Acoustics'08 Paris
June 29-July 4, 2008
www.acoustics08-paris.org

# Exposure of building roofs to road traffic noise; consequences on the field performance of skylights

Michel Villot and Philippe Jean

CSTB, 24 rue Joseph Fourier, 38400 Saint-Martin-d'Hères, France
michel.villot@cstb.fr

In this paper, the exposure to road traffic noise of building roofs is studied both theoretically and experimentally. First, the incident field is estimated using a BEM approach, taking into account the sound diffraction on the roof edge. The theoretical results show significant differences in noise exposure between roofs and vertical façades, particularly with relatively tall buildings; these differences are then confirmed by field measurements. The grazing incidence of the sound fields on roofs raises the question of the acoustic performances of skylights in real situation, as opposed to their laboratory performances measured under diffuse sound field; this problem is experimentally investigated by laboratory measurements of glazing under different angles of incidence, using a big size plane wave generator.

# 1 Introduction

In the French Building Acoustics Regulations, there is no distinction between exposure of roofs and skylights to road traffic noise and exposure of vertical façades. However, for buildings of a certain height in particular, and especially in warm regions where roof slopes are small, roofs and skylights are certainly less exposed than vertical façades. In this paper, the exposure of roofs to road traffic is studied both theoretically using calculation models, and experimentally by performing field tests. The calculation models used are presented and experimentally validated in the second section of the paper. Using these models, a parametric study is then performed in order to identify the relevant parameters; the results are presented in section 3 and compared to the results of a second set of field tests. The grazing incidence of the sound fields on roofs raises the question of the acoustic performances of skylights in real situation, as opposed to their laboratory performances measured under diffuse sound field; this problem is experimentally investigated by laboratory measurements of glazing under different angles of incidence, using a big size plane wave generator; these laboratory results are presented in the fourth and last section of the paper.

# 2 Calculation models

Two very different models were used for this study, both in a 2 ½ D geometry where street and buildings are infinite in one direction (see Fig. 1 below) but the sound source is a incoherent line source representing a stream of cars: (i) the RAYDIF software, developed at CSTB is based on the classical ray tracing method; a special module using the Geometrical Theory of Diffraction (GTD) has been implemented in the software for modeling the diffraction effects; (ii) the MICADO software [1], also developed at CSTB is based on the Boundary Element Method (BEM); the diffraction effects are implicitly taken into account in the BEM approach.

All the problems of convergence and sound absorption through air and façades (in order to lead to realistic reverberation times) as well as the problem of sound propagation in shadow areas (diffraction effects) were carefully solved. In particular, the models were validated / calibrated from experimental reverberation times of U-shaped roads found in the literature.

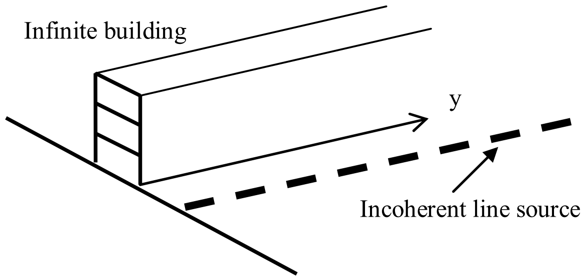


Fig. 1 2D ½ geometry modeled

A first experimental validation campaign was carried out in the simple case of a house exposed to the noise of a loudspeaker placed in front of a façade as shown in Fig. 2; the source was not in direct view of the roof. The measured and calculated results were expressed in terms of difference in 1/3 octave band between the sound level at the façade and the sound level at the roof. These two sound levels were measured a few centimetres from the walls and averaged over a surface area of approx. 2m². The results shown in Fig. 3 are average results for 2 adjacent source positions either measured or calculated using the two methods (MICADO and RAYDIF software). The orders of magnitude are the same, but the calculated results somehow minimise the effects (the real attenuation between vertical façade and roof is greater than the calculated attenuation); the MICADO results are closer to the measurements.

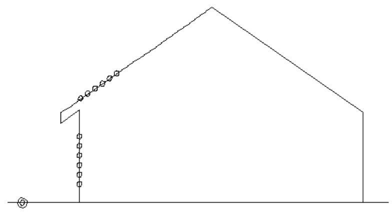

Fig.2 Vertical section of the house, showing the source position and the measurement surfaces

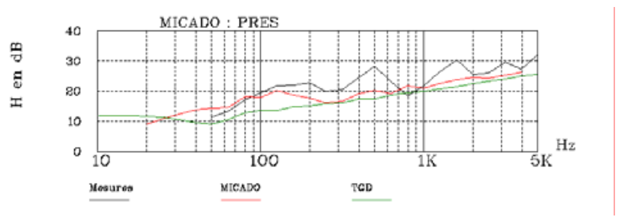


Fig.3 Comparison between measured and calculated attenuations (results of MICADO and RAYDIF (TGD) software)

In all the results shown in this paper, the calculations of roof exposure have been performed using the MICADO software and the calculations of vertical façade exposure (without diffraction) have been performed using the RAYDIF software (much faster).

## 3 Parametric study

The MICADO calculation model was applied to a basic configuration corresponding to a 3-storey building with a 20° sloped roof and a similar building 12 m in front as shown in Fig. 4. Incoherent line sources were distributed in the width of the street. Several other cases corresponding to different roof angles, different street widths, different heights of buildings, as well as an isolated single building were also considered.

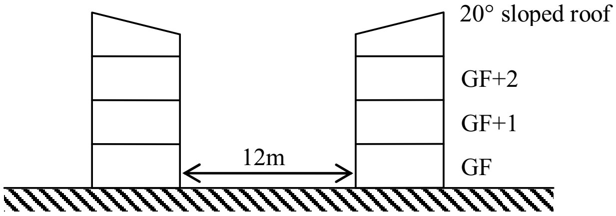


Fig.4 Basic configuration studied

The 1/3 octave band results presented in Fig. 5 correspond to the basic configuration described above and are expressed in terms of difference in exposure compared to the ground floor. The sound levels are spatially averaged over a surface area the size of a window. Four locations are considered: first floor (GF+1), second floor (GF+2), third floor (roof on street side) and third floor (roof on yard side). The differences in exposure were considered to be significant, if of the order of 5 dB, which corresponds to the width of the French road infrastructure classes. The results show that (i) only the exposure differences for the roof are significant, (ii) even a big roof slope (60 °) produces an attenuation of 5 dB, (iii) an attenuation close to 10 dB can be achieved with flat roofs (slopes around 20° or less), (vi) "yard-side" roof attenuations are much bigger, from 15 to 25 dB increasing with frequency for an average slope of 30-40°.

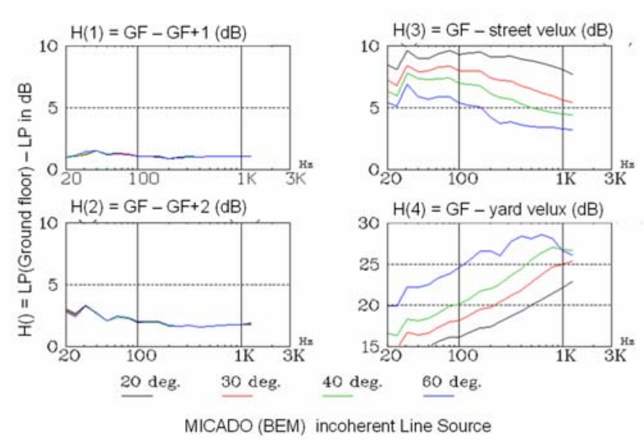


Fig.5 1/3 octave exposure differences obtained using the MICADO software.

## 4 Field tests

The GF+4 building chosen had a sloping roof (angle of 27°), symmetrical on both street side and yard side, was located in a 16 m wide U-shaped street and had a quiet back yard protected by other buildings. Measurements were made in front of the building (reference microphone at ground floor level) and on the roof both on street side and yard side successively.

The traffic noise from the street was used as noise source and the sound levels were obtained by linear averaging during 2-3 seconds. No traffic survey was conducted and the traffic direction as well as the type and number of vehicles were not identified. The results presented in Fig. 6 are expressed in terms of difference in 1/3 octave band between the sound level at the façade (reference microphone) and sound levels measured on the street-side roof and yard-side roof; the sound levels are averaged over 6 different events.

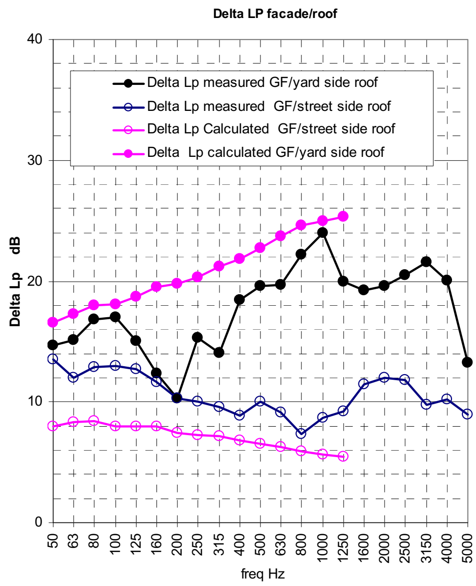


Fig. 6 Attenuation between sound level in the street (ground floor façade) and at the roof; comparison between measured and calculated results

The results show that for a roof slope close to 30°, the roof exposure attenuation (compared to façade exposure at ground level) is roughly 10 dB for the street-side roof and between 15-25 dB (increasing with frequency) for the yard-side roof; a comparison with the calculated attenuations shows that the calculated orders of magnitude and frequency slopes are correct.

## 5 Roof and skylight sound insulation

Because of sound diffraction on the lower edge of roofs, the sound exposure of roofs has the particularity of being at grazing incidence, which raises the question of the acoustic field performances of skylights, as opposed to their laboratory performances measured under diffuse sound field; this problem has been experimentally investigated by laboratory measurements of glazing under different angles of incidence, using a big size plane wave generator developed during a recent PhD at CSTB [3].

A double-glazing (10-10-4) was installed in a concrete support wall in the CSTB laboratory, glazing and wall (outer side) being coplanar in order to simulate a realistic roof/skylight configuration. First, the glazing was measured under standardized conditions with excitation by a reverberant room (diffuse incidence); then, the emission room was removed and replaced by a plane wave generator, as shown in Fig. 7, placed at different angles of incidence (0, 30, 50, 70 and 80°); the 80° angle simulated the grazing incidence. The results expressed in terms of R index are shown in Fig. 8.

Fig. 7 View of the laboratory configuration and the plane wave generator

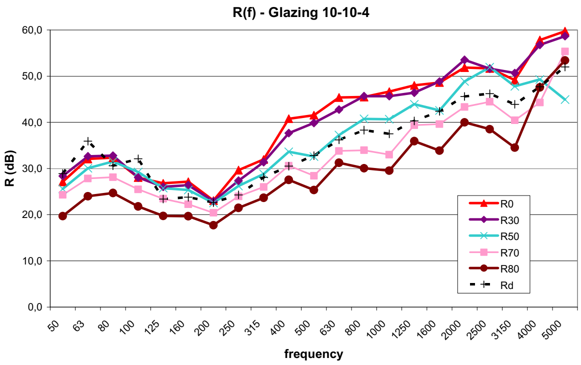


Fig. 8 R index spectra of the 10-10-4 glazing tested in laboratory under diffuse field or single incidence

Fig. 8 shows significant differences of R index values, depending on the excitation type (diffuse field or single incidence). However, the relevant quantity is the sound level difference showed in Fig. 9 where the low R index under grazing incidence is partly compensated by a (also) low incident energy flow due to the high angle of incidence; the differences are then smaller (but still 3-5 dB) and mainly at mid and high frequencies; in terms of single number value $D_{2m,nT,A,\ tr}$ (A weighted standardized sound level difference for traffic noise), the difference between diffuse field and grazing incidence is not more than 0.4 dB(A), thereby showing that roof insulation is little affected by grazing incidence, at least in terms of single number value.

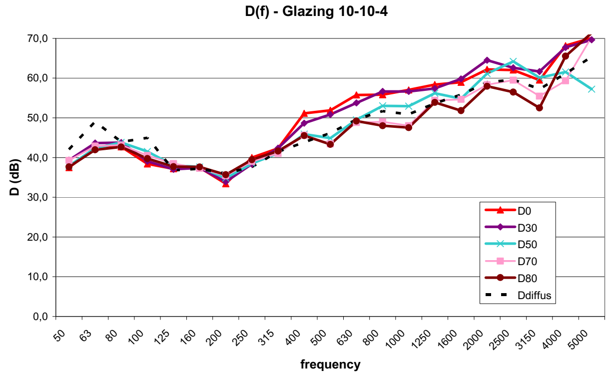


Fig. 9 Standardized sound level difference $D_{2m,nT}$ corresponding to the R index in Fig.8.

## Acknowledgments

The authors gratefully acknowledge the financial support of this work by VELUX France as well as by the French Environmental Agency ADEME.

## References

[1] P.Jean, "A variational approach for the study of outdoor sound propagation and application to ralway noise ", *Journal of Sound and Vibration*, 1998, **212**(2), 275-294

[2] C. Bruitel-Vuilmet, “Taking into account the angle of incidence in the laboratory characterization of the acoustic transmission of façade elements”, CSTB/ADEME PhD thesis presented at the Lyon MEGA Doctoral School in November 2005.