PREDICTION OF L_{10} NOISE LEVELS FROM ROAD TRAFFIC: DISTANCE CORRECTIONS FOR INHOMOGENEOUS GROUND COVER

D.C. HOTHERSALL (1) and S.N. CHANDLER-WILDE (2)

(1) School of Civil and Structural Engineering, University of Bradford, Bradford BD7 1DP

(2) Department of Mathematics, Coventry Lanchester Polytechnic, Coventry, CV1 5FB

INTRODUCTION

The index L_{10}18hr is used in the UK as an indicator of annoyance caused by noise from road traffic. The index is incorporated in legislation concerned with insulation and a standard prediction method has been published [1]. The prediction method is divided into two sections. The first estimates the base noise level at 10.0m from the kerb using the traffic parameters. The second part modifies this result to allow for the propagation conditions at the site. Two important factors in this second category are the distance from the road to the receiver and the composition of the ground surface beneath the propagation path. In the UK prediction method for L_{10} these effects are described by two expressions. When the ground beneath the propagation path is 'hard' (e.g. paving) the distance correction which must be applied to the base noise level is given by

$$\Delta L_1 = 10 \log_{10} \left(\frac{13.5}{d'}\right) \qquad (1)$$

where d' is the slant distance from source to receiver. This expression describes cylindrical spreading of the sound waves from an idealised source line. In common with all the corrections described in this paper the correction is in dB(A) and is added to the base noise level in dB(A).

If the ground is predominantly 'soft' (e.g. grassland) the distance correction is

$$\Delta L_2 = \Delta L_1 + \Delta L_3 \qquad (2)$$

where

$$\Delta L_3 = \begin{cases} 5.2 \log_{10} \left(\frac{3h}{d}\right) & 1\text{m} \leq h \leq d/3 \\ 0 & h > d/3 \end{cases} \qquad (3)$$

The height of the reception point above the ground surface is h and d is the horizontal distance from source line to receiver.

These expressions were derived from a wide range of experimental data and the results of computer simulations and have been successfully applied. In most practical situations however the intervening terrain between source and receiver consists of various kinds of ground cover and it is obviously desirable to develop an expression which can allow for the type and distribution of ground cover instead of using the limiting cases covered by equations (1) and (2). A numerical method of predicting the attenuation of road traffic noise over inhomogeneous ground cover is reported here. A

PREDICTION OF L_{10} NOISE LEVELS FROM ROAD TRAFFIC: DISTANCE CORRECTIONS FOR INHOMOGENEOUS GROUND COVER

distance correction of fairly simple form is developed which allows propagation of sound over combinations of soft and hard ground cover to be described.

SIMULATION METHOD

Consider the situation shown in Figure 1. Monofrequency point source S and receiver R lie above an infinite plane which is divided into two regions by a boundary which lies perpendicular to the line joining source and receiver. The region on the source side of the boundary is hard ground with zero admittance. The other region is soft ground of finite and homogeneous admittance. The surface is assumed to be locally reacting with admittance defined by the equation of Delany and Bazley [2] using a flow resistance of 250,000 Nsm^{-4}.

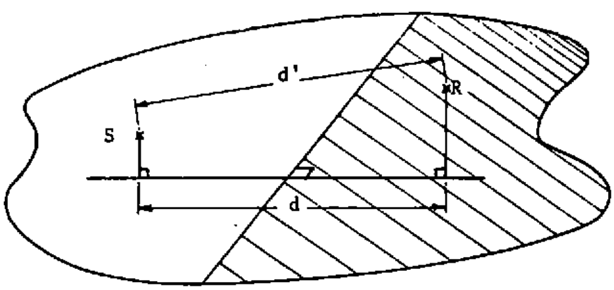

Figure 1

The acoustic pressure at the receiver position when the surface configuration is as shown in Figure 1 has been expressed approximately in an integral form in reference [3]. The integral can be evaluated numerically.

In order to calculate the pressure at R due to a single vehicle source at S it is necessary to consider the frequency content of the noise. Representative 1/3 octave sound power spectra have been derived from previous roadside measurements for light and heavy vehicles in the UK [4,5]. The division between light and heavy vehicles is at a weight of 1500kg. Using a source height of 0.5m for light vehicles the sound field at R can be calculated for each 1/3 octave centre frequency using the numerical method described above. By applying these results to the sound power spectrum for light vehicles the total sound pressure at the receiver can be calculated. A simple correction for air absorption dependant on distance and frequency is also included. A similar procedure was carried out for the heavy vehicles, using a source height of 1.0m.

In figure 2 the excess attenuation of the sound pressure level at the receiver over the sound pressure level expected from spherical spreading from the source is plotted against the horizontal distance from source to receiver (d). For each line the proportion of soft ground beneath the propagation path (p_s) is constant. The receiver height is 2.0m. The excess attenuation for

PREDICTION OF L_{10} NOISE LEVELS FROM ROAD TRAFFIC: DISTANCE CORRECTIONS FOR INHOMOGENEOUS GROUND COVER

propagation over hard ground(p_s = 0.0) rises from 0dB(A) at about 10m from the source to a peak of 3.5dB(A) at about 100m from the source. As the distance between source and receiver

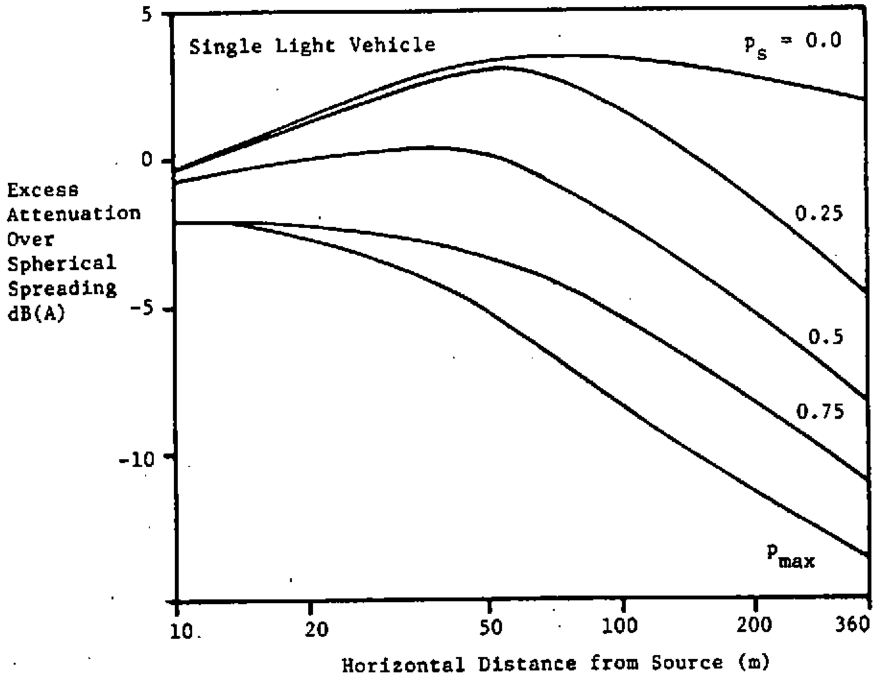

Figure 2

increases the path difference between direct and reflected rays reduces so that constructive interference occurs over an increasing proportion of the spectrum and this explains the upward trend of the curve. Using this argument the excess attenuation would be expected to approach +6.0 dB(A) at very large distances. However at large distances air absorption becomes important and results in the downward trend of the curve beyond about 100m.

The curves in Figure 2 can be related approximately to the sound received at a fixed receiver position when a vehicle passes along a line parallel to the boundary, through S. Only when the vehicle is closest to the receiver will the results be strictly applicable. At other positions of the vehicle, although the value of p_s will remain constant the boundary will not lie perpendicular to the line joining source and receiver. There is some evidence that the effect of this obliquity in small and in any case the main

PREDICTION OF L_{10} NOISE LEVELS FROM ROAD TRAFFIC: DISTANCE CORRECTION FOR INHOMOGENEOUS GROUND COVER

contribution to the total noise level is from vehicles in the region closest to the receiver. From the curves, using appropriate vehicle speeds, a temporal distribution of the noise level at R can be derived for the passage of a single light and a single heavy vehicle along the source line. A speed of 84km/hr was used for light vehicles and 73km/hr for heavies. The temporal distributions for single vehicles can be combined in a statistically valid fashion to produce the temporal noise distribution for the passage of a stream of vehicles [6]. A representative flow of 1000vehicles/hr with 20% heavies was used. The L_{10} noise level is obtained from the temporal noise distribution.

The calculations of L_{10}were carried out for 9 values of d between 10m and 200m, values of h = 1.0, 1.5, 4.0, 10.0 and 30.0 m, values of p_s = 0 ,0.25, 0.5, 0.75 and also the condition p_{max} when the soft ground extended for a distance of (d-3.5)m. This corresponds to the case where soft ground is present from the kerb edge to the receiver point.

DISCUSSION OF RESULTS

The L_{10} levels calculated using the simulation method can be expressed in the following way

$$L_{10} = L_0 + 10 \log_{10} \left(\frac{13.5}{d^1}\right) + \Delta L_4 \qquad (4)$$

L_0 is the calculated L_{10} level at 13.5m from the source line and the second term is an attenuation due to cylindrical spreading. The excess attenuation represented by the final term is plotted in Figure 3 as a function of d for various conditions of ground cover. The height of the receiver is 1.5m. The abscissa represents the hard ground correction in reference [1]. The calculated results for hard ground are close to the abscissa for d less than about 100m. At greater distances the observed trend can be attributed to the attenuation caused by atmospheric absorption. A systematic decrease in the value of ΔL_4 is observed as p_s increases. The dotted line indicates the soft ground correction from reference [1] which is given in equation 3. For all receiver positions the excess attenuation predicted using equation 3 was smaller than the calculated result for p_{max}. However it must be remembered that neutral atmospheric conditions are assumed in the calculations. For receiver positions downwind of the source, when a wind velocity gradient occurs a significant reduction in the calculated results for excess attenuation can be expected.

To investigate the effect of the soft ground further the excess attenuation ΔL_5 at each point was calculated as the difference between the calculated L_{10} level with given ground conditions and the L_{10} level calculated for the same point when the ground was hard. Using the results for p_{max} only and the functional form in equation 3 the equation which produced the best least squares fit was

PREDICTION OF L_{10} NOISE LEVELS FROM ROAD TRAFFIC: DISTANCE CORRECTIONS FOR INHOMOGENEOUS GROUND COVER

$$\Delta L_s = 8.00 \log_{10}\left(\frac{3.72h}{d}\right) \qquad 1m < h < \frac{d}{3.72}$$
$$= 0 \qquad h > \frac{d}{3.72} \qquad (5)$$

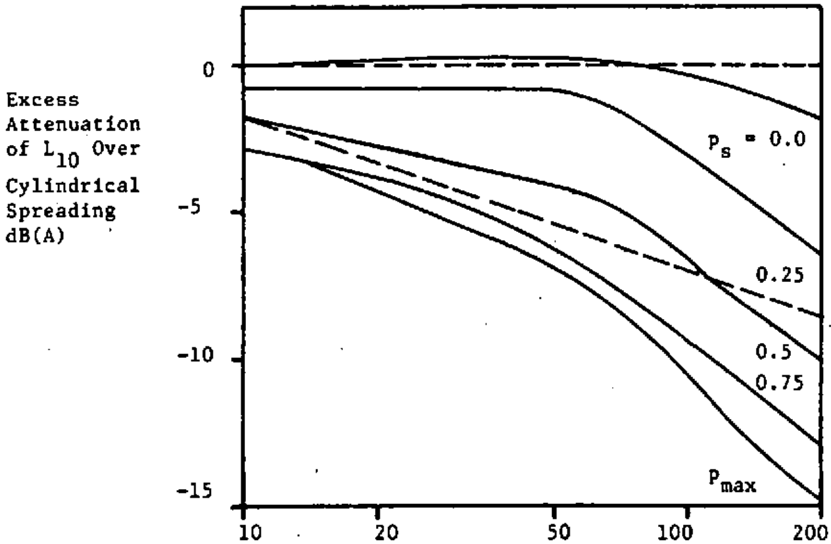

Figure 3

Using this equation as a limiting condition the equation for ΔL_s was extended to include the effect of p_s. The best fit, covering all the calculated results was given by

$$\Delta L_s = 8.00 \log_{10}\left(\frac{3.72h}{d}\right) - 10.34h^{(d/319)} \log_{10}(p_s) \qquad (6)$$

when $8.00 \log_{10}\left(\frac{3.72h}{d}\right) - 10.34h^{(d/319)} \log_{10}(p_s) < 0$.

Otherwise the value of ΔL_s is zero.

A simpler form of the second term in equation 6 would be as a product of a constant and the logarithm of p_s. However this form did not follow the observed trend in the points particularly when ΔL_s was small [7].

PREDICTION OF L_{10} NOISE LEVELS FROM ROAD TRAFFIC: DISTANCE CORRECTIONS FOR INHOMOGENEOUS GROUND COVER

CONCLUSION

A simulation method has been described to calculate the L_{10} level from a stream of vehicles when the noise propagates over a simple configuration of hard and soft ground. The distance corrections determined by this method have been compared with those used in the standard UK prediction method for hard and soft ground. The soft ground attenuation in the standard method appears conservative.

An expression for the excess attenuation as a function of receiver position and the proportion of soft ground below the propagation path has been developed in equation 6.

REFERENCES

[1] The Calculation of Road Traffic Noise, Department of the Environment, HMSO, (1975).

[2] Delany, M.E. and Bazley, E.N., Acoustic Properties of Fibrous Absorbent Materials, Applied Acoustics, 3, 105-116, (1970).

[3] Chandler-Wilde, S.N. and Hothersall, D.C., Sound Propagation above an Inhomogeneous Impedance Plane, J.Sound.Vib., 98, 475-491, (1985).

[4] Lewis, P.T. The Noise Generated by Single Vehicles in Freely Flowing Traffic, J.Sound Vib., 30, 191-206, (1973).

[5] Jones, R.R.K. & Hothersall, D.C., Effect of Operating Parameters on Noise Emission from Individual Road Vehicles. Applied Acoustics, 13, 121-136, (1980).

[6] Nelson, P.M., A Computer Model for Determining the Temporal Distribution of Noise from Road Traffic, Transport and Road Research Laboratory Report LR611, (1973)

[7] Hothersall, D.C. and Chandler-Wilde, S.N., Prediction of the Attenuation of Road Traffic Noise with Distance, J. Sound. Vib., 115, 459-472, (1987).