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THE ACOUSTICAL PERFORMANCE OF A RIGHT ANGLED BARRIER

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Acoustic barriers erected alongside roads to reduce traffic noise have been applied in many situations. Very long (infinite) barriers have been found to offer reasonable protection to sites situated behind them. In order to protect a localised site, one might think of a simple finite barrier situated along the roadside boundary. Such a simple barrier gives some benefit but problems arise in zones near the lateral boundaries of the site when the unscreened portion of the road as seen from a reception point is too large.

It was decided to investigate the performance of an alternative form of barrier (right angled barriers) to see if they would provide a solution to this problem and result in adequate attenuation in these poorly protected zones.

Outline of procedure

The procedure followed in the course of this investigation can be divided into three main stages.

The first stage involved the development of a computer model to predict the performance of the finite simple barrier and the right angled barrier with respect to noise from a stationary point source.

The second stage involved validation of this computer model. This was achieved by conducting a series of scale model experiments. The results obtained experimentally were compared with those obtained from the computer model.

The third stage involved the combination of the stationary point source model with a computer model which simulated the effect of freely flowing traffic.

This second computer model was used to predict the attenuations due to a number of right angled barrier and finite barrier configurations.

Finally a comparison was made between the attenuations afforded by right angled barriers and those afforded by equivalent length finite barriers.

THE STATIONARY SOURCE COMPUTER MODEL

This computer model calculates the attenuation in noise which reaches the receiver via two different paths. The first path is via the barrier top, the other path is via one of the barrier vertical edges. In the case of finite barriers this edge was considered to act as a thin barrier and for right angled barriers it was considered to act as a thick barrier.

The model was based on Makaewa's experimental design chart which has been reduced by Delany to the form of a polynomial which can be used to calculate the attenuation (Att.) due to thin barriers [1].

Delany's expression is as follows:

$$Att = 13.33 + 8.34x + 2.445x^2 - 0.8838x^3 - 0.3012x^4 + 0.1644x^5 + 0.01832x^6 - 0.010024x^7 \quad (1)$$

for a receiver position in the shadow zone of the barrier and

$$Att = 0.22 + 0.304x + 2.063x^2 - 1.022x^3 - 1.2214x^4 - 0.241x^5 \qquad (2)$$

for the receiver position in the illuminated zone of the barrier where x = Log N and N is the Fresnel number for a particular frequency.

The procedure followed in the computer model is as follows:

a) Define the position of the receiver point (R) and the source (S), and their relation to the barrier, the type of barrier (finite or right angled barrier) and all the essential dimensions of the barrier.

b) For finite barriers calculate the path difference between the direct unscreened sound path and the two shortest screened paths, one via the barrier top and the other via the edge, δ_1, δ_2 respectively.

c) In the case of right angled barriers calculate the path difference via the top (δ_1) as in step (b) and also calculate the two path differences δ_2, δ_3 as defined in Figure 1, where E, K are two points on the barrier end which give the shortest path from S to R via the edge and S', R' are two points obtained by turning the lines ES, KR respectively to be in the plan of the perpendicular part of the barrier. (Figure 1).

d) Calculate the Fresnel numbers for each path difference in each of the seventeen third octave bands from 50 Hz to 2kHz

$$N1_j = 2\delta_1/\lambda_j \qquad N2_j = 2\delta_2/\lambda_j \qquad N3_j = 2\delta_3/\lambda_j \qquad (3)$$

where λ_j is the wavelength corresponding to the centre frequency f_j of the jth frequency band of the spectrum.

e) In the case of finite barriers and for each centre frequency combine the attenuation via the top $Att(N1_j)$ and that via the edge $Att(N2_j)$ to find the effective attenuations of the barrier.

f) In the case of right angled barriers calculate the attenuation via the top $Att(N1_j)$ as described above for the finite barrier, and for the edge, using the Kurze formula [2] providing the source is in a position similar to 1 and the wavelength in consideration is smaller than the length l (Figure 2). The program calculates the attenuations $Att(N2_j)$, $Att(N3_j)$ and applies the Kurze formula to find the attenuation via the edge

$$\text{Edge } Att_j = Att(N2_j) + Att(N3_j) - 5 + 20 \log \frac{S'R'}{SR} \qquad (4)$$

g) In the case of right angled barriers when the source is in positions similar to 2 or 3 or the length l (Figure 2) is smaller than the wavelength in consideration the barrier is treated as thin and finite.

THE SCALE MODEL EXPERIMENT

In order to validate the technique described above, the predicted results were compared with results obtained from measurements made on a 1:10 scale model. The models were constructed of 12 mm thick chipboard and housed in an anechoic room belonging to the Building Science Department, Sheffield University.

The equipment used consisted of a sound source, two ½" B&K type 4165 microphones, a B&K real time analyser, type 2131, microcomputer and printer. The source of sound employed in the model was an omni-directional air jet which gave a reasonable high level of sound over all of the 1/3 octave bands of interest (500 Hz - 20 kHz corresponding to 50 Hz - 2KHz in the prototype). One of the microphones was used to pick up the sound at the receiver position, and the other was used as a reference microphone.

The microcomputer was used to control the measurement processes. The output from the real time analyser was transferred to the microcomputer. At each frequency it stored the screened levels at the reception point and the unscreened levels at the reference microphone position. From the latter it calculated the unscreened level at the reception point and used this data to calculate the attenuation.

The computer model results have been compared with the scale model measurements for many different arrangements of the two types of barrier.

Figure 3 shows some of the results obtained where the measured and the predicted values of attenuation are plotted against frequency. From these results it was found that there was a reasonable agreement between the measured and predicted values of attenuation. The results of this comparison between the two values of attenuation showed that the computer model developed in the course of this work can be employed to predict the performance of any of the two shapes of barriers for noise emanating from a stationary point source.

ASSESSMENT OF THE PERFORMANCE OF RIGHT ANGLED BARRIERS WITH RESPECT TO NOISE FROM ROAD TRAFFIC

Since the model considered above enables the prediction of the attenuation of barriers for a stationary noise source, it was decided to develop it to be able to find to what extent a right angled barrier improves the attenuation of noise from road traffic compared to finite barriers. The difference between noise emanating from stationary sources and that emanating from road traffic is that the latter consists of a number of moving sources and the level of noise experienced at any point arising from a traffic stream is a function of time. Therefore it was decided to employ a computer model to simulate traffic noise with the former model employed as a sub-routine to calculate the barrier performance.

The important traffic parameters in determining the level of noise are traffic volume 'Q', mean speed 'V' and percentage of heavy vehicles 'P'. These were used as inputs to the computer which established the distribution of vehicles along a road. The spacing between any successive vehicles follows a negative exponential distribution with average spacing $\bar{S}$ where $\bar{S}$ = Q/V.

The composition of the stream is determined using a random number having a value between 0 and 1 generated by means of a computer sub-routine. This is compared with the value of P/100 and if it is less than this the vehicle is assumed to be heavy, otherwise it is assumed to be a car.

The unscreened levels of noise emanating from any vehicle at a distance 'd' can be calculated by using Lewis' formula [3]:

$$SPL(car) = 32.8 \text{ Log } v + 14.9 + (20 \log \frac{7.5}{d}) \qquad (5)$$

THE ACOUSTICAL PERFORMANCE OF A RIGHT ANGLED BARRIER

$$SPL(heavies) = 26.9 \, Log \, v + 34.2 + (20 \log \frac{7.5}{d}) \quad (6)$$

When the unscreened level and barrier configuration are provided to the sub-routine, it calculates the screened level. The calculations are made using Lewis' octave band traffic noise spectrum. The unscreened and the screened levels due to sources near enough to affect the level as experienced at the receiver position are calculated. Then all vehicles are shifted along the roadway. The magnitude of the shift is determined by the sampling rate and mean traffic speed. The new levels are calculated and this process is repeated until the required number of samples is achieved. In the last step the computer finds the unscreened and the screened levels which were exceeded for 10% of the sampling time ($L_{10_{uns}}$) ($L_{10_{scr}}$) respectively and then calculates the attenuation.

$$Att = L_{10_{uns}} - L_{10_{scr}} \quad dBA$$

This program was used to predict the attenuation for 18 reception points positioned behind a finite barrier. The résults were then compared with results obtained over the same points behind four different configurations of right angled barriers of equivalent length. These barriers were assumed to be formed by turning lengths of 2, 4, 6 and 8 m respectively from the original barrier through a right angle.

RESULTS

It was found as a general trend that right angled barriers offered more attenuation than the corresponding finite barriers. Figure 4 shows a comparison in attenuations which are offered by infinite, finite and right angled barriers with the same height and relation to the reception points. It can be seen that the right angled barriers in some situations act virtually as infinite barriers and give much greater protection than finite barriers. The difference between the two values of attenuation due to finite and right angled barriers depends on the barrier-receiver relationship and it can be related to the angle between two lines from the receiver point, one to the edge of the finite barrier and the other to the edge of the equivalent length right angled barrier. Figure 5 shows this angle Θ and demonstrates that Θ has two zones corresponding to positive and negative values. It was found that when the receiver is in a positive zone of Θ there is some extra attenuation and the greater the value of Θ, the greater is this extra attenuation.

The relation between Θ in degrees and the extra attenuation can be seen in Figure 6 for a barrier of height 3 m, situated 6 m away from the traffic line and for receivers situated 1 m or 2 m above the ground. The traffic parameters used in the model were 1000 veh/hr, 20% heavy vehicles and a speed of 80 Km/hr.

CONCLUSION

The observed extra attenuation obtained by employing right angled barriers confirm the initial hypothesis that this shape of barrier will be more effective than a finite barrier of the same total length. With the technique of computer model simulation developed in the course of this work it is possible to extend the study to include other barrier configurations. From this study design charts can be produced which would enable the designer to assess the benefits to be expected from a number of alternative barrier configurations.

THE ACOUSTICAL PERFORMANCE OF A RIGHT ANGLED BARRIER

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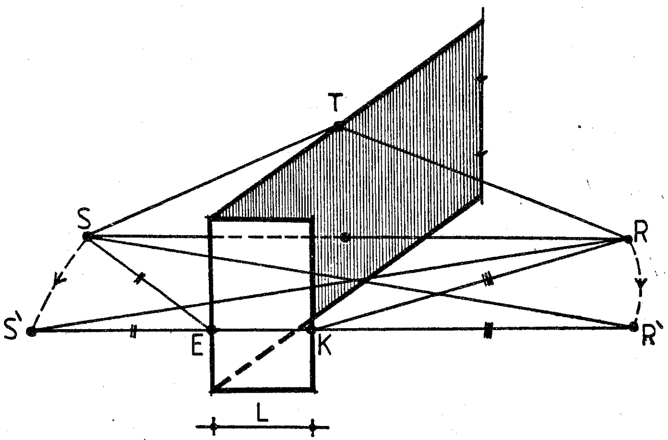

Figure 1 Right Angled Barrier

δ_2 = S' R' - S' R

δ_3 = S' R' - S R'

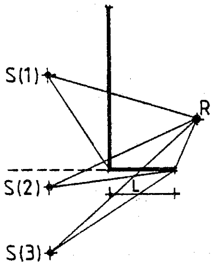

Figure 2 Source Positions

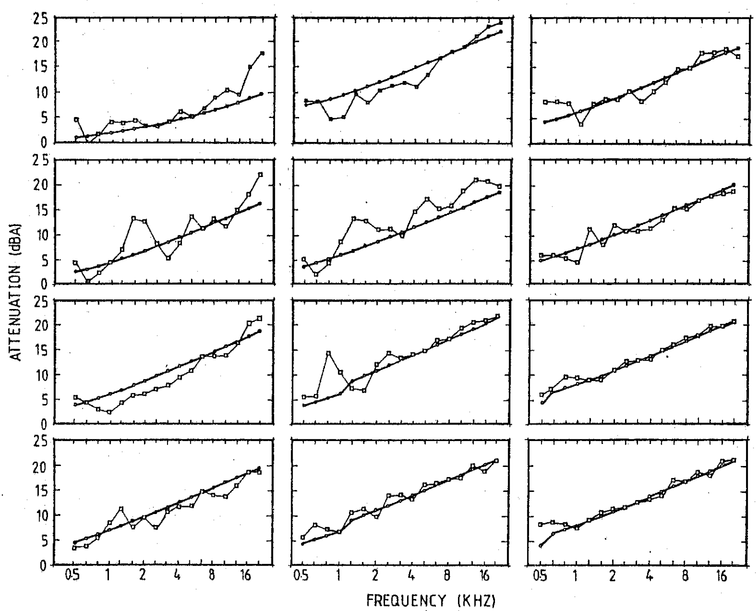

Figure 3 Comparison of Predicted and Measured Attenuation