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Road traffic noise from viaducts in mountainous areas

Jérôme Defrance, Matthieu Beyret, Marine Baulac and Philippe Jean

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

Mountainous zones in Europe, such as the Alps, represent huge areas where many viaducts are built, most of them for motorways. The way the sound grazes the asphalt surface from the low and high traffic equivalent sources up to the road edges, and how it then diffracts towards dwellings is a complex mechanism. The standard approaches are suited to plain situations but fail in predicting finely sound propagation behaviour for such geometries. In this paper, one gives the main trends of received noise levels from viaducts as a function of both their geometry and the receiver location. A 2D Boundary Element Method is used for predictions since meteorological effects can be neglected for the short propagation (a few hundreds meters). This assumption makes sense since the viaduct considered in this work is sufficiently high (20 m) and the ground effect is weakly affected by refraction. Different configurations are then simulated in order to address and discuss several geometrical effects, such as: platform elevation, low height barriers addition, complex shape barriers and presence of a central gap in the platform.

1 Introduction

The aim of this research is to achieve a parametric study of the acoustic environmental impact of a set of road viaducts as a function of both their geometry and the receiver location. Several effects are addressed here: the platform height, the adding of a 1 m high barrier at the edge, the of the complexity shape of the barrier, the presence of a mid-height horizontal slit along the edge barrier and the presence of a central gap in the platform.

This work has been achieved within the frame of the Interrreg IIIB alpine space project ALPNAP (Monitoring and Minimisation of Traffic-Induced Noise and Air Pollution Along Major Alpine Transport Routes) [1] (www.alpnap.org).

2 Methodology

2.1 MICADO-BEM code

MICADO, a 2D-BEM code developed at CSTB by Jean and presented elsewhere [2,3] is used here since meteorological effects can be neglected for the short propagation. Moreover this assumption makes sense since the viaduct considered here is sufficiently high (20 m) and the ground effect is not affected by refraction.

Calculations are performed on the frequency range 100 to 5000 Hz with 20 frequencies per 3rd-octave band.

2.2 Definition of the insertion loss

The aim is to determine the acoustical efficiency of the noise protections on the viaduct by calculating their insertion loss IL referred to a reference case. For a given 3rd octave-band Δf, the insertion loss is given by:

$$IL(\Delta f) = 10\log_{10}\left|\frac{p_{config}(\Delta f)}{p_{ref}(\Delta f)}\right|^2 \qquad (1)$$

where $p_{config}(\Delta f)$ and $p_{ref}(\Delta f)$ are the average acoustical pressures on Δf for the studied configuration and for the reference case, respectively.

The global insertion loss IL_A expressed in dB(A) is given by the following equation:

$$IL_A = 10\log_{10}\left(\frac{\sum_{f\in\Delta f} 10^{\frac{LwA(\Delta f)+EA_{config}(\Delta f)}{10}}}{\sum_{f\in\Delta f} 10^{\frac{LwA(\Delta f)+EA_{ref}(\Delta f)}{10}}}\right) \qquad (2)$$

where $EA_{config}(\Delta f)$ and $EA_{ref}(\Delta f)$ are the average excess attenuations on Δf for the studied configuration and for the reference case, respectively, and $L_{wA}(\Delta f)$ is the traffic noise power level on Δf applying EN 1793-3 spectrum shape [4].

2.3 Definition of the 2 reference cases

Two reference cases (1 and 2) are considered: without (Fig.1) and with (Fig.2) a 1 m high barrier at the edge.

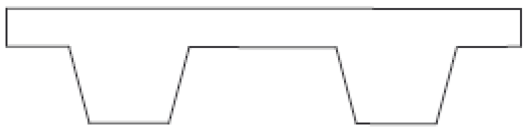

Fig.1. Geometry of "reference 1 case"

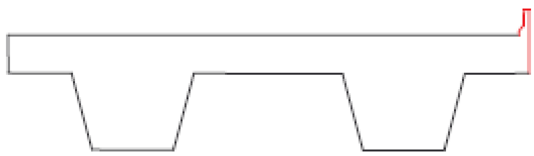

Fig.2. Geometry of "reference 2 case", with the low barrier

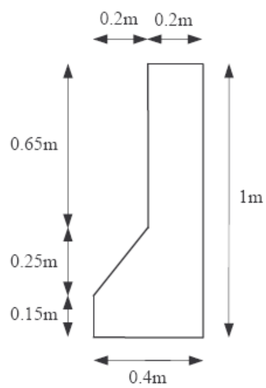

Fig.3. Size of the 1 m high barrier

The barrier size is given in Fig.3. The device is covered with a 10 cm layer of glasswool, characterized by its flow resistivity σ=30 kPa s m^{-2} (using Delany & Bazley model then). For road asphalt, we consider σ=20000 kPa s m^{-2}.

2.4 Sources and receivers locations

Sources are representative of road traffic noise. For each of the 4 lanes, one considers on its central axis 3 equivalent sources with heights above asphalt of: 0.05 m (S1 to S4), 0.3 m (S5 to S8) and 0.75 m (S9 to S12) (see Fig.4).

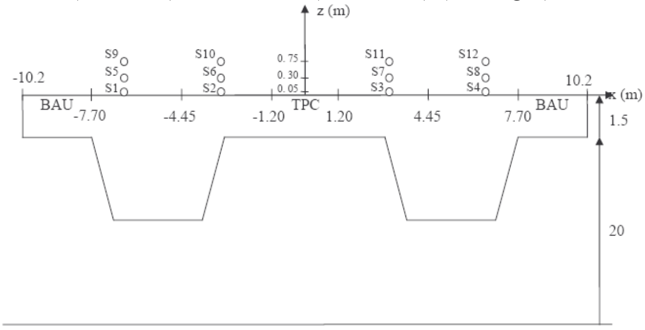

Fig.4. Sources locations

Then one applies the *Harmonoise* engineering road source model [5,6] in which for light vehicles the noise emitted by the lowest, the intermediate and the upper source is weighted by 75%, 25% and 0% respectively, and for heavy vehicles by 50%, 0% and 50% respectively.

Receivers are located on a 200mx40m vertical grid as shown in Fig.5.

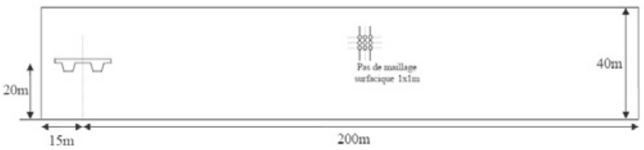

Fig.5. Receivers locations

3 Analysis of simulations

One gives hereafter the trends of noise emission from viaducts as a function of both their geometry and the receiver location. In order to summarize the major trends obtained from simulations, one considers three receiving zones (lower, medium and upper) defined from the position of the right platform edge (see Fig.6).

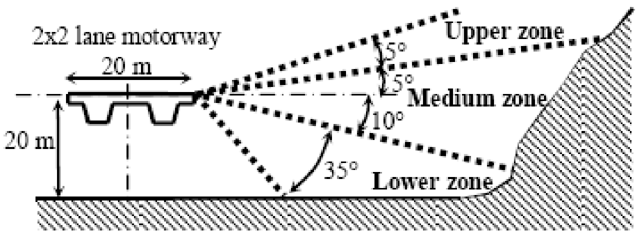

Fig.6. Definition of the 3 receiving zones

3.1 Effect of platform height

The question addressed here is: what is the difference from the sound receiver point of view between a zero-elevation motorway (plain situation) and a motorway on an elevated viaduct? If one stands on a flat terrain 100 m away from the motorway, the average received noise will be maximum when the elevation is around 5 m and minimum for an elevated viaduct (5 to 10 dB(A) less).

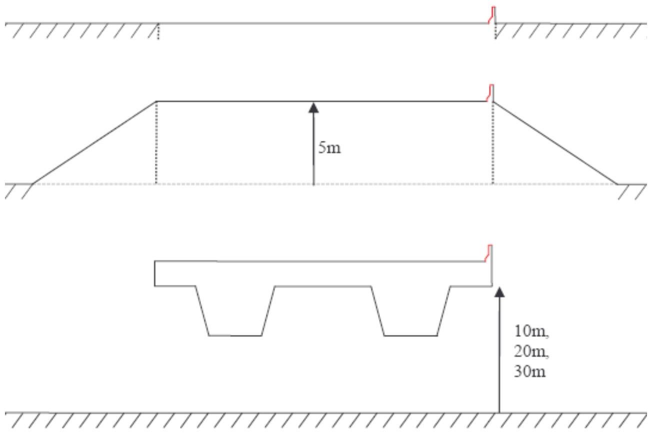

Fig.7. Geometries of the flat terrain, the embankment and the viaduct configurations

In the case of a receiver 1.50 m above the road platform level (i.e. receiver on a slope ground for the viaduct cases) 100 m away from the motorway, the maximum sound level is observed for the elevated platform when the minimum occurs for a zero-elevation road (3 to 10 dB(A) less depending on the meteorological conditions).

3.2 Effect of 1 m high barrier at the edge

Fig.8 shows the noise attenuation results due to an absorbing 1 m high barrier at the edge of the platform (we use here reference 1 case). For a plain situation, the effect of the 1 m high barrier is weak. In the case of a viaduct, the effect is sensitive with a maximum attenuation in the medium zone (up to 10 dB(A) improvement). However the effect remains limited in the lower zone.

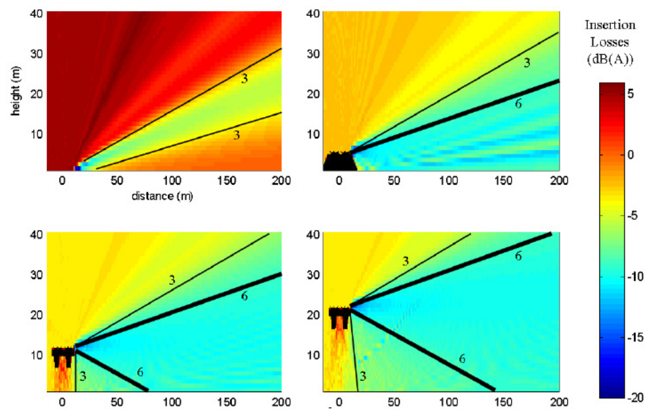

Fig.8 IL_A calculated for a 1 m high absorbing barrier constructed at the right edge of the road platform, as a function of its elevation. From top left to bottom right: 0 m (natural terrain level), 5 m (embankment), 10 and 20 m high (viaducts).

3.3 Effect of the complex barrier shape

In order to improve the efficiency of the 1 m high barrier in the lower zone of a 20 m viaduct, one may carry out a shape optimization.

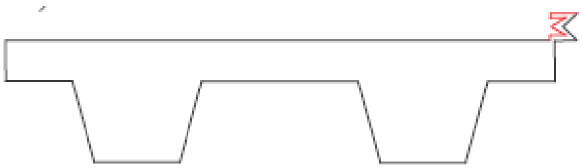

Fig.9. Geometry of the configuration

For instance, for the case of a sigma-shaped 1 m high barrier (as described in Fig.9), the extra attenuation calculated compared to the case of the straight barrier (as described in Fig.7, i.e. reference 2 case) is between 3 and 6 dB(A) in the lower zone (see Fig.10)

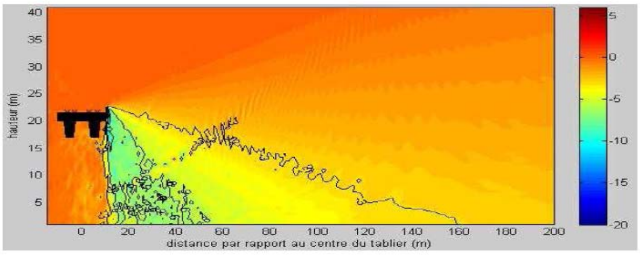

Fig.10. IL_A calculated for geometry shown in Fig.9.

3.4 Effect of a mid-height horizontal slit along the edge barrier

A horizontal slit of about 20 cm is often encountered on the Alpine viaduct barriers (Fig.11).

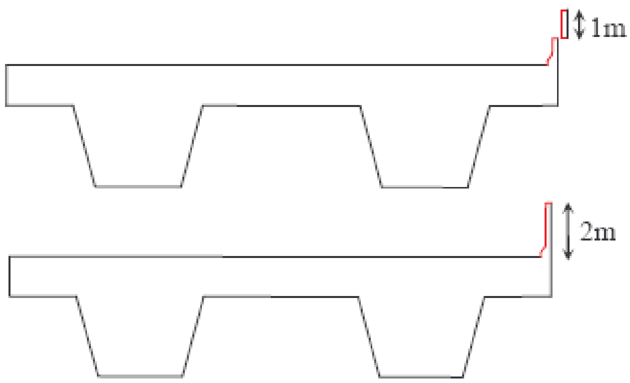

Fig.11. Geometry of the studied configuration (upper) compared to the barrier without slit (lower) (red parts are absorbing – 10 cm of glasswool)

The reason is that the lowest part (usually a concrete 1 m high barrier) stands for security when the upper part (usually a 1 to 2 m high Plexiglas panel) is used as a wind screen. But it also shields from noise.

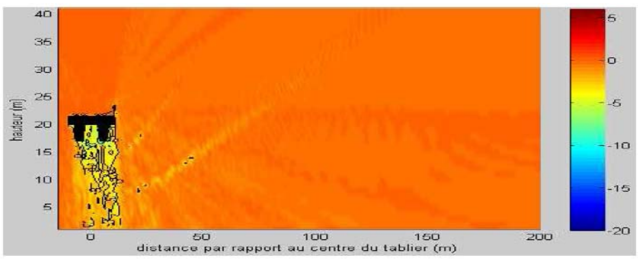

Fig.12. IL_A calculated for geometry shown in Fig.11 (upper) referred the case in Fig.11 (lower)

The MICADO-BEM calculations show that the presence of a 20 cm slit at the mid-height of a 2 m high straight barrier does not lead to any sensible noise gain in the three receiving zones (Fig.12).

3.5 Effect of a central gap in the platform

The viaduct is sometimes made of two parallel platforms separated by a few meter wide gap (Fig.13).

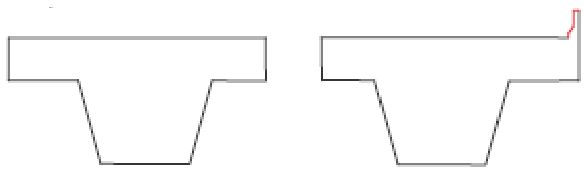

Fig.13. Geometry of the configuration

The presence of this void brings about an important increase of the received noise level (6 to 15 dB(A), referred to reference 2 case) in the zone located just below the viaduct. In the lower, medium and upper zones, the impact of the gap remains small in the order of a few dB(A) (Fig.14).

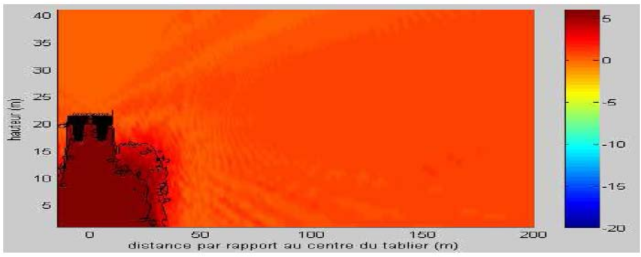

Fig.14. IL_A calculated for geometry shown in Fig.13

This environmental noise degradation can be cancelled by the addition of complementary absorbing barriers at the two gap edges (Fig.15 and Fig.16).

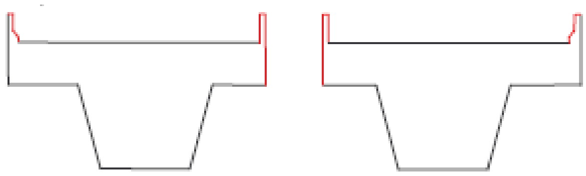

Fig.15. Geometry of the configuration (red parts are absorbing – 10 cm of glasswool)

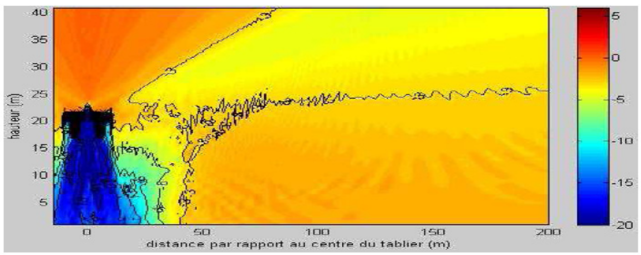

Fig.16. IL_A calculated for geometry shown in Fig.15

3.6 Effect of wedge opening at the center of the platform

One finally compares the IL_A calculated for a straight, thin 1 m high absorptive barrier (or "closed" wedge) (Fig.17) and an absorptive 90° wedge (Fig.18).

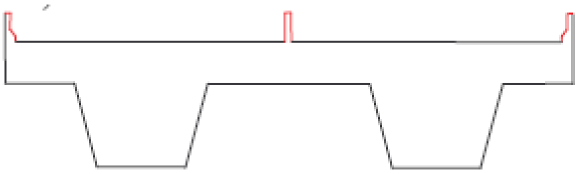

Fig.17. Geometry of the thin barrier configuration (red parts are absorbing – 10 cm of glasswool)

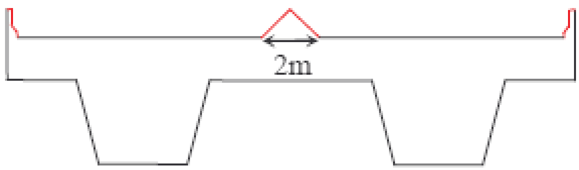

Fig.18. Geometry of the wedge configuration (red parts are absorbing – 10 cm of glasswool)

The wedge brings about to an improvement of 1 dB(A) in the lower and medium zones (Fig.19 and Fig.20) In the upper zone, the impact remains negligible.

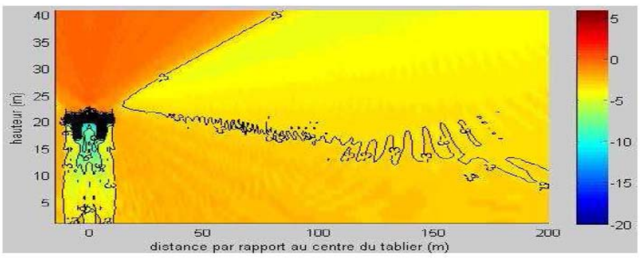

Fig.19. IL_A calculated for geometry shown in Fig.17

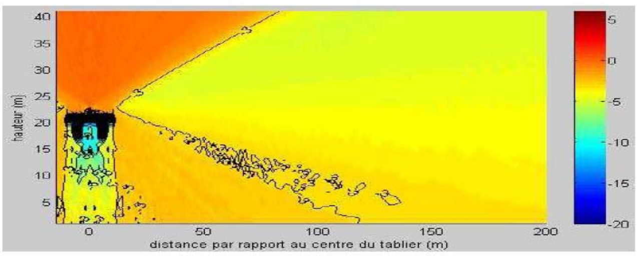

Fig.20. IL_A calculated for geometry shown in Fig.18

3.7 Searching for optimized solutions

By combining different results, one may propose optimized solutions in terms of noise abatement. One example is shown here. The geometry is given in Fig. 21.

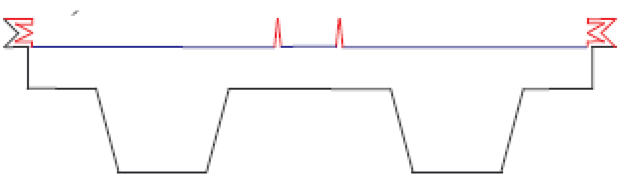

Fig.21. Geometry of the optimized configuration (red parts are absorbing – 10 cm of glasswool)

The simulations show a very high efficiency of such solutions (reference 2 case used here). In the medium zone, the expected abatement is about 10 dB(A), when in the lowest zone it may rise to 15 dB(A).

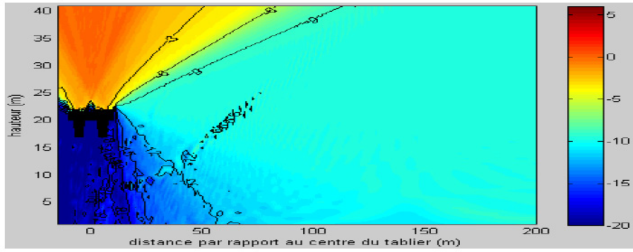

Fig.22. IL_A calculated for geometry shown in Fig.21

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