a sound screen between kilometric points 13.800 and 14.440 in the left border in Benavente direction and located of 6 meters of the axis of the road.

The projected screens have all a height of 4 meters, formed by 4 modules of 1 meter that are united until the formation of this height. The length overall of the screens is 1770 meters. The surface of the absorbent acoustic screens is: 2200 m2 in Janodembra, 2320 m2 in Viloria de La Jurisdiccción and 2560 m2 in selected screens in Cembranos. The selected screens are of steel galvanized by both faces, being the front face perforated in a surface of 40 %. The material of the sound insulation is wool of the rock of 40 millimeters of minimum thickness. The wool of the rock is an elaborated mineral wool of the basaltic rocks that present/display remarkable characteristics like absorbent hearing aid.
In order to obtain the wished results the minimum characteristics of the screens must be:

Table 2. Airbone noise isolation.

f (Hz)	125	250	500	1000	2000	4000
R (dB)	25	25	22,5	29	46,5	53,5

Rw (ISO 717): 28 dB

Table 3. Absorption in diffuse field.

f (Hz)	125	250	500	1000	2000	4000
α	0,23	0,59	0,81	0,89	0,94	1,05

5. RESULTS OF THE SOLUTIONS

The use of the projected acoustic screens, assures that in year 2023 all points of the present affected urban will not surpass the recommendations of the European Union on acoustic contamination, as much in the diurnal section as in the nocturnal one.
In concrete analyzing the data by populations we obtain the following results:

5.1. Janodembra

In the diurnal section without intervention could be arrived at levels from up to 70 dBA. With the intervention it is obtained that the less favored receivers are in the surroundings of the 60 dBA (below the 65 dBA recommended by the WHO). In the nocturnal section, the predicted levels get to go up to around 65 dBA, that is reduced with the solutions contributed until levels below 55 and, even, 50 dBA. Analyzing the situation on several concrete receivers we can see better the effectiveness of the solution.

Table 4. Reduction of diurnal levels in Janodembra.

JANODEMBRA (DAY)			
Receiver	**L_{eq} without screens (dBA)**	**L_{eq} with screens (dBA)**	**Reduction (dBA)**
11	68,9	59,2	9,7
12	66,8	58,0	8,8
13	61,5	54,4	7,1
14	62,3	55,8	6,5
15	62,3	56,2	6,1
16	66,6	57,8	8,8
17	58,2	53,0	5,2
Average	--	--	7,4

Table 5. Reduction of diurnal levels in Janodembra.

JANODEMBRA (NIGHT)			
Receiver	**L_{eq} without screens (dBA)**	**L_{eq} with screens (dBA)**	**Reduction (dBA)**
11	65,3	55,8	9,5
12	63,2	54,6	8,4
13	57,9	51,0	6,9
14	58,7	52,1	6,6
15	58,7	52,8	5,9
16	62,9	54,2	8,7
17	54,5	49,4	5,1
Average	--	--	7,3

The reduction in this section is excellent, arriving at reductions superior to 6 dBA.
The main reason that the reduction is so abrupt is the proximity from the houses to the highway and, therefore, the screens, so that the houses are totally under the action and the protection of the acoustic barriers.

5.2. Viloria de La Jurisdicción

In the nocturnal section in this locality the equivalen noise level is in 55 dBA, in the limit of the WHO. We propose down this levles to 48-55 dBA following the recomendations of European Green Book. The effectiveness of the screens on receivers located at random during the night is the following one:

Table 6. Reduction of nocturnal levels in Viloria de La Jurisdicción.

VILORIA DE LA JURISDICCIÓN (NIGHT)			
Receiver	**L_{eq} without screens (dBA)**	**L_{eq} with screens (dBA)**	**Reduction (dBA)**
41	51,8	49,3	2,5
42	50,2	46,6	3,6
43	48,7	46,1	2,6
44	51,2	48,4	2,8
45	52,3	49,6	2,7
Average	--	--	2,9

The reduction obtained in this zone is 3 dBA. It is necessary to consider that the screens are not continuous, being a part exposed in the zone of a interchanger, for this reason we consider this diminution in the levels like very satisfactory.

5.3. Cembranos

The levels anticipated in Cembranos during the night in year 2023 surpass in some points the 55 dBA, in the superior limit propose by Green Book, for this reason sound screens have been implemented moving these values towards the inferior part of the limit, towards safer values. The effectiveness of the propose solution is reflected in the following table for receivers placed at random during the nocturnal period:

Table 7. Reduction of nocturnal levels in Cembranos.

CEMBRANOS (NIGHT)			
Receiver	**L_{eq} without screens (dBA)**	**L_{eq} with screens (dBA)**	**Reduction (dBA)**
41	52,6	49,2	3,4
42	52,6	51,0	1,6
43	52,9	50,9	2,0
44	52,3	49,8	2,5
45	53,3	50,8	2,5
Average	--	--	2,5

The reduction in the locality of Cembranos is minor who in the previous localities. It is because the locality is remoter of the highway, which reduces the effectiveness of the screens. Although the screen absorbs a part of the acoustic energy, but another part affects this population.
The summary of the acoustic screens to place is the following table:

Table 8. Length of screens.

	initial KP	**final KP**	**lenght (m)**	**height (m)**
Janodembra	2+950	3+500	550	4
Viloria de La Jurisdicción	12+500	13+080	580	4
Cembranos	13+800	14+440	640	4
Total Amount			**1770**	

6. CONCLUSIONS

The evolution of the traffic and the sonorous levels would have to be reviewed periodically and to be adapted to the temporary characteristics of vehicles and buildings, considering the effects that environmental noise causes on environment of the affected zones.
The results of the made performances must be controlled, improving continuously the followed model.
The proximity of the receivers to the screen. This supposes that the perception of the noise is going to diminish between 50 and 100 % in the places more affected by the highway (reduce 3 dBA the level noise suppose to diminish the sound pressure to half).
There are not receivers with equivalent sound pressure levels superior to 60 dBA during the day and 55 dBA during the night, inside, therefore, of the recommendations of the WHO.

ACKNOWLEDGEMENTS

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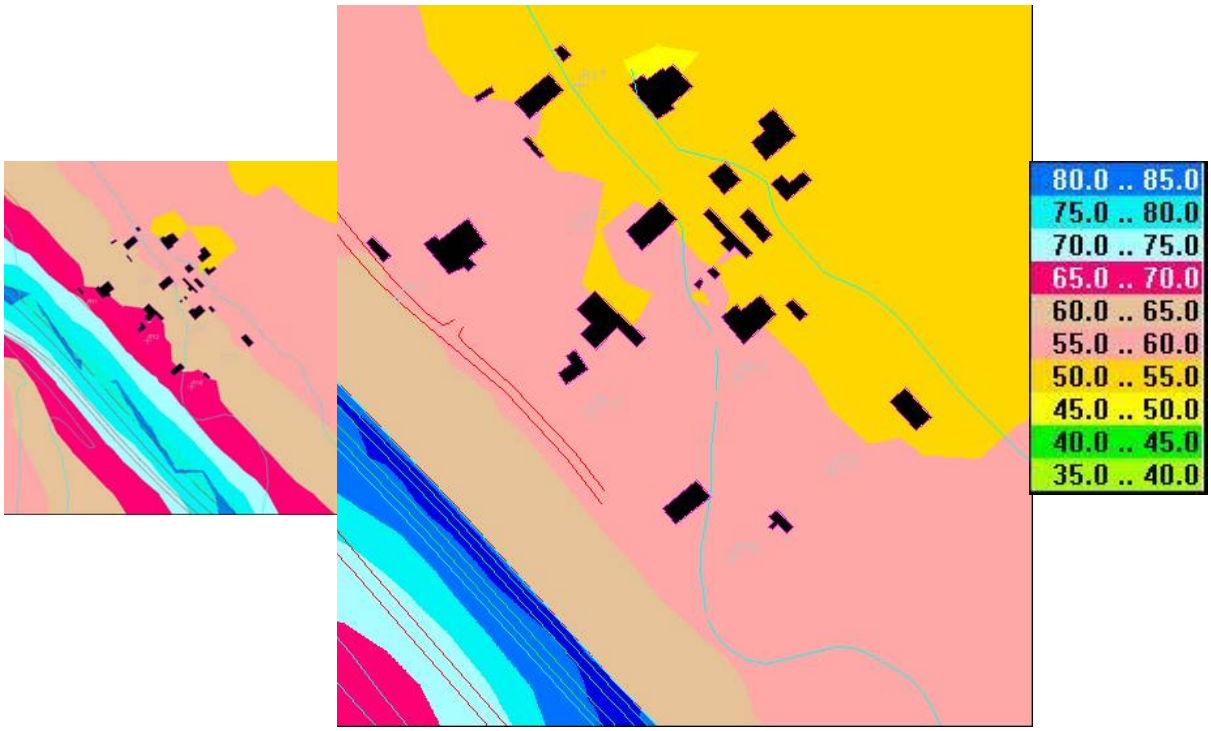

Figure 1: Diurnal acoustic map without screens (left) and with screens (right) - Janodembra.

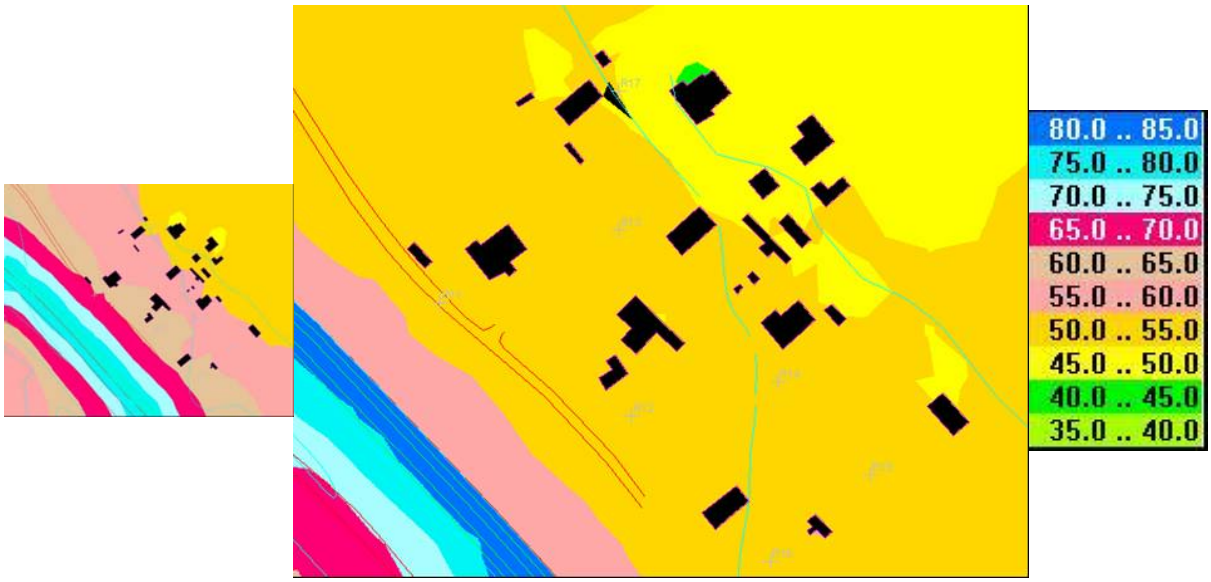

Figure 2: Nocturnal acoustic map without screens (left) and with screens (right) - Janodembra.

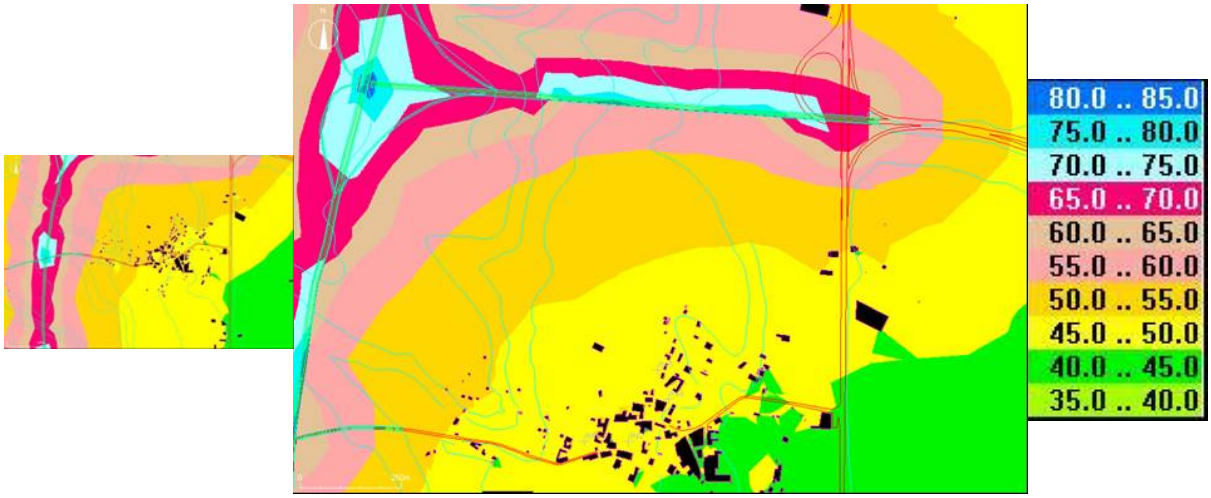

Figure 3: Nocturnal acoustic map without screens (left) and with screens (right) - Viloria de La Jurisdicción.

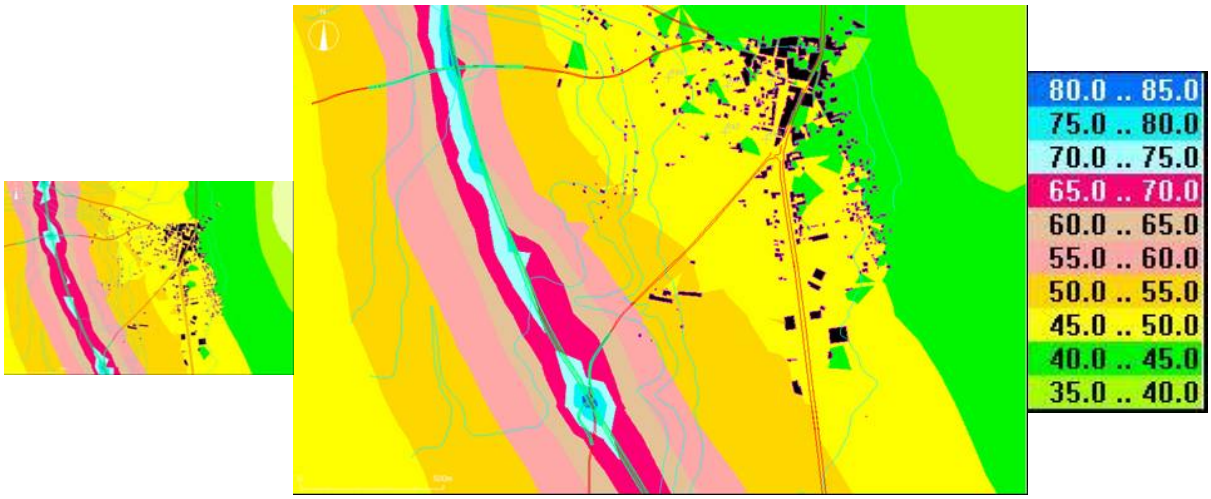

Figure 4: Nocturnal acoustic map without screens (left) and with screens (right) - Cembranos.