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VERTICAL EFFICIENCY OF SPEEDWAY ACOUSTIC FRAMES

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ABSTRACT
In this work tridimensional acoustic fields near highway frames are examined, both through experimental measurements and by a numerical simulation of the phenomena using a commercial software. In the first part the measurements taken in front of and behind the highway frames are presented. The highway is going through a peripheral urban area nearby Milan and wooden acoustic frames are placed near an elementary school to reduce the acoustic pollution. Acoustic measurements have been taken at different levels from the ground and in the whole range of the octave band spectrum between 31,5 Hz and 4000 Hz in different position respect to the frame. This work has been carried out both to calibrate and validate the software, which has been used to extend the analysis to the whole area around the school. Through the simulation 3D isophonic representations have been then produced for each frequency band. It gives a clear view of the spectral interaction between the frame and the buildings or among the frame, field, building and other walls.

1 - INTRODUCTION
During winter 1998-99 a set of experimental measurements has been carried out in the surrounding of the "Luini" elementary school in the Sesto S. Giovanni community, located near the pay-tool line on the Milano East Highway.
Measurements took place in various locations around the school and at different levels above ground, behind and in front of the frame and in the spectrum range between 31.5 and 4000 Hz. The measured values have been utilized for the calibration of the numerical model implemented through a commercial software. Using the numerical model, first a scenario has been created which describes the actual situation, and furthermore other two different scenarios, which represent possible alternative environmental configurations; all of them have been evaluated at different height above the ground to represent the phenomena with three-dimensional view for each frequency band.

2 - MEASUREMENT ACTIVITY
The measurements have been executed in the range between 31.5 and 4000 Hz at different levels above ground.

2.1 - Measurements locations
Two main locations have been chosen for evaluating the frame efficiency, respectively named "A" and "B". The "A" location was situated behind the frame just in front of the school facade, in a green area with grass and little trees. The ground level, in location A, is 90 cm lower than the highway level; thus the microphone was located on a telescopic tripod, placed over the roof of the service car, to use as reference for its height the highway level.
The "B" location was instead placed between the highway and the frame, to measure the incident sound level on the frame itself; the ground level there is the highway level.

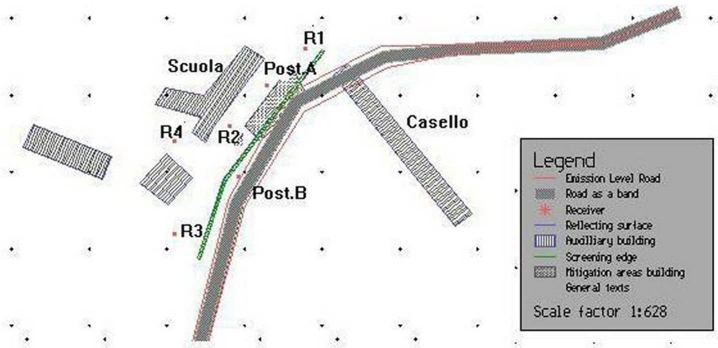


Figure 1: Map of the measurement locations.

2.2 - Measured data

In the "A" location, the measurements have been executed between 10.30 and 12.30 a.m. in the frequency range from 31.5 to 4000 Hz, at different heights (1.5, 2.3 and 3 m). In the "B" location the measurements have been executed between 13 and 13.30 a.m. instead at only 1.5 m height.
All the measurements have been taken in equivalent level for three minutes, Leq_3.

Location A	**Measured values [dB]**							
Receiver Height [m]	**31,5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
1,5	50.1	51.1	51.3	51.4	51.5	51.9	51.0	50.0
2,3	52.2	51.7	51.7	52.4	52.5	52.9	52.6	51.4
3,0	49.8	50.2	50.3	50.3	51.7	52.6	50.9	50.3

Table 1: Values of Leq_3 [dB] measured in location A.

Location B	**Measured values [dB]**							
Receiver Height [m]	**31,5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
1,5	53,8	53,6	54,8	58,1	58,4	63,4	61,0	54,8

Table 2: Values of Leq_3 [dB] measured in location B.

3 - COMPUTER MODEL

The environmental acoustic performance of the site has been reproduced using a commercial acoustic software. The scenario has been built describing the landscape, the building and the highway geometry and their acoustic properties. The acoustic source has been modeled using the values measured in "B" location, and to simulate the values measured in "A" location a virtual receiver (software numerical output) has been "placed" in the same position of real test site. To draw a more detailed view of the site performance other four virtual receivers (program outputs) have been also defined, located in several significant positions. Since the software is not directly supporting spectral analysis, that has been realized using the frequency band acoustic level of the source instead of the total level.

3.1 - Model parameters

For each building, the frame and the various ground surfaces standard reflection coefficients have been chosen from a specific database selecting them among similar site situations.

ZONE	**Reflection loss Coeff.**							
	31,5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
School	0	0	0	0	0	2	2	0
Building A	0	0	0	0	1	3	3	0
Building B	0	0	0	0	1	3	3	0
Trees area	0	0	0	0	0	0.2	0.05	0
Pavement area	0	0	0	0	0	0	0	0
Grass area	1	1	1	1	1	1	1	1

Table 3: Spectral reflection loss coefficients for different surfaces.

3.2 - Model calibration

The model calibration is a fundamental task, being the software validated for total quantities and not for spectral ones. It was based on absorption coefficients adaptation and was made for each frequency band using the measurements at 1.5 m above the ground, modifying the absorption coefficient of the buildings and of the ground surface and moreover working on the source geometry. With the final adopted coefficients the results shown in tab. 4 have been achieved.

Location A -Height [m]	**Measured and calculated values [dB]**							
	31,5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Measured values at 1,5	50.1	51.1	51.3	51.4	51.5	51.9	51.0	50.0
Calculated values at 1,5	48.23	48.03	49.23	52.53	51.14	53.79	52.89	49.23

Table 4: Values of Leq_3 [dB] measured and calculated in location "A".

4 - PERFORMANCE SIMULATIONS

Each acoustic performance simulation produce as output sound levels numerical values only for the "virtual receivers". To obtain a numerical distribution representative for the whole site, four virtual receivers, placed in different positions, have been selected. In addition the software is giving as output isophonic maps (graphics program output). These maps are based on an x-y grid with pre-definable steps and referred to a specific height above the ground.

4.1 - Actual spatial distribution

In each selected location (four) the virtual receiver (i.e. the numerical program output) was "placed" at different height above ground with reference to the frame level, obtaining the Leq $_3$ values reported in table 5. The acoustic parameters utilized in the software are of course those obtained after the calibration stage against the measurements.

Virtual location	**Frequency**							
	31,5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
R1 at 1.5 m	44.350	44.150	45.350	48.650	48.783	52.950	51.004	45.350
R1 at 2.3 m	44.602	44.402	45.602	48.902	49.031	53.116	51.214	45.602
R1 at 3.0 m	44.897	44.697	45.897	49.197	49.318	53.316	51.463	45.897
R2 at 1.5 m	42.358	42.158	43.358	46.658	45.842	48.557	47.170	43.358
R2 at 2.3 m	42.882	42.682	43.882	47.182	46.294	49.055	47.655	43.882
R2 at 3.0 m	43.423	43.223	44.423	47.723	46.745	49.562	48.142	44.423
R3 at 1.5 m	45.866	45.666	46.866	50.166	50.351	55.290	52.908	46.866
R3 at 2.3 m	45.988	45.788	46.988	50.288	50.430	55.362	52.982	46.988
R3 at 3.0 m	46.124	45.924	47.124	50.424	50.515	55.443	53.064	47.124
R4 at 1.5 m	39.060	38.860	40.060	43.360	42.719	45.777	43.604	40.060
R4 at 2.3 m	39.377	39.177	40.377	43.677	42.952	46.003	43.848	40.377
R4 at 3.0 m	39.653	39.453	40.653	43.953	43.182	46.218	44.087	40.653

Table 5: Values of Leq_3 [dB] simulated for each virtual location at each reference level above the ground.

4.2 - Spatial distribution in other scenarios

To evaluate the importance of several environmental parameters on the site acoustic performances, in presence of a sound frame, different scenarios have been implemented based on the measured data (for the source) and on modified acoustic properties of buildings, ground, etc. For the frequencies of 31.5, 1000, 4000 Hz different simulations have been carried out according to the following conditions:

- without buildings and uniformly absorbent ground;
- real site but with both the frame's surfaces absorbents;
- same as b) and building's facade in front of the frame uniformly absorbent.

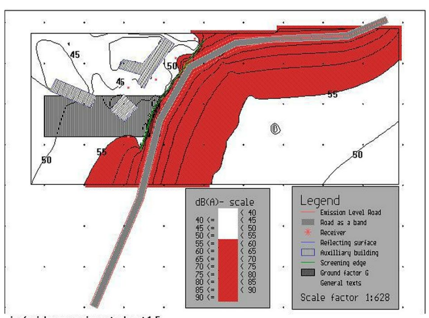
Virtual Location	**H 1.5 m**			**H 2.3 m**			**H 3 m**		
	31,5	**1000**	**4000**	**31,5**	**1000**	**4000**	**31,5**	**1000**	**4000**
R1 scenario a	43,8	53,40	44,80	44,02	53,62	45,02	44,29	53,89	45,29
R1 scenario b	44,18	52,95	45,04	44,43	53,12	45,28	44,71	53,32	45,56
R1 scenario c	43,95	52,79	44,92	44,19	52,95	45,15	44,47	53,13	45,43
R2 scenario a	38,67	48,27	39,67	39,24	48,84	40,24	39,82	49,42	40,82
R2 scenario b	41,25	48,56	41,46	41,69	49,06	41,94	42,14	49,56	42,42
R2 scenario c	39,88	47,52	40,66	40,39	48,09	41,18	40,90	48,66	41,70
R3 scenario a	45,67	55,27	46,67	45,74	55,34	46,74	45,82	55,42	46,82
R3 scenario b	45,77	55,29	46,72	45,84	55,36	46,80	45,93	55,44	46,88
R3 scenario c	45,71	55,27	46,70	45,78	55,33	46,78	45,87	55,41	46,86
R4 scenario a	39,04	48,64	40,04	39,20	48,80	40,20	39,32	48,99	40,32
R4 scenario b	38,53	45,78	37,53	38,76	46,00	37,78	38,99	46,22	38,03
R4 scenario c	35,44	43,35	35,77	35,71	43,62	36,06	35,98	43,88	36,35

Table 6: Values of Leq_3 [dB] simulated for each virtual location at each reference level a.g. and different scenarios.

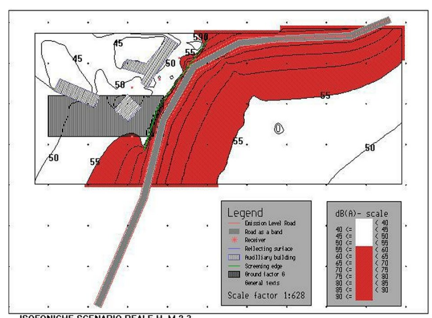
4.3 - Isophonic maps

The site acoustic performance of each scenario have been also represented through isophonic maps with a regular grid of 5x5 m for any of the considered height and frequency band:

- actual situation: heights 1.5, 2.3, 3 m; frequencies 31.5, 1000, 4000 Hz;
- scenario a: heights 1.5, 2.3, 3 m; frequencies 1000, 2000 Hz;
- scenario b: heights 1.5, 2.3, 3 m; frequencies 1000, 2000 Hz;
- scenario c: heights 1.5, 2.3, 3 m; frequencies 31.5, 1000, 4000 Hz.



(a): Actual situation at 1.5 m height.



(b): Actual situation at 2.3 m height.

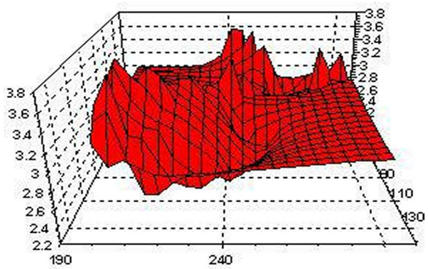
Figure 2: Isophonic maps.

4.4 - 3D – isophonic maps

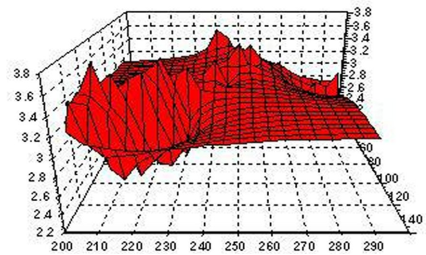
To simplify the site analysis giving an immediate view of the complying with legal constraints (max Leq value), a 3D- isophonic map has been developed. Its surface represents the limiting Leq value and all the points below comply with it.

5 - CONCLUSIONS

Spectral calibration of a commercial computer program using spectral experimental data allowed to use such software to extend the site analysis to alternative scenarios for each frequency band. In this way it is possible to assess the effectiveness of each action, which can be foreseen as noise reduction measurement. To give a clear view of the complying with legally required limits on the acoustic level, a isophonic 3-D map has been developed. All the buildings parts and ground areas which are below such surface have an equivalent level less than the limiting value associated to this isophonic surface, thus they are complying with the law; instead all of those which are above are non complying with.



(a): Actual situation.



(b): Scenario c.

Figure 3: 50 dB Leq_3 3D isophonic maps at 1000 Hz.

This 3D − Isophonic map can be used both for total analysis than spectral one.

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