OF ABSORBING SCREENS IN THE PRESENCE OF HIGH-SIDED VEHICL

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1. INTRODUCTION

In this paper we investigate the performance of vertical barriers with varying amounts of absorbing material from cover over the total area of the front and rear faces to small sections near the top of the barrier. Calculations are performed using a numerical approach based upon the boundary element method [1]. The investigation is extended to cover one situation where barrier performance may be degraded in practice. This is due to multiple reflections between the face of a high-sided vehicle passing close to the barrier and the barrier itself. Clairbois [2] suggested that these multiple reflections effectively increase the height of the source and lead to higher than expected noise levels on the far side of the barrier.

2. NUMERICAL MODEL

The numerical model used, based on the boundary element method, has been described in detail elsewhere [3-5]. It is a two-dimensional model which in three dimensions is equivalent to an infinite coherent line source, and an infinitely long barrier parallel to the source. The barrier is of uniform cross-section and surface covering along its length. The model calculates the wave field behind the barrier by solving a reformulation of the Helmholtz equation as an integral equation, and this is solved by discretising the barrier into boundary elements of length no greater than $\lambda/5$ (where λ is the wavelength). The effects of ground cover and absorptive surface treatment of the barrier can also be predicted.

The results are presented in terms of Insertion Loss (IL), defined by $IL = 20 \log_{10} (P_g / P_b)$ dB where P_g is the acoustic pressure at the receiver for the given source position with the flat ground present and P_b is the pressure when the barrier is introduced. In addition to examining spectra of Insertion Loss determined at third octave frequencies, the Insertion Losses for a broad-band source representative of A-weighted traffic noise are presented and discussed. In this paper the barrier rests on homogeneous rigid ground and the acoustical parameters of the barrier surfaces (assumed locally reacting) are specified according to the semi-empirical formulations of Delany and Bazley [6]. Where the use of absorbing material is specified it has a flow resistance of 20,000 Nsm^{-4} and a layer depth of 0.1m. This corresponds to a specific acoustic impedance akin to that of mineral wool or a similarly strong absorber. The equivalent statistical absorption coefficient is shown in Figure 1 as the line labelled α_s. The average value is around 0.8.

The implementation of the model assumes that the barrier's cross-section is polygonal and the corners of the barrier and surface treatment of each part are input as data for the model. The thickness of all elements is 0.2m. The coherent line source assumed by the model is unrealistic, but the insertion loss predictions from the model agree well with those obtained experimentally, both indoors and outdoors, with the line source replaced by a point source at the same distance form the barrier [4]. The model can deal with multiple parallel as well as single barriers. An additional feature is that the barriers do not necessarily have to be in contact with the ground surface. This feature is used to model diffraction around the body of a high-sided vehicle.

The pressure is calculated at third octave centre frequencies between 63Hz and 3.16 kHz for nine receiver positions at heights of 0,1.5 and 3m above the ground and at distances of 20, 50 and 100m from the centre line of the barrier. The Insertion Loss for a broad-band noise source, with a spectrum representative of A-weighted road traffic noise was obtained at each of the receiver positions by combining the calculated results at third octave centre frequencies for propagation with and without the presence of the barrier. The arithmetic mean of the six receiver positions above the ground is used as an overall measure of efficiency and this figure is henceforth denoted as the Average Insertion Loss.

Two source locations are investigated. The first represents sound emission from a vehicle in the nearside lane of a motorway, 5.5m from the barrier and 0.5m above the ground. The second position, 15m from the surface of the barrier and 0.5m above the ground, represents a vehicle in the far lane of the nearside carriageway of a motorway.

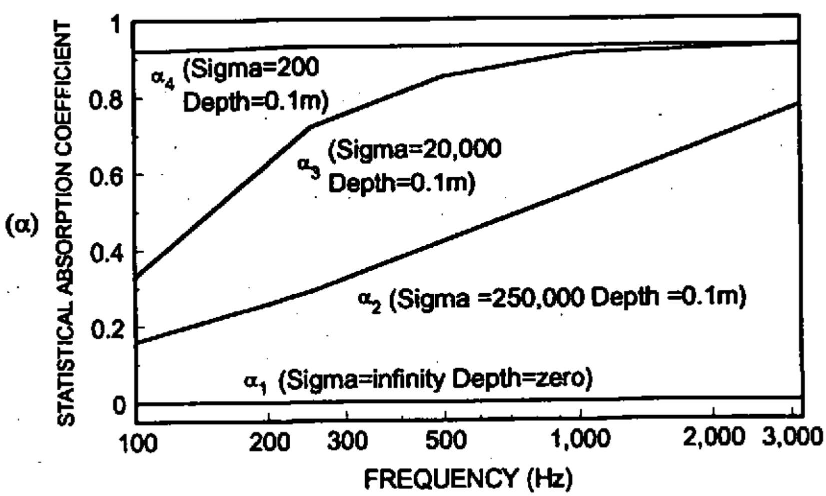

Figure 1 - Statistical absorption coefficient as a function of frequency for parameters used to describe the surface properties of materials in the model.

3. RESULTS

3.1 Absorbing barriers

The numerical method allows for any section of the barrier to be allocated a specific acoustic impedance. Table 1 shows the effect of adding a progressively larger absorbing section (from the top of the barrier downwards) onto an otherwise rigid barrier. Results are shown for such a treatment on the source side only and on both sides of the barrier, and for the two source positions discussed earlier. The barrier height is 2m and the results are presented in terms of the improvement in Average Insertion Loss over an equivalent fully reflective barrier.

Extent of absorbing material (m) from top of barrier downwards	Vertical thin screen 2m in height			
	5.5m from source		15m from source	
	Source side only	Both sides	Source side only	Both sides
0.1	0.3	0.5	0.1	0.2
0.2	0.4	0.5	0.2	0.3
0.3	0.3	0.5	0.2	0.4
0.4	0.4	0.6	0.2	0.4
0.5	0.5	0.7	0.2	0.4
1.0	0.5	0.8	0.2	0.4
2.0	0.5	0.8	0.2	0.4

Table 1 - Effect of increasing amounts of absorbing material on one or both sides of a 2m barrier. Results are in terms of the improvement in Av. IL over a 2m barrier with rigid surfaces (dB).

It can be clearly seen that the benefits to be gained from introducing absorbing material, occur mainly around the upper 0.5m of the barrier. This is reflected throughout the table for both source positions and for treatment on both sides or just the source side of the barrier. Table 1 also shows that the benefits of absorbing barriers are marginal, only becoming significant when the barrier is very close to the source. This is in agreement with results of other workers. When the diffracting angle is small ie. when source and receiver are a considerable distance from the barrier, the effect is negligible [7]. However, when the diffracting angle is large (for example, if the source is close to the barrier) then the introduction of absorber is expected to produce a significant improvement in Insertion Loss [8].
In the same manner as Table 1, Table 2 shows different degrees of absorption on a 3m barrier. Note that as the barrier is higher, the diffracting angle is larger and hence, the degree of absorbency is greater. However, it can be seen that the same trends exist for the 3m barrier.

Extent of absorbing material (m) from top of barrier downwards	Vertical thin screen 3m in height			
	5.5m from source		15m from source	
	Source side only	Both sides	Source side only	Both sides
0.1	0.4	0.6	0.1	0.3
0.2	0.6	0.8	0.2	0.3
0.3	0..6	0.8	0.3	0.5
0.4	0.6	0.8	0.3	0.5
0.5	0.5	0.8	0.3	0.6
0.6	0.5	0.9	0.4	0.6
0.7	0.6	0.9	0.4	0.6
0.8	0.7	1.0	0.4	0.7
0.9	0.7	1.1	0.4	0.6
1.0	0.7	1.1	0.4	0.6
2.0	0.8	1.1	0.3	0.6
3.0	0.7	1.1	0.3	0.5

Table 2 - Effect of increasing amounts of absorbing material on one or both sides of a 3m barrier. Result are in terms of the improvement in Av. IL over a 3m barrier with rigid surfaces (dB).

3.2 Reflections from high-sided vehicles.
Figure 2 shows the simulation in the model of a vehicle of height 3m at a distance of 5.5m from a 3m high vertical noise barrier. The source is located 0.1m below and to the side of the nearside bottom edge of the vehicle. In this case the vehicle and source conditions remain constant whilst the effects of varying distributions of absorbing material on the barrier surface are studied. These results are shown in Table 3 and are presented in terms of the degradation in Average Insertion Loss compared to the case of a barrier with rigid surfaces and no vehicle present.

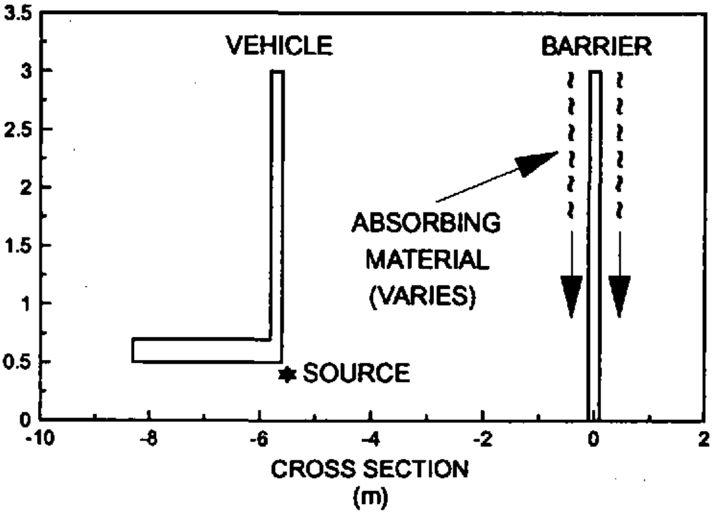

Figure 2 - Simulation of a high-sided vehicle in the model.

Extent of absorbing material from top of barrier downwards (m)	3m barrier 5.5m from source	
	Source side only	Both sides
None (rigid)	6.4	6.4
0.2	6.2	6.0
0.5	6.0	5.7
1.0	5.9	5.6
1.5	4.8	4.5
2.0	4.0	3.7
3.0	2.8	2.4

Table 3 - Effect of increasing amounts of absorbing material on one or both sides of a 3m barrier in the presence of a high-sided vehicle. Results are in terms of the degradation in Av. IL over a 3m barrier with rigid surfaces and no vehicle present (dB).

From Table 3 it is clear that when the vehicle is introduced there is a large decrease in the efficiency of the barrier. This degradation can be combated in part with the use of absorbing material, but even when both sides of the barrier are totally absorbing there is still a degradation of 2.4 dB. This degradation can significantly alter the effectiveness of a barrier close to a road and further study of this effect is essential to decide whether some allowance for this should be taken into consideration when designing a noise barrier. The scenario of a high-sided vehicle passing a noise barrier is hard to model numerically as the vehicle is assumed to be infinitely long and of uniform cross-section, thus no account is made of possible scattering effects from different parts of the vehicle (in the case of railway noise this might be a better approximation). Furthermore, vehicles on the inside lane of the motorway are likely to have some shielding effect for the vehicles in the far lanes.

It is also clear that the use of absorbing material becomes extremely significant in this case. The trend observed earlier, whereby only the upper region of the barrier seemed to be significant in gaining the maximum benefit of using absorbing material is no longer valid. This is due to the multiple reflections incurred by the introduction of the high-sided vehicle to the model.

Figure 3 shows a spectral comparison between a rigid barrier with no vehicle present, a rigid barrier after a vehicle is introduced and an absorbing barrier with the vehicle present. The absorbing barrier is 3m high with absorbing material on both sides for the upper 2m. This was chosen as in practice the lower region of the barrier is likely to be part of the foundation which is usually rigid. It can be seen that the trends observed in Table 3 are apparent in this spectral comparison of the Insertion Loss for a receiver position in the ground surface at a distance of 50m from the barrier.

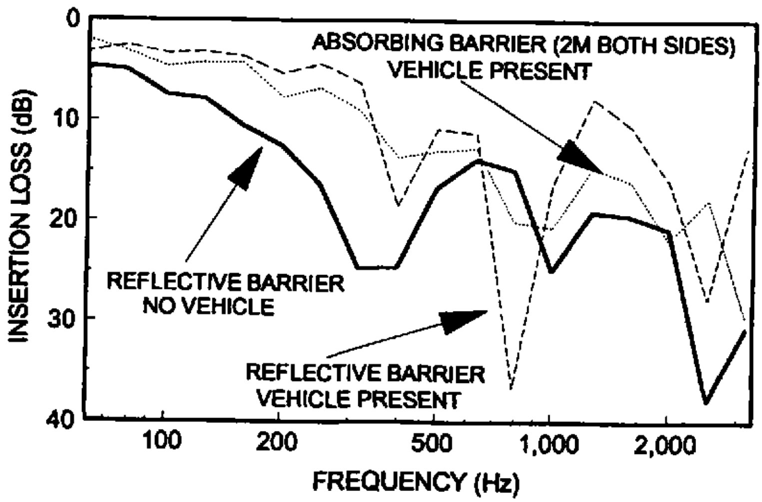

Figure 3 - Spectral comparison of absorbing and rigid barriers in the presence of a high-sided vehicle.

The effects of varying the height of the vehicle were then studied. Firstly, for a 3m barrier with rigid surfaces and secondly for the same barrier with absorbing material extending downwards for 2m on either side. The results are given in Table 4.

Vehicle Height	Rigid 3m barrier. 5.5m from source	3m barrier with 2m of absorbing material on both sides. 5.5m from source
1.6	2.2	0.7
2.0	3.0	1.3
2.5	5.0	1.7
2.8	6.0	3.5
3.0	6.4	3.7
3.2	6.9	4.0
3.5	7.8	4.8
4.0	9.1	5.6

Table 4 - Effect of increasing the height of the simulated vehicle on a rigid 3m barrier and a 3m barrier with 2m of absorbing material on both sides. Results are presented in terms of the degradation in Average Insertion Loss over a 3m barrier with rigid surfaces and no vehicle present (dB).

This shows that even a vehicle of height 1.6m can significantly degrade the performance of a barrier. As before the absorbing barrier significantly decreases the amount of degradation. Nevertheless, when the vehicle is around the same height or higher than the barrier then the performance of the barrier is extremely poor, even with an absorbing covering. Figure 4 shows spectra of Insertion Loss at a receiver position 50m from the barrier in the ground surface for the worst case, when the vehicle height is 4m.

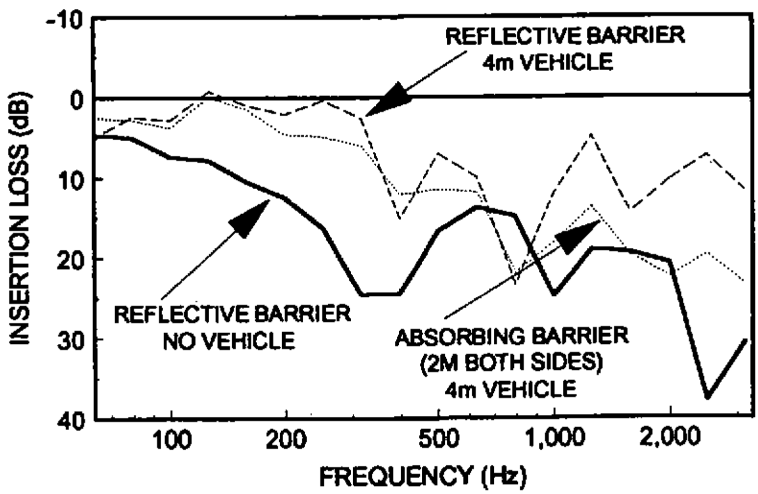

Figure 4 - Spectral comparison for rigid and absorbing barriers in the presence of a 4m barrier.

4 CONCLUSIONS

The numerical model predicts that the effects of introducing absorbing material on the surfaces of a barrier are small, unless the barrier is very close to the noise source. It was found that the benefits obtained could be achieved using only small absorbing sections on the upper regions of the barrier.

When the face of a vehicle is added to the model, there is a significant reduction in the effectiveness of the barrier, due to reflection effects. This degradation increases with vehicle height. In this case, the absorbing material on the face of the barrier becomes extremely important, and the degradation is considerably less when the total area of the barrier surface is absorbing. In this case, it becomes essential to cover the whole of the barrier and not just the upper region.

The limitations in the ability of the two-dimensional model to predict effects of road traffic in site conditions must be remembered. However, it is believed that the model gives a good indication of the relative effects of changes in barrier configuration on the Insertion Loss.

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