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MULTIPLE ROAD TRAFFIC NOISE BARRIERS

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1. INTRODUCTION

A numerical method has been developed which enables the Insertion Loss for various noise barriers of complex profile and surface cover to be calculated [1,2].

The barrier, assumed infinitely long with uniform surface cover and cross-section, is situated on a flat plane of uniform impedance. The coordinates of the corners of the barrier cross-section are input as data for the model. The surface characteristics in the form of the impedance of each linear segment can be defined independently. The numerical model is two-dimensional and the source is assumed to be a coherent line source of infinite length, parallel to the barrier. While this is an unrealistic situation, the predictions of Insertion Loss obtained give valuable information on the relative performance of different barrier designs, and agree well with indoor and outdoor experimental measurements using a variety of barrier shapes and ground surface impedances and a point source of sound [1,2].

In this paper the model is applied to multiple combinations of barriers.

2. THE NUMERICAL METHOD

The numerical approach uses the boundary element method applied to a boundary integral equation similar to the Kirchoff-Helmholtz integral equation. In formulating the integral equation via Green's theorem, the Green's function for propagation over a homogeneous impedance plane is used as the fundamental solution so that the integral extends only over the barrier cross section which is therefore the only part of the boundary which needs to be divided into elements. The boundary elements have length no greater than $\lambda/5$ where λ is the wavelength of the source, and the computational cost of the method increases sharply as the number of elements increases.

The results shown below are presented in terms of Insertion Loss, defined by $IL = SPL_g - SPL_b$, where SPL_g is the sound pressure level at the receiver position with only the flat ground present and SPL_b is the level when the barrier is introduced. Throughout, broad band Insertion Loss results are given, which are predictions for a source with a single vehicle, A-weighted, road traffic noise spectrum. These are calculated by finding the attenuation, with and then without the barrier present, of each third octave centre frequency between 63 and 3150 Hz using the boundary element model. These figures are then applied to a third octave A-weighted spectrum characteristic of a single road vehicle in free-field conditions to give sound pressure level values with and without the barrier.

The results of the model are further combined to produce an Average Insertion Loss. This is the arithmetic mean of the Insertion Loss at six representative receiver positions. In each case these positions are at heights above the ground of 1.5 and 3.0 m, at distances of 20, 50 and 100 m from the centre line of the barrier furthest from the source.

3. RESULTS

3.1 The Geometry Considered

Figure 1 shows the geometry used, unless otherwise stated. A 3m high vertical, reflecting barrier was placed at a distance of 15m from the source, and was kept fixed in this position. The source was placed in the ground surface. This barrier, and all others reffered to in the paper, were given a thickness of 20 cm.

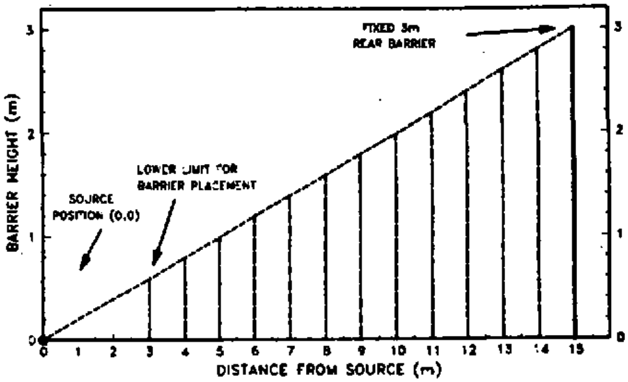

FIG 1 – THE STANDARD GEOMETRY USED IN THE MODEL

When further barriers were introduced they were positioned so that the line of sight from the source to the rear barrier grazed their upper edge as indicated in Figure 1. (For example, it can be seen that if a second barrier is placed at a distance of 3m from the source, its height would be 0.58m). This ensured that whilst studying the relative efficiency of different barrier designs, the length of the ray path grazing the top of the barrier between the source and each receiver position, remained constant. The different designs are said to have the same 'effective height'.

3.2 Results For Double Barriers

The middle line plotted in Figure 2 shows the effect of adding a second barrier at different positions between the source and the fixed rear barrier. The height of the second barrier decreases as it is moved closer to the source, as indicated in Figure 1.

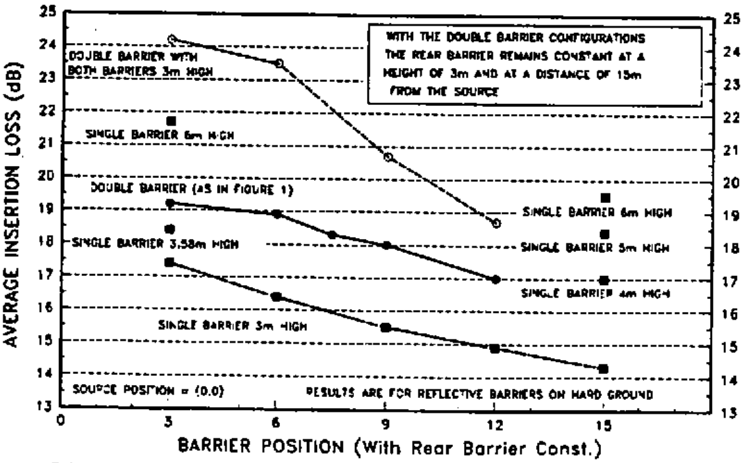

FIG 2 – COMPARISON BETWEEN DOUBLE AND SINGLE BARRIERS

It is seen that there is a substantial increase in Average Insertion Loss upon placement of a second barrier, and that the greater the separation of the barriers, the greater the Average Insertion Loss, even although the amount of construction material being used decreases, and the ray path from source to receiver is unchanged.

Therefore the most efficient double barrier design, given the arrangement of Figure 1, is when one barrier is placed at 3m from the source and the other at 15m (This will henceforth be denoted by (3\15)), which gives an Average Insertion Loss of 19.2 dB. This is a very significant improvement over the value of 14.4 dB for the standard 3m barrier 15m from the source.

Figure 2 also shows results for a single 3m high barrier at different positions along the source line (although this increases the length of the path from source to receiver via the top of the barrier). It shows that at a distance of 3m from the source, it is 2dB less efficient than the double barrier (3\15). Similarly, a 3.58m high barrier at a distance of 3m from the source is about 1 dB less efficient, although it uses the same amount of material.

The effect of increasing the height of a single barrier 15m from the source is also shown. Note that the double barrier configuration (3\15) gives an Average Insertion Loss similar to a 6m single barrier at 15m from the source.

Also shown in Figure 2 are the results for double barrier configurations using only 3m high barriers. Although ray paths will be considerably altered in this case it does illustrate how a double barrier design may be used in practice. As expected, it was found that the Average Insertion Loss increases dramatically with the introduction of a second 3m barrier, and that the Average Insertion Loss increased as the distance between the barriers increases. At maximum separation the 3m double barrier (3\15) gives an Average Insertion Loss of 24.2 dB, almost 10dB better than the standard 3m single barrier. As a more valid comparison in terms of cost, a single barrier 6m high at distances of 15 and 3m from the source gave Average Insertion Losses of 19.5 and 21.7 dB respectively. At worst, the 3m double barrier (3\15) is still 2.5 dB more efficient, and would create less problems associated with wind-loading and visual intrusion.

3.3 Multiple Barriers

Having established that double barrier configurations could be extremely efficient, and that the attenuation produced was proportional to the separation, the investigation was extended to look at combinations of 3 and 4 barriers. The results are shown in Figure 3. Again, the height of the additional barriers are determined by the line of sight from the source to the 3m high rear barrier (Fig 1). Other results not presented here confirmed that it was most efficient to space the barriers evenly, given the geometry of Figure 1. This meant that the three barrier combination was at (3\9\15) and the four barrier combination at

(3\7\11\15). It is clear that as another barrier is added the separation decreases, and this is reflected in the change in slope of the lines in Figure 3. Other results not presented here showed that if the separation remains constant, then the increase in Average Insertion Loss from two to three and three to four barriers is more pronounced. Also shown in Figure 3 are the results for combinations of 2 and 3, 3m high barriers.

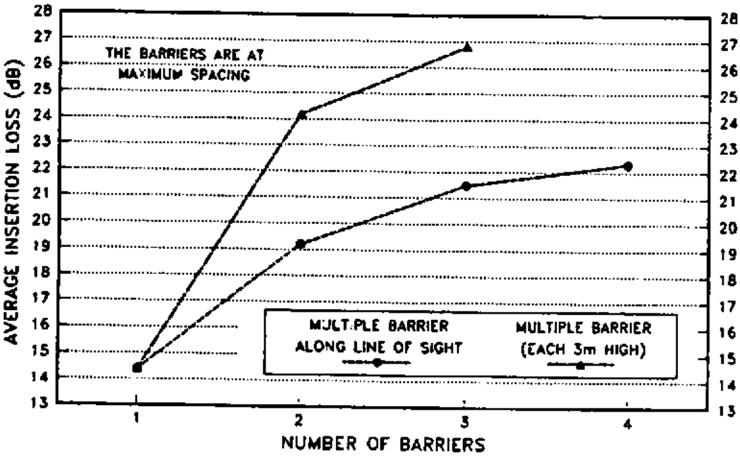

FIG 3 - MULTIPLE BARRIER COMBINATIONS

Spectral analysis of the multiple barrier configurations (of the form shown in Figure 1) indicated the same trends as the values for Average Insertion Loss and showed that they were not frequency dependent, occurring throughout the spectrum.

3.4 Effect of absorbent coverings and soft ground

Figure 4 shows the effects of covering the barriers completely with an absorptive treatment representing mineral wool. The surface admittance was calculated using the Delany and Bazley equations [3], with a flow resistivity of 20,000 NSM^{-4} and a layer of depth 0.1m. It can be seen that the use of absorptive treatment of this kind on vertical barriers gives only a marginal increase in Average Insertion loss over their reflective counterparts for single barriers. This is in keeping with previous results obtained using the boundary element model. However, small increases are observed as the number of barriers increases.

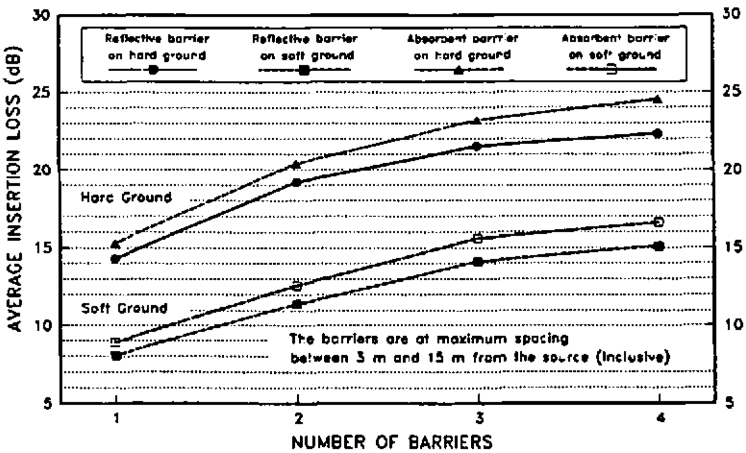

FIG 4 - EFFECT OF ABSORBENT COVERING AND SOFT GROUND

Figure 4 also shows the effect of using soft ground representative of grassland (flow resistivity = 250,000 NSM^{-4}) with multiple barrier configurations. The results show an absolute difference of around 6 - 7 dB between the hard and soft ground, but the relative trends within each group are very similar. Again this is in keeping with previous comparisons of the effects of hard and soft ground surfaces on other configurations [2,4].

3.5 Effect of the source height

Figure 5 shows the effects of raising the source position out of the ground to heights of 0.5 and 1.0m (intended to represent the emission from cars and lorries respectively). Note that the barrier heights have not been adjusted and are determined by assuming that the source is still in the ground, as in Figure 1. Although there is a slight increase in Average Insertion Loss when the source is at 0.5m, it is only significant for the single barrier. However, when the source is raised to 1m, the efficiency of the multiple barrier configurations drops considerably.

In Figure 6 the barrier heights have been increased so that the line of sight from the source in question to the fixed, 3m high rear barrier once again grazes the top of any barriers in between. When the source is now raised to 0.5m there is a significant increase in Average Insertion Loss, but when the source is raised to 1.0m the increase is less pronounced. This

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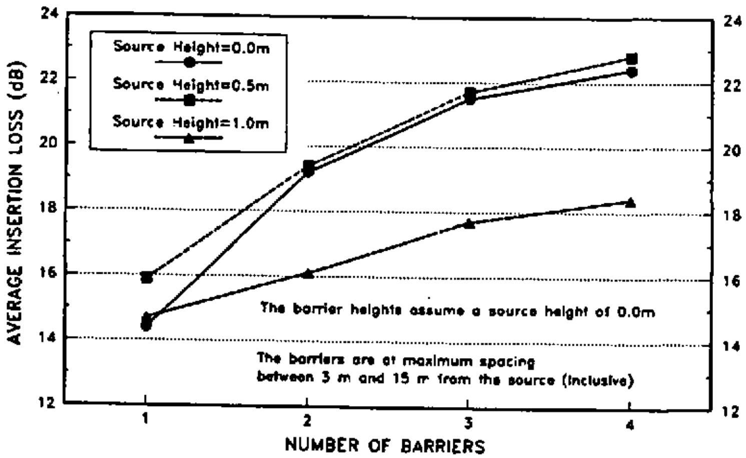

FIG 5 – EFFECT OF SOURCE HEIGHT (BARRIER HEIGHTS UNCHANGED)

would suggest that during the development of a multiple barrier design, it would be prudent to assume a high source position in deriving barrier heights.

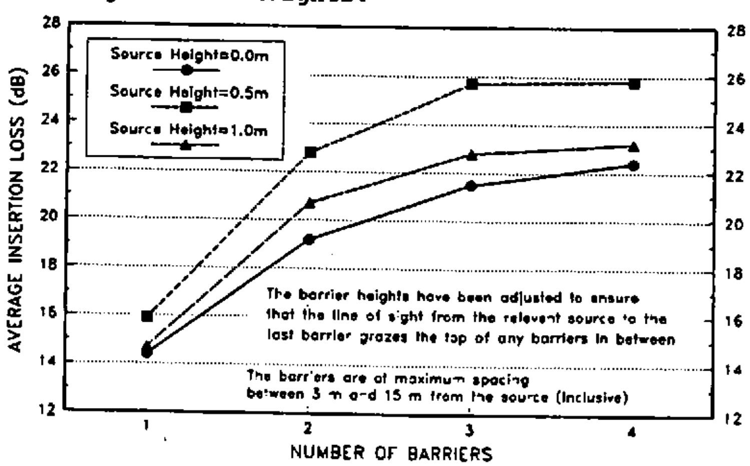

FIG 6 – EFFECT OF SOURCE HEIGHT (BARRIER HEIGHTS CHANGED)

4. CONCLUSIONS AND DISCUSSION

The results of the boundary element model indicate that the following conclusions can be drawn.

1. Double barrier configurations in which the line of sight from the source to the rear barrier grazes the upper edge of the first barrier, can be extremely efficient in attenuating road traffic noise, in comparison with a vertical screen of the same effective height. The attenuation improves as the distance between the barriers increases.

2. As further barriers are added the efficiency increases, although, if working within a limited ground space, there may be a trade-off between the addition of another barrier and the subsequent reduction in barrier spacing.

3. If the source is located above the ground then the barrier heights should be adjusted accordingly to graze the line of sight between the source and the rear barrier. Because of the uncertainty concerning the source height in practice, it would be prudent to assume a high source position in deriving barrier heights.

4. Multiple barrier configurations using barriers of the same height may therefore be a more practical design. Figure 2 showed that a significant increase in Average Insertion Loss could be obtained by installing two 3m barriers instead of a single 6m barrier, for the geometry considered. The double barrier has the added advantage of reducing problems associated with visual intrusion and wind loading.

5. Absorptive covering of multiple barriers leads to a small increase in Insertion Loss.

5. REFERENCES

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