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HOW MULTIPLE REFLECTIONS CAN CAUSE A DEGRADATION OF PERFORMANCE FOR NOISE BARRIERS

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1. INTRODUCTION

When predicting the performance of noise barriers, vehicules are too often considered as point or line sources, neglecting their motion, body and reflective sides. Using sound absorptive materials helps to reduce the sound reflections between vehicle body and noise barriers, and the interaction phenomenon is generally neglected. For reflective barriers, by contrast, this phenomenon is severe. Even when dealing with absorptive barriers, for example, when they are close to the vehicles, the multiple reflections phenomenon becomes more important and can lead to a degradation of performance. In these cases, multiple reflections should be taken into account when designing noise barriers.

This paper presents some typical cases of multiple reflections for trains and for high sided road vehicles along barriers. The effect is emphasized on calculations based on the time evolution of the instant level L(t) and its integration to L_{eq} values.

Results of calculations on similar cases, but based on a boundary elements method (BEM), are also presented for information purpose and rough comparison, as far as the initial hypotheses are quite different (sources in motion or motionless, 3D model or 2D model).

2. BARRIER/VEHICLE REFLECTIONS

When one considers vehicles emitting noise as point sources, as the majority of the predicting models does, one neglects the fact that multiple reflections between the body of these vehicles and close obstacles (noise barriers or any wall) can occur.

The multiple scattering between the vehicle and the obstacle adds several reflected noise sources, each one less efficiently diffracted at the top of the obstacle when the order of reflection increases.

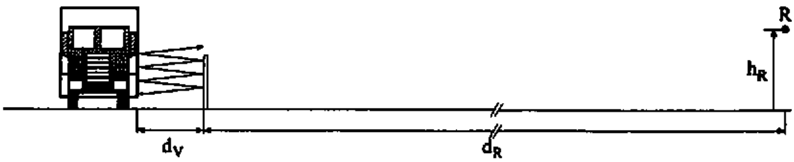

Fig.1: Multiple reflections: configuration for calculation

These "additional" noise sources increase the level of noise to which a receiver is exposed, when we initially wish to protect it by a barrier.
The resulting degradation of performance can be severe; one can even find cases for which a noise barrier can increase the noise level when a high sided vehicle passes in front of the barrier. We can have a barrier which maybe decreases L_{eq}, but increases the L_{max} of passing lorries, for sure an unwanted effect!
The degradation of performance is a function of the relative height and distance between the barrier and the vehicle, its length, height, position and speed. The worst cases occur with long profiled trains (High Speed Trains), and, for road traffic, with lorries which are high sided, long, and almost always closer to the barriers that any other vehicle.

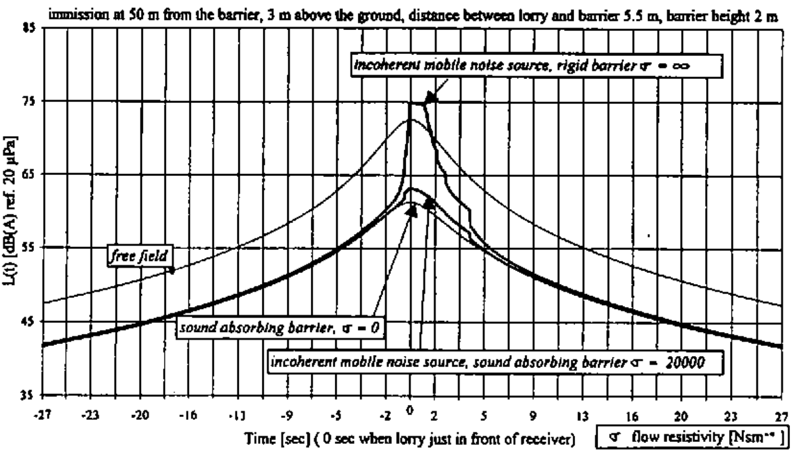

Fig. 2: level / time evolution during the passage of a lorry at 100 km/hr

Fig. 2 shows the time evolution of the sound pressure level at a receiver 50 m away from a 2 mH barrier. The receiver is at 3 mH above an assumed soft ground when the vehicle is a double lorry of 20 mL, 5.5 m distant to the barrier, and moving at 100 km/hr on an assumed rigid road covering. Four cases are presented: the free field conditions (without any barrier), using a perfectly sound reflecting barrier ($\sigma = \infty$), using a classical sound absorbing noise barrier (σ =20.000 Nsm $^{-4}$), and finally using a perfectly sound absorbing barrier (σ = 0) [4]. Calculations are done assuming an incoherent mobile noise source (moving lorry). One can clearly see that, for that particular case, an increase of L(t) occurs when the lorry passes, and the noise then is even higher than without any barrier (free field). Using classical sound absorbing barriers improves drastically the situation, though a difference still exists with the ideal case (σ = 0). Integrating the L(t) evolution along the whole passage of one lorry per hour gives the respective L_{eq} 44.4, 42.4, 35.6, and 34.8 dB(A) for free field, perfectly sound reflecting, normal sound absorbing and perfectly sound absorbing cases.

3. PREDICTING MODELS

This effect of multiple reflections only exists for a limited period of time during which the reflections occur, that is the reason why it is no more possible to consider the traffic flow as a simple sum of the contribution of several "fixed" noise sources, nor as a simple line source. We must now take into account that the vehicles are *moving*. Thus, we must add a new dimension to the classic way of modelling: *the time dimension*. Models should thus preferably use a 3D representation in function of the time, considering moving reflecting volumes.

BEM/FEM methods are more often based on 2 or 2.5 D assumption, though 3 models appear; but these methods are more suitable for *stationary pure tone signals* than for road or rail traffic *noise*.

For instance, we consider that the noise emitted by trains or road traffic is *almost never coherent*: neither with the noise emitted by the same vehicle but a few meters farther, nor with its corresponding images at a specific instant *t*.

We must remember that vehicles emit two types of noise: mechanical and rolling noise. As the first could be considered stationary in ideal conditions, rolling noise cannot be considered coherent with itself ever.

In that way, we modelize the effect of multiple reflections mostly considering uncoherent moving noise sources with their moving reflecting body attached [6].

4. COHERENT NOISE

In Fig. 2, we presented a practical case for which the calculations have been done assuming that all the noise was *not* coherent.
In the following Figs. 3 and 4, we did the same calculation, but assuming that the noise is 100 % of a mechanical origin, allowing the extreme case for which, at each position of the vehicle, the original source and all the images corresponding to its position could be coherent.

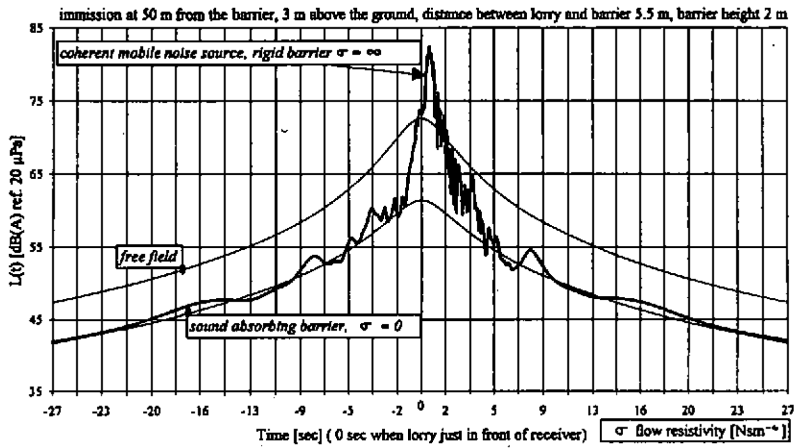

Fig. 3: L(t) of a passing lorry at 100 km/hr (rigid barrier)

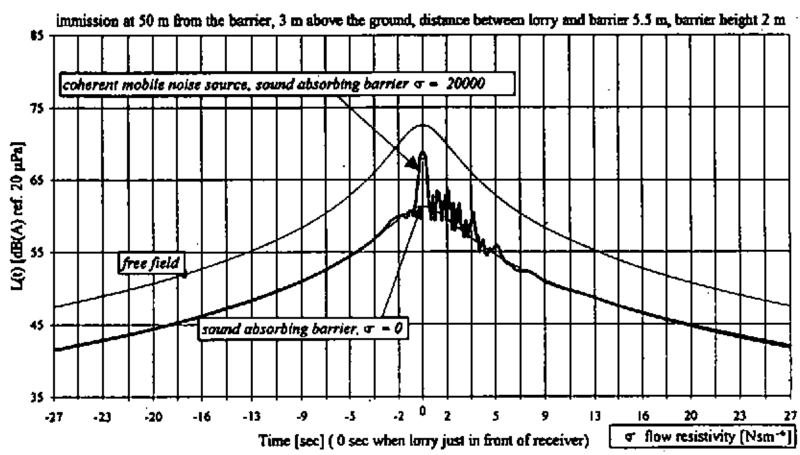

Fig. 4: L(t) of a passing lorry at 100 km/hr
(classical sound absorbing barrier)

Results give large variations of L(t), mainly due to the interferences between reflections, and the fact that these reflections are here considered specular.
Fig. 3 presents the results for a rigid barrier, while fig. 4 shows the results for a classical sound absorbing barrier.
Though Figs. 3 and 4 are giving integrated results L_{eq} rather similar to these calculated in Fig. 2, the time evolution L(t) is clearly different and understandable.
After having done the calculation for numerous cases, we come into the conclusion that even the hypothesis that the reflections of a source at its position is coherent is *not valid* for rail and road traffic noise.

5. COMPARISON WITH BEM

D.C. Hothersall and S.A. Tomlinson [2] did several calculations based on a 2D BEM model. Rough comparison seems worthwhile, though the hypothesis are quite different as they assumed 2D and coherent sources. The comparison (see Table 1) uses the Mean Insertion Loss as defined in [2] as the arithmetic mean of the Insertion Loss values over six receiver positions (at 20,50 and 100 m to the barrier, 1.5 and 3 m above the ground).

barrier at	MEAN IL [dB(A)] FOR A RIGID BARRIER						
d [m]	Lmax	Leq	Lmax	Leq	Lmax	Leq	L
2	-4.4	-7.7	-4.4	-0.6	-3.3	1.9	4.6
5.5	-1.3	-4.8	-1.3	2.7	-8.6	-0.2	4.6
18.5	1.7	-1.0	1.7	4.6	-2.7	3.5	4.2
22	2.1	-0.3	2.1	4.6	-2.4	3.4	4.0
Model	I.S. Fixed Incoherent		I.S. Mob. Incoherent		I.S. Mob. Coherent		BEM [2]

Table 1: Comparison between Images-Sources and BEM calculations

Instead of this Mean Insertion Loss, the I.L. at each receiver should be compared in order to have a better comparison, but one can see that the results are rather different.

6. CONCLUSIONS

Multiple reflections can seriously degrade the performance of a noise barrier; several designs can be considered in order to reduce these (absorbing materials, inclined barriers...).
Even with classical sound absorbing materials, though reduced, these reflections can degrade the performance of barriers.
One should consider this effect for the accurate design of barriers (materials and forms); 4D (3D + time) models are more appropriate and one should avoid to consider moving vehicles as fixed sources of coherent noise.
Further investigations could be done with diffuse models for reflections instead of specular ones, or even a combination of the 2 effects.

7. REFERENCES

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