inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 3.1

FACTORS AFFECTING THE PERFORMANCE OF TRAFFIC NOISE BARRIERS

G. Watts

TRL, Old Wokingham Road, RG45 6AU, Crowthorne, Berkshire, United Kingdom

Tel.: +44 13 4477 0414 / Fax: +44 13 4477 0918 / Email: grwatts@trl.co.uk

Keywords:
BARRIER, DIFFRACTION, LEAKAGE, ABSORPTION

ABSTRACT
The Transport Research Laboratory (TRL) have carried out for the Highways Agency a wide range of studies with the aim of identifying cost effective designs of road traffic noise barrier. This paper summarises the results of this research. The factors explored were diffraction effects at the barrier top, sound leakage, absorptive materials, ground surface properties and meteorological effects. The methods employed included full-scale testing and numerical modelling.

1 - INTRODUCTION
Common factors that affect acoustic performance of a wide variety of noise barriers are:

- Sound leakage through the barrier
- Absorptive effects − absorptive elements on the traffic face or diffracting edge
- Diffraction effects − basic geometry, elements or caps at the top of the barrier
- Ground surface properties
- Meteorological effects

At TRL a noise barrier test facility (NBTF) has been used to test barriers at full-scale barriers under controlled conditions. The facility consists of a powerful loudspeaker source, road surface and flat grassland beyond the barrier. Additionally boundary element methods (BEM) have been developed in collaboration with Brunel and Bradford universities to provide versatile numerical modelling techniques for examining the efficiency of a wide range of designs. Model results have been validated using full-scale and roadside measurements.

2 - BEM MODEL DESCRIPTION
The BEM program calculates the wave field at a particular frequency by solving a reformulation of the Helmholtz wave equation in terms of an integral equation. For this purpose the surfaces are divided into boundary elements of length in general no greater than $\lambda/5$ where λ is the wavelength. The effects of ground cover and absorptive surfaces are included in the definition of the elements. The vehicle model is two-dimensional which means that the traffic is effectively a coherent line source. Despite this limitation results have shown good agreement with measured values. For the purposes of barrier studies a typical rural dual 3-lane motorway has been modelled. The vehicle sources used in the model were represented by using average vehicle shapes for light and heavy vehicles with sources at heights of 0.05 m and 0.1 m respectively under the nearside and farside edges of the vehicle body. The source spectra for light and heavy vehicles were based on measured peak values for individual vehicle pass-bys at the edge of a motorway [1]. In most cases the road surface was assumed to be acoustically hard and the verge and flat ground beyond the barrier was assumed to be acoustically soft. Suitable parameters were chosen for flow resistivity, porosity, layer depth and tortuosity to represent typical values for reflective and absorptive surfaces including grassland. Predictions were made in terms of the A-weighted levels based on centre

frequencies of one-third octave band levels from 100 Hz to 5 kHz. The calculation method described in ISO 9613-1 was used to take account of air absorption assuming 15°C and 50% humidity.

3 - SOUND LEAKAGE

An effective noise barrier will reduce the sound energy transmitted through its construction to much lower levels than the sound diffracted over and around the barrier. However, in some cases leakage will occur as a result of shrinkage, warping and splitting of the panels and weathering of acoustic seals. A TRL roadside survey indicated that timber barriers had poorer sound transmission performance due to leaks than might be expected from the mass per unit area of the barrier [2]. BEM predictions were made with and without horizontal gaps of various dimensions and spacings in barriers of various heights. These predictions were compared with an approximate but simpler sound intensity approach with generally good agreement. The method assumes that sound spreads evenly from each gap and that logarithmic addition of the secondary sound sources at the gaps on the rear face of the barrier with the sound diffracted over the barrier top can be used to obtain the resultant noise level. It can be shown that the resultant increase in level for a barrier of height h is approximately given by:

$$10\log\left[1+\frac{2Gh}{\pi}\frac{(d_s+d_r)}{d_s d_r}10^{-B/10}\right]$$

Where d_s and d_r are the horizontal distances from source to barrier and from barrier to receiver respectively and G is the fraction of the barrier area with air gaps. Figure 1 shows predictions for a barrier with realistic air gaps (3% of total area).

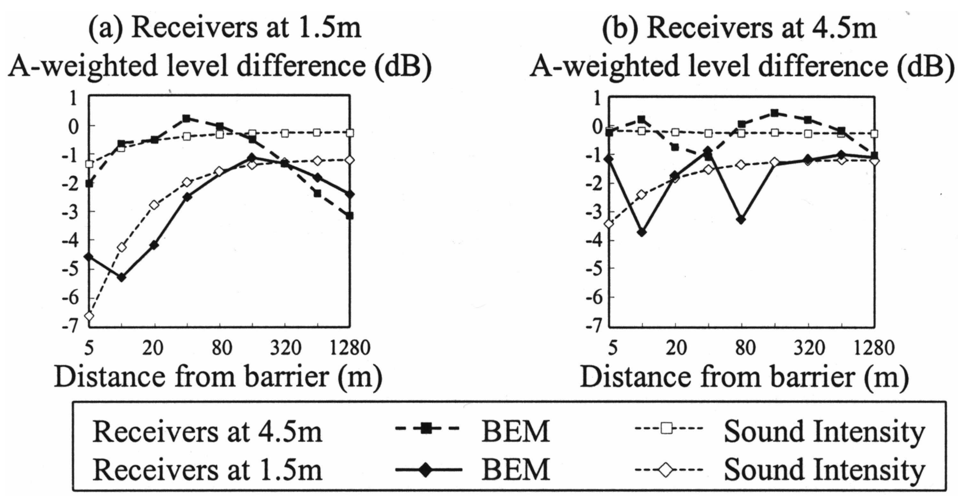

Figure 1: Changes in insertion loss due to 3% gaps.

The barrier potential correction B (a negative value) was obtained from the CRTN method [3]. It was found that generally the reduction in screening performance caused by gaps was greatest close to the barrier and reduced with distance. It follows that a barrier of higher sound insulation than provided by a typical single leaf timber barrier is required to prevent significant decreases in screening performance at distances behind a tall barrier of less than about 20 m.

4 - ABSORPTIVE EFFECTS

Where plane vertical barriers exist on both sides of the road there exists the possibility of multiple reflections leading to a loss of screening performance. Sound absorptive panels located on the sides of the barriers facing the traffic can reduce the reflected contribution by absorbing the sound energy from the incident wave. There are several types of system that are used for sound absorbing barriers. Clearly, to be effective the barrier material must be highly absorptive at frequencies that are significant in highway traffic noise spectra and this is recognised in the recent CEN standard EN 1793 (part 1) which gives a test method for deriving a single number rating. This method weights the absorption coefficients from 100 Hz to 5 kHz with a typical traffic noise spectrum (part 3). While most of the absorptive materials perform adequately at mid to high frequencies the absorption at low frequencies varies considerably. Thick layers of absorptive materials or the use of a cavity behind the absorber are possible ways of improving performance. The effectiveness of absorptive materials in reducing noise levels will depend on the distance between parallel barriers/barrier height. Roadside tests have shown the largest reductions from applying good absorbers are generally a few dB(A) [4]. Table 1 shows the maximum increases that reflective farside barrier have produced in well controlled roadside studies where source strength and wind component have been taken into account. Larger effects of > 5 dB have been predicted using physical and mathematical models due to the simplifying assumptions that are not realised in practice e.g. screening effects of traffic, reflections from safety barrier and absorption by grassed embankments, influence of road curvature and meteorological effects.

Experimental design	Barrier separation/height ratio	Maximum increase in L_{Aeq}
Pairwise comparison [5]	8.6: 1	2.8
Barrier alteration [4]	9.3: 1	2.3
Barrier erection [6]	15: 1	1.4

Table 1: Increase in L_{Aeq} dB due to the farside reflective barrier.

5 - DIFFRACTION EFFECTS

The insertion loss of barriers can be determined in simple cases using the path difference approach [7]. With suitable adjustments this approach was incorporated into the UK traffic noise prediction model CRTN [3]. In the case of more complex shapes the procedure may underpredict performance even when the effective height of thick barriers are taken into account e.g. cranked barriers comprising a simple barrier with an extension overhanging the carriageway. This is illustrated in Figure 2 (a to e) where the maximum insertion loss gains for receivers at 1.5 m above the ground produced by extensions of various lengths are based on BEM and path difference calculations.

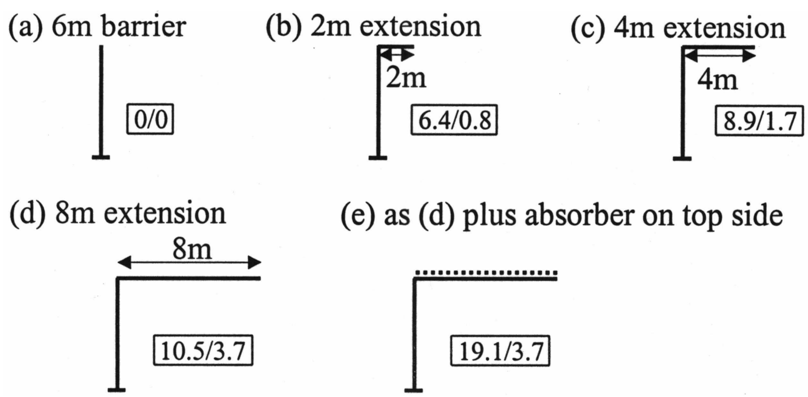

Figure 2: Maximum changes in insertion loss due to extensions (BEM / CRTN predictions in dB(A) posted).

Barriers have been altered in cross-section in an attempt to reduce the noise diffracted into the shadow zone [8,9]. Many designs have been examined using mathematical and scale modelling and the more promising designs have been tested at full scale at the NBTF. Figure 3 (a to l) shows some of the designs in cross-section that have been tested with the average improvement in insertion loss posted.

The designs included T-shaped barriers and multiple edged barriers as well as commercially available designs e.g a rounded absorptive cap 0.5 m in diameter and a device designed to exploit the principle of sound interference. The average reduction in noise levels for barrier profiles compared with a simple reflecting barrier of identical overall height were up to 3 dB. Adding the most efficient profiles has the same effect as raising the height of a simple plane barrier by 0.5-1.0 m. Roadside tests have confirmed that such reductions are possible in practice [10]. Such barrier profiles might therefore be useful for screening traffic noise in situations where the maximum height of barriers needs to be limited because of other environmental considerations (e.g. visual intrusion, reduction in sunlight) or where extra screening is required from an existing barrier and the costs of increasing the height would be excessive.

6 - GROUND SURFACE PROPERTIES

The insertion loss of a barrier will depend on the road surface and the ground type in the screened area. It has been possible to model these effects using a combination of BEM modelling and site measurements to

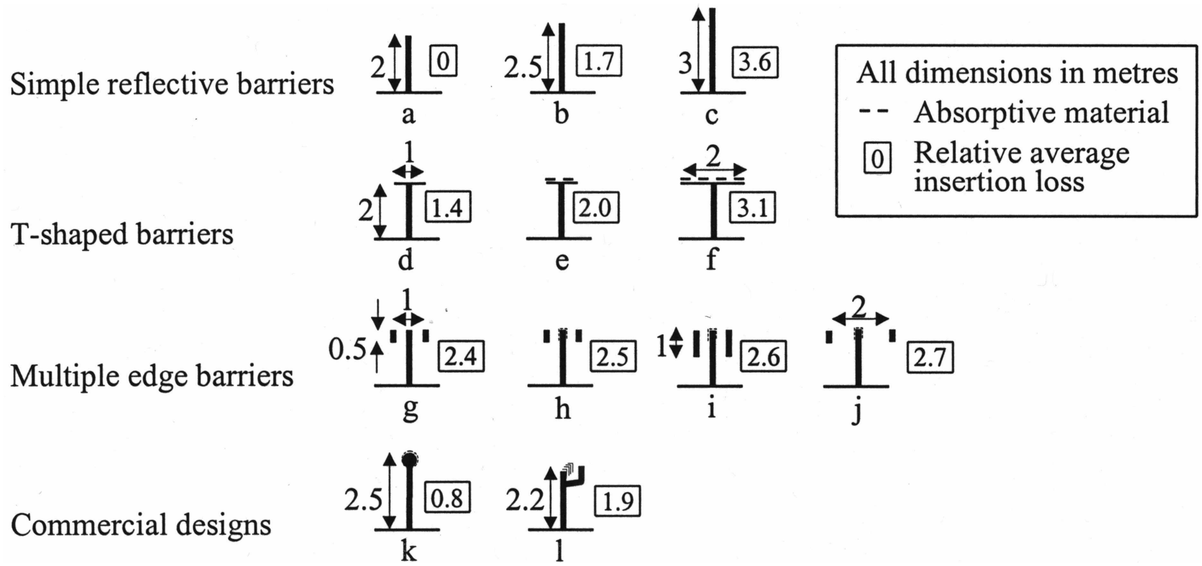

Figure 3: Insertion loss changes due to barrier caps.

calibrate the model. The resulting effect has been shown to be different from the sum of the individual effects [1]. Figure 3 shows the change in insertion loss when 2 m and 8 m high barriers are placed adjacent to a porous asphalt (PA) road surface compared with a conventional asphalt surface (HRA). Porous asphalt is strongly absorptive in the frequency range 1-1.6 kHz. Generally by changing to PA there is a decrease in the performance that depends on the distance behind the barrier and the height of the barrier. The largest decrease in performance for receivers at 1.5 m height above grassland was predicted for the 8 m high barrier where the loss was nearly 3 dB(A) at a distance of 80 m behind the barrier. The nature of the ground over which sound passes beyond the barrier also has an important effect on the insertion loss of the barrier. Generally the more absorptive the ground the smaller the insertion loss of the barrier.

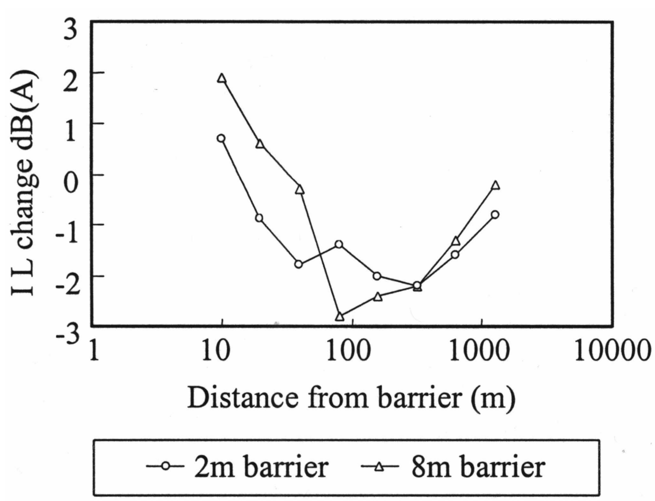

Figure 4: Change in insertion loss from HRA to PA at 1.5 m above ground.

7 - METEOROLOGICAL EFFECTS

Modelling work has indicated that the effectiveness of simple barriers is seriously degraded by wind blowing in the direction from the road to the receiver [11]. Further research is needed to model these atmospheric effects sufficiently accurately so that it will be possible to predict the performance of barriers under different meteorological conditions. Research is planned involving developments in the BEM approach to include layered atmospheres and the use of other techniques, e.g. the parabolic equation approach, so that the effects on screening of wind and temperature gradient conditions can be calculated.

In addition it is likely that air movements over the diffracting edge have a significant effect on acoustic screening performance. With greater understanding of the nature of this interaction it may be possible to produce designs that are more efficient than plane barriers across a wide range of wind conditions.

8 - CONCLUSIONS

It is difficult to accurately predict the insertion loss of barriers using the simple models in current use if they depart from the plane reflective barrier or the barrier is sited on varying ground conditions both in terms of impedance and height profile. The BEM approach has proved useful in making assessments of the efficiency for complex barrier shapes and absorptive surfaces and is being extended to take account of varying ground. Multiple edge barriers and other barrier shapes are a solution to enhancing the acoustic performance of barriers without raising the overall height of the barrier system. The effects of sound leakage should be considered where the screening required is high and the receiver is close to the barrier. The effect of meteorological factors on barrier performance is an important factor that requires further study that could lead to improved prediction methods and barrier designs.

ACKNOWLEDGEMENTS

This programme of research was undertaken for the Highways Agency of the Department of Environment, Transport and the Regions.

REFERENCES

1. **G R Watts, S N Chandler-Wilde and P A Morgan**, The combined effects of porous asphalt and barriers on traffic noise, *Applied Acoustics*, Vol. 58, pp. 351-377, 1999

2. **G R Watts**, In situ method for determining the transmission loss of noise barriers, *Applied Acoustics*, Vol. 51, pp. 421-438, 1997

3. **Department of Transport and Welsh Office**, *Calculation of road traffic noise*, HMSO, London, 1988

4. **G R Watts and N S Godfrey**, Effects on roadside noise levels of sound absorptive materials in noise barriers, *Applied Acoustics*, Vol. 58, pp. 385-402, 1999

5. **G G Fleming and E J Rickley**, *Parallel barrier effectiveness under free-flowing traffic conditions*, U S Department of Transportation, Cambridge (MA), 1992

6. **R W Hendricks**, *Field Evaluation of acoustical performance of parallel highway noise barriers in California* , Transportation Research Record, Washington DC, 1993

7. **Z Maekawa**, Noise reduction by screens, *Applied Acoustics*, Vol. 1, pp. 157-173, 1968

8. **K Fuijiwara and T Ishiduka**, Noise shielding efficiency of barriers with multiple absorbing edge obstacles, In *Internoise'99* , pp. 451-454, 1999

9. **G R Watts, D H Crombie and D C Hothersall** , Acoustic performance of new designs of traffic noise barriers: full scale tests, *Journal of Sound and Vibration*, Vol. 177 (3), pp. 289-305, 1994

10. **G R Watts**, Acoustic performance of multiple edge noise barrier profile at motorway sites, *Applied Acoustics* , Vol. 47, pp. 47-66, 1995

11. **A Muradali and K R Fyfe**, Accurate barrier modelling in the presence of atmospheric effects, *Applied Acoustics* , Vol. 56, pp. 157-182, 1999