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DESIGN CRITERIA FOR EFFICIENT NOISE BARRIERS

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1. INTRODUCTION

Noise is an important source of pollution of the environment, particularly in urban areas and near major transportation corridors. The fundamental way of reducing environmental noise is to reduce the emission levels from the sources. This has been achieved very effectively for aircraft over the past 30 years and also to some extent for road vehicles. Noise reduction at source is achieved for new vehicles by statutory maximum levels of emission for type approval of new road vehicles (e.g. in the Road Vehicles Construction and Use Regulations in the UK) and aircraft (e.g. FAA and ICAO Regulations). The noise output from vehicles also depends on the operational conditions and these can be modified by traffic calming methods or for aircraft by minimum noise routing etc.

The second approach to noise reduction is to modify the propagation path from the source to the receiver. For indoor environments this can be achieved by improving the sound insulation of the building elements, particularly the windows by double glazing. For outdoor environments the best approach is to separate the source and sensitive area as far as possible at the planning stage. Where this is not possible, or for existing problems, blocking of the sound path by a noise barrier is a useful approach. Noise barriers are now widely employed throughout the world, particularly for the abatement of road traffic noise.

The purpose of this review is to describe briefly several standard methods of predicting the effects of noise barriers. These methods are used to illustrate some of the design criteria for efficient noise barriers. Other factors affecting the design and efficiency of barriers including the effects of incorporating sound absorbent surfaces on barriers and the effects of the atmosphere on barrier performance are discussed.

2. STANDARD METHODS FOR THE PREDICTION OF NOISE ATTENUATION BY BARRIERS

An accurate and efficient method of predicting noise indices is clearly an important part of a strategy for planning with noise control in mind. Prediction methods have, in the past, generally been dedicated to specific noise sources, e.g. road traffic, aircraft, industrial. Many different prediction methods are in use around the world but the basic methodology tends to be similar. Recently the trend has been to aim for some rationalisation of approach, particularly in EU countries. L_{Aeq} is very widely accepted as a suitable index for describing noise from a range of sources.

The standard prediction methods are now increasingly being provided in the form of computer software. This allows complex conditions to be considered, particularly if mapping software can be used to provide accurate site data. Two such methods are the US Federal Highways Administration Traffic Noise Model (TNM) introduced in 1999 and the Nordic2000 model, which will be introduced in Nordic countries in 2001.

Examples of standard methods of predicting the performance of noise barriers which are usually incorporated in wider prediction procedures are given below.

2.1 Road Traffic Noise

A typical standard method for predicting the attenuation of traffic noise by barriers is that given in the Calculation of Road Traffic Noise, CRTN [1]. The method strictly applies to $L_{A10,18hr}$ but can be expected to also predict the attenuation of L_{Aeq}. The path difference, δ, is calculated in a vertical plane which is perpendicular to the road (and the barrier) as shown in Figure 1. The noise source is assumed to lie at 3.5m from the nearside kerb and 0.5m above the road surface. The barrier attenuation (or 'potential barrier attenuation') can then be read from Figure 1. The barrier attenuation is also a function of the frequency of the sound but in this case a specific type of source spectrum (that typical of road traffic) is assumed so the frequency effect is automatically included in the curve.

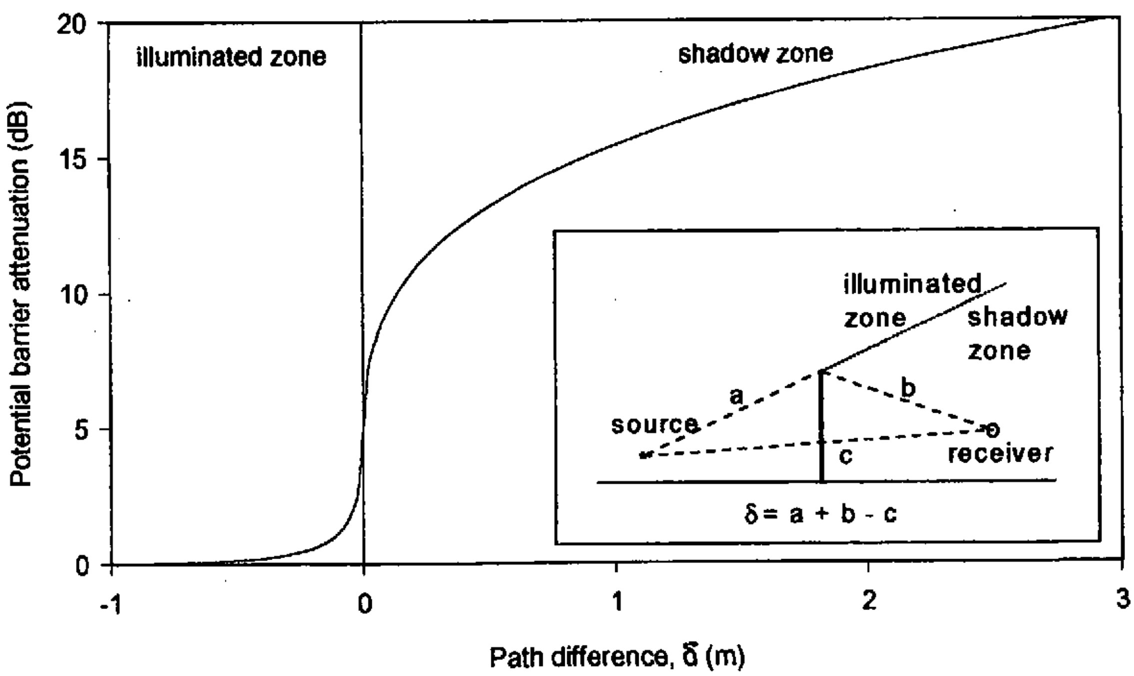


Figure 1. Potential barrier attenuation as a function of path difference, from [1].

When the source line is just visible over the barrier ($\delta = 0$) the attenuation is 5dB. The attenuation quickly drops to zero in the illuminated region. In the shadow region the attenuation increases with δ but the curve flattens at around 20dB and this is probably the maximum attenuation achievable in practice.

The CRTN prediction method also allows the attenuation of traffic noise to be estimated when it propagates over absorbent ground (such as grassland). The ground attenuation correction is factored depending on the proportion of absorbent ground area between the road and receiver. The effect can be very significant at longer distances from the road and when the sound path from source to receiver is close to the ground. When there is a barrier between source and receiver the prediction method states that a ground attenuation of zero must be assumed. Below are four examples which use the CRTN method to illustrate important considerations in barrier design.

2.1.1 Example 1

Figure 2 shows the cross section between a road traffic noise source and a receiver. The ground is rigid. The attenuation of the noise at the receiver produced by a thin barrier of 2m in height when it is situated first at position A can be determined by calculating the path difference, $\delta_A = 0.225$m.

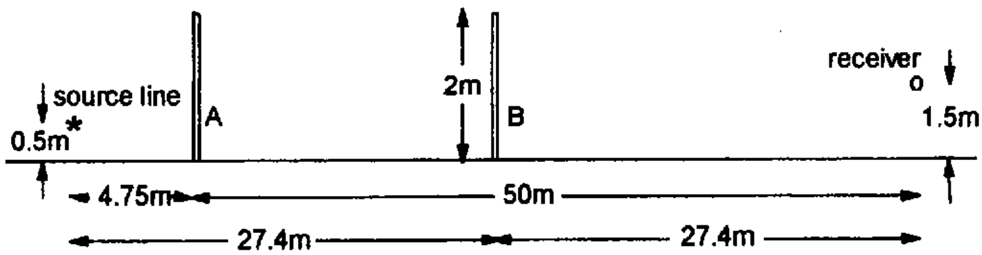


Figure 2. Example 1.

It then follows from Figure 1 that the barrier attenuation, $Att_A = 11.1$dB(A). When the barrier is at position B, $\delta_B = 0.036$m and $Att_B = 7.9$ dB(A). Thus for a given barrier height the greatest path difference and therefore the greatest attainable attenuation occurs when the barrier is as close as possible to the source (or receiver).

2.1.2 Example 2

Figure 3 shows the cross section between a road traffic noise source and a receiver. The ground between position C and the receiver is grassland and a thin barrier, 2m in height, is installed at C.

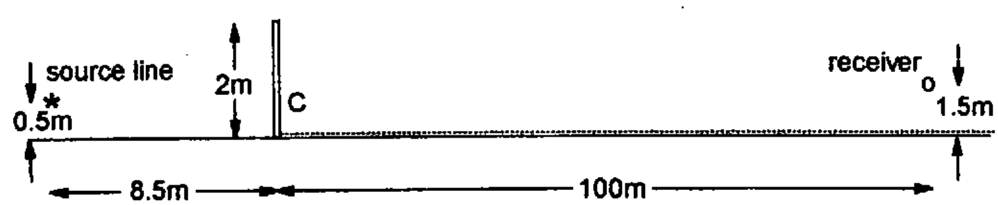


Figure 3. Example 2.

When the barrier is not present sound is attenuated as a result of passing over the grassland. This attenuation can be calculated using CRTN to be $Att_{grass} = 8.0$dB(A). When the barrier is present the path difference, $\delta_C = 0.128$m and from Figure 1 $Att_C = 9.8$ dB(A). In this case the attenuation for the grass is zero. Hence the increase in attenuation due to the barrier is

$$\left(Att_C - Att_{grass}\right) = (9.8 - 8.0)$$
$$= 1.8\text{dB(A)}.$$

The predicted effect of installing the barrier in these conditions is to reduce the noise level at the receiver by 1.8dB(A).

2.1.3 Example 3

An expression is given in CRTN for the minimum mass per unit area of the barrier for which the sound transmitted through the barrier is negligible in comparison with that diffracted over the upper edge. This is the condition for a 'massive' barrier. The expression is

$$M = 3 \times 10^{\left(\frac{Att-10}{14}\right)} \ kg/m^2$$

where *Att* is the predicted attenuation of the sound passing over the barrier from Figure 1.

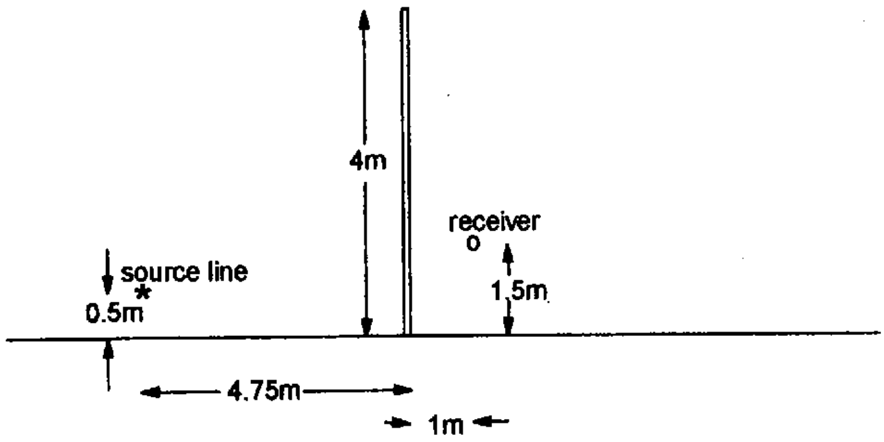


Figure 4. Example 3.

Consider the barrier configuration in Figure 4. For the given source and receiver positions, $\delta = 2.756$m and from Figure 1 $Att = 19.7$ dB(A). For this case

$$M = 3 \times 10^{\left(\frac{19.7-10}{14}\right)}$$
$$= 14.8 kg/m^2$$

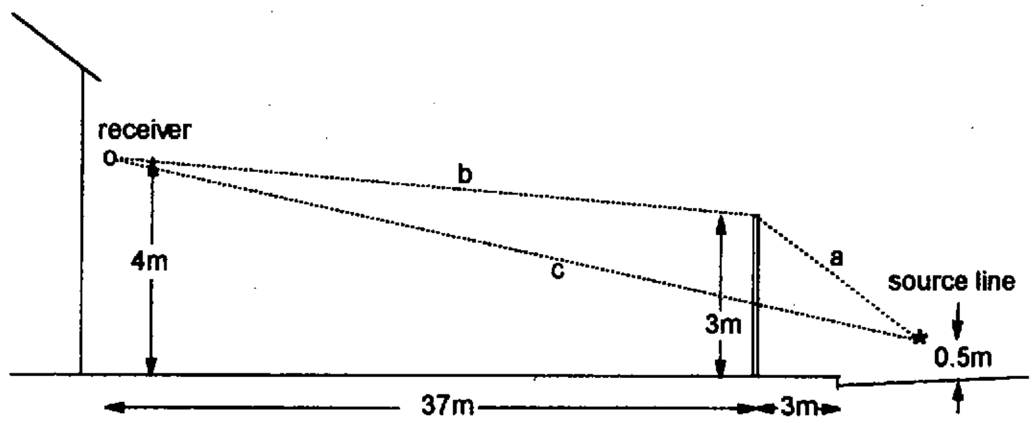
A substantial barrier construction is necessary to reduce sound transmission for this geometry.

2.1.4 Example 4

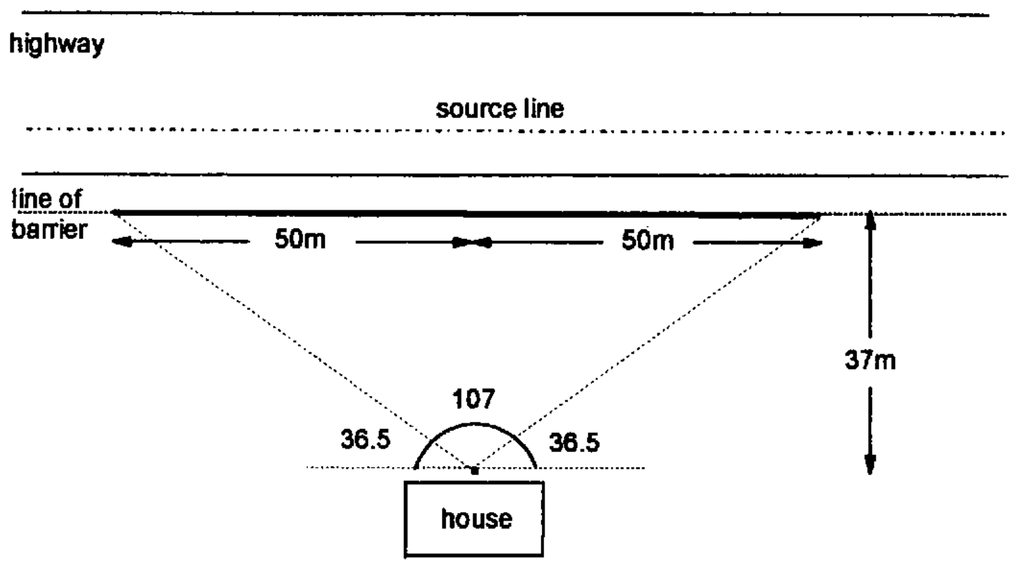
Consider the straight highway shown in cross section and in plan in Figure 5. The $L_{A10,18hr}$ level from traffic on the road measured at 1m from the upstairs window of the house is 72.0dB(A). The ground between the road and the house is 50% grassland. It is possible to predict the $L_{A10,18hr}$ level at this reception point if: a) a very long barrier 3m high is constructed in the position shown, and b) the noise barrier is only 100m long and symmetrically placed along the road with respect to the house.

Solutions, calculated using CRTN are:
a) The $L_{A10,18hr}$ level at the reception point with a long barrier = 61.2 dB(A)

b) Contribution to the $L_{A10,18hr}$ from the barrier section = 58.9 dB(A)
Contribution to the $L_{A10,18hr}$ from the unshielded sections = 68.1 dB(A)
Combined $L_{A10,18hr}$ from the two sections = 68.6 dB(A)



Cross-section (not to scale)



Plan (not to scale)

Figure 5. Example 4.

Notice that when the length of the barrier is reduced to 100m the $L_{A10,18hr}$ level increases from 61.2 to 68.6dB(A). In the solution to part (b) the contributions to the total $L_{A10,18hr}$ from the screened and unscreened sections can be compared. The total noise level is dictated by the contribution from the unscreened section of road. For the system to be efficient it would be necessary to erect a much longer barrier parallel to the road. This would not be a cost effective solution for reducing sound levels at a single dwelling. The degree of shielding could be improved without too much increase in length if reverse sections were erected on the ends of the 100m barrier.

2.2 Railway Noise

A survey of barrier effects in many railway noise prediction models is given by Van Leeuven [2]. Although the source position chosen varies considerably amongst the different methods the path difference approach is generally adopted. In the UK standard method [3] when the barrier is less than 12m from the train a correction is added to allow for the reduced efficiency of a rigid barrier due to multiple reflections between the side of the train and the barrier. In the Nordic standard method [4] it is assumed that practical trackside barriers will be designed in a fairly restricted number of configurations. Attenuation values are given for a range of specific track and barrier geometries.

2.3 Construction Site Noise

A method of predicting noise barrier attenuation is given in BS 5228 [5] which is specifically designed to predict noise levels from construction sites. In this case the site conditions are not only complex but may also change as construction proceeds. A very simple scheme is suggested, as shown in Table 1.

Site Conditions	Barrier Attenuation (dB)
Plant in clear view from receiver position	0
Plant just visible from receiver position	5
Plant not visible from receiver position	10

Table 1

This provides a very valuable baseline check on more complex prediction methods.

2.4 General methods for Outdoor Noise from Localised Sources

2.4.1 ISO 9613

A method of prediction of the effects of noise barriers is given in ISO Standard 9613 [6]. The method is applicable to a variety of noise sources and environments. The basic calculation is carried out for a point source of sound. It could be applied directly or indirectly to most situations concerning road or rail traffic, industrial noise sources, construction activities and many other ground-based sources. It does not apply to sound from aircraft in flight or blast waves from mining, military or similar operations.

After definition of the source characteristics a series of corrections are applied to account for various factors which affect outdoor sound propagation. The absorbent ground attenuation does not apply if a barrier attenuation is included. The screening attenuation is calculated separately for each octave band. A minimum barrier mass per unit area of 10 kg/m^2 is recommended.

2.4.2 Sound Control for Homes Method

Sound Control for Homes [7] is a valuable design guide covering many aspects of sound control in the built environment. The path difference is calculated in the usual way and the barrier attenuation is determined for octave bands between 125Hz and 2kHz using a chart. It is suggested that the attenuation of broad band sounds can be calculated by A-weighting the octave band attenuations and adding the effects. The recommendations in Table 2 are made about the mass of the barriers.

Calculated Attenuation (dB)	Minimum Superficial Mass (kg/m^2)
Up to13	5
13 to 17	10

Table 2

The design guide contains useful suggestions for screening using barrier blocks. These are buildings which themselves form noise barriers. They consist of linear buildings which lie close to, and parallel to, the noise source. The blocks will commonly be taller than a conventional barrier and so are more effective. It is desirable to return the ends of the blocks to provide maximum protection for the area behind them. Internal planning options may be restricted and rooms on the noisy side of the building may need heavy insulation if they are for domestic use. The blocks may consist of less noise sensitive commercial or industrial premises.

Suggestions are also made in the design guide for self-protecting dwellings. For example, a staggered row of low-rise terraced housing arranged to shield most windows from noise.

3. PRACTICAL ASPECTS OF NOISE BARRIER PERFORMANCE

3.1 Barriers with Sound Absorbent Surfaces

In some specific cases there is evidence that using barriers with sound absorbent surfaces will be more efficient than using barriers with rigid surfaces. The main use of absorbent surfaces is to remove problems arising from reflected sound.

Figure 6 shows how the attenuation of a nearside barrier can be degraded by reflections from a parallel barrier on the opposite side of the road. Since this parallel barrier is erected to protect an area behind it a reciprocal reflection effect also occurs. The effect of the reflections can be described in terms of image sources of the vehicles in the two reflecting planes. Table 3 shows results of site experiments to determine the degradation in the insertion loss of a single barrier when a parallel barrier is erected. The maximum measured changes are given in terms of the W/H ratio where W is the separation of the barriers and H is the height.

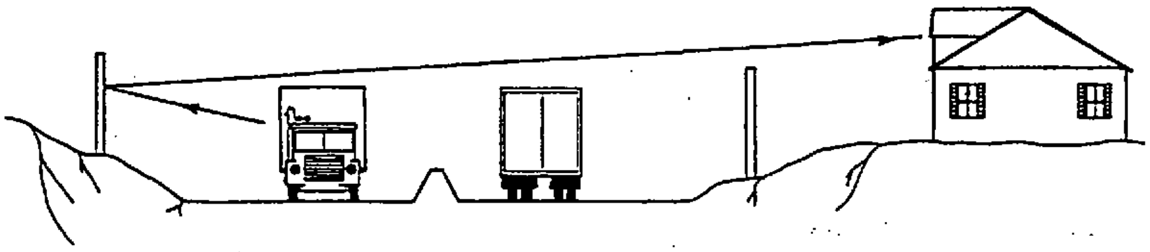


Figure 6. Sound reflection from parallel barriers with rigid surfaces, from [8].

The effect is strongest when the barriers are high and close together and negligible for widely spaced, low barriers. Model studies tend to overestimate these effects as a result of the difficulties in accounting for the scattering encountered in practical site conditions. The sound between the barriers is scattered by the road furniture and the vehicle bodies, and sound will also be absorbed by verges and central reservations on dual carriageways.

Study	Max IL degradation, dB	W/H
Dulles	6.2	6
Maryland [9]	2.8	8.6
Japan	1.5	8 to 10
California [10]	1.4	15
Canada	0	25

Table 3 Maximum insertion loss degradation for parallel, reflecting road traffic noise barriers [8].

Two methods are proposed for removing this problem. The first is to slope the rigid faced barriers so that the sound is reflected upward (see Figure 7). If the sloping surface has dimensions less than the predominant wavelength of the sound (which may occur if the surface is made up of several sloping panels in a zigzag configuration) then the sound will be scattered rather than reflected. The appropriate slope depends on the separation of the barriers. Slutsky and Bertoni [11] showed that for a barrier separation of 45m a slope angle of 3° was sufficient. For a separation of 18m an angle of 10-15° is required. The drawback with this approach is that the reflected sound may cause problems elsewhere since rays may be refracted downwards as a result the atmospheric effects described in section 3.4.1.

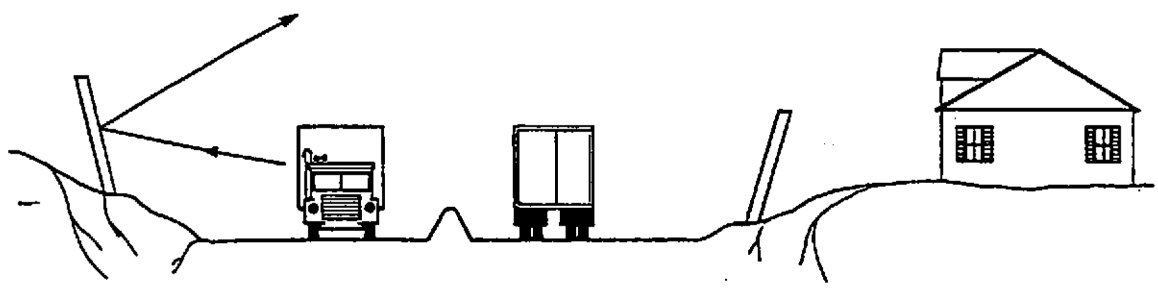


Figure 7. Sound reflection from rigid sloping parallel barriers, from [8].

The second method is to employ sound absorbent surfaces. Table 4 shows the results of site experiments to assess the effects of introducing sound absorbent surfaces to the traffic facing sides of parallel barriers.

Study	Improvement, dB	W/H
US	6	4
Japan	2 to 5	5
UK [12]	2.3 (Max)	9.3
Canada	0	25

Table 4 Improvement in insertion loss of parallel road traffic noise barriers when the traffic facing sides are treated with sound absorbent material. Adapted from [8].

The results from Tables 3 and 4 show that the absorbent surfaces have removed the degradation of attenuation attributable to the parallel rigid barrier configuration. These results suggest that for a *W/H* ratio of greater than about 15 the advantages of using sound absorbent surfaces on screens are very small. Some countries and states do not consider that they are cost effective in general use for parallel barrier configurations.

The side of a vehicle can also act as a reflector of sound, which can degrade the performance of a barrier. The multiple reflections as shown in Figure 8 can be described in terms of a series of images of the vehicle. The problem can be significant for high-sided vehicles when they pass close to a barrier. The reflections only occur when the vehicle is opposite the receiver position since the reflecting surface is quite short, but it is in this position when the contribution of the vehicle to the total noise level is the greatest.

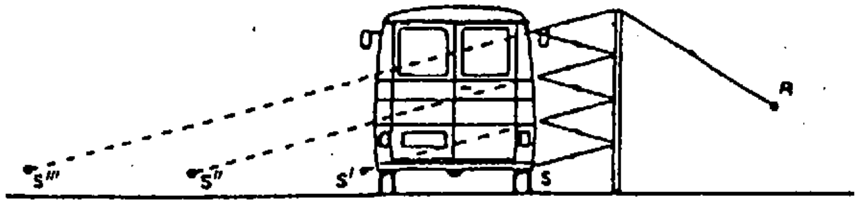


Figure 8. Showing multiple reflections of sound between a rigid barrier and a vehicle, from [8].

A two-dimensional Boundary Element calculation has been carried out to model this effect for the configuration shown in Figure 9. The source of sound is in the position indicated and a typical road traffic noise spectrum was assumed. In Figure 10 the mean insertion loss of the screen over a range of receiver positions behind the barrier is plotted against the height of the vehicle. For a rigid surface, as the height of the vehicle body increases the mean insertion loss reduces. As the vehicle side becomes visible above the (2m high) barrier a sudden further reduction in insertion loss is observed. The maximum reduction in the mean insertion loss is 5dB. Curves are also given showing the effect of applying different configurations of absorbent material to the traffic-facing surface of the barrier. When the top 0.5m is absorbent there is a significant improvement in insertion loss, which increases as the area of absorber is increased. When all the surface is absorbent the efficiency of the barrier is almost completely restored to the result calculated with no vehicle body is present (height 0.5m) [13].

It is quite difficult to translate these results directly to road traffic but Clairbois [14] suggests that the peak level from vehicles would reduce by 6dB and the average or L_{Aeq} would be reduced by up to 3dB if an efficient absorber were placed on the barrier face. Watts and Godfrey [12] carried out site tests on a barrier 3m high and 5.6m from the edge of the nearside lane of a motorway. The sound levels were measured for various heights at 9.5m behind the barrier with a rigid and then with an absorbent surface facing the traffic. A maximum difference between the results of less than 0.5dB was observed for both L_{Aeq} and L_{A10}. For railways the vehicle length is much greater and the effect is clearer.

In a confined complex urban situation it is extremely difficult to quantify the effects of an absorbent barrier relative to a barrier with a rigid surface. The increased cost of installing a barrier with an absorbent surface means that there is pressure for a quantifiable improvement to be defined. However it is clearly desirable that sound energy is extracted by an absorbent surface facing the noise source since any reflected sound is likely to have a detrimental effect at some other point in the urban fabric and will produce an overall increase in the noise environment. It is in this situation that complex modelling is desirable.

Figure 11 shows a complex situation where two roads at different levels, each with four lanes, have been modelled using a two-dimensional Boundary Element approach. The noise abatement measures are indicated. These include noise barriers with absorbent surfaces, the lining of the underside of the elevated road and the building facades with sound absorbent materials. The effect of these measures is given in terms of insertion loss in Table 5. The limitation of this approach is that the model is two-dimensional and the results are difficult to translate directly into three dimensions [15].

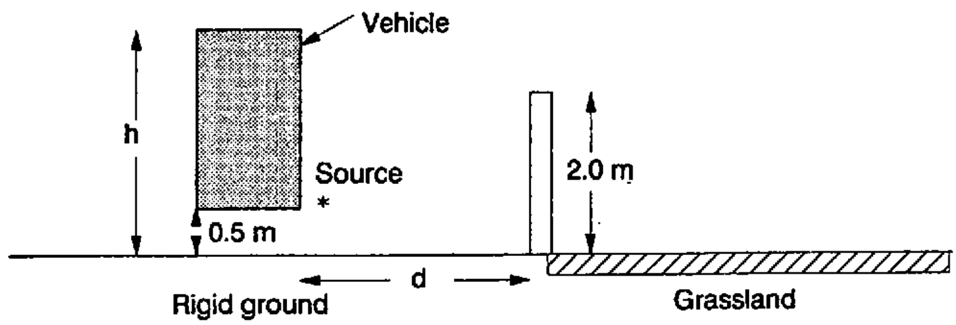


Figure 9. Vehicle and barrier configuration for the results in Figure 10, from [13].

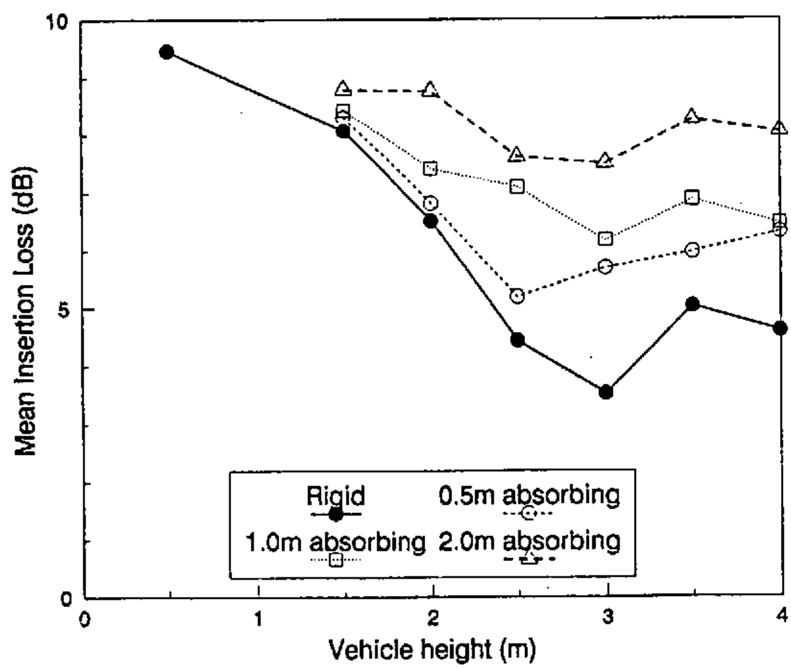


Figure 10. Mean insertion loss behind the barrier in Figure 9 as a function of vehicle height, h, for d=5.5m. Curves are shown for a rigid faced barrier and for barriers with sound absorbent treatment over the traffic facing side. The extent of the absorbent region from the upper edge is indicated.

3.2 Specific Designs

Barriers cantilevered toward or over the roadway are quite common, particularly in Japan. They have high insertion loss because the path difference is large for this configuration, particularly if the barriers are on elevated roads. Cantilevered barriers can produce high levels of reflected sound and so are commonly constructed with absorbent surfaces facing the traffic. They also require high-grade foundations (or support structures on elevated roads).

A tunnel is the ultimate noise screen. Leakage of the reverberant sound in the tunnel can be reduced at the portals by lining the tunnel for a short distance (of the order of 20m) with sound absorber. The main disturbance problem near the portals is the startle effect as vehicles exit. Ventilation is a major expense and this can be overcome in tunnels which are not required to provide support over the roadway by using a cover of sound absorbent louvres oriented so that there is no direct line of sight from receptors to the highway.

In order to reduce the visual intrusion of barriers it is desirable to gain the maximum possible insertion loss for a barrier of given height. Some improvement in insertion loss of a plane screen can be achieved by modifying the upper, sound diffracting edge. Several designs have been discussed, such as cylindrical sound absorbent caps [16], T-shaped barriers with absorbent [17,18] or reactive [19,20] upper surfaces, multiple edge designs [18] and a wave interference design [21,22]. A reactive cylindrical cap has also been considered [23] and a form with slow-waveguide filters passing through the barrier [24].

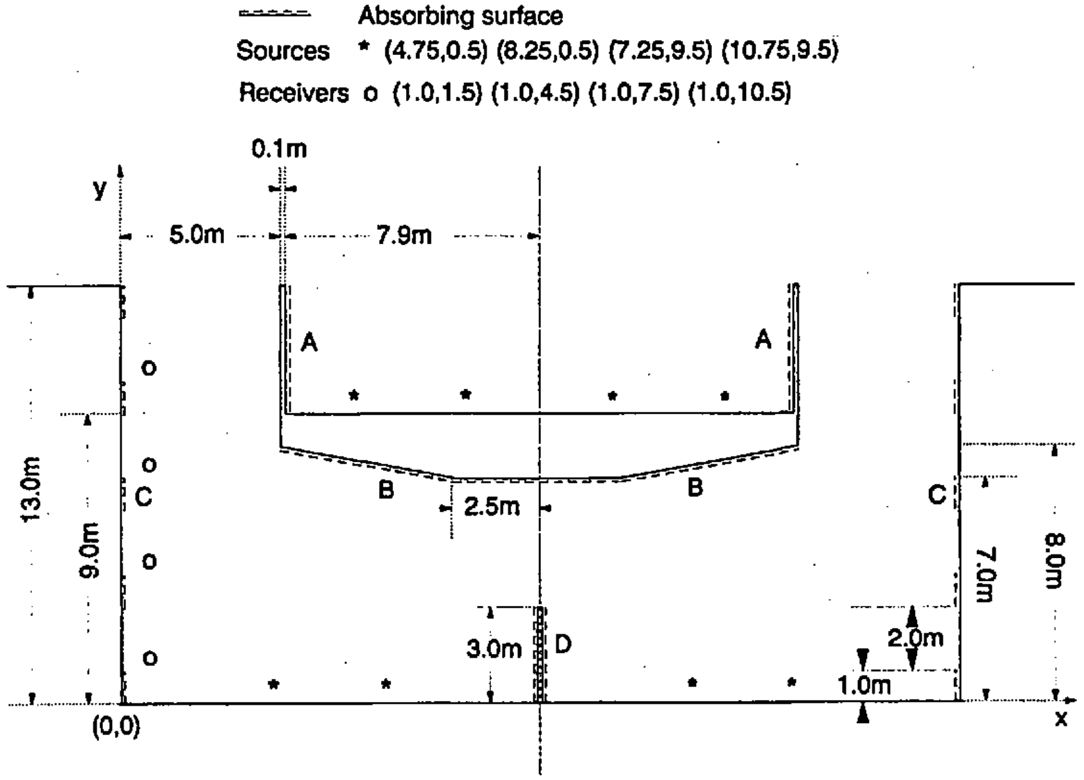


Figure 11. Section of a two-level highway system used to investigate the effects of noise abatement methods [15]. The methods are:
A – treatment of noise barriers on the upper highway with sound absorbent material.
B – treatment of the underside of the elevated road with sound absorbent material.
C – treatment of the building facades with intermittent sections of sound absorbent material.
D – installation of a median noise barrier with sound absorbent surfaces on the lower highway.

Receiver Position	Insertion Loss (dB)			
	A	A+B	A+B+C	A+B+C+D
1.0,1.5	0.1	2.1	7.2	11.0
1.0,4.5	1.7	4.6	11.0	13.9
1.0,7.5	1.3	7.1	8.5	9.0
1.0,10.5	2.2	7.5	9.4	10.3

Table 5. Mean insertion loss at receiver positions 1m from the building façade for the noise abatement measures shown in Figure 11. From [15].

The performance of these devices is strongly dependent on the source-receiver-barrier geometry. Caps are most efficient when the source and receiver are well below the top of the barrier. This often applies for barriers on elevated roads. Theoretical investigations of the performance of caps, which have generally been carried out using two-dimensional theoretical methods, often predict considerable improvements in insertion loss over a plane screen of the same height. Scale model experiments and full scale testing using localised sources generally show reduced improvement. Site testing, where the effects of a wide range of source positions are averaged usually show the least improvement. However some designs may offer improvements up to 3dB over the plane screen case on site, which is equivalent to either an increase in height of a plane screen of the order of 1m, or a reduction in traffic of about 50%.

Variation in the height of a barrier in the longitudinal direction offers the possibility of interference between sound rays of different path length passing over different parts of the barrier. Scale model tests have been carried out on a barrier with a random edge profile in its upper section by Ho et al. [25] who reported that the design gave poorer low frequency performance but better high frequency performance than the equivalent plane screen.

Earth berms offer a very acceptable alternative, in terms of visual and environmental impact, to a plane screen construction of manufactured materials. In practical conditions and in the shadow region a grass covered berm with a flat top and sides with a gradient of the order of 1:2 will have a similar insertion loss to a plane screen situated at the centre point of the berm [8]. Designs have also been reported in which low walls are incorporated on the top of low berms with shallow sloping sides [26].

Belts of trees provide desirable visual screening, but hedges and thin belts of trees provide very little noise screening. Kragh [27] reported experiments on belts of deciduous trees of between 15 and 40m in width which produced attenuations of the order of 3dB or less in L_{Aeq} for traffic noise. In experiments on a belt of dense evergreens 10m in width attenuations of about 4-5dB were reported [28].

There is some evidence that vegetation on barriers can act as a sound absorber. The soil is active at low frequencies and the vegetation at high frequencies (>1kHz) [29,30].

On dual carriageway roads it is possible to incorporate barriers on the central reservation as a noise control measure. These are 'median' noise barriers. A commonly proposed design for such barriers is that they should be low, say 1m in height, and have surfaces which are capable of absorbing sound. The performance of median noise barriers has been investigated using a pseudo three-dimensional Boundary Element model for a six-lane road and it has been shown that for a realistic design of barrier, 1m in height, with a sound absorbent surface, an attenuation of the order of 1-2dB is expected. This attenuation is also observed to be additive to any predicted attenuation for roadside barriers [31].

3.3 Barriers and porous road surfaces

Roads with porous asphalt surfaces are becoming common. Open channels in the surface layer allow water to drain away but also produce a reduction in the noise emission from the highway. A typical reduction in level is 3dB(A) but reductions of 7dB(A) have been reported for new roads.

Noise reduction is achieved by two mechanisms. The noise from vehicles at high speed comes primarily from the tyres. A porous road surface reduces the tyre noise by reducing the air pumping effects when the tyre is in contact with the road. The second is that the porous surface provides a small amount of sound absorption and changes the phase of the reflected sound. Thus the direct sound and the reflected sound can interfere destructively at some positions and produce reduced noise levels. Unfortunately these regions are localised and there will also be regions of constructive interference where noise levels will be enhanced.

Clearly the primary effect, that of reducing tyre noise and the direct sound absorption in the road surface will be additive to any barrier attenuation. The propagation effects will interact, but since these are localised and tend to be averaged out by the distribution of sources on the road their effect on barrier attenuation is negligible [32,33].

3.4 Other Factors Affecting Barrier Performance

3.4.1 Atmospheric effects

A curving of the sound rays due to atmospheric refraction can reduce or enhance the performance of noise barriers for downwind and upwind propagation respectively. Also, since the barrier projects into the air stream a wake of turbulent air will result. The effect of this wake is very difficult to investigate but scattering of sound in it could be expected to increase the sound level behind the barrier in downwind and also possibly in upwind conditions. Standard methods tend not to include atmospheric effects explicitly but provide results for 'typical downwind conditions'.

As an example of these effects Figure 12 shows the results of experiments carried out at a flat grassland site with an earth berm barrier near a six-lane highway which is shown in cross section.

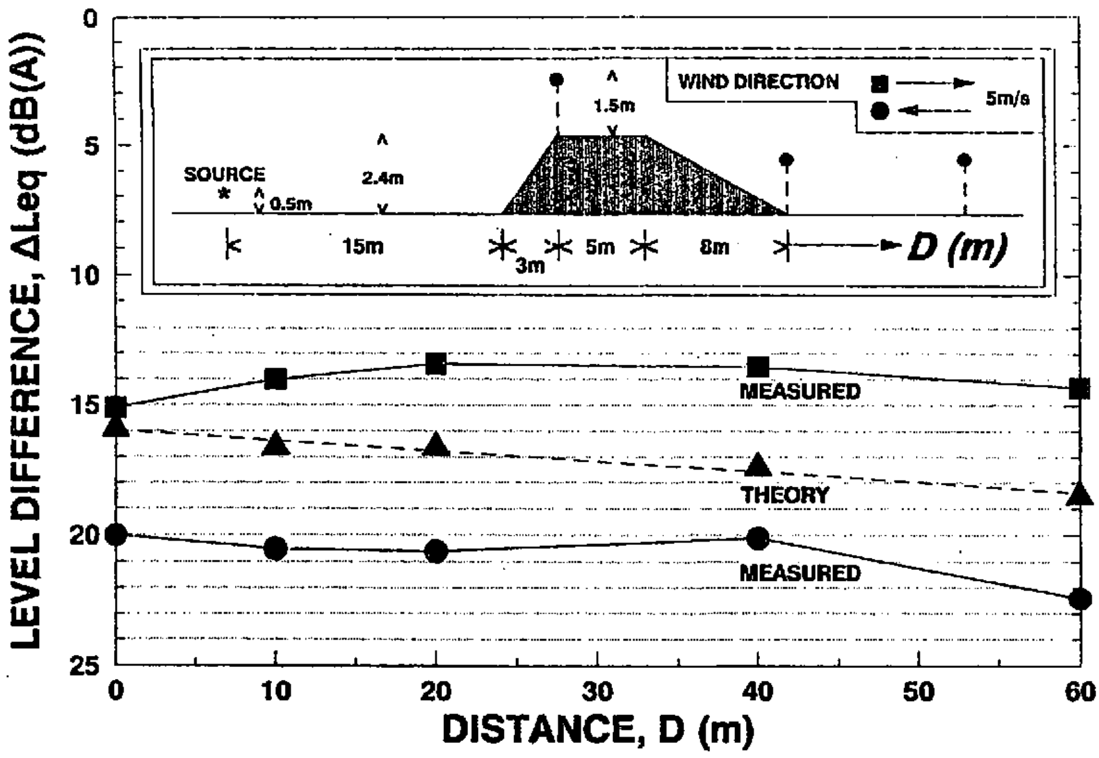


Figure 12. Results of site measurements near a 6-lane motorway showing the effect of wind conditions on the attenuation of an earth berm noise barrier. The theoretical result was obtained for still air using a 2D Boundary Element calculation.

The $L_{Aeq,15min}$ was measured at 1.5m above the top of the berm and simultaneously at 1.5m above the ground at various distances *D* behind the berm. The level difference between these values provides a measure of the attenuation, normalised for the traffic flows. Two sets of measurements were carried out on days when the wind speed was ~5m/s from road to berm (squares) and ~5m/s from berm to road (dots). The attenuation in each case was approximately constant up to a distance of 60m behind the berm. The difference between the two sets of results was 5dB immediately behind the berm and 7dB at 60m. The theoretical curve (triangles) was calculated using a two-dimensional Boundary Element numerical model for homogeneous air conditions and with a nominal traffic noise source in the position indicated.

3.4.2 Access gaps

Access to road or railways is important for maintenance and emergency services. It is also necessary to provide an escape route. It is important to ensure that no leakage of sound occurs through the barrier system at the access points. Sealed doors can be incorporated in the barrier design. A second method is to overlap two sections of barrier with a gap between them. Lining at least one face of the overlap with sound absorbent material reduces leakage of sound through this gap. This approach can also be applied at a larger scale to prevent leakage through barrier systems in the region of access roads. An important criterion for the length of the overlap is that the source should not be visible from the sensitive receptor positions.

4. CONCLUSIONS

The main characteristics of the acoustic performance of noise barriers are:

- Attenuation increases with increasing barrier height, but there is a law of diminishing returns.
- For a barrier to act efficiently the sound energy passing through it should be at least 10dB lower than that diffracted over it.
- There must be no gaps or holes in or beneath the barrier.
- For maximum efficiency the barrier should be as close as practicable to the source (or receiver).
- The still air insertion loss of a barrier can be changed by ±5dB in down or upwind conditions.
- Trees are not effective barriers except in very broad stands of evergreens.
- Barrier blocks of single aspect dwellings of non-sensitive commercial properties can provide shielding.
- Barriers with sound absorbent surfaces are desirable in some conditions to prevent multiple reflections from parallel configurations or the sides of vehicles.
- Attenuation of noise by extended barrier shapes increases with the steepness of the sides, the absorption of the material on the upper surface and the number of corners.
- Various modifications to the upper edge of a single screen can produce some improvement in insertion loss without an increase in height.
- Noise barriers must be seen as one aspect of a strategy for noise control. The total noise control strategy adopted will be critically dependent on the particular conditions at the specific site.

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