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NUMERICAL MODELLING OF NOISE PROPAGATION OVER BARRIERS

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INTRODUCTION

Many methods have been proposed for calculating the attenuation produced by noise barriers. A major group is formed by the very practical energy calculations in which the barrier shape is not considered in detail. Many results have also been published in which diffraction over various shapes of barrier has been investigated theoretically. Results in these cases are generally restricted to a particular class of barrier shape, possibly related to a vertical screen for comparison.

In order to compare, with some degree of uniformity of method, the effects of a range of barrier configurations several studies have been undertaken using experimental models. The facilities and effort required to carry out these investigations are considerable.

The boundary element method [1,2] enables a wide ranging investigation to be carried out of the effects of shape and surface cover on the efficiency of noise barriers in controlled conditions. There is some evidence to suggest that the results of two dimensional calculations can give a reasonable indication of effects expected for propagation from a point source. It is probable that the results will also give an indication of the relative performance of different barriers in shielding road traffic noise.

This paper reports the results of a series of boundary element calculations of the Insertion Losses of a range of single barrier forms. The calculation method assumes that the propagating medium is stationary and homogeneous so that atmospheric effects such as turbulence and velocity and temperature gradients which can considerably influence propagation of sound outdoors are not considered. This may not be a serious limitation if the aim is to assess the relative performance of barrier shapes. However it is probable that the shape of the barrier will have a significant effect on the form of the turbulence pattern produced when wind is present.

CALCULATION METHOD

The two dimensional model is illustrated in Figure 1. Flat ground of constant admittance is assumed, on which is positioned the barrier which has cross sectional shape defined by the line γ. The admittance can be variable along γ and γ can be extended along the ground plane. In the implementation of the boundary element method adopted by the authors, the shape and admittance are defined in terms of a sequence of line segments which are input as data for the calculation. By incorporating null segments barriers with holes, parallel barriers [3] and sections of ground of variable admittance can be incorporated in the model.

The Boundary Integral Equation (BIE) formulation used by the authors expresses the pressure field at any point in the propagating medium due to a monofrequency source in terms of an integral involving the pressure field on γ [2,4]. The BIE formulation used is significantly simplified by assuming that the boundaries are locally reacting. The Green function for a homogeneous impedance boundary [5,6] is involved in the kernel of the integral equation. The pressure field in γ can be determined by a boundary element method following which the pressure at any receiver position above the surface can be calculated. A straightforward solution method is used in which the pressure in γ is calculated at equally spaced points. To provide adequate resolution these points are spaced a distance $\lambda/5$ apart where λ is the wavelength of the source. With this arrangement the computing resources necessary to solve the problem depend on the product of the length of γ and the frequency of the sound and can be considerable.

Figure 1

When the admittance of the ground surface is zero the BIE formulation used has a non-unique solution at certain eigen frequencies of the interior region enclosed by γ and the reflection of γ in the flat ground surface [2,4]. The occurrence of non uniqueness is a well known phenomenon when boundary element methods are used to model scattering from closed shapes. The effect does not occur when the admittance of the ground is finite and can be circumvented in the case of ground of zero admittance by introducing a strip of absorbing ground beneath the barrier [2,4].

Results for Excess Attenuation over free field propagation and for Insertion Loss have been calculated for a wide range of receiver positions and source frequencies. The admittance of the locally reacting surfaces was defined by a single parameter, the flow resistance (σ), in the model of Delany & Bazley [7]. For absorbent barrier coatings with σ = 20,000 kg/sm^4 a hard back layer was assumed and a second parameter the depth of the layer (d = 0.1m) was introduced.

RESULTS AND DISCUSSION

In order to verify the validity of the calculation method and the software Insertion Losses were calculated for a barrier of semicircular cross section of constant surface admittance which rested on a surface of zero admittance. An analytical solution exists for the scattering of sound from an obstacle of this nature, in the form of a convergent series. The agreement between the numerical and analytical results for Insertion Loss was very good. The closeness of agreement improved as the length of the boundary elements used was decreased.

The boundary element calculation is carried out in two dimensions in the plane containing a cross section perpendicular to the surface of the barrier in common with many analytical approaches. The corresponding three dimensional configuration is of a coherent line source of sound parallel to a straight infinitely long barrier of constant cross section. Although three dimensional boundary element calculations describing propagation from point sources are possible the computing requirements using present algorithms are prohibitive.

There is some published evidence to suggest that results for Insertion Loss calculated using a two dimensional model give a reasonable indication of results expected from point source propagation [e.g. 8,2]. Figure 2 shows results used to investigate this phenomenon. The solid line describes the results of an outdoor model experiment reported by Rasmussen [9]. A square barrier section was used with zero surface admittance, and the ground surface was described by a flow resistance of 150,000 Kg/sm^4. The source and receiver geometry are indicated in the figure and the measurements of Excess Attenuation were made using 1/3-octave bands of sound. The points represent the results of the boundary element calculation carried out at each of the 1/3-octave centre frequencies for these conditions. The agreement is very good over the whole of the frequency range. A similar degree of agreement was observed for other receiver positions. These results also suggest that the Insertion Losses calculated at 1/3-octave centre frequencies give a good indication of the results measured using the full 1/3-octave of sound in this particular case.

The three main factors which are expected to affect the relative performance of barriers are the height, the cross sectional shape and the surface cover. The ground type will grossly affect the absolute values of Insertion Loss, but the effect on the relative values of Insertion Loss will be much less and has not been investigated. The factors described are not independant, but the assumption is made that their interaction is secondary. For useful comparison the source and receiver positions were fixed and the barrier inserted with its highest point at a horizontal distance of 15m from the source. For barriers which were symmetrical in section the line of symmetry was positioned 15m from the source. For the comparison of shape and surface cover a standard maximum height of 3m was used. When the source and receiver are above the ground surface the interference patterns caused by ground reflections are the predominant factor and make comparison of the results in terms of the barrier configuration difficult to interpret. The effects of the barrier as a diffracting edge can best be observed if the source and receiver are in the ground surface.

Figure 3 shows three representative spectra calculated at 1/3-octave centre frequencies between 63Hz and 4KHz for propagation over the barrier shapes indicated. All surfaces have zero admittance and the source and receiver are in the ground surface at 15m and 50m respectively from the centre line of the barriers. At high frequencies all the barriers show an improvement of Insertion Loss of about 3dB/octave. The broad wedge shape is the least efficient, producing Insertion Losses of less than 1dB for frequencies less than about 315Hz. The spectrum for the vertical screen

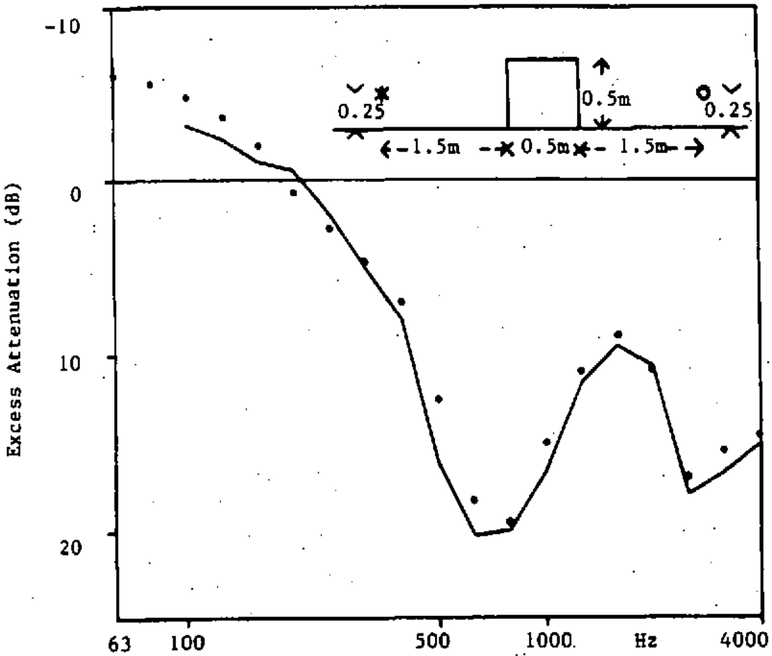

Figure 2

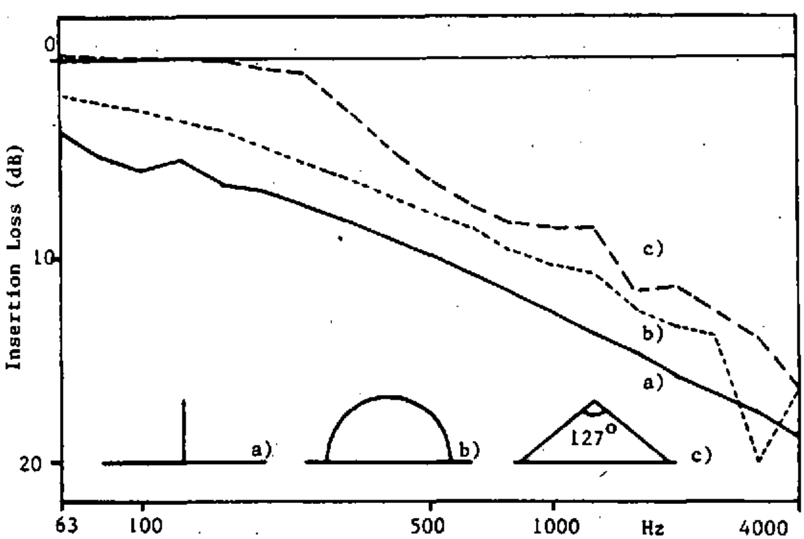

Figure 3

is typical of configurations where the sides of the barrier are predominantly vertical. The application of absorbent material to the vertical surfaces produced only small changes. When calculations were carried out for the extended shapes, with a surface characterised by a flow resistance of 300,000 kg/sm^4 significant changes occurred in the spectra. Although the values of Insertion Loss at low frequencies were unaffected the rate of improvement in Insertion Loss with increasing frequency increased to about 5dB/octave at high frequencies.

Useful comparisons of the efficiency of barriers for reception points above the ground can be made if a broad band sound source is considered. An A-weighted 1/3-octave spectrum characteristic of road traffic noise in the U.K. was used [10]. The Excess Attenuation with the barrier in place was calculated at the 1/3-octave centre frequencies and then subtracted from the spectrum. The results were added over all bands from 63Hz to 4KHz. The procedure was repeated using the Excess Attenuation results for open ground propagation. Hence the Insertion Loss for the broad band source was determined. The results obtained can be related approximately to absolute values of Insertion Loss for an internal combustion engine source which approximates an omnidirectional point source near the ground. However the results do not give absolute values for the Insertion Loss of a barrier parallel to a road. Traffic on a road approximates to a series of point sources which are known to give very significantly different Insertion Loss results to a single point source [11].

Figure 4 shows results for Insertion Loss for the broad band source plotted against the horizontal distance of the receiver from the centre line of the barriers (D). The receiver height is 1.5m and the source is in the surface, 15m from the centre line of the barrier. Up to 20m from the barrier there is considerable variation in the results, but beyond this distance use of a broad band spectrum has averaged interference effects and consistent trends occur. Both forms of grass covered earth mound show lower values of Insertion Loss than the vertical screen case. The flat topped mound shows significant benefit over the plain wedge shape. The Insertion Loss results for the two mound shapes when the surface admittance was zero were approximately 1.5dB lower than those shown on Figure 4.

At a constant value of D the Insertion Loss changes with the height above the ground. Figure 5 shows this effect for D = 20m. The Insertion Loss decreases as the shadow boundary is approached. A decrease is also observed of ~3dB as the surface is approached. The shadow boundary occurs at a height of 7.0m for cases a) & b) and at 7.5m for cases c) & d). At the boundaries the respective Insertion Losses are 5.8, 5.3, 5.5 and 6.5 dB for cases a) to d).

CONCLUSION

The boundary element method can be used to derive the sound field in the region of a barrier using a two dimensional model. The method enables the performance of barriers of different cross-sectional shape and cover to be compared.

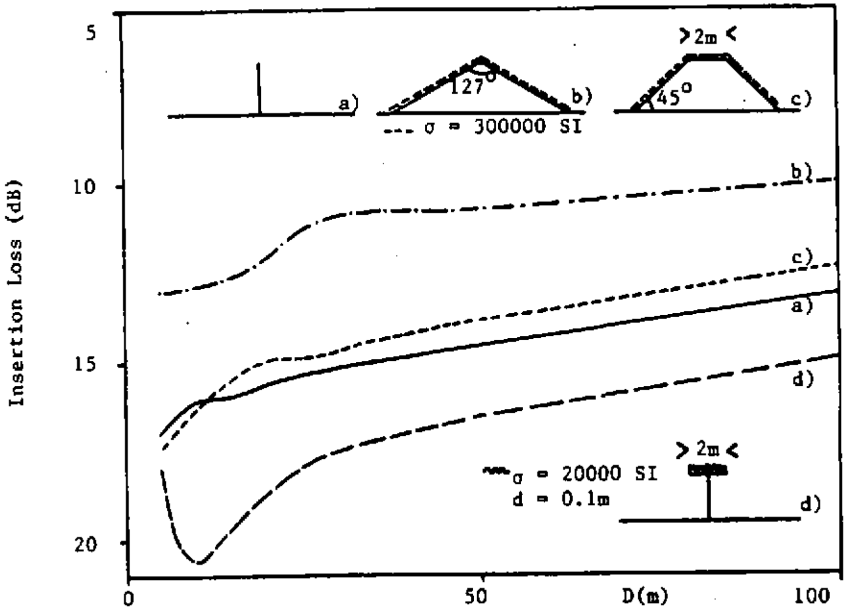

Figure 4

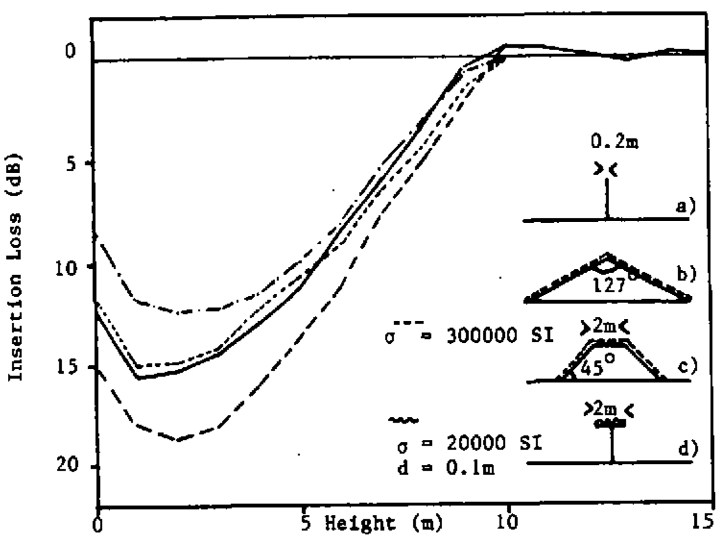

Figure 5

An outdoor model experiment using a point source and 1/3-octave bands of sound provides excellent agreement with the boundary element method for the cases considered.

When the barrier surfaces have zero admittance those with vertical components produce higher insertion loss than those with sloping sides. Introduction of absorbent materials on vertical faces of barriers provides negligible improvement in efficiency, but is effective on sloping sides. Efficiency can be significantly increased by the introduction of absorbent materials on the flat upper surfaces of barriers. Further analysis to derive a single figure measure of the efficiency of a range of barrier configurations is in progress.

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