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THE PROPAGATION OF ROAD TRAFFIC NOISE OVER EARTH MOUNDS

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1. INTRODUCTION

Many papers have been published describing experimental measurements of the propagation of sound over barriers, but only a small number deal with road traffic noise over earth mounds and often the information contained in them is limited [1,2]. There are also many theoretical analyses of the barrier problem, some of which have lead to useful approaches in predicting shielding effects [3,4]. The more common prediction methods are based on experimental and analytical work on simple vertical wall or fence type barriers but they are often used to describe the effects of more complicated barrier shapes.

The purpose of this paper is to present experimental measurements of road traffic noise near an earth mound barrier in a standard situation and to compare these with the results of commonly used prediction methods.

2. SITE MEASUREMENTS

To enable a systematic investigation of the effects of earth mounds to be made and to allow useful comparison with prediction methods it is important that the site is free from complicating factors which may affect the sound field in an unknown manner. Such standard sites are extremely difficult to find. The site selected for these measurements was an area adjacent to the M1 motorway near Leeds.

A plan is shown in figure 1. The motorway follows a large radius curve and to the south of the area gradually goes into cutting. To the north the barrier is terminated by a reverse. However, over a length of about 200m the site conditions remain fairly constant and it was in the middle of this areathat measurements were taken. The field behind the barrier was rough grassland and although there were some buildings in the area beyond the field it is expected that they were sufficiently distant to have little effect on the noise. Measurements were taken along the line XY perpendicular to the motorway and a section along this line is shown in figure 2. The boundary of the motorway was marked by a post and rail fence and a thin hedge. The height of the mound was about 3m with a steep gradient on the motorway side and a gentler gradient on the other side, making a total width of about 14m. The field behind the barrier had an appreciable slope, but this has been accentuated by the scaling of the section in figure 2.

Recordings of the traffic noise were made with microphones placed at 1.5m above the ground at positions 1 to 6, using a stereo tape recorder. One track of the recorder measured the noise at position 1 to provide a reference while the other track was used to sample the noise at points 2 to 6 sequentially over 10 minute periods. Vehicle flows during the measurements were around 2,500 per hour with about 20% heavies.

Two sets of measurements were carried out in different atmospheric conditions. For conditions A the wind speed, measured by anemometer at

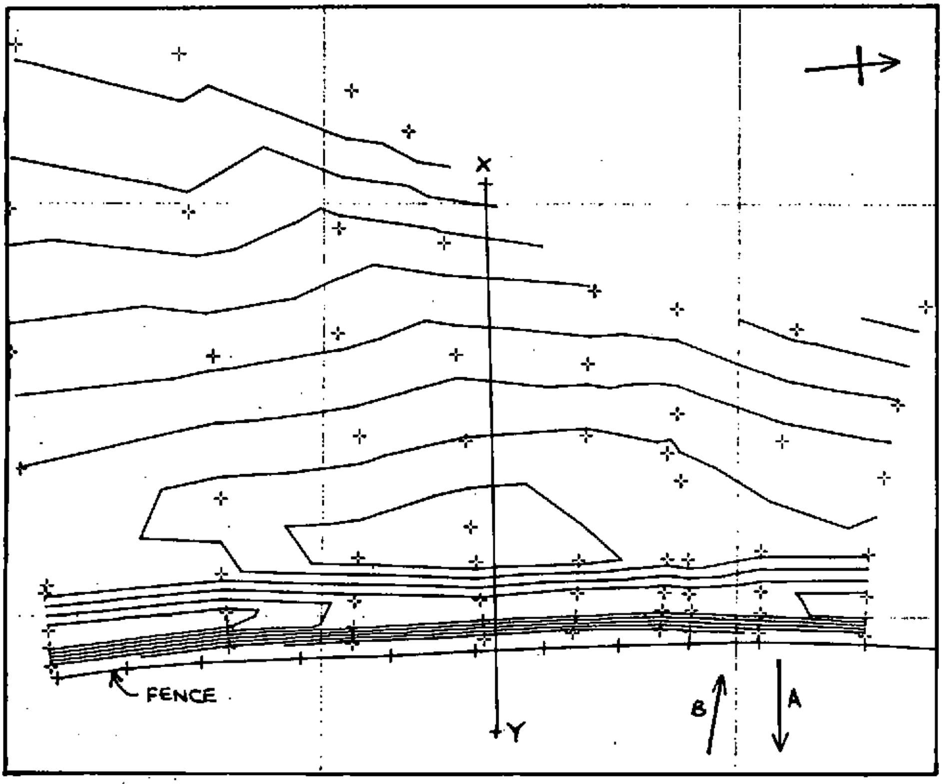

Figure 1 Site plan, contours are at 0.5m intervals, 100m grid.

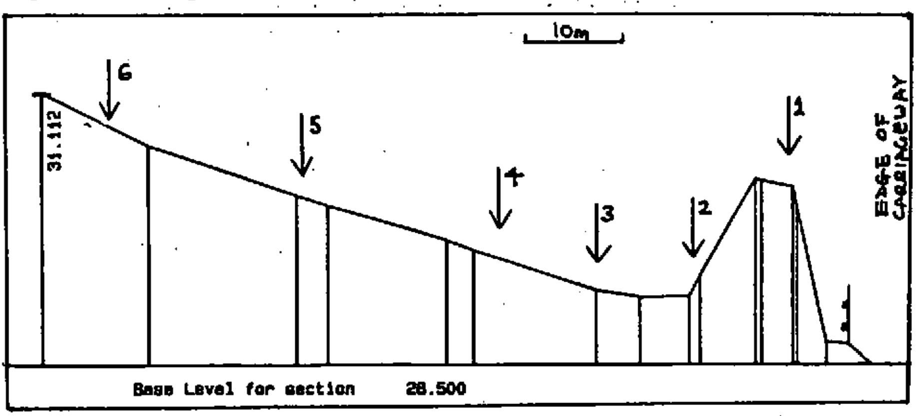

Figure 2 Section XY showing measurement points 1 to 6.

1.5m above the mound at position 1 was 5m/s in the direction shown on figure 1, from barrier to road. For conditions B the wind speed, measured in the same position was again 5m/s but in this case in an almost diametrically opposite direction from road to barrier (see fig. 1). No facilities were available for measuring wind velocity gradients above the ground or turbulence.

3. RESULTS

The recordings were analysed in the laboratory, initially to obtain the statistical noise indices and L_{eq}. The results are presented in tables 1 and 2.

Position / Attenuation (Δ)	dB(A)			
	L_{eq}	L_{10}	L_{50}	L_{90}
Pos 1	76.6	80.5	75.0	68.8
Pos 2	56.6	59.8	55.5	51.3
Δ	20.0	20.7	19.5	17.5
Pos 1	76.5	80.3	75.3	67.5
Pos 3	56.0	59.0	55.3	52.0
Δ	20.5	21.3	20.0	15.5
Pos 1	76.8	80.3	75.8	70.0
Pos 4	56.2	58.8	55.5	52.8
Δ	20.6	21.5	20.3	17.2
Pos 1	75.7	79.3	74.5	68.5
Pos 5	55.6	58.5	55.0	52.0
Δ	20.1	20.8	19.5	16.5
Pos 1	77.3	80.5	76.5	71.5
Pos 6	54.9	57.3	54.5	52.0
Δ	22.4	23.2	22.0	19.5

Table 1 Measured noise indices. Wind condition A (barrier to road)

The differences in each of the measured values of the indices at position 1 as given in table 1 are small and are wholly attributable to changes in traffic flow and composition from one measurement to the next. A similar effect is observed in the values in table 2. On comparison of the results for position 1 between the two tables it can be seen that the differences are small, again of the order expected from changes in vehicle flow rate and composition. Thus the change in wind direction appears to have had no effect on the noise propagation to position 1 which was about 15m from the edge of the nearside carriageway. Detectable differences in noise level due to changes in wind direction at 15m from a road have been reported [5].

The effects of the propagation path on the noise indices measured at positions 2 to 6 can be isolated from variations in the traffic source by subtracting the results from those simultaneously measured at position 1. The results (Δ) are given in tables 1 and 2. In table 1 this attenuation is remarkably constant at positions 2 to 5 with a value of about 21 dB(A) in L_{10}. A greater attenuation of 23.2 dB(A) in L_{10} is observed at position 6. A similar picture emerges from table 2. As the distance of the observation point behind the barrier increases an increased attenuation due to distance

Position / Attenuation (Δ)	dB(A)			
	L_{eq}	L_{10}	L_{50}	L_{90}
Pos 1	76.5	80.0	74.5	67.0
Pos 2	61.4	64.8	60.5	56.5
Δ	15.1	15.2	14.0	10.5
Pos 1	76.9	80.5	75.5	69.8
Pos 3	62.9	65.5	62.5	59.3
Δ	14.0	15.0	13.0	10.5
Pos 1	76.9	80.0	75.5	70.0
Pos 4	63.5	66.0	63.3	59.5
Δ	13.4	14.0	12.2	10.5
Pos 1	77.3	81.0	75.8	69.0
Pos 5	63.8	66.8	63.3	59.5
Δ	13.5	14.2	12.5	9.5
Pos 1	77.0	80.5	75.0	68.8
Pos 6	62.7	65.5	62.3	59.3
Δ	14.3	15.0	12.7	9.5

Table 2 Measured noise indices. Wind condition B (road to barrier)

from the source is apparently balanced by a reduced shielding effect from the barrier.

The difference in wind direction between the two sets of results produced a 5.5 dB(A) difference of L_{10} immediately behind the barrier (position 2) rising to a difference of 8.2 dB(A) at 60m beyond the barrier (position 6).

A frequency analysis of the recordings was then carried out which produced an L_{eq} value for the period of the sample for each 1/3 octave band. Attenuation spectra were calculated as the difference between results at points behind the barrier and the simultaneously measured spectra at position 1. The values followed well defined trends apart from a few notable diffraction effects . In figure 3 the attenuation spectra for positions 2 and 6 are plotted. All the curves show strong changes around 250 Hz. Attenuations above this frequency are considerably greater than those below. The change in wind direction produces changes of attenuation of around 3dB below about 250 Hz. Above this frequency very large differences are observed at both positions.

By considering the barrier as an opaque, semi infinite screen the diffraction pattern behind the screen produced by waves from the source can be easily calculated. Maekawa [6] combined these results with a geometrical reflection effect from the ground surface and developed a prediction method for the attenuation of the barrier as a function of the frequency of the sound and the geometry of the system. The geometry is described in terms of a single parameter, the path difference between the direct source-receiver ray and the rays from source to receiver via the edge of the barrier.

This prediction method was applied to the site under investigation and the

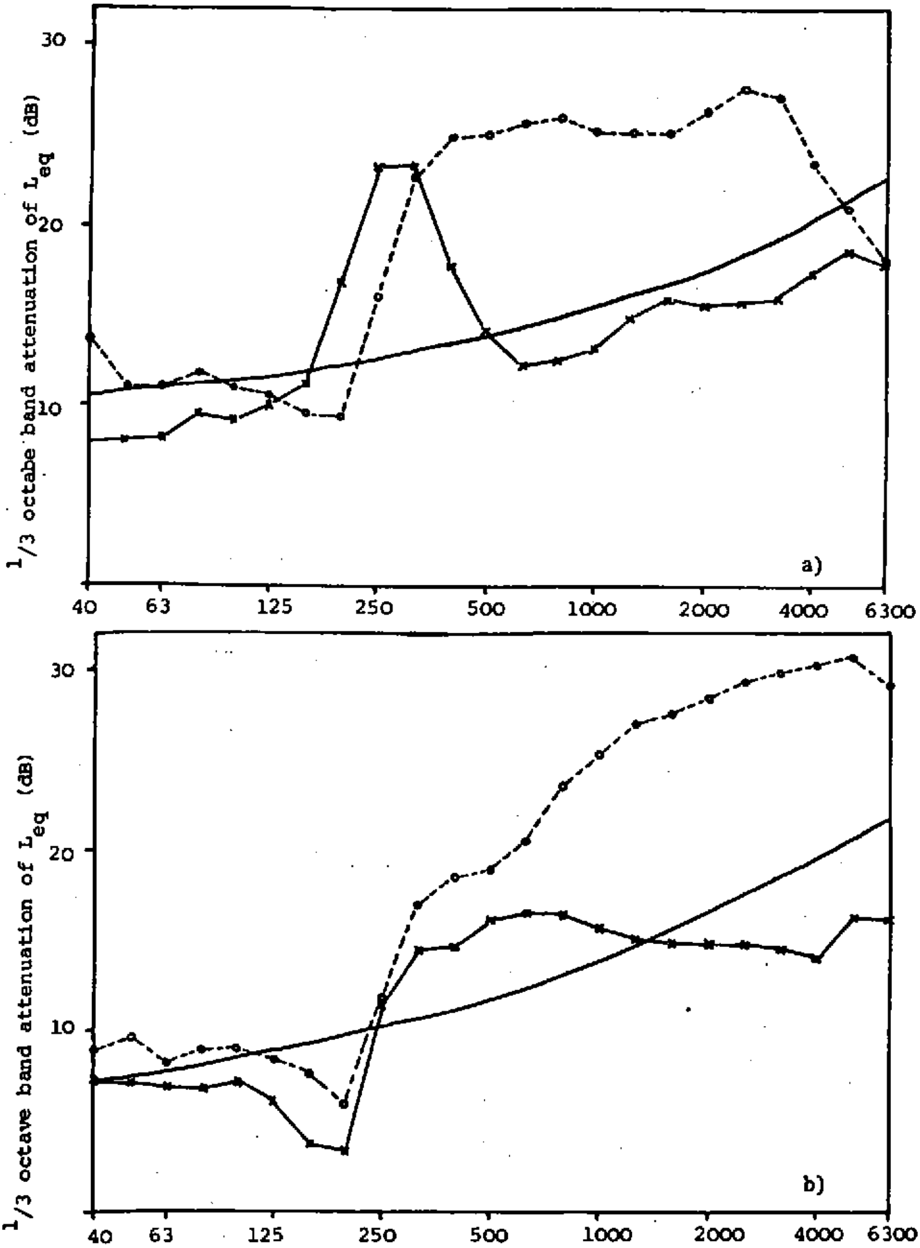

Figure 3 Difference in 1/3 octave L_{eq} level; a) between positions 1 and 2, b) between positions 1 and 6. o...o wind conditions A; x-x wind conditions B. curve is predicted from reference [6].

results for positions 2 and 6 are shown on figure 3. The agreement at low frequencies is reasonable for both sites and for both wind conditions. At higher frequencies the prediction lies closer to the results for wind conditions (B). However, it must be noted that the differences between the predicted and measured curves are usually less than the differences between the experimental curves measured in different atmospheric conditions.

The attenuation of the barrier on road traffic noise can be calculated by applying the prediction relation discussed above to a traffic noise spectrum. The standard U.K. prediction method [7] for traffic noise (L_{10}) was based on this approach with adjustment in the light of experimental data [8].

Prediction for the attenuation between position 1 and positions 2-6 using the standard U.K. method for traffic noise are given in table 3. At positions 5 and 6 excellent agreement is observed with measurement taken under wind conditions (B). Closer to the barrier the method has underpredicted the experimentally determined attenuation.

Using the prediction method the "insertion loss" of the barrier can be calculated (see table 3). This is the difference in L_{10} level at each position before and after erection of the mound. It is an important parameter as it is related to the improvement in amenity resulting from the construction of the barrier. The low figures arise from the fact that the ground cover is grass which, in unshielded conditions, produces good attenuation of sound with distance. The soft ground attenuation effect is lost when the barrier is constructed as the ground rays are obstructed.

In order to predict more accurately the attenuation of the barrier it is necessary to consider the shape in more detail and also the ground cover beneath the propagation path. The results will of course be frequency dependant.

Two approaches are possible. The first is to use modelling techniques, where a model of a specific site is investigated. The second is to develop a more sophisticated analytical model. Solutions for the wave field behind barriers of wedge or trapezoidal shape have been presented (e.g.[9]) but they are unsuitable for application to practical conditions and the diffraction effects which they display are very sensitive to ground elevation and acoustic impedance. It is possible to extend the concepts of Maekawa's method to a wedge shaped barrier and to include allowance for ground cover of finite impedance [2].

In this approach the acoustic pressure at the receiver is given by,

$$p = p_{sr} + p_{s'r} + p_{sr'} + p_{s'r'}$$

By reference to figure 4, p_{sr} is the acoustic pressure at the receiver r from the source at s. $p_{s'r}$ is the pressure at r due to the source at s' modified by the reflection coefficient for the ground surface type at X which can be defined as Q_1. This reflection coefficient is a complicated function if the impedance of the ground is finite at the frequency under consideration. The other terms are similarly derived. The phase of the contributions to p is affected by the diffraction over the barrier and by Q_1 and Q_2. This idea can be extended to cover trapezoidal shapes [3,10]. The few results in the literature comparing the predictions from these methods with experiment show

Position	L_{10} attenuation dB(A)			Predicted Insertion loss dB(A)
	Measured (A)	Measured (B)	Predicted	
2	20.7	15.2	11.2	5.3
3	21.3	15.0	12.5	4.8
4	21.5	14.0	13.0	3.9
5	20.8	14.2	14.2	0.6
6	23.2	15.0	15.2	0

Table 3 Predicted attenuation and insertion loss for the earth mound using reference [7]

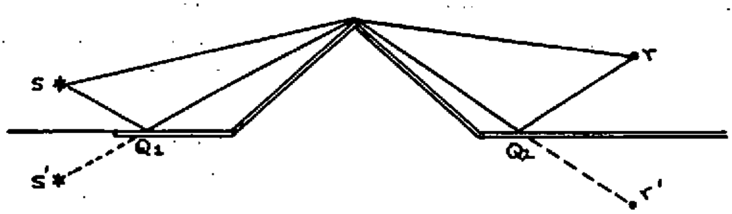

Figure 4

the diffraction characteristics to be expected with the inclusion of phase effects. However, it is not easy to see that the very great increase in computational effort over the simpler methods produces a similar improvement in useful accuracy in the prediction of practical cases. Sound propagation over barriers of arbitrary shape can be approached by the boundary element method of Seznec [11]. This has a high potential accuracy but requires a great deal of computational effort.

4. CONCLUSION

The different wind conditions observed had an undetectable effect on the received traffic noise levels at 15m from the nearside edge of the road. However, behind the barrier differences in L_{10} were observed ranging from 5.0 dB(A) immediately behind the barrier (pos. 2) to 8.2 dB(A) at 60m beyond that point (pos. 6) in agreement with other workers [5]. However, the wind produced differences much greater than this in the high frequency portion of the spectrum.

Maekawa's prediction method showed reasonable agreement with observed attenuations particularly when the wind was from road to receiver. The U.K. prediction method for L_{10} underpredicted the barrier attenuation close to the barrier but was accurate at larger distances in "worst case conditions" (B).

In describing the propagation of sound over barriers a balance must be sought between accuracy and complexity. For prediction of effects on pure tones where standard ground conditions are encountered the more complicated methods may be appropriate. However, for broad band sounds and where difficult variations in ground cover and elevation are encountered a simple method such as that of Maekawa is appropriate. Atmospheric effects can produce large changes in spectra.

The development of sophisticated analytical methods is a useful aid in understanding the effects of changes in shape and construction of barriers and may lead to the development of more efficient configurations.

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