MOTORWAY TRAFFIC NOISE REDUCTION BY MEANS OF BARRIERS: A DESIGN EXAMPLE BASED ON PREDICTION MODELS AND EXPERIMENTAL VERIFICATION.

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SUMMARY

In this paper the results of a concrete example of noise abatment carried out on an Italian motorway are reported. The research was based on an accurate experimental study of traffic noise both before and after the intervention. A numerical model, based on the German Standard RLS81 [1], was implemented, and used both for the analysis of the initial situation, and for the design of noise barriers.

Although it required a large amount of human and instrumental resources, the method used made it possible to predict with accuracy the traffic noise propagation even in very complex orographic areas. Furthermore, it was possible to correctly establish the dimension of the barriers protecting people living close to the motorway, thus implementing the noise limits set by governement rules [2] (65 dB(A) by day and 55 dB(A) by night).

The noise measurements, carried out at many points around the studied area, made it possible initially to check the reliability of the prediction model used. The repetition of the measurements after the intervention made it then possible to check the correspondence between the abatment obtained and the predictions. This validated the reliability of the part of the model which predicts the noise abatment of barriers.

DESCRIPTION OF THE MODEL

The prediction model used is based on the German Standard RLS81 [1]. The model was used both for the analysis of the initial situation and for the design of noise barriers.

The model requires an input of data regarding the average hourly traffic, separated into heavy and light vehicles, the average speed for each group, the dimension and type of the road and of any natural and artificial obstacles.

The model takes into account the main characteristics which influence the propagation of noise, such as obstacles, vegetation, air absorption, reflections and diffraction. It makes it possible to verify the noise reduction produced by barriers, taking into account their lenght. The model takes into account also the reflections produced by the opposite screens, but it is necessary that they be classified according to the Standard ZTV81 [3], which gives directly the reduction of the reflected field in dB(A) for the typical sound spectrum of highway traffic.

The model first enables the calculation of a reference Sound Level, at 25m from the sound source, based on the traffic and road data. After this, a set of statistical values of correction factors and empirical formulae like the one proposed by Maekawa [4] for diffraction and screen attenuation are used to compute the attenuation of sound levels at greater distances. The model takes into account mirror images of the sound source, plus an overall “reverberation” correction for multiple reflections; the prediction values obtained are generally well correlated with the experimental verification [5].

The model, initially simply implemented for the prediction of traffic noise at a single point, was developed by the authors so as to allow the study of altimetrically complex environments, and the automatic contour mapping of noise levels in vertical or horizontal sections, or following the land's altimetry. This procedure yielded interesting results from a representational point of view, but required a very long calculation time. Furthermore, it was necessary to build an interface to 3-D digital land altimetry representation packages.

One of the advantages of this method is the possibility of exporting the results in graphic form to the AutoCad environment, superimposing the contour lines to the plan, section or perspective representation of the site.

DESCRIPTION OF THE SITE AND EXPERIMENTAL MEASUREMENTS

The study was carried out in a section of the A4 motorway between Venice and Trieste. In this section, the motorway goes through a built up area, containing also a school. In some cases, the buildings (including the school) were less than 5 meters away from the road. The land was altimetrically complex with a succession of woods and huge masses of carsic rock.

The aim of the study was to design noise barriers in order to guarantee the respect of the noise limits for this area type set by Italian legislation [2].

First of all, a study of the traffic noise level was carried out. Measurements were made at 31 different points which were considered to be of particular significance to the study. At the same time, information on the traffic, including the speed of the vehicles, was gathered, and average hourly and daily traffic was calculated, divided into day and night traffic, and light and heavy vehicles. The average traffic was:

- Day time (6 am - 10 pm): 1300 light vehicles and 250 heavy vehicles/hour;
- Night time (10 pm - 6 am): 300 light vehicles and 180 heavy vehicles/hour.

A separate count of the vehicles was carried out while each noise level was being measured, in periods of 15 minutes. These data were used to normalize each sound level to the average traffic (assumed as standard).

The topographic characteristics of the area, particularly around the most affected buildings, were measured by detailed measurements taken with a theodolite and an infra-red distance meter.

As can be seen in Fig. 1 and in Table 1, the noise levels were well above the limits set by the Italian law. Since the excess was at some points over 13 dB, it became clear that very high and well-insulating barriers were necessary.

It also became clear that, in many places, the need to put barriers on both sides of the road would give rise to problems of noise reflection from opposite barriers. It was thus necessary first to take into account the reflected sound energy in the calculation procedures, and secondly to use sound-absorbing barriers.

SIMULATIONS AND DESIGN OF NOISE BARRIERS

First of all, the model was used to reproduce the real situation in standard traffic conditions. To do this, the model was accurately calibrated, by changing certain geometric parameters. In this way, it was possible to make the computed noise levels to approach the normalised experimental measurements. The model was then used to obtain a contour mapping of the situation without the noise barriers.

The barriers were designed working on vertical sections, and their height was calculated so that the noise level would be within the limits on the top floor of the affected buildings.

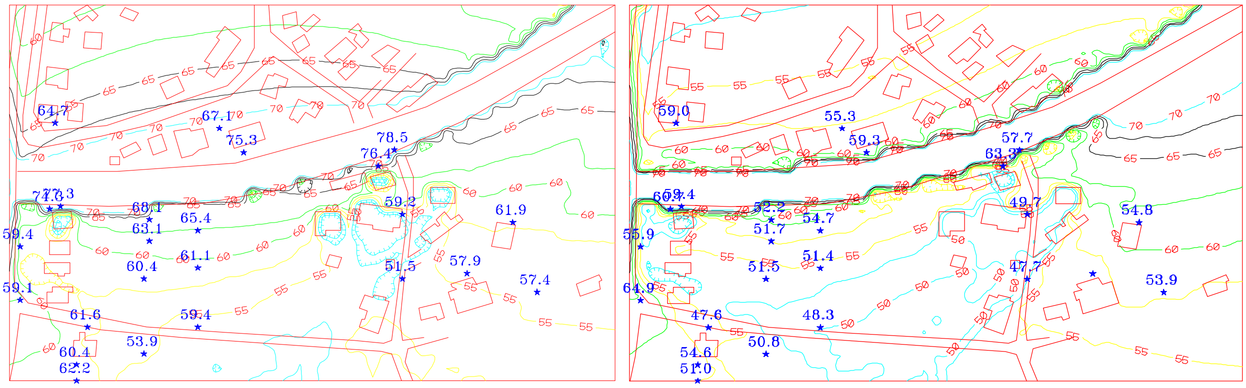


Fig. 1 - Contour Map of Sound Pressure Levels (computed) and Experimental Values, before (left) and after (right) the installation of barriers

It soon became clear that the worst situation, and therefore the one to be considered in the design of the barriers, regarded night-time. In fact, at night the noise level decreased by about 3.3 dBA due to traffic reduction, but the limit set by the law is 10 dBA lower at night than during the day. This limit applies only to residential buildings and not, for example, to the school, which is only used during the day.

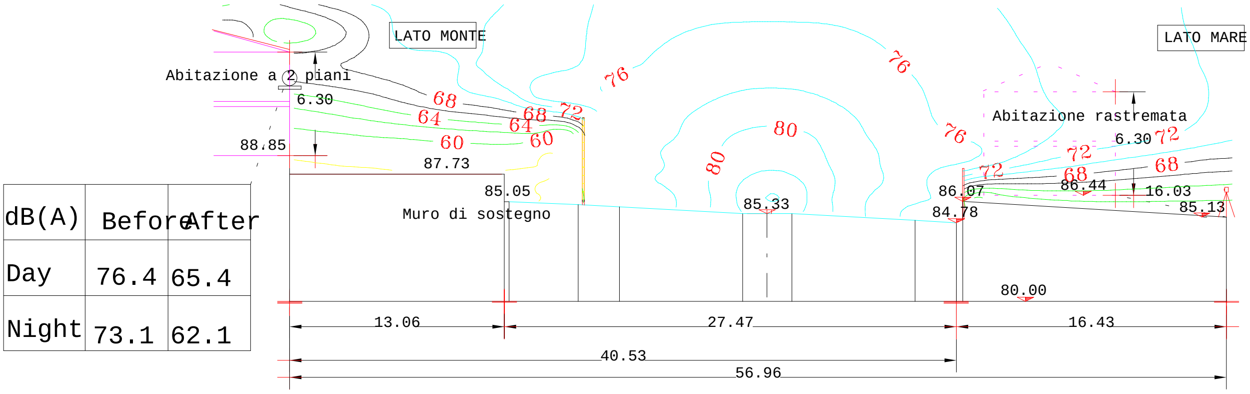
The calculation also gives, for each section, the "standard additional length", which is the length the barrier should have, on each side of the section, to ensure that the noise coming from the end of the barrier does not affect the calculated abatment.

Due to the varied altimetry of the land, the hight of the barriers changed greatly according to the position of the affected buildings.

The barriers used were of a "sound absorbing" type according to ZTV-81: they are panels made of concrete, covered on the side facing the road with undulated panels in expanded clay. These panels resulted in a reflection loss of 4 dBA measured according to ZTV-81, which was enough to avoid the increase of level due to reflections on the opposite barrier.

It is important to note that in some cases barriers 7 meters high had to be used, which presented problems for static calculation (in this area winds can blow at 250 km/h). Furthermore, in order to reduce the impact on the landscape, glass panels were used whenever possible.

Figure 2 shows a section during the barrier calculation, clearly exploiting the distorting effect on the countour lines produced by reflections on the opposite wall.



dB(A)	Before	After
Day	76.4	65.4
Night	73.1	62.1

Fig. 2 - Vertical cross-section used for barrier calculation

EXPERIMENTAL VERIFICATION

After the barriers were built and installed along the highway, measuremente were taken again in the same locations used the first time. Also in this case a simultaneous measurement of the traffic flow was made, showing that the average traffic had not changed, and enabling the normalization of the measured levels.

Table 1 reports both experimental and computed data, before and after the installation of barriers. It can be shown that the sound pressure levels are now below the law limits at all points.

Table 1 - Comparison of Sound Pressure Levels: 0 is before barriers, 1 after,
“Exp” is experimental, “The” is theoretical (computed by RLS-81)

Pt. N.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Exp-0	75.3	67.1	76.4	78.5	74.3	77.3	64.7	59.4	59.1	60.4	61.6	63.1	68.1	60.4	53.9	62.2	59.2	51.5	57.9	61.9	57.4	65.4	61.1	59.4
The-0	76.6	68.5	75.4	78.3	75.6	76.9	65.4	62.4	64.2	60.7	61.2	64.9	68.2	62.1	56.9	62.9	59.7	53.7	59.2	60.9	57.4	65	61.4	57.6
The-1	59.5	57.2	65.4	57.7	67.6	57.3	56.8	57.2	62.4	58.3	57	58	61.2	55	54.5	59.9	49.7	52.8	58.3	63	59.8	58.7	54.8	51.9
Exp-1	59.3	55.3	63.3	57.7	60.7	59.4	59	55.9	64.9	54.6	47.6	51.7	52.2	51.5	50.8	51	49.7	47.7	/	54.8	53.9	54.7	51.4	48.3

CONCLUSIONS

The results show that an effective, large reduction of sound pressure levels in all the points previously exceeding the limits was achieved. In some points the sound reduction appears to be even greater than required, but it must be considered that meanwhile a new draining road paving was installed, slightly contributing (2-3 dBA) to the overall sound reduction.

In the three most critical points (1, 4 and 6), the sound reduction was respectively 15.8, 20.4 and 18.3 dBA, with a maximum deviation of 1.5 dB from the numerical previsions. At some points located very far from the highway, however, larger deviations have been found, probably due to effects connected with other noise sources (not included in the model), such as other minor roads. At most points the discrepancy is lower than 3 or at most 4 dBA, and this is still a good result, considering the high approximations included in the mathematical modeling.

This work is an example of the utility of studying the original situation, simulating the sound propagation and designing the sound attenuating devices within an integrated framework. Thus the probability of errors is minimized, the overall analysis time is minimized and it is possible to define better the sound reduction required. Although the numerical models were very useful in reducing the computation time and enabling a direct graphic interface both for introducing the geometrical description of the land and for displaying the results, the importance of accurate experimental measurements of the acoustic field and of the actual land orography was confirmed.

The numerical model is now being updated, to comply with the new version of RLS, namely RLS-90.

REFERENCES

[1] Der Bunderminister fur Verkehr - "Richtlinien fur den Larmschutz an Strassen" - RLS81 (1981).

[2] D.P.C.M. 1 march 1991 “Limiti massimi di esposizione al rumore negli ambienti abitativi e nell’ambiente esterno” - Gazzetta Ufficiale della Repubblica Italiana, n. 57, 8 march 1991.

[3] Der Bunderminister fur Verkehr - “Zusatzliche Techinsche Vorschriften und Richtlinien fur die Ausfuhrung von Larmschutzwanden an Strassen” - ZTV-Lsw 81 (1981).

[4] Z. Maekawa - “Noise Reduction by Screens” - Applied Acoustics, vol. 1 (1968), p. 157-173.

[5] A. Farina, G. Semprini - "RLS81" - Atti del Convegno A.I.A. 1989 "Metodi Numerici di previsione del rumore da traffico" - Parma, 12 aprile 1989.